Quantification of Hungry Horse Reservoir Water Level Needed to Maintain or Enhance Reservoir Fisheries

Methods and Data Summary: 1983 - 1987

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By:

Bruce May. Project Biologist
and
Steve Glutting, Tom Weaver. Gary Michael, Beth Morgan,
Paul Suek, John Wachsmuth. Chuck Weichler. Project Technicians

Special Projects Bureau
Montana Department of Fish, Wildlife and Parks
P.O. Box 67, Kalispell. Montana 59903

Prepared for:

Dale Johnson, Project Manager
U.S. Department of Energy
Bonneville Power Administration
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EXECUTIVE SUMMARY

The Hungry Horse Reservoir study is part of the Northwest Pover Planning Council's resident fish and wildlife plan. The plan is responsible for mitigating damages to the fish and wildlife resources caused by hydroelectric development in the Columbia River Basin. The major goal of our study is to quantify seasonal water levels needed to maintain or enhance the reservoir fishery. This study began in May, 1983, and the initial phase will be completed July, 1988.

This report summarizes limnological, fish abundance, fish distribution and fish food habits data collected from 1983 to 1988. The effect of reservoir operation upon fish habitat, fish food organisms and fish growth is discussed.

The morphology of the reservoir and habitat for fish and their food organisms are impacted by reservoir operations. The annual drawdown and refill cycle causes large changes in surface area, vater volume and depth. The timing of the drawdown appeared to be more important than the total depth. Drafting of the reservoir during the summer and fall, appears to have more impact on the reservoir's biota than the deep winter drawdown. Reductions in the littoral zone appear to be especially harmful to aquatic insects and trout growth.

Hungry Horse Reservoir was usually isothermal from approximately the end of November to mid April. Thermal stratification began in May and continued into October vith the thermocline depth between 15 to 20 m. Maximum surface water temperatures during summer were generally 20 to 10°C Ice formation usually began in December and the entire reservoir was frozen from mid January to April. Dissolved oxygen concentration and pH values vere within the optimum range for production of westslope cutthroat and bull trout. The euphotic zone depth varied between three m in spring to 20 m in fall.

Hungry Horse Reservoir is an unproductive system with low nutrient input and primary productivity. Based on Chlorophyll A concentrations and observed daily area productivity rates, Hungry Horse vas classed as ultraoligotrophic. Area differences in primary productivity were noticeable with production highest in the Emery area (lower area), intermediate in the Murray area (middle area), and lowest in the Sullivan area (upper area).

Daphnia, *Diaptomus*, *Cyclops*, and *Bosmina* comprised approximately 90 percent of the biomass of zooplankton populations from 1984 to 1987 vith *Daphnia pulex* accounting for 18 percent of the standing stock. The warmer vater temperatures in spring, 1986, advanced the seasonal progression of zooplankton abundance. In general, zooplankton populations vere low in April, peaked in July at approximately 10,000·M , declined during the summer, peaked

again in November and declined markedly in December. Densities of zooplankton differed among the areas in the same order as primary productivity. Zooplankton were concentrated in the upper 20 m of the water column which corresponds to the euphotic zone.

Downstream loss of zooplankton was greatest from December through March when the reservoir was isothermal and zooplankton were circulated deep in the water column. Declining pool elevations and large water releases from the dam increased dovnstream loss. The densities of zooplankton in the South Fork of the Flathead River varied from one to 28 percent of the population in the Emery area.

Dipteran larvae comprised approximately 80 percent of the biomass in benthos samples. The mean weight of dipterans in the permanently wetted area vas 6.9 fold greater than in the area annually dewatered. In contrast, production of dipteran in the littoral zone after it had been reflooded was about three times greater than in the permanently wetted area. This is probably a result of the higher water temperatures in the littoral zone than in the deeper limnetic zone. The limnetic zone was below the thermocline vhere water temperature averaged less than 7.0°C year-round. Overall, the drawdown greatly reduced production of macro-invertebrates in the littoral zone by: 1) dewatering much of the zone during the growing season; 2) causing high overwinter mortalities and subsequent lov populations in the spring when it was reflooded: 3) precluding the development of rooted aquatic vegetation; and 4) altering the aquatic insect species complex so that the most important food items for trout disappeared or were greatly reduced in abundance.

