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QUANTIFICAITON OF HUNGRY HORSE RESERVOIR WATER LEVELS NEEDED TO MAINTAIN OR ENHANCE RESRVOIR FISHERIES

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QUANTIFICAITON OF HUNGRY HORSE RESERVOIR WATER LEVELS NEEDED TO MAINTAIN OR ENHANCE RESRVOIR FISHERIES

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Period Covered:

May 16, 1983 to October 14, 1983

Project Number: BPA 83-465

EXECUTIVE SUMMARY

This report reviews activities of the Hungry Horse Reservoir fisheries study from May 16 - October 14, 1983. The first six months of the project were concerned with testing of equipment and developing methodologies for sampling physical-chemical limnology, fish food availability, fish food habits, seasonal distribution and abundance of fish, migration patterns of westslope cutthroat trout and habitat quality in tributary streams. Suitable methods have been developed for most aspects of the study, but problems remain with determining the vertical distribution of fish. Catch rates of fish in vertical nets were insufficient to determine depth distribution during the fall. If catches remain low during the spring and summer of 1984, experimental netting will be conducted using gang sets of standard gill nets. Purse seining techniques also need to be refined in the spring of 1984, Sample design should be completed in 1984.

A major activity for the report period was preparation of a prospectus which reviewed: 1) environmental factors limiting gamefish production; 2) flexibility in reservoir operation; 3) effects of reservoir operation on fish populations and 4) model develop ment. Production of westslope cutthroat trout may be limited by spawning and rearing habitat in tributary streams, reservoir habitat suitability, predation during the first year of reservoir residence and fish food availability. Reservoir operation affects fish production by altering fish habitat and food production through changes in reservoir morphometrics such as surface area, volume, littoral area and shoreline length. The instability in the fish habitat caused by reservoir operation may produce an environment which is suitable for fish which can utilize several habitat types and feed upon a wide variety of food organisms. Analysis of factors governing reservoir operation indicated that some flexibility exists in Hungry Horse operation. Changes in operation to benefit gamefish populations would have little impact on total power production, but would entail shifts in the generation schedule.

We hope to develop, in cooperation with the USGS, a model which will predict the effects of reservoir operation on fish production. The model 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.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance rendered by numerous persons associated with the study. Ray Zubik, Steve Glutting, Gary Michael and Beth Morgan spent many long hours in the field collecting data under adverse conditions and many tedious hours in the laboratory. Ray had overall responsibility for processing collections of fish food organisms. Analysis of fish stomachs was done primarily by Beth. Steve was responsible for analyzing stream habitat and electrofishing data, and Gary aged fish scales, summarized fish trapping and movement data and prepared graphics. Terry Rolinger was an able field hand and Joyce Lapp's assistance in the laboratory was greatly appreciated.

Delano Hanzel assisted in computer work and he and Scott Rumsey aided in the preparation of boat and barge for purse seining. Joe Huston provided background information on reservoir fish populations and tributary habitat. Cathy Turley-Addington and Shirley Peterson typed various manuscripts.

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INTRODUCTION

The Pacific Northwest Electric Power Planning and Conservation Act passed in 1980 by Congress has provided a mechanism which integrates and provides for stable energy planning in the Pacific Northwest. The Act created the Northwest Power Planning Council and charged the Council with developing a comprehensive fish and wildlife program to protect and enhance fish and wildlife impacted by hydroelectric development in the Columbia River Basin. Implementation of the plan is being carried out by the Bonneville Power Administration. The Hungry Horse Reservoir study is part of that Council's plan.

The answer to the question of how reservoir operation can be modified to best benefit game fish populations is not a simple one. Reservoir operation affects game fish production by altering the physical environment through changes in reservoir morphometrics such as surface area, water volume, mean depth and shoreline length. Annual drawdown for flood control and power production adversely affects primary productivity (Woods 1982), benthos production (Benson and Hudson 1975), and fish production in reservoirs (Jenkins 1970). Graham et al. (1982) indicated that increased levels of drawdown in Hungry Horse Reservoir from 1965 to 1975 adversely affected the growth and survival of westslope cutthroat Trout(Salmo clarkilewisi).

This report presents data collected during the first year of a four year study designed to quantify seasonal water levels needed to maintain or enhance principal game fish species in Hungry Horse Reservoir. A maximum drawdown of 85 feet was proposed by Graham et al. (1982). This drawdown proposal may need to be reviewed in light of the additional data that will be generated by this study and the proposed changes in operation due to the "water budget" flows designed to enhance downstream migration of salmon smolts in the Columbia River.

This study was initiated in 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 zooplankton community, the benthic community, surface insects and forage fish. Quantify the use of each food

item by important fish species seasonally.

3) Determine how drawdown changes reservoir habitat for fish and fish food organisms and affects competition for food and space among fish.

4) Develop a model which will estimate impacts of various levels of drawdown on affected fish populations.

The first three years of the study will be concerned primarily with analysis of the effects of reservoir operation upon game fish production. Information was collected on the following aspects of the study during 1983.

1) Collection of water quality data including water temperature, dissolved oxygen, pH, conductivity and light transmission.

2) Collection of data on fish food organisms, including zooplankton, insects on surface film and benthos.

3) Collection of data on seasonal food habits of westslope cutthroat trout, bull trout (Salvelinus confluentus), mountain whitefish (Prospium williamsoni) and northern squawfish (Ptychocheilus oregonensis).

4) Collection of data on geographical, vertical and shoreline or offshore distribution of fish.

5) Assessment of movement patterns of westslope cutthroat trout and bull trout.

6) Assessment of habitat quality and barriers to upstream migration of cutthroat and bull trout spawners.

7) Testing and modification of equipment and methods.

8) Age and growth of game fish species.

9) Methods of data analysis.

10) Modification of sample design.

This report is concerned primarily with the analysis and modification of equipment, methods and sample design. Information is presented on the results of fish trapping, tagging operations and electrofishing population estimates in tributary streams, since these aspects of the study were completed for the field season. Data collected on other aspects of the study were incomplete and will be presented in the next report when an entire field season of information will be available.

This report also presents a prospectus which: 1) discusses environmental factors which may be limiting game fish production: 2) reviews criteria for reservoir operation and discusses flexibility which may exist in the system that may benefit game fish; and 3) discusses conceptual models which would predict the effect of reservoir operation on game fish production.

DESCRIPTION OF STUDY AREA

Hungry Horse Dam was completed in 1953 and the reservoir reached full pool elevation of 3,560 feet msl in July, 1954. The dam impounded the South Fork of the Flathead River eight km upstream from its confluence with the Flathead River (Figure 1). Hungry Horse is a large storage reservoir whose primary benefits are flood control and power production. The principal power benefit comes from generation at downstream projects. Water passes through 19 downstream projects, generating approximately 4.6 billion kilowatt hours of energy as compared to 1.0 billion at the Hungry Horse project.

The South Fork drains an area of approximately 4,403 km2 on the west side of the Continental Divide in northwestern Montana. The basin is underlain principally by sedimentary rocks. The entire basin is almost entirely within lands administered by the U.S. Forest Service with the upper part being in the Bob Marshall Wilderness area.

WATER QUALITY

Water quality data collected during 1978 indicated that Hungry Horse Reservoir is an oligotrophic body of water with low nutrient input and primary productivity. Low nutrient concentrations, transparent water and low algal standing crops are related to the basin's geology, the comparatively pristine nature of the South Fork watershed and reservoir morphology. Most of the drainage area is underlain by nutrient-poor Precambrian sedimentary rock which is frequently deficient in carbonates and nutrients. Mean concentrations of surface water total phosphorous, and dissolved orthophosphorous ranged, from 0.008 to 0.029 mg/l and 0.005 to 0.013 mg/l, respectively. Average concentrations of chlorophyll a in surface waters ranged from 0.45 to 0.82 mg/m^3 (Bureau of Reclamation 1981). Phosphorous concentrations were higher in the upper end of the reservoir, but chlorophyll a concentrations were highest near the dam and lower towards the upper part of the reservoir.

MORPHOMETRICS

The reservoir at full pool is 56 km in length with an area of 23,800 acres and a volume of 3,468,000 acre-feet. Useable storage for power production starts at elevation 3,336 msl and includes 2,982,000 acre-feet which is 86.0 percent of total full pool volume. Maximum drawdown of 224 feet would leave only 14.0 percent of full pool capacity (Table 1). The maximum drawdown on record of 128 ft. in 1972 reduced the volume to 37 percent of full pool. The recommended drawdown of 85 feet reduces reservoir volume to 53 percent of full pool capacity.

Annual retention and flushing times in Hungry Horse Reservoir vary between 2.51-3.12 and 0.84-5.31 years, respectively. Monthly values vary from 0.16 to 7.28 years for retention time and 0.21-

Table 1. Morphometric data for Hungry Horse Reservoir.

Drainage area (sq. miles)	1,700 (4,403 sq. km)
Average annual discharge (acre-ft)	2,386,918 (2.95 cubic km)[a/]
Surface area (acres)	23,800 (9,632 ha)
Pool length (miles)	35 (56 km)
Shoreline length (miles)	133 (213 km)
Shoreline developnent	5.95
Mean Depth	146 (44.5 m)
Storage capacity (acre-ft)	3,468,000 (4.24 cubic km)
Useable storage (acre-ft)	2,982,000 (3.68 cubic km)
Elevation at full pool (ft)	3,560 msl (1085.8 m)
Elevation at minimum pool (ft)	3,316 msl (1011.4 m)

a/ Based on unregulated flow from 1929-51.

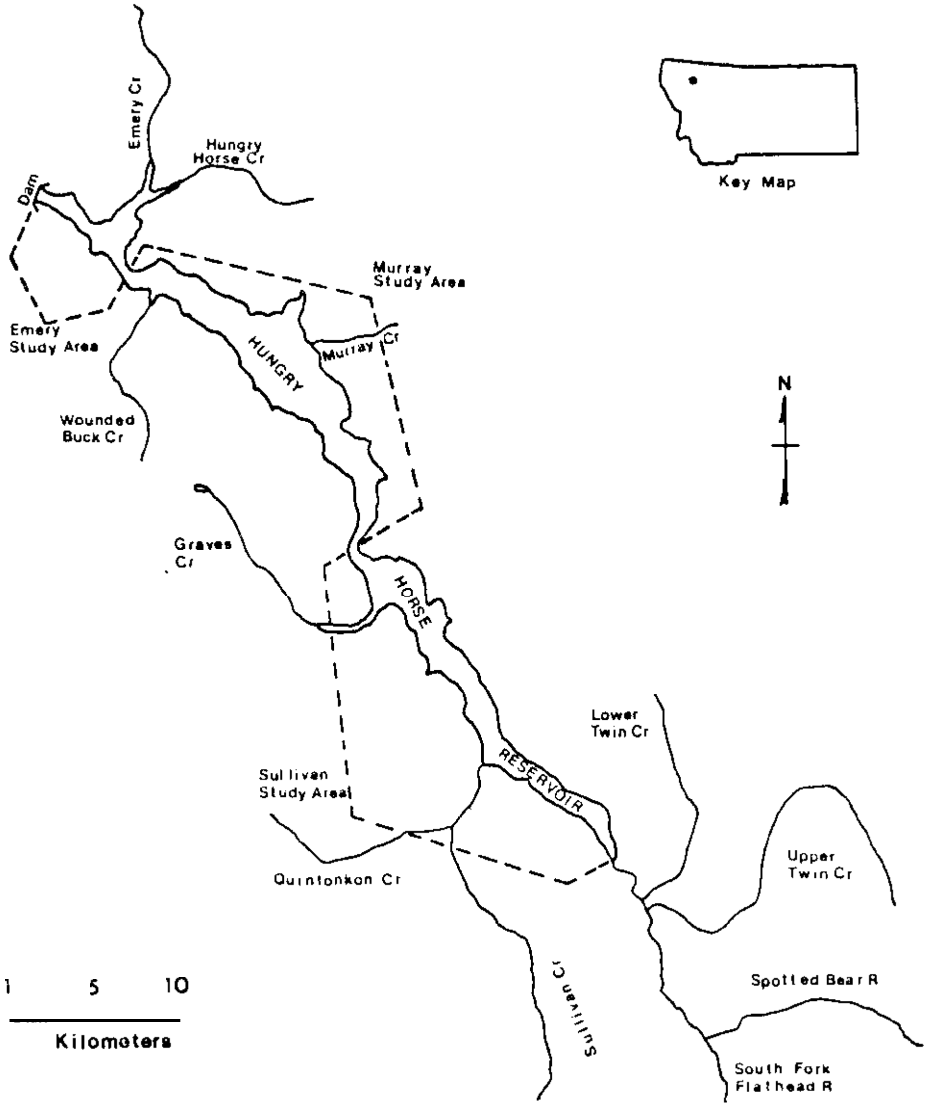

Figure 1. Map of Hungry Horse Reservoir showing study areas and major tributaries.