The distribution of terrestrial insects on the surface film was extremely patchy both spatially and temporally throughout the study. Numbers were low in the spring and early summer, reaching a maximum of about $1{,}600 \cdot ha^{-1}$ in August, then gradually declining to low numbers in November. There was no significant difference in numbers betveen the littoral and limnetic zones. Drawdown may reduce the recruitment of terrestrial insects to the reservoir because the dewatered land area inhibits the spread of insects from shoreline areas to the water, and rising thermal air currents from the bare land may form a barrier to air-borne transport tovard the water.

The annual diet of westslope cutthroat trout vas similar from 1983 to 1987. Terrestrial insects comprised most of the food folloved by aquatic dipteran and Daphnia pulex. The diet varied seasonally in response to food availability. In the spring, aquatic dipteran dominated the diet. From June through October, cutthroat ate primarily terrestrial insects and switched to Daphnia pulex in December.

Fish was the principal component of the bull trout diet comprising over 99 percent of the biomass. Adults consumed suckers, mountain whitefish, northern squawfish and cutthroat trout. Juveniles ate primarily suckers, squawfish and mountain whitefish. The food habits vere similar among the years, except cutthroat vere a larger component of the diet in spring, 1985.

Mountain whitefish ate primarily _Daphnia pulex_ folloved by aquatic dipteran, _Epischura_ and terrestrial insects. The diet was remarkably uniform with little seasonal variation.

Fish were the primary food item ingested by northern squawfish, comprising over 90 percent of the annual biomass consumed. The species eaten in order of abundance were bull trout, mountain whitefish, northern squawfish, suckers and westslope cutthroat trout. Habitat separation in Hungry Horse Reservoir appeared to reduce predation on westslope cutthroat trout by squawfish.

Gill net catches have been comparatively stable among the years, indicating that relative abundance of fish species has varied little. The mean catch of westslope cutthroat trout in floating nets vas 2.7 and 1.4 fish per net in the spring and fall, respectively. Bull trout catches in sinking nets were also higher in the spring, averaging 5.6 fish per net compared to 4.3 fish per net in the fall. The catch of both species was higher in the Sullivan area than in the Emery and Murray areas. Gill net catches of mountain whitefish vere highest in the fall, averaging 13.0 fish per sinking net. Catches of northern squawfish and suckers peaked in the summer when water temperatures were above 15°C

The catch of cutthroat in the fall was highest in the Sullivan area probably as a result of the Sullivan area having a more extensive littoral zone than the other tvo areas. Terrestrial and aquatic insects appear to be more available as food in the littoral zone than in the deeper offshore waters.

The spawning runs of westslope cutthroat trout into Hungry Horse Creek have declined from a high of approximately 1,200 fish in the late 1960’s to approximately 600 in 1972 and 400 in 1984. This long-term reduction in spavners appears to have been influenced primarily by the drawdown beginning in August or September. Reservoir drawdown in the late summer may increase mortality of juvenile cutthroat by increasing competition and making the juveniles more accessible to predators. Drawdown also appears to reduce growth of cutthroat by reducing food availability. The recruitment of juvenile cutthroat to the reservoir from Hungry Horse Creek also has declined during this period. The catch of juveniles in the fish trap has ranged from 2,700 fish in 1969 to 912 in 1984.

A study of the substrate composition in Hungry Horse Creek indicated that fine sediment concentrations are high enough to be adversely affecting incubation success of cutthroat eggs.

However, in a natural stream channel high concentrations of fines may be partially mitigated by groundwater upwellings in spavning areas. The standing stock of juveniles in Hungry Horse Creek is above average for the Flathead drainage.

Annual survival and exploitation rates of adult westslope cutthroat trout vere calculated from return of tags by anglers. The survival rates of tagged westslope cutthroat trout in the reservoir ranged from 52 to 63 percent. Angler harvest of tagged adult cutthroat varied betveen eight to 14 percent.