26.21 years for flushing time. Hungry Horse Reservoir has a comparatively low water exchange rate in comparison to Lake Koocanusa where annual retention and flushing times range between 0.14-0.66 and 0.14-0.62 years, respectively (Woods 1982). Short retention and flushing times were an important factor in limiting primary productivity in Lake Koocanusa, because they produced a weak thermal structure which allowed circulation of phytoplankton out of the euphotic zone. The comparatively long retention and flushing times in Hungry Horse Reservoir indicate thermal structure should be much less influenced by inflow and outflow currents than in Lake Koccanusa.

METHODS

RESERVOIR MORPHOMETRY

Hungry Horse Reservoir was segregated into the Emery, Murray and Sullivan areas based on reservoir morphometry and the effects of drawdown (Figure 2). Within each of these study areas a permanent sampling site was selected for water quality and zooplankton sampling. Vertical fish distribution and benthic macroinvertebrate samples were collected near these permanent sites. In addition to permanent sampling sites, transects were established across the reservoir at visual landmarks where randomly selected zooplankton, surface insect and purse seine samples were collected.

For this report, contour maps of the reservoir made prior to impoundment were used to determine surface area and shoreline length of the reservoir at 20 foot contour intervals. Contour intervals were digitized by geographic area (Emery, Murray and Sullivan).

Eventually, each 10-foot contour interval will be digitized by geographic area. 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.).

PHYSICAL LIMNOLOGY

Water temperature (°C), dissolved oxygen ($mg \cdot l^{-1}$), pH and specific conductivity (umhos.cm) were measured at the permanent sites. Measurements were taken biweekly from May through October with a Martek Mark V digital water quality analyzer, and monthly from November through March, when access to the reservoir was available. The vertical profile data were collected immediately below the water surface, 1, 3, 5, 7, 9, 11, 13, 15, 18, 21m and every three meters down to 60 m, then every five meters from 60 m to 100 m or the bottom. Calibration of the meter was done in the field from July through October and will be done in the laboratory immediately prior to field measurements from November through March when ambient air temperatures are below 0.0°C.

Light transmittance was measured in foot candles using a Protomatic photometer. Incident light was measured immediately above the water's surface. Light penetration was measured at depths of 90, 60, 30,15, 5 and 1 percent of the incident light. Greeson et al. (1977) defined the lower boundary of the euphotic zone as the 1.0 percent of incident light depth.

Water temperature, dissolved oxygen, pH, conductivity and light transmittance data by depth will be entered into computer data files and transferred to the U.S. Geological Survey WATSTORE system and the Environmental Protection Agency STORET system. Isopleth diagrams will be generated using a computer program titled

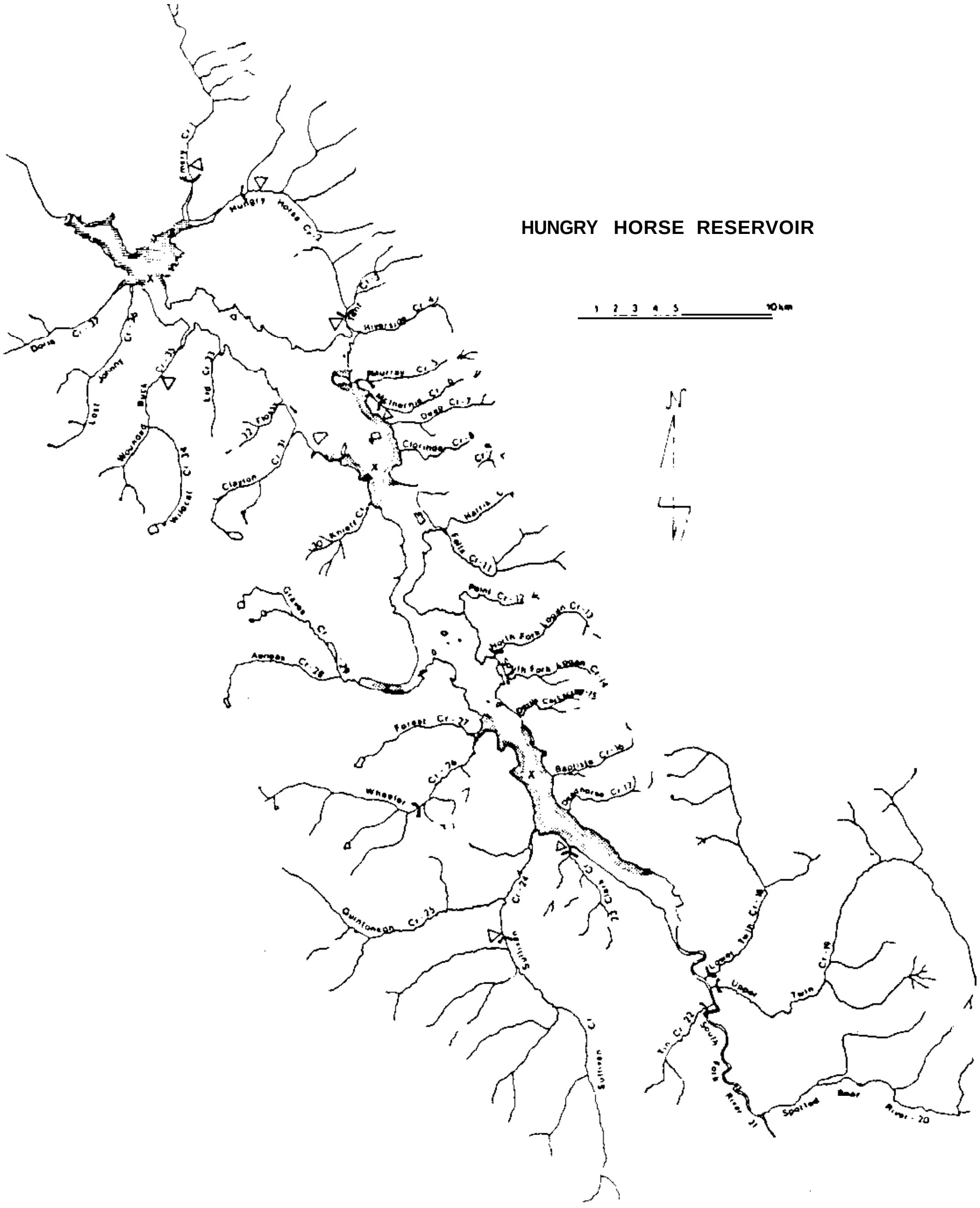

Figure 2. Map of Hungry Horse Reservoir showing nett(▒) areas water quality, vertical net and zooplankton stations (X), fish trap location (v), and electrofishing sections (V).

STAMPEDE (Wocds and Falter 1982). This data base will be used in correlation analyses of vertical zooplankton and fish distribution.

Several problems were encountered during measurements of physical-chemical profiles. Field calibration of the Martek meter requires approximately one hour at each sampling station. At ambient air temperatures below 0.0°C, field calibration was impossible and the conductivity probe would not function.

Water quality data collected in 1983 was within the range of values found in 1978 (Bureau of Reclamation 1981). The D.O., pH, and conductivity measurements were within tolerance levels for fish species within the reservoir.

Water quality data should be collected until October, 1984. After this date, temperature profiles will be taken biweekly and D.O., pH, and conductivity measurements seasonally. The U.S.G.S. should also collect primary productivity data from at least one area of the reservoir.

FISH FOOD AVAILABILITY

Zooplankton

Crustacean zooplankton were sampled from the upper 30 m of the water column. Three 30 m vertical tows were made biweekly in the Emery and Sullivan areas and two in the Murray area from late July through mid-December, 1983. A 153-micron mesh conical plankton net having a diameter of 0.115 m was used. In each area samples were collected at the permanent limnological buoy and a randomly selected site. An additional sample was taken in the Emery and Sullivan areas in Emery and Graves bays, respectively. 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 duplicate 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 collected monthly in the three areas at the permanent limnological buoys from mid-August through mid-December.

All zooplankton samples were preserved in the field with a mixture of four percent formalin and 40 $g.l^{-1}$ sucrose. Plankton net samples were diluted or concentrated in the laboratory to a volume where each one ml subsample contained approximately 80 to 100 organisms. Five 1.0 ml subsamples were counted and identified in a Sedgewick-Rafter counting cell using a binocular compound microscope at 40X total magnification. Separate counts were made to estimate the densities of Leptodora and Epischura using a Bogorov counting chamber (Gannon 1971) and a dissecting microscope at 38X total magnification. These organisms were relatively large, but seldom appeared in subsamples due to their low densities. Schindler trap samples were concentrated to approximately 10 ml. One ml subsamples were counted and identified in a Sedgewick Rafter counting cell until the whole sample had been enumerated. Biomass of zooplankters will be estimated using length-weight relationships (Bottrell etal.1976).

Cladocerans were classified to genus (Daphnia, Leptodora, Bosmina), and copepods were segregated into Calanoids (genus Diaptomus and Epischura) and Cyclopoids (genus Cyclops). All juvenile copepods were identified as nauplii. Densities were expressed as number per liter except for Epischura and Leptodora which were expressed as number per m^3 due to their low numbers. One random one ml subsample was used to measure carapace length of each individual plankter, using a graduated field in one ocular of the microscope.

The methods used to sample and analyze zooplankton samples appear to be suitable for providing the data required for this part of the study. We don't anticipate any significant changes in the zooplankton methodology, except taking additional samples which would increase precision of population estimates and their variances.

Surface Insects

Surface insects were sampled using a net towed along the water surface. The net consisted of a one meter wide frame attached to 3.17 mm mesh ace bobbin netting which 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 mesh netting to filter the surface water and retain all insects.

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

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

Temporal distribution of adult aquatic and terrestrial insects on the water surface was patchy. However, distributions in general were consistent between inshore and offshore zones at individual transects sampled. The time of sampling should be standardized to mid-afternoon. Samples should be collected more frequently to estimate temporal variation in the insect distribution.

Benthos

Benthos samples were collected during the fall and winter season with a Peterson dredge which sampled .042 sq. meters of reservoir bottom from a permanent transect. Three replicate samples were taken from each of the following depth intervals for a total of nine samples: 1) full pool elevation (3,560 ft.) to recommended drawdown elevation of 3,475 feet; 2) recommended to maximum drawdown on record at elevation 3,432 feet: and 3) below elevation 3,432 feet.

Benthos samples were sieved in the field through 5.6, 0.85, and 0.52 mm sieves and the material retained on the 0.52 mm sieve was preserved. All macroinvertebrates were picked from the sample and identified to order or class (Diptera, Ephemeroptera and Oligocheates). Number and total blotted wet weights were determined and densities were expressed as number$\cdot m^{-2}$ and grams$\cdot m^{-2}$.

FOOD HABITS

Food habits of the major fish species were assessed seasonally in all three areas. We collected stomachs from up to 10 westslope cutthroat and bull trout mountain whitefish and northern squawfish per size class. Food habits data will be analyzed according to methods of Leathe and Graham (1982).

Analysis has not been completed on stomach samples. Preliminary analysis of coarsescale and longnose sucker stomachs collected during August indicated they contained unrecognizable vegetable and detrital matter. We discontinued collecting sucker stomachs during fall sampling, but will continue cursory examination of sucker stomachs to ascertain whether they are consuming plankton or macroinvertebrates at any time during the year.

FISH ABUNDANCE AND DISTRIBUTION

Horizontal Floating and Sinking Gill Nets

Standard 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 19, 25, 32, 38, and 51 mm 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) fished perpendicular from shore. A sinking net consisted of a single net fished perpendicular from shore, Seven double floaters and three sinkers were set in the evening and retrieved the next morning on a monthly basis in each area (Figure 2).

All fish were removed from the nets, identified to species, with length (mm) and weight (g) recorded for each fish. Sex and state of sexual maturity (ripe, spent, mature, immature) were recorded for game fish. Scale samples were taken from all game fish and representative numbers from nongame fish.

Horizontal gill nets were effective in sampling for all fish species when they were distributed in inshore areas, except for pygmy whitefish (Prosopium coulteri and (Cottus sp.) sculpins. A more intensive effort on a seasonal basis, however, may provide more reliable data on fish abundance in nearshore areas than monthly collections.

Eight vertical gill nets were set monthly in two banks of four at permanent buoys in the Emery and Murray areas (Figure 2). Nets were set in the evening and retrieved the next morning using the methods described by Horak and Tanner (1964). The nets used were 3.1 m wide and 45.6 m deep. 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 recorded along with mesh size.

Vertical nets were inefficient in collecting fish in deep offshore waters in October and November. If catches in vertical nets remain low, we should develop another method to determine the vertical distribution of fish in relation to water temperature. This could entail the use of paired gang sets of floaters and sinkers and midwater sets of standard gill nets.

Acoustical Sampling

Hydroacoustic sampling was conducted using a recording chart depth sounder. Three permanent transects were located in each area. Hydroacoustic runs were made across these transects once monthly during the day and at night, beginning in October (Figure 2).

Comparatively few fish were detected with the acoustical gear in October and November. The gear identifies only a small percentage of the fish located near the surface, bottom and shoreline. If the number of fish located by hydroacoustic remains low, this sampling technique will be discontinued.

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 panels 76.2 m long 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 effectiveness of the seine. We have modified the seine by removing the bunt and replacing it with a 30.5 m long section of 19 mm mesh to reduce the drag during pursing. Intensive purse seining will be done during the spring and fall when fish are concentrated near the water's surface (McMullin 1979 and Leathe and Graham 1982) and thus susceptible to capture by the seine. Population estimates of major game species will be made using an area-density formula.

TRIBUTARY FISH POPULATIONS ANU HABITAT

Electrofishing Population Estimates

Population estimates were obtained on seven streams (Figure 2) to determine fish abundance. The two-pass procedure (Zippin 1956) was used to make estimates in streams with flows less than about 10-15 cfs. At higher flows the mark-and-recapture method was utilized (Vincent 1971). The section length for the mark-recapture estimate was 300 m as compared to 150 m for the two-pass method. A braided nylon block net (12.7 mm mesh) was placed at the lower and upper boundary of the shocking section for two-pass estimates. The fish were collected by electrofishing. A stationary plate located in the water near the generator was used as the cathode. The anode was hand held and connected to the Variable Voltage Pulsator with enough electrical cord to extend over the entire section. In general, methods outlined by Shepard and Graham (1983a) were used, except that block nets were not used in the mark-recapture sections.

Migratory Fish Populations

Box traps and leads covered with 6.4 mm square mesh hardware cloth were installed in Emery, Hungry Horse, Tent, Murray McInernie, N.F. Logan, S.F. Logan, Lower and Upper Twin, Tin, Clark, Sullivan and Wheeler creeks (Figure 2). Traps were checked twice daily and all fish were removed, anesthesized, measured and weighed. Species, length, weight, tag number, tag type and date were recorded for each fish. All fish longer than 250 mm were tagged with numbered anchor tags and fish 100 to 250 mm in length were tagged with numbered dangler tags. Scales were taken for age determination from representative samples of fish from each stream.

A velocity barrier and upstream trap was designed and installed at the permanent trap site in Hungry Horse Creek (Figure 2). A Wolf type downstream trap will be installed in spring, 1984 to monitor the downstream movement of juvenile and adult westslope cutthroat trout. An upstream box trap will be installed to capture spawning adults. Downstream traps will also be fished in Emery, Lower Twin, Sullivan, Forest and Wheeler creeks.

Habitat Quality

Habitat surveys were conducted in Emery, Hungry Horse, Tent, McInernie, Clark and Wounded Buck creeks (Figure 2) according to methods presented by Graham et al. (1980a). Reaches were separated on U.S.G.S. contour maps (1:24,000) using valley characteristics, channel gradient and amount of tributary inflow.

FISH AGE AND GROWTH

Scales were taken from a representative number of fish collected in traps and gill nets to determine growth and age composition of the population. The scales were collected from an area just above the lateral line along an imaginary line drawn between the posterior insertion of the dorsal and anal fins. Distances from the focus to annuli were measured to the nearest millimeter and the data recorded on computer coding sheets. The FIRE I program (Hesse 1977) will be used to calculate the body-scale relationship.

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 littoral 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 intergrated physical-chemical measurements will be correlated to depth distribution of zooplankton and fish to investigate what, if any, environmental 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 area1 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 relative 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 transform the net catch data to logrithmic numbers in order to normalize it. This will enable us 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. 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. Tags returned by anglers will bias the migration data, because anglers concentrate in the Emery area of the reservoir (Huston 1974). A fishing pressure survey is needed to correct the tag return data for this bias caused by differences in fishing pressure among the reservoir areas. 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 MDEWP (1983a, 1983b).

RESULTS AND DISCUSSION

TRIBUTARY FISH POPULATIONS

Electrofishing Population Estimates

Electrofishing population estimates for westslope cutthroat trout were made in Clark, Emery, McInernie, Quintonkon, Sullivan, Tent and Wounded Suck creeks in fall, 1983. Estimates were also made for bull trout in Quintonkon, Sullivan and Wounded Buck creeks. The locations of the electrofishing sections are shown in Figure 2 The cutthroat estimates ranged from 92 fish per 300 m of stream in Quintonkon Creek to 288 fish per 300 m in Emery Creek (Figure 3). Hull trout estimates in Quintonkon, Sullivan and Wounded Buck creeks ranged from 46-167 juveniles per 300 m of stream. Cutthroat and bull trout densities in the tributaries sampled indicates the fish habitat and productivity of these streams were comparable to other headwater streams in the Flathead drainage (Shepard 1983b).

Migratory Fish Populations

A total of 1,249 juvenile and 107 adult westslope cutthroat trout and 63 juvenile bull trout moved through downstream traps fished in tributaries of Hungry Horse Reservoir in 1983 (Table 2 and 3). The location of the traps is shown in Figure 2. Trapping efficiencies were low for most streams due to high stream flows in June and July. Many juvenile cutthroat emigrated prior to trap installation and after trap removal. Consequently, the number of fish trapped in each stream represents only a small percentage of the total juvenile emigration. Traps were installed later in the west side tributaries (Clark, Sullivan, Tin and Wheeler creeks), because stream flows remained high in these streams until late July.

Evaluation of the importance of each stream's juvenile cutthroat contribution to the reservoir recruitment is difficult for the reasons stated previously. It appears that Emery and Lower Twin creeks produce substantial numbers of juvenile cutthroat for the reservoir. Previous work by Huston (1973 and 1974) indicated that Hungry Horse and Sullivan creeks supported major spawning runs of westslope cutthroat trout. A total of 703 adults and 1,951 juvenile cutthroat were trapped in Hungry Horse Creek in 1971.

Trap data collected in 1983 indicates the North Fork Logan, McInernie and Tent creeks may also provide important spawning and rearing habitat for adfluvial cutthroat from the reservoir. The catch of outmigrant juveniles in these streams ranged from 71-141 fish. The catch of outmigrant juveniles in Clark, S.F. Logan, Murray, Tin and Wheeler creeks was quite low, ranging from four to 21 fish. Even though catches of cutthroat were low in Wheeler creek, it may support a large spawning run of westslope cutthroat

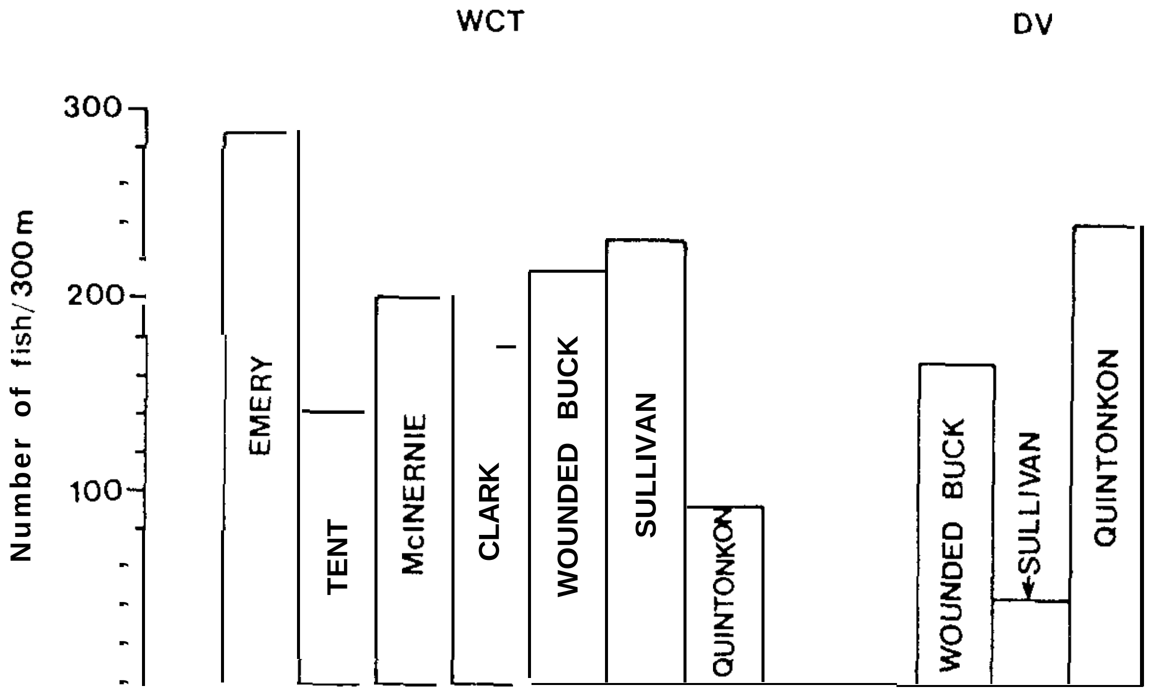

Figure 3. Population estimates for westslope cutthroat and bull trout per 300 meters of stream. Estimates are based on two-pass and mark-recapture electrofishing data collected in fall 1983.

Table 2. The catch of juvenile westslope cutthroat trout in downstream traps fished in tributaries to Hungry Horse Reservoir and the South Fork Flathead River, 1983.

Stream	Period trap operated	Days operated	Range and mean length of catch in mm	Catch			
				Jun	Jul	Aug	Total
Clark	7/19-8/2	14	126<163>210	--	19	2	21(9)[a]
Emery	6/23-7/4	9	107<153>215	253	192	--	445
Hungry Hrose	6/22-7/17	11	100<146>206	37	87	--	124
Logan, NF	6/15-7/15	16	92<129>210	73	40	--	113
Logan, SF	7'5-7'15	8	92<109>117	--	4	--	4
McInernie	6/15-7/15	21	95<128>168	106	35	--	141
Murray	6/14-7/5	13	106<149>174	29	--	--	29
Sullivan	7/22-8/10	14	118<170>217	--	69	19	88(16)
Tent	6'15-7'15	11	100<143>185	33	38	--	71
Tin	7'23-8'2	11	109<134>152		6	0	6
Twin, Lower	7'18-8'19	25	110<169>237	--	124	76	200(38)
Wheeler	7'26-8'9	14	151<170>188	--	4	3	7
TOTAL				531	618	100	1249

a/ Juvenile bull trout caught in parentheses.

Table 3. The catch of spent westslope cutthroat trout spawners in downstream traps fished in tributaries to Hungry Horse Reservoir, 1983.