We also estimated the population of adult westslope cutthroat trout in the reservoir by three different methods. These included estimates based on: 1) mark-recapture data, 2) survival of the annual recruitment to the reservoir, and 3) relationship between exploitation and annual harvest. The estimates indicated a population of between 9,900 to 16,000 adult cutthroat in the reservoir. These estimates of survival, exploitation and population numbers require further verification and an intensive mark-recapture study wi11 be conducted next year.

Estimating the annual recruitment of westslope cutthroat trout to Hungry Horse Reservoir vas a difficult task, because of the number of tributary streams and the complex life cycle. We estimated the standing crop of adfluvial juveniles at 81,946 fish in tributaries utilized for spawning by reservoir cutthroat. Approximately 30 percent of these juveniles or about 24,600 fish should be recruited to the reservoir annually.

Growth of juvenile westslope cutthroat trout in the reservoir was most rapid during the late summer and fall. From August through November, juvenile cutthroat attained 55 percent of their annual growth in length and 68 percent of their biomass increase. Cutthroat trout grew an average of 129 mm their first year in the reservoir. Growth in length declined markedly in succeeding years, averaging 67 mm the second year and 38 mm the third year. Drafting of the reservoir in the late summer and fall appeared to reduce the growth of cutthroat trout.

Movement of westslope cutthroat trout in the reservoir was determined from returns of tagged fish by anglers, creel intervievs and gill net catches. Most of the adults tagged moved upstream vith the longest verified journey measuring 54.4 km. Upstream movement of cutthroat was influenced by spawning periodicity and the availability of littoral habitat. Cutthroat which moved downstream were affected by the reservoir drawdown which forced fish from the upper part of the reservoir to relocate.

The data from this study has been used to develop the predictive trophic level model. The initial phase of the model will be completed in July 1988. Refinement and verification will occur from July, 1988. to July, 1991.

INTRODUCTION

The Pacific Northwest Electric Poker 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 Poker 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. Bonneville Pover Administration (BPA) provides the major funding to implement the Council's program. The Hungry Horse Reservoir (HHR) study is part of the Council's program.

This technical report contains methods, data summaries and discussions about the effects of reservoir operation upon fish habitat, fish food abundance and fish growth. The data collected in this study has been used to develop the predictive trophic level model. The predictive capabilities of the model will be used to forecast the effect of different operation scenarios upon the reservoir biota. Information from these simulations wi11 be used to recommend seasonal water levels needed to maintain or enhance game fish populations.

A maximum drawdown of 85 ft was recommended by Graham et al. (1982) for HHR. This recommendation was subsequently adopted by the Council as part of its fish and wildlife program. The maximum drawdown proposal and timing of drawdown wi11 be revieved in light of the data generated by this study, proposed changes in operation anticipated due to "water budget" flows, intertie development, irrigation needs and changing power demands in the northwest.

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 HHR from 1965 to 1975 adversely affected the growth and survival of westslope cutthroat trout (<u>Salmo clarki lewisi</u>).

Hungry Horse Dam was completed in 1952 and the reservoir reached full pool elevation of 3,560 feet msl in July 1953. 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, operated by the Bureau of Reclamation, whose primary benefits are flood control and power production. The principal power benefit comes from generation at dovnstream projects. Water passes through 19 downstream projects, generating approximately 4.6 billion kilowatt hours of energy annually as compared to 1.0 billion at the Hungry Horse project.