Stream	Period trap operated	Days operated	Range and mean length of catch in mm	Catch			
				Jun	Jul	Aug	Total
Clark	7/9-8/2	14	---	--	--	--	--
Emery	6/23-7/4	9	363<377>397	3	--	--	3
Hungry Horse	6/22-7/17	11	291<347>397	14	10	--	24
Logan, NF	6'15-7'15	16	268<344>387	11	1	--	12
Logan, SF	7/5-7/15	8	---	--	--	--	--
McInernie	6/15-7/15	21	297<360>400	5	2	--	7
Murray	6/14-7/5	13	305<342>364	8	--	--	8
Sullivan	7/22-8/10	14	329<374>416	--	8	6	14
Tent	6/15-7/15	11	305<359>392	23	1	--	24
Tin	7/23-8/2	11	---	--	--	--	--
Twin, Lower	7/18-8/19	25	250<337>400	--	9	6	15
Wheeler	7/26-8/9	14	---	--	--	--	--
TOTAL				64	31	12	107

and produce considerable numbers of juveniles for the reservoir (Joe Huston, pers. comm.). The trap was installed in 1983 after the peak emigration of cutthroat juveniles had occurred. More trap and habitat data needs to be collected on tributaries before their importance as spawning and rearing streams for adfluvial cutthroat trout from the reservoir can be determined.

The size range and average lengths of juvenile cutthroat caught varied among the streams. The largest cutthroat were trapped in Dower Twin and Sullivan creeks and averaged 169 and 170 mm in total length, respectively. Cutthroat in Emery and McInernie creeks averaged 153 and 128 mm in total length, respectively. The lengths of the fish trapped indicates that most emigrants were age class II and III. Shepard et al. (1982) and May (1975) reported that juvenile cutthroat emigrants from Middle Fork Flathead tributaries and Young Creek were comprised primarily of age II and III fish.

Juvenile bull trout were trapped in Clark, Sullivan and Lower Twin creeks. Population estimates indicated that Sullivan and Quintonkon creeks have good populations of juvenile bull trout (Figure 3). Sullivan and Quintonkon creeks are reported to have spawning runs of bull trout (Joe Huston, pers. comm.).

FISH MOVEMENTS

Data on the temporal and spatial distribution of migrating fish in the Hungry Horse Reservoir are necessary to identify the effects of reservoir operation upon fish stocks and movement patterns. Previous work (Huston 1974) indicated that distinct stocks of westslope cutthroat trout may inhabit the reservoir. It appeared that some fish spawning and rearing in Sullivan Creek migrated to the lower part of the reservoir, while cutthroat from Hungry Horse Creek had a tendency to move to the upper part of the reservoir. Drawdown should impact the Hungry Horse Creek cutthroat more severely than the Sullivan Creek stock because of the more pronounced effects of drawdown upon fish habitat in the upper part of the reservoir. An 80 foot drawdown reduces the surface area by 50 percent in the Sullivan area.

During the field season, a total of 2,167 juvenile westslope cutthroat and 144 bull trout were marked with dangler tags in 15 tributaries to Hungry Horse Reservoir and the South Fork Flathead River immediately upstream from the reservoir (Table 4). Approximately 56 percent of the cutthroat were caught in traps, 30 percent by angling and 14 percent by electrofishing (Table 5).

Movement information was obtained on 13 juvenile cutthroat by the return of 10 tags by anglers and three tags from gill net catches. Most fish were caught within 10 km of the stream mouth in which they were tagged (Figure 4). One juvenile cutthroat tagged in the North Fork Logan Creek was recaptured 28.2 km downstream

Table 4. Number of juvenile and spent and adult westslope cutthroat trout (WCT) and juvenile bull trout (DV) tagged in tributaries to Hungry Horse Reservoir and South Fork River in June, July, August and September of 1983.

	Number of juvenile WCT tagged					Number of adult WCT tagged					Number of juvenile DV tagged				
Location	Jun	Jul	Aug	Sep	Total	Jun	Jul	Aug	Sep	Total	Jun	Jul	Aug	Sep	Total
Clark	---	19	2	47	68	---		---			---	9		---	9
Emery	257	191	---	72	520	3	---		---	---	---	---		---	---
Hungry Horse	71	89		48	208	21	10	---		31		---			
Logan, N.F	68	38	---		106	12	1			13		---			
Logan, S.F.	---	4	---		4	---		---				---			
McInernie	99	34	---	35	168	5	2	---	---	7		---		5	5
Murray	22	---	---		22	8	---	---	---	8		---			
Quintonkon	---	---	---	11	11	---		---				---		7	7
Sullivan	---	156	338	43	537	---	10	2		12		11	6	10	27
Tent	33	38	---	31	102	21	1	---		22	---	---	---	2	2
Tin	---	6	---	---	6	---	---	---		---	---	---	---	---	---
Twin Lower	---	129	237	---	366	---	9	18		27		25	14		39
Twin, Upper	---	2	---		2		---	---				---			
Wheeler	---	7	13		20			---				---			
Wounded Buck	---	---	---	27	27			---				---		25	25
TOTAL	570	713	590	314	2,167	70	33	20	---	123	---	45	20	49	114

Table 5. Number of juvenile and spent adult westslope cutthroat trout (WCT) and juvenile bull trout (DV) tagged in tributaries to Hungry Horse Reservoir and South Fork River, 1983. These fish were collected in fish traps and by electrofishing and angling.

	Number of juvenile WCT tagged				Number of adult WCT tagged				Number of juvenile DV tagged			
Location	Trap	Electro-fishing	Angling	Total	Trap	Electro-fishing	Angling	Total	Trap	Electro-fishing	Angling	Total
Clark	21	47	--	68	--	---	---	---	9	---	---	9
Emery	439	72	9	520	3	---	---	3	--	---	---	--
Hungry Horse	122	48	38	208	31	---	---	31	--	---	---	--
Logan, N.F.	106	---	---	106	13	---	---	13	--	---	---	--
Logan, S.F.	4	---		4	--	---	---	---	--	---	---	--
McInernie	133	35	II	168	7	---	---	7	--	5	---	5
Murray	22	---	--	22	8	---	---	8	--	---	---	--
Quintonkon	--	11	--	11	--	---	---	---	--	7	---	7
Sullivan	88	43	406	537	6	---	6	12	16	10	1	27
Tent	71	31	--	102	22	---	---	22	--	2	---	2
Tin	6	---	--	6	--	---	---	---	--	---	---	--
Twin Lower	200	---	166	366	13	---	14	27	38	---	1	39
Twin, Upper	2	---	--	2	--	---	---	---	--	---	---	--
Wheeler	7	---	13	20	--	---	---	---	--	---	---	--
wounded Buck	--	27	--	27	--	---	- -	---	--	25	---	25
TOTAL	1221 (56)a/	314 (14)	632(30)	2,167	103(84)	---	20(16)	123	63(55)	49(43)	2 (2)	114

a/ Percent of trout caught by trapping, electrofishing and angling.

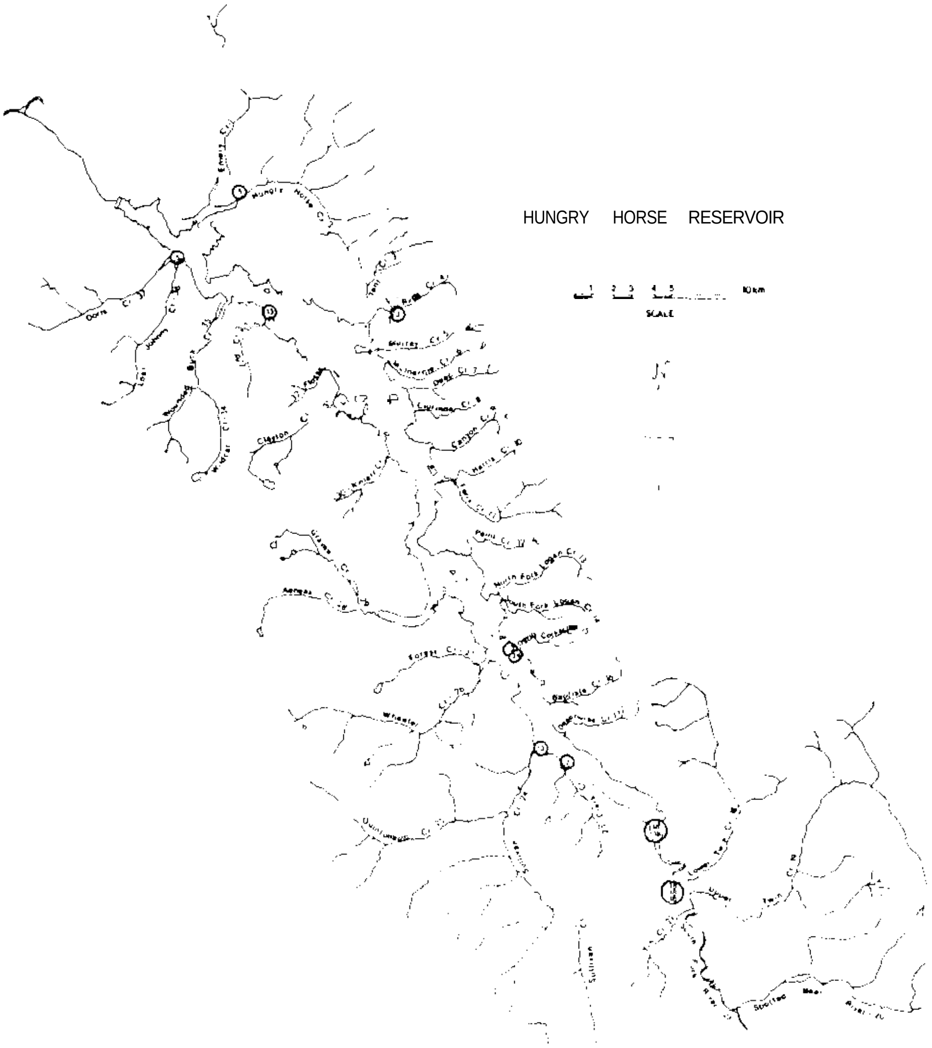

Figure 4. Map of Hungry Horse Reservoir showinq locations of westslopc cutthroat trout taq returns. The circled numbers indicate location of tag return with the **number** indicating the stream in which the fish was taqged.

near Lid Creek. The one bull trout return indicated that the fish had moved approximately 5.2 km downstream.

During 1983, 123 adult westslope cutthroat trout were tagged in eight tributaries to Hungry Horse Reservoir and the South Fork Flathead River (Table 4). One hundred three (84%) of these fish were caught in traps as compared to only 20 (16%) captured by hook and line sampling (Table 5). Only five adult tags were returned during the summer and fall of 1983 (Figure 4). One fish tagged in Hungry Horse Creek was recaptured approximately 50 km upstream near Clark Creek. More tag return data are needed before it can be ascertained if there are distinct cutthroat stocks inhabiting specific areas of the reservoir.

PROSPECTUS

INTORDUCTION

The Pacific Northwest Electric Power Planning and Conservation Act of 1980 included a mandate to provide for effective mitigation measures for damage to fishery resources caused by existing hydroelectric projects. As a result, the Northwest Power Planning Council created by the Act developed a fish and wildlife program for the Columbia River Basin. The program included a "water budget" which would allow fishery managers to manipulate flows in the mid-Columbia and lower Snake rivers to improve survival of anadromous salmonid smolts. Large headwater storage reservoirs such as Hungry Horse may be required to change their operation schedule to meet the demands of the water budget for increased spring and early summer flows in the Columbia River. Operations at Hungry Horse Dam have recently been modified to improve conditions for spawning and incubation of kokanee eggs in the mainstem Flathead River.

The current study was designed to evaluate reservoir drawdown guidelines which would maintain or enhance populations of the primary game species in Hungry Horse Reservoir. When completed, this study will provide the information needed to determine the effectiveness of the drawdown limit and balance potentially conflicting demands for Hungry Horse water both in reservoir and downstream.

This prospectus reviews: 1) previous work on reservoirs, 2) life histories of important fish species in Hungry Horse Reservoir, 3) how reservoir operation may affect these fish populations, 4) flexibility in reservoir operation and how it could be modified to increase production of westslop cutthroat trout, and 5) models which may be used to predict the effects of reservoir operation upon important fish species such as cutthroat trout.

Reservoir fish populations often develop in the following manner. Immediately following impoundment, fish populations expand and an adjustment is made from a fish community dominated by lotic species to one dominated by lentic species. Fish populations increase because more surface area of habitat is available and high water levels flood terrestrial areas increasing food supplies and nutrients (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 a loss of a portion of the food supply and nutrients (Ellis 1937).

Aass (1960, cited in Ploskey 1982) stated that 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 implies that planktivorous fishes 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 Jacobi 1978, Benson and Hudson 1975, Claflin 1968, Elder 1964, Fillion 1967, Kimsey 1958). Conversely, zooplankton populations often increase dramatically immediately following impoundment and remain relatively constant (even in fluctuating reservoirs). Declines in zooplankton abundance after impoundment have been attributed to loss of productivity caused by leaching of nutrients from the recently flooded reservoir bottom (Kimsey 1958, Grimas 1967, Miller and Paetz 1959, Nilsson 1964).

The fishery in Hungry Horse Reservoir is unique to most western coldwater reservoirs in that the principal sport fish, westslope cutthroat and bull trout, are native species which are maintained entirely by natural reproduction. Most game fish populations in large coldwater storage reservoirs are maintained by plants of hatchery rainbow and brown trout (Marrin and Erman 1982, Geer 1978).

PHYSICAL-CHEMICAL ENVIRONMENT

Reservoir volume and surface area decrease rapidly as drawdown occurs (Figure 5). Shoreline length actually increases at intermediate levels of drawdown (Figure 6). Inflection points in the curves occur at approximately elevation 3480 where extensive flat areas are dewatered, especially in the upper part of the reservoir. Reduction in volume is largest from elevations 3560-34880, where 45 percent of the storage capacity is contained.

Reservoir operation has varied considerably since Hungry Horse was first filled. Annual drawdown for flood control and power production usually reaches its maximum in March or April. Historic operation can be classified into three periods based on average annual maximum drawdown: 1) 1955-64 when drawdown averaged 64 ft., 2) 1965-75 when drawdown averaged 92 ft., and 3) 1976-82 when drawdown averaged 66 ft. Maximum drawdown has ranged from 31 ft. in 1963 to 128 ft. in 1972 with a mean of 76 ft. (Figure 7). Maximum drawdown in 28 years of record has been below the proposed 85 foot level in eight years. Water requirements for water budget flows may modify reservoir operation in 1984.

Retention and filling times for Hungry Horse Reservoir are high ranging from 2.51-3.12 and 0.84-5.31 years, respectively. It appears that reservoir operation has less effect upon the thermal structure of Hungry Horse Reservoir than bake Koocanusa.

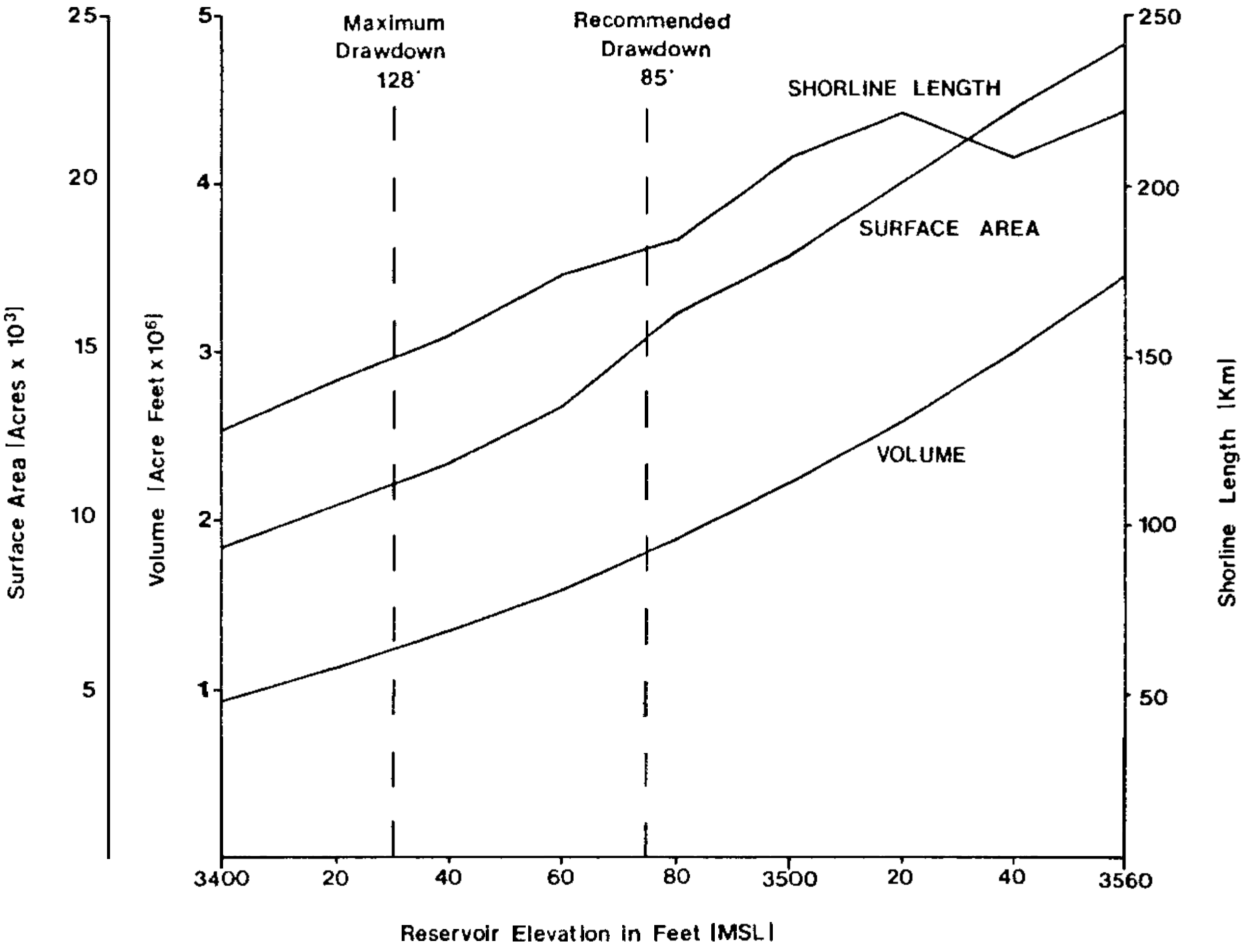

Figure 5. The relationship of reservoir elevation to surface area, volume and shoreline length of Hungry Horse Reservoir.

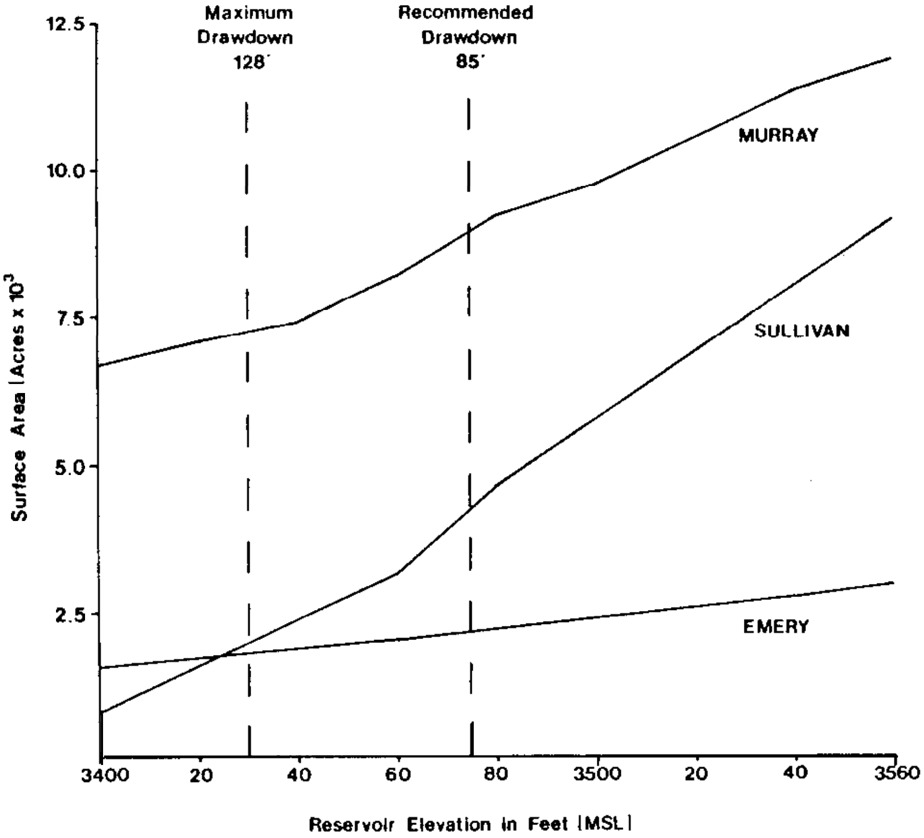

Figure 6. The relationship between surface area and reservoir elevation in the Emery, Murray and Sullivan areas of Hungry Horse Reservoir.

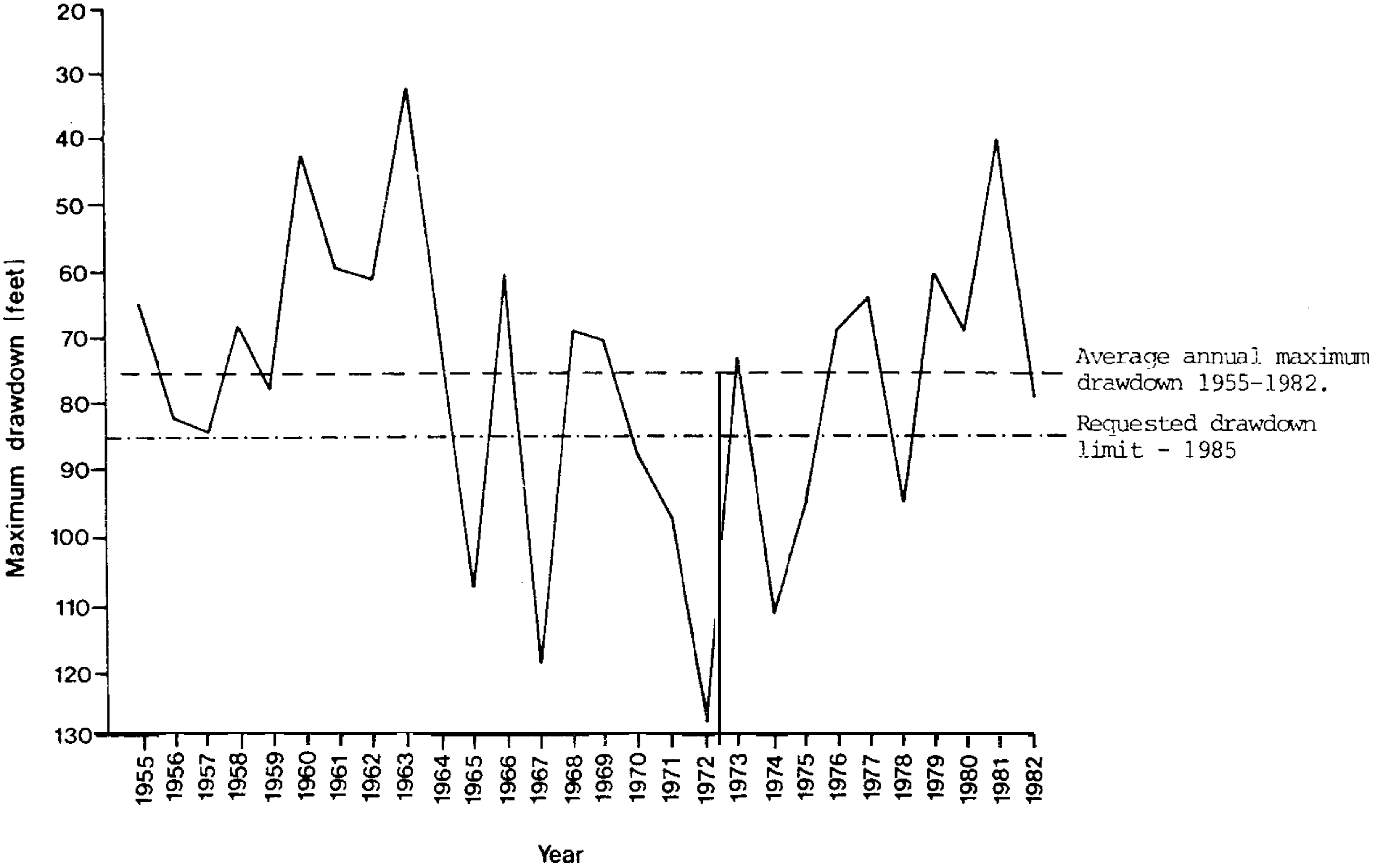

Figure 7 Annual maximum drawdown of Hungry Horse Reservoir for the years 1955-1982. Includes drafting for flood control as well as power production. Reservoir did not fill during 1973 and 1977.