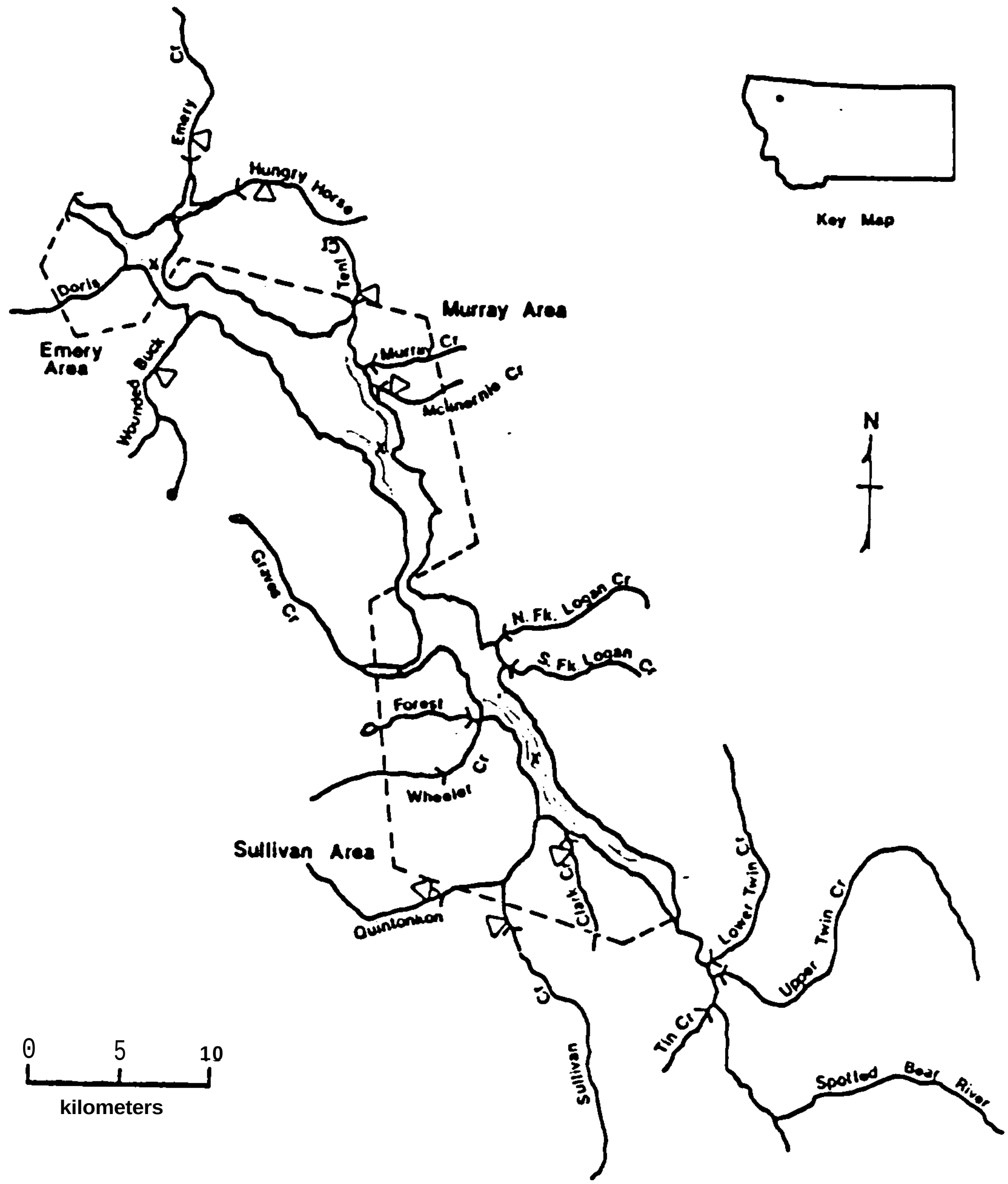


Figure 1. Map of Hungry Horse Reservoir showing study areas, netting areas (▒), water quality, vertical net and zooplankton stations (X), fish trap location (>), and electrofishing sections (△).

OBJECTIVES

This study proposes to quantify seasonal water levels needed to maintain or enhance principal game fish species in HHR. The specific study objectives are:

1. Quantify the amount of reservoir habitat available at different water level elevations:
2. Estimate recruitment of westslope cutthroat trout juveniles from important spawning and nursery areas;
3. Determine the abundance, grovth, distribution and use of available habitat by major game species in the reservoir:
4. Determine the abundance and availability of fish food organisms in the reservoir;
5. Quantify the seasonal use of available food items by major fish species;
6. Develop relationships between reservoir drawdown and reservoir habitat use by fish and fish food organisms;
7. Estimate the impact of reservoir operation on major game fish species.

RESERVOIR MORPHOLOGY AND HABITAT

Methods

Morphological data and the relationship between reservoir elevation and morphological features vere determined from maps and tables provided by the Bureau of Reclamation. Contour maps of the reservoir were digitized at 20-foot contour intervals and the data was used as the basis for a physical framework model of the reservoir. This model was used to calculate water volumes, surface area and shoreline lengths.