Little data has been collected on the water quality in Hungry Horse Reservoir. As noted previously, Hungry Horse is an oligotrophic body of water, low in nutrients and total solids as indicated by specific conductance.

BIOTIC COMMUNITY

Phytoplankton

Primary productivity studies have not been conducted on Hungry Horse, but Chlorophyll a concentrations in 1978 ranged from 0.45 to 0.82 mg/m^3 (Bureau of Reclamation 1981). Primary productivity as indicated by Chlorophyll a concentrations is comparable to Lake Koocanusa (Woods 1982) which was on the low end of the oligotrophic scale.

Phytoplankton are the primary producers in the open-water zones of lakes and are especially important in fluctuating reservoir environments where annual dewatering of the littoral zone prevents the establishment of rooted aquatics. Production of phytoplankton is controlled primarily by energy (sunlight) and nutrient availability. Phytoplankton are the primary producers in Hungry Horse Reservoir, primary consumers are zooplankton and benthic invertebrates, secondary consumers are zooplankton or fish and tertiary consumers are fish.

Fish Food Organisms

Initial analysis of the zooplankton samples collected in 1983 indicated that population densities in Hungry Horse were comparable to those found in Flathead Lake, but lower than densities in Lake Koocanusa (Leathe and Graham 1982, Irving and Falter 1981).

Zooplankters occupy an important position in the food web and energy relationships of lakes and reservoirs. Zooplankton feed upon phytoplankton and are the primary consumers in the food chain (Reid 1961). Westslope cutthroat and bull trout pass through an early growth stage in which zooplankton is the major source of food. Underlying all evaluations of productivity of animals are their trophic relationships with plants and other animals (Wetzel 1975). Zooplankton, benthos and terrestrial insects provide a pathway through which energy is transferred from primary producers to fish.

The benthos community of Hungry Horse Reservoir consisted primarily of Dipteran larvae and Oligochaetes. Dipterans were utilized by cutthroat in Lake Koocanusa primarily in the spring and early summer when they emerged and were available in the water column. Oligochaetes were not consumed by cutthroat or rainbow trout (McMullin 1979).

Fish Species

Historic Status

Prior to construction of Hungry Horse Dam in 1954, the South Fork Flathead River drainage was considered the major spawning area for adfluvial fish stocks from Flathead Lake. Substantial numbers of bull trout and westslope cutthroat trout spawned in the South Fork drainage along with smaller numbers of mountain whitefish and kokanee salmon (Oncorhynchus nerka). Native fish species in the South Fork drainage prior to dam construction included west-slope cutthroat, bull trout, mountain whitefish, northern squawfish, largescale sucker (Catostomus macrocheilus), longnose sucker (Catostomus catostomus), pygmy whitefish (Prosopium coulteri) and sculpins (Cottus sp.).

The native species comprise almost the entire fish population in the reservoir. They are considered abundant except for pygmy whitefish and longnose suckers which are rated as rare and common, respectively (Table 6). Pygmy whitefish may be more abundant than net data indicates, because they are not vulnerable to being caught in shoreline net sets.

Exotic species, such as arctic grayling (Thymallus arcticus), yellowstone cutthroat (Salmo clarki bouvieri), and rainbow trout (Salmo gairdneri) are present but rarely collected. Approximately five million grayling fry were planted in the reservoir in the mid-1950's and 13,000 adult fish in 1965. No other fish species have been planted in the reservoir. However, rainbow trout and Yellowstone cutthroat trout reached the reservoir by drifting downstream from high mountain lakes planted from 1930's through 1960. Since 1970, westslope cutthroat trout has been the only species planted in the South Fork drainage. Interbreeding has occurred between westslope cutthroat, Yellowstone cutthroat and rainbow trout in six tributaries which have lakes as their source (Leary et al. 1983). The adfluvial strain of westslope cutthroat trout inhabiting the reservoir appears to be a pure strain, but more electrophoretic work is needed to substantiate the stock integrity.

Fisheries studies on Hungry Horse Reservoir began in 1958 and consisted primarily of monitoring spawning runs of westslope cutthroat trout into Hungry Horse Creek, modifying and/or removing barriers to upstream fish migration, and monitoring reservoir fish populations with sinking gill nets.

Cutthroat populations in the reservoir were initially limited by inadequate recruitment of juveniles from the tributary streams. Fish passage problems caused by poor culvert installation on the road around the reservoir were improved from 1963 to 1965 by the Montana Department of Fish, Wildlife and Parks and U.S. Forest Service (Huston 1970). This program resulted in increased spawning

Table 6. The relative abundance of fish species in Hungry Horse Reservoir as determined by gill net catches and creel surveys from 1958 to 1983. Abbreviations are given in parentheses.

Species	Scientific name	Relative abuncance a/
	Native Species	
Westslope cutthroat trout (WCT)	*Salmo clarki lewisi*	A
Bull trout (DV)	*Salvelinus confluentus*	A
Mountain whitefish (MWF)	*Prosopium williamsoni*	A
Pygmy whitefish (PWF)	*Prosopium coulteri*	R b/
Northern squawfish (NSQ)	*Ptychocheilus oregonensis*	A
Largescale sucker (CSU)	*Catostomus macrocheilus*	A
Longnose sucker (LnSU)	*Catostomus catostomus*	C
Sculpin species	*Cottus sp.*	R
	Exotic Species	
Rainbow trout (RB)	*Salmo gairdneri*	R
Yellowstone cutthroat trout (YCT)	*Salmo lewisi bouvieri*	R
Arctic grayling (GR)	*Thymallus arcticus*	R

a/ Relative abuncance: A= abundant, c = common, R = rare.

b/ Pygmy whitefish may be more abundant than net catches indicated because they inhabit deep offshore waters and are not vulnerable to shoreline net sets.

success and subsequent recruitment of juvenile cutthroat to the reservoir.

Westslope cutthroat trout is the primary species sought by anglers in Hungry Horse Reservoir. From 1961 through 1969, westslope cutthroat comprised 95 percent of the catch with the remainder consisting of mountain whitefish, bull trout and grayling (Huston 1971). A fishery for mountain whitefish occurs in tributary streams having spawning runs in the fall.

The larger average drawdown from 1965-1975 appeared to adversely affect westslope cutthroat trout populations (Huston 1975). Spawning runs into Hungry Horse Creek declined and growth of age IV cutthroat trout was slower during this period then during periods of smaller drawdowns.

Life History of Westslope Cutthroat Trout

Cutthroat trout inhabiting Hungry Horse Reservoir are thought to be derived from Flathead Lake fish trapped behind Hungry Horse Dam when it impounded the South Fork. Three distinct life history patterns of westslope cutthroat commonly occur throughout their native range (Behnke 1979). Juvenile adfluvial westslope cutthroat spend one to three years in the tributaries before emigrating to Hungry Horse Reservoir. They generally reside in the reservoir for one to three years, mature and return to their natal stream in June and July to spawn and complete the life cycle. Fluvial westslope cutthroat trout are found in the mainstem of the South Fork. These fish have a similar life cycle to the adfluvial strain, except that they grow and mature in a large river rather than a lake or reservoir. The resident strain of westslope cutthroat trout completes its entire life cycle in small headwater streams. These fish seldom reach total lengths longer than 200 mm, whereas fluvial and adfluvial cutthroat trout attain total lengths up to 400-450 mm.

The spawning run of cutthroat trout into Hungry Horse Creek typically begins during the last week of May and continues into the first week of July (Huston 1972). Spawning runs into west side tributaries generally occur two to three weeks later than in Hungry Horse Creek due to later runoff and cooler water temperatures. Reservoir cutthroat utilize tributaries to the South Fork of the Flathead River from the head of the reservoir to Meadow Creek. Meadow Creek gorge, located 37 km upstream from the reservoir, appears to be a barrier to further upstream movement in the South Fork (Huston 1973). Fish passage during spring runoff is especially difficult due to the high water velocities and violent turbulence.

Cutthroat trout in tributaries of the North Fork Flathead River spawned over gravels ranging in size from 2-50 mm (Shepard et al. in prep.). Average water depths over redds ranged from 17 to 20 cm and average water velocities ranged from 0.30 to 0.37 mps. Incubation time varies inversely with temperature with eggs hatching within 28 to 40 days. Fry remain in the gravel for approximately two weeks after hatching and emerge 45-75 days after egg fertilization, depending on water temperatures. Fry emerge from the streambed from early July to late August in upper Flathead River Basin tributaries.

Cutthroat trout emerged as fry at a length of approximately 20 mm and grew 20 to 40 mm during the first year. Cutthroat trout in the upper Flathead River tributaries did not form an annulus the first year if only one or two growth rings (circuli) had formed by the beginning of the first winter (Shepard et al. in prep.). An estimated 61 percent of the cutthroat trout from the upper Flathead basin had not formed a first year annulus, similar to results from North Fork Clearwater and Upper St. Joe rivers. Preliminary analysis of scales from Hungry Horse Reservoir tributaries indicates that many cutthroat did not form an annulus the first year. Fish from east side tributaries had a higher frequency of annulus formation than the west side streams.

Westslope cutthroat trout juveniles generally begin moving downstream out of tributaries when streamflows decline in June. Peak emigration from Hungry Horse Creek occurred in July and continued into August (Huston 1972). Smaller numbers of juveniles continued to emigrate from tributaries of Lake Koocanusa in August, September and October (May 1975).

In 1968 and 1970, the juvenile emigrants from Hungry Horse Creek averaged 32.8 percent age I, 56.0 percent age II, and 11.2 percent age III (Huston 1972). Juvenile cutthroat from North and Middle Fork tributaries emigrated primarily at age II or III with fewer fish leaving at age I and IV (Shepard et al. 1982).

Growth of juvenile cutthroat in Hungry Horse Creek was faster than other streams in the upper Flathead basin. Age III fish averaged 162 mm in total length as compared to 132 and 138 mm in Worth Fork and Middle Fork tributaries, respectively (Fraley et al. 1981). Growth was most rapid during the first year of residence in the reservoir with migration class two fish attaining a growth increment of 133 mm (Huston 1972).

Habitat preference of juvenile cutthroat trout during their first year of life in the reservoir is unknown. We suspect these juveniles are especially vulnerable to predation until they become too large for the majority of predators to consume. Initial data collected in this study indicate that juveniles concentrate in the upper part of the reservoir, The upper reservoir is characterized by extensive littoral areas and cover in the form of driftwood, fallen trees and stumps. It appears that juvenile cutthroat remain near shoreline areas feeding primarily upon aquatic Diptera and terrestrial insects. Cover could be a key factor in reducing predation rates on juvenile cutthroat trout. Consequently, reductions in the quality and quantity of cover may adversely affect the survival of juvenile cutthroat.

Distribution of westslope cutthroat trout after their first year of reservoir residence appears to be influenced primarily by temperature and food availability. Cutthroat trout in Lake Koocanusa preferred temperatures in the 15-18°C range and avoided temperatures higher than 19°C (McMullin 1979). When surface water temperatures were greater than 19°C, Lake Koocanusa cutthroat sought cooler waters. When surface temperatures were below 17°C, cutthroat were concentrated in the upper three meters of the water column. Dwyer and Kramer (1975) found that the scope of activity for cutthroat trout was highest at 15°C.

The diet of westslope cutthroat trout in Lake Koocanusa was comprised primarily of Daphnia terrestrial insects and aquatic Diptera (McMullin 1979). Small cutthroat (<330 mm in length) fed primarily upon Daphnia except for the summer. Approximately 45 percent of the growth energy was supplied by Daphnia with terrestrial insects and aquatic Diptera providing an estimated 42 and 13 percent of the growth energy, respectively. Daphnia was the most important food item in the diet of large cutthroat in the winter. Use of aquatic Diptera (mostly pupae) peaked in May and June. Terrestrial insects were the most important food during the summer and fall.

Cutthroat trout caught in Hungry Horse Reservoir in July and August, 1978 differed substantially in their food habits from cutthroat caught in Lake Koocanusa during the same period. Terrestrial insects and aquatic Diptera adults made up most of the diet. Daphnia was a minor constituent in the stomachs of Hungry Horse fish, but an important constituent in Lake Koocanusa fish. Terrestrial insects were especially important in the diet of small cutthroat in Hungry Horse Reservoir.

Life History of Bull Trout

Bull I-rout also have populations which exhibit the resident, fluvial and adfluvial life cycle patterns. Bull trout, however, are fall spawners and their eggs hatch in March as compared to July and August for cutthroat. Bull trout mature later, live longer and the adults are much more piscivorous than cutthroat.

Adult bull trout in the upper Flathead River spawned during a relatively short period in September and October. Spawning activity began when maximum daily water temperatures dropped below 9°C (Shepard et al. 1982). Huston (1973) noted bull trout in Hungry Horse Reservoir congregated at the upper end in the spring and began their spawning movements up the South Fork in June and July. Spawning occurred in September and October in the upper South Fork. Tag return data indicated that bull trout spawned as far upstream as Danaher Creek, approximately 110 km upstream from the reservoir. Passage through the Meadow Creek gorge was possible in July and August because of reduced flows. Reservoir tributaries used by bull trout include Wheeler and Sullivan creeks. Adults move into these streams in August and September and spawned in September and October.

Areas selected for spawning were characterized by lower channel gradient, high stream order, a large percentage of gravel and cobble in the streambed (Shepard et al. 1982). Adult bull trout also selected areas: 1) directly influenced by groundwater recharge: 2) at interfaces between high gradient and low gradient portions of a stream channel; and 3) where the stream split into multiple channels. The latter two sites are characterized by an aggrading stream channel where loosely compacted gravels have been recently deposited.

Timing of emigration was similar to that of cutthroat in the North and Middle Forks of the Flathead River. Juvenile bull trout emigrate6 during June and July (Shepard et al. 1982). Juvenile bull trout were captured while emigrating from Lower Twin and Sullivan creeks in July and August, 1984. Outmigration probably began in June, but fish traps were not installed until July due to high flows.

The age composition of bull trout emigrants from the upper Flathead River tributaries was 18, 49 and 32 percent for age I, II and III fish, respectively. These results are comparable to those found in other large lake-river systems of Idaho and British Columbia.

Habitat preferences of juvenile bull trout during their first year of residence in reservoirs has not been documented, but we speculate that they are closely associated with the bottom in shoreline areas where concentrations of small fish are located. The importance of cover as a habitat component in reservoirs is not known, but juvenile bull trout in streams are closely associated with cover. A paucity of suitable cover due to reservoir drawdown may be an important factor influencing survival of juvenile bull trout during their first year of life in the reservoir.

In Flathead Lake, the diet of juvenile bull trout less than 350 mm in length in Flathead Lake consisted almost entirely of fish (Leathe and Graham 1982). Less than one percent of their diet consisted of invertebrates. Initial analysis of juvenile bull trout stomachs from Hungry Horse Reservoir indicated that terrestrial insects were eaten in the summer and fall.

Fish were the most important item in the diet of large bull trout (>350 mm in length) in Flathead bake (Leathe and Graham 1982). The three whitefish species (mountain, lake (<u>Coregonus clupeaformis</u>) and pygmy) were the most important year round item food item. Mountain whitefish were the dominant food item eaten by bull trout in Hungry Horse Reservoir (Joe Huston, MDFWP personal communication). Bull trout in other inland northwest lakes were found also to feed primarily on fish.

The distribution of bull trout after their first year of life in the reservoir appears to be primarily controlled by water temperature and food availability. Bull trout are a benthic oriented species concentrated in relatively shallow water in the spring and fall (Leathe and Graham 1982). In Flathead Lake, summer catches were highest in sinking nets set in water deeper than 14 m and corresponding to the lower end of the thermocline with temperatures of 15°C or less. The catch of bull trout in Hungry Horse Reservoir in 1984 indicated that bull trout moved into deeper waters when surface temperatures were above 17-18°C.

Growth of bull trout from Hungry Horse Reservoir was faster than recorded in Flathead Lake and Lake Koocanusa (May and Huston 1979). Age IV bull trout from Hungry Horse averaged 324 mm in total length as compared to 292 mm for Flathead Lake and 309 mm for Lake Koocanusa. Age VII bull trout from Hungry Horse Reservoir averaged 584 mm in length. Growth increments from age IV to age VII ranged between 75 to 108 mm (Graham et al. 1982).

Life History of Northern Squawfish

Northern squawfish do not become sexually mature until their fifth or sixth year of life. At this time, females average 350 to 500 mm in length and produce approximately 6,000 to 27,000 eggs (Brown 1971). Squawfish spawn from late May to July (Scott and Crossman 1973, Patten and Rodman 1969). Spawning takes place in gravelly shallows, sometimes along a lakeshore, sometimes near tributary streams and sometimes a short distance upstream. It appears that lake dwelling forms spawned in streams only when suitable gravelly shallows were not available in lakes. Eggs are deposited at random over gravel beds. The eggs are adhesive, demersal and one mm in diameter. Hatching occurs in approximately one week at 17°C.

The northern squawfish is typically a lake species, preferring still waters to swift streams. The young inhabit inshore waters in summer months, moving offshore into deeper waters in fall and winter. Adults tend to remain offshore although they frequent the shoreline when foraging. Squawfish in Hungry Horse Reservoir appear to utilize both benthic and surface habitat in the inshore areas during the summer.

Young squawfish, 25-100 mm in length feed heavily on insects. As they grow larger, fish become increasingly important in the diet and very large squawfish feed almost exclusively on other fishes. Squawfish sometimes feed on salmon and trout, commencing when they are only 100 mm large in the case of sockeye (Ricker 1941). Hall (1979) also noted that squawfish are significant predators on salmon. Brown (1971) observed that this species is considered to be a serious predator on young salmon and trout. He also noted that squawfish may compete with salmon and trout for the same food supply.

Squawfish are slow-growing, comparatively long lived fish. The approximate total length for Montana squawfish is as follows: age I - 51 mm; age II - 89 mm; age III - 114 mm; age IV - 152 mm; age V - 188 mm and age X - 305 mm. The oldest individuals in Montana were 19 years and the largest was 561 mm and weighed 1.9 kilograms (Brown 1971). Specimens up to 13.6 kilograms have been reported elsewhere.

FACTORS LIMITING FISH PRODUCTION

Westslope Cutthroat Trout

Densities of westslope cutthroat trout in Hungry Horse Reservoir are controlled primarily by: 1) recruitment of juveniles from tributary streams, 2) survival of juveniles the first year in the reservoir, and 3) growth as determined by food availability. Both abiotic and biotic environmental variables interact to influence year class strengths of cutthroat and food abundance in the reservoir.

Prior to 1963, recruitment of juvenile cutthroat appeared to be limiting populations of cutthroat trout. Starting in 1963, a program was begun to provide access into reservoir tributaries blocked to spawning cutthroat by road culverts and log jams (Huston 1970). As a result, access was improved to approximately 57 km of streams. Even though about 30 km of this stream length was comprised of low quality habitat in high gradient tributaries, increases in cutthroat populations were documented in the reservoir in succeeding years.

Predation by bull trout and northern squawfish may be an important factor in determining survival of juvenile cutthroat trout and year class strengths of adults. Cutthroat are most vulnerable to predation during their first year of reservoir residence.

Food availability and temperature determine the growth and production of fish in reservoirs (Ploskey and Jenkins 1982). When food requirements exceed available food, the standing crop decreases to a level at which it can be maintained. Decreased growth rates can result in increased predation as fish remain in vulnerable size classes longer.

The availability of these food resources on a seasonal basis is an important part of the current study. Initial data indicate zooplankton are less abundant in Hungry Horse than in Lake Koocanusa and constitute a smaller part of the diet of cutthroat trout. Densities of the larger species of Daphnia preferred by cutthroat may be low in Hungry Horse Reservoir.

Terrestrial insects are the most important component of the westslope's diet in the summer and fall. Any factor which would reduce their availability could have adverse impacts on cutthroat growth. Aquatic Diptera were an important item in the diet of cutthroat trout in the spring and summer in lake Koocanusa. Diptera are probably utilized by cutthroat in Hungry Horse Reservoir during the same period. Water level fluctuations which reduce benthos production may limit growth of cutthroat by reducing the number of Dipterans available in the spring and summer.

Bull Trout

High catch rates of bull trout in sinking gill nets in Hungry Horse Reservoir suggest they are more abundant than in Flathead Lake or Lake Koocanusa. It does not appear that spawning and recruitment are limiting bull trout numbers since they are able to use much of the South Fork above Meadow Creek gorge. Lower flows make fish passage through the gorge much easier in the summer when spawning emigrations of bull trout occur than in the spring when adult cutthroat move upstream. Survival of juveniles the first year in the reservoir may be influencing year-class strengths of this species. The primary food item (mountain whitefish) of bull trout is abundant in Hungry Horse Reservoir and food does not appear to be a limiting factor.

RESERVOIR OPERATION

Effects on Fish Population

Changes in reservoir volume, surface area and shoreline length affect fish production through altering the physical environment of the reservoir. These environmental changes affect fish populations through their influence on: 1) access into tributary streams for spring spawners; 2) survival of juvenile fish; 3) production and availability of fish food organisms, 4) habitat stability, and 5) species interactions. Annual drawdown for flood control and power production can reduce access into tributary streams for spawning westslope cutthroat trout by exposing barriers such as natural falls to upstream movement of fish. The end result would be reduced recruitment of cutthroat from these tributaries into the reservoir.

Annual drawdown may expose juvenile cutthroat to increased predation rates by concentrating them into a smaller volume of water with less escape cover. The combination of these two factors would probably intensify predation by bull trout and northern sguawfish. Stevers and Miller (1983) noted that predation on salmon smolts increased in low flow years, because the young are concentrated in smaller river volumes where they are more readily caught by squawfish. Huston (1971) noted that angler catch rates of westslope cutthroat trout were highest at low reservoir elevations apparently because the fish were concentrated in smaller volumes of water. The reduction in reservoir volume concentrates all fish and may result in competition for food and space between juvenile cutthroat and other juvenile fish such as squawfish and mountain whitefish.

Extensive littoral areas are dewatered during drawdown, especially in the Sullivan area. Production of benthic macroinvertebrates is adversely affected by drawdown. Paterson and Fernando (1969) discovered that approximately 90-95 percent of the Dipteran larvae died after exposure to freezing conditions in a dewatered reservoir area. Populations of Diptera larvae in Hungry Horse Reservoir were five times more abundant in areas which were not dewatered as compared to areas which were exposed to desiccation and freezing conditions by annual drawdowns. Consequently, reservoir operation significantly reduces the numbers of aquatic Diptera available as food for cutthroat trout, especially in littoral areas.

Water level fluctuations result in large changes in fish habitat in the reservoir. This habitat instability caused by reservoir operation may produce an environment suitable for fish which can utilize several habitat types and feed upon a wide variety of food organisms.

Factors Controlling Reservoir Operation

Operation of Hungry Horse Reservoir is controlled by a combination of interacting factors which include: flood control, generation of hydroelectric power, recreational use of the reservoir, resident fish flows for the Flathead River, and water budget flows. The reservoir is drafted in the fall to provide advance power for direct service industries. The major evacuation of water, however, occurs from December through March for flood control and power production. The reservoir is usually filled by the end of July and remains at full pool until after Labor Day to provide summer recreation opportunities. Operation is also regulated to provide flows for spawning and incubation of kokanee eggs in the Flathead River downstream from the mouth of the South Fork. From October 15 to December 15, flows in the Flathead River near Columbia Falls are maintained between 3,500-4,500 cfs. A minimum flow of 3,500 cfs is maintained from December 15 through April 30. Water may be provided for water budget flows in the spring to facilitate the downstream movement of salmon smolts in the Columbia River.

Operation of Hungry Horse Dam is integrated with the operation of the entire Columbia River system. Flood protection is provided for Columbia Falls and Kalispell, as well as for the lower Columbia River. The Columbia River is considered to be at flood stage when more than 450,000 cfs is passed by Dalles Dam. Flood stage at Columbia Falls and Kalispell occurs when the flows are above 45,000 cfs.

Power generation at Hungry Horse is a part of the Pacific Northwest power system. Water released from Hungry Horse Dam passes through 19 downstream projects. The firm load for the Pacific Northwest is 18,200 megawatts. In an average water year, 14,500 megawatts are generated by hydropower and 3,700 from other energy sources, primarily thermal. Approximately 6,400 megawatts are produced by other resources in a critical water year as compared to 11,800 by hydropower. The amount of secondary power (that sold out of the region or supplied to high energy industry) is based on availability of water in excess of that needed to meet firm loads. hiring all but the driest years, hydropower produces secondary power.

Operational rule curves (ORC) are developed each year for each project in the system. The ORC for each project is derived from a series of curves which have been developed for flood control and power production in critical water years (Figure 8). These curves are:

1) A mandatory rule curve (MRC) or flood control curve which is adjusted monthly from January to July based on run-off forecasts and fixed the rest of the year. The MRC at Hungry Horse from the end of July through December is full pool which means the reservoir does not have to be drafted for flood control during this period.
2) A group of four critical rule curves (CRC) are designed to allow for optimum energy to meet system firm loads during a four-year critical period and are based on the historic low water years of August 1928 through February 1932. The CRC's are fixed curves for the entire year.
3) An assured refill curve (ARC) which provides for power production along with assured refill of the reservoir for the second lowest historical run-off (1931). The ARC is a fixed curve for the entire year.
4) A variable refill curve which allows for power production and a 95 percent probability of refill based on the monthly run-off forecasts from January 1 through July. The VRC changes monthly based on power needs and run-off forecasts.
5) A lower limit energy content curve (LLECC) protects the ability of the project to meet its firm load from January through March if the run-off forecasts are too low.

The operational rule curve (ORC) is derived from the above set of curves. From August through December, the ORC is determined to be the higher of the ARC or CRC, unless the MRC is lower. The ORC is controlled by the same method from January through June, except that the VRC becomes the ORC if it is lower than the CRC, ARC or MRC and higher than the LLECC.

In summary, the operation of the Hungry Horse project is controlled by several factors including flood control, power generation, resident fish flows, water budget flows and recreation in the reservoir. Reservoir operation varies seasonally and annually

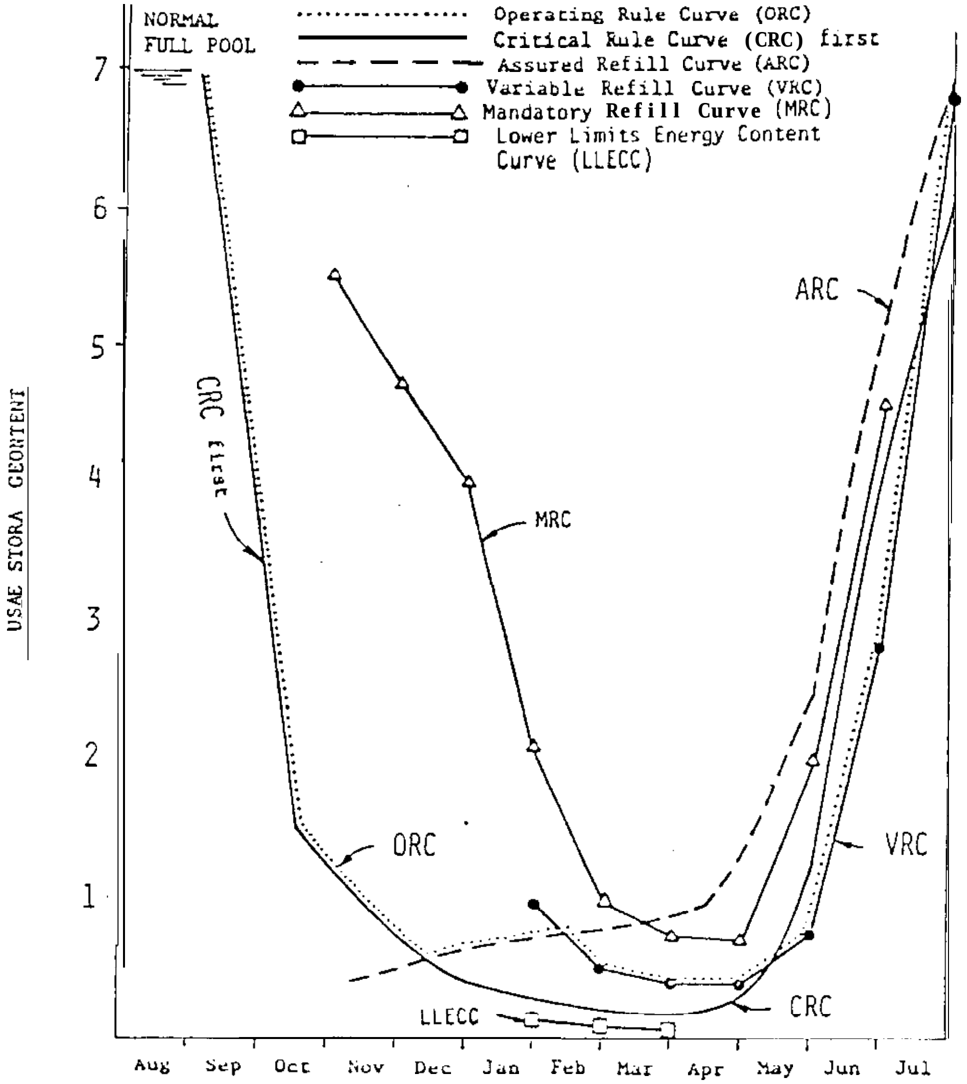

Figure 8. Hypothetical rule curves illustrating how an operational rule curve (ORC) is formed for Columbia River flood control-hydroelectric projects (modified from Columbia River Treaty Committee 1983).

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.

with changes in these factors and precipitation in the drainage. It follows that changes in reservoir operation to benefit game fish populations would impact other variables controlling reservoir operation except for precipitation.

BPA has the overall responsibility of reviewing the recommended operational guidelines to improve game fish production. They would have to determine the impacts on power production associated with changes in reservoir operation to increase game fish production, and decide whether or not these operational changes are feasible. The Bureau of Reclamation would then review the oparational changes recommended by BPA and decide whether or not to implement them.

Enhancement of Fish Populations

Integration of the factors controlling production of westslope cutthroat trout with reservoir operation indicates that three possible changes in operation exist which would benefit cutthroat populations. These include: 1) delaying the drawdown in the fall until the end of October, 2) reduce frequency of drawdowns deeper than 85 feet to those required for flood control and in critical water years, and 3) filling the reservoir earlier in the spring. These three changes would reduce the likelihood of competition for food and space between juvenile cutthroat and other fish species and reduce predation on juvenile trout. The first change would also extend the growing season longer into the fall and improve growth of cutthroat trout, thereby reducing predation. A reduction in the frequency of drawdowns deeper than 85 feet would benefit benthos populations, resulting in more food for cutthroat trout. Item three would provide better access into tributary streams for spawning cutthroat.

The changes in reservoir operation would entail alterations in the schedule of power produced at the Hungry Horse project. Delaying the drawdown in the fall to the end of October would result in shifting that power produced by the drawdown in September and October to the winter months. Filling the reservoir faster in the spring and limiting drawdown to less than 85 feet in most years would also result in shifting of power generation to other periods. Refill in the spring would still require saving sufficient storage to prevent spill in case run-off is greater than forecasted. As long as water does not have to be spilled, these shifts in generation should have comparatively little impact on total power produced at the project. However, shifting power generation may result in reduced revenues due to the power being less valuable. When the final operational recommendations are made at the completion of the study, BPA will review the changes and balance the benefits to game fish production against any loss of power revenues.

Predicting Benefits to the Reservoir Fishery

Cur goal is to recommend reservoir water level operational criteria which will benefit the fishery, yet allow for other downstream uses such as power production and water budget flows. 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 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. 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 recruitment of cutthroat from tributary streams and nutrient input to reservoir. We plan to strive for a model which will be as simple as possible. However, reaching this end will require testing variable combinations to select the best model and then validation of the model using field data. We plan to develop our 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).

Fish production in the reservoir is controlled by a number of factors including:

1) recruitment of fish to the reservoir from in-reservoir and off-reservoir spawning and rearing areas,

2) amount, quality and availability of food resources,

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

4) amount of useable habitat (escape cover may be an important habitat component for fish subject to 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.

Juvenile survival within the reservoir depends upon being able to find food without being preyed upon. Once a fish grows to a certain minimum size, predation is significantly reduced as a mortality factor. The density of various size classes of predator dictates the probability of encounter and subsequent ingestion for usable 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 divided into two basic types; density-independent and density dependent (Everhart and Youngs 1981). Density-independent types are not a result of any actions of the fish populations and include floods, droughts, extreme temperatures, and pollution. Density dependent factors are closely associated with actions of the fish populations such as cannibalism, disease, predation and exhaustion of food. Density dependent factors are normally compensatory, that is, the occurrences tend to regulate the population in the direction of long-term averages which are in balance with the available habitat. Reservoir operation influences natural mortalities through controlling the amount of habitat available to the fish. Thus, operation could increase or decrease natural mortality depending upon its impact upon fish food resources and habitat. 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.

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 output as input variables for our model in order 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 partitioning available food resources to meet food requirements of reservoir fish. We hope to link this food availability - habitat preferred model to similar models developed by the Fish and Wildlife Service's Habitat Evaluation Procedures Group.

CONCLUSIONS

1) The water quality data collected in 1983 is similar to that collected in 1978 by the Bureau of Reclamation. The D.O., pH, conductivity measurements are within tolerable levels for fish species within the reservoir.

2) Temporal distribution of adult aquatic and terrestrial insects on the surface was quite spotty; however, distributions in general were consistent between inshore and offshore zones at individual sample sites.

3) Standard floating and sinking gill nets were effective in sampling for all but smaller fish species such as sculpins and pygmy whitefish when they were distributed in inshore areas.

4) Vertical gill nets were inefficient in sampling fish in deep offshore waters.

5) Comparatively few fish were detected with the acoustical gear in October and November.

6) The purse seine needed modification to permit faster pursing and was inefficient in capturing fish in November and December.

7) Little is known about the habitat requirements of juvenile cutthroat their first year in the reservoir, but it does appear to be a critical period in their life that influence year class strengths.

8) Northern squawfish and bull trout may be important predators on juvenile westslope cutthroat trout.

9) There appears to be flexibility in the operation of Hungry Horse Reservoir which could be utilized to alter the reservoir environment to benefit game fish populations. Changes in reservoir operation to benefish game fish populations would probably require alteration in power production schedules.

10) Drawdown of the reservoir below elevation 3,480 dewaters an extensive littoral area in the upper part of the reservoir.

RECOMMENDATIONS

Continue the study with the following modifications:

1) Enter water quality data in the USGS WATSTORE data system so it can be retrieved and analyzed using WTSTORE or STORET data systems.

2) Sample fish populations with gill nets seasonally using a more intensive effort.

3) If catches in vertical nets remain low, develop another method to determine vertical distribution of fish. This may entail the use of gang sets of floaters.

4) Concentrate purse seining in spring and fall when trout are distributed within 3-6 meters of the water surface.

5) Determine if cover plays an important role in the distribution of juvenile cutthroat by conducting underwater fish surveys in inshore areas.

6) Determine spawning periodicity and areas used for spawning, including streams, by northern squawfish.

7) Collect more squawfish stomachs to ascertain if they are important predators of juvenile cutthroat trout.

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WATERS REFERRED TO:

Stream name	Code No.
Clark Creek	08-1520-10
Emery Creek	08-2560-01
Hungry Horse Creek	08-3580-01
Hungry Horse Reservoir	08-8860-05
N.F. Logan Creek	08-6670-01
S.F. Logan Creek	08-6670-01
McInernie Creek	08-4660-01
Murray Creek	08-4980-01
Quintonkon Creek	08-7080-01
S.F. Flathead River	08-6660-01
Sullivan Creek	08-7080-01
Tent Creek (Dudley)	08-2380-01
Tin Creek	08-7280-01
Twin Creek, Lower	08-7500-01
Wheeler Creek	08-7720-01
Wounded Buck	08-7920-01