Monthly lake-filling and hydraulic-residence times were calculated using the formulas adapted from Woods (1982). Lake-filling time represents the time required to replace the volume of a reservoir at a given inflov vhereas hydraulic-residence time represents the time required to replace the volume of a reservoir at a given outflow.

$$LFT = \frac{V}{I} \times 0.0833$$

$$HRT = \frac{V}{O} \times 0.0833$$

LFT = lake-filling time in years
HRT = hydraulic-residence time in years
v = mean monthly reservoir volume in acre-feet
I = monthly inflow in acre-feet
0 = monthly outflow in acre-feet
0.0883 = conversion of months to years

Results and Discussion

At full pool elevation of 3,560 msl, the reservoir is 56 km in length with an area of 23,800 acres and a volume of 3,468,000 acre-feet. Usable storage for pover production starts at elevation 3,336 msl and includes 2,982,000 acre-feet which is 86 percent of total full pool volume. The average annual inflow is 2,386,918 acre-feet and the storage ratio is 1.45:l.0 (Table 1).

The morphology of the reservoir and habitat for fish and their food are influenced greatly by reservoir operation. The annual drawdown and refill cycle causes large changes in surface area, vater volume, depth, shoreline development and in lake-filling and hydraulic-residence times. The amount of littoral area varies with reservoir elevation along with volume of water in the euphotic zone, volume of water in preferred temperature ranges for zooplankton and fish growth, and area of reservoir bottom dewatered. The thermal structure of reservoirs is influenced by the large seasonal inflow and outflow volumes (Woods 1982).

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 development	5.95
Mean depth (ft)	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)
Storage ratio	1.45:1.0
Elevation at full pool (ft)	3,560 msl (1,085.8 m)
Elevation at minimum pool (ft)	3,316 msl (1,011.4 m)

a/ Based on unregulated flow from 1929-51.

Reservoir volume and surface area decrease rapidly as reservoir elevation declines (Figures 2 and 3). Inflection points on the surface area curves occur at approximately elevation 3,480 where extensive littoral areas are dewatered, especially in the upper part of the reservoir. These littoral areas provide good habitat for benthic macroinvertebrates and cutthroat trout when they are flooded. Reduction in volume is largest from elevations 3,560 to 3,480 where 45 percent of the storage capacity is contained.

Shoreline length declines from elevation 3,560 to 3,540, increases from 3,540 to 3,520 then declines steadily with further reduction in reservoir elevation. The increase in shoreline length between elevation 3,540 and 3,520 is due to an unusual increase in the meander pattern of the shoreline between these elevations.

Maximum drawdown during the study has ranged from 45 ft in 1983 to 85 ft in 1985 (Figure 4). The amount of time the reservoir has been at full pool varied from almost eight weeks in 1983 to about one week in1985 (Figure 5). The length of time at full pool is largely determined by power demands in the northwest during the late summer and fall. In below-average water years, the reservoir is drafted as early as July. Even in the best water years, the relatively short period at full pool has adverse effects on the productivity of the critical littoral zone.

The lake-filling and hydraulic-residence times for Hungry Horse are high when compared to Libby Reservoir. The annual lake-filling times for Libby Reservoir varied between 0.14 to 0.66 year (Woods 1982) as compared to 2.51 to 3.12 years for HHR (Table 2). The lake-filling and hydraulic-residence times for the Hungry Horse study period were comparatively high because of below-normal inflows to the reservoir. It appears that reservoir operation has less effect upon the thermal structure of HHR than Libby Reservoir. This is primarily due to the fact that in HHR, the usable storage capacity of 2,982,000 acre-feet is higher than the mean annual discharge of 2,386,000 acre-feet.

Hydraulic-residence times appear to have an important influence on zooplankton production (Mayhew 1977). He found that hydraulic-residence times of below one year were associated with reduced zooplankton populations. Increased flushing rates resulted in cooler water temperatures and the density of zooplankton decreased in a linear fashion. Annual hydraulic-residence times in HHR are generally above one, except in high water years. Hovever, the monthly residence times vary considerably and were often below one from January through March and in September. These are periods when the reservoir is being drafted.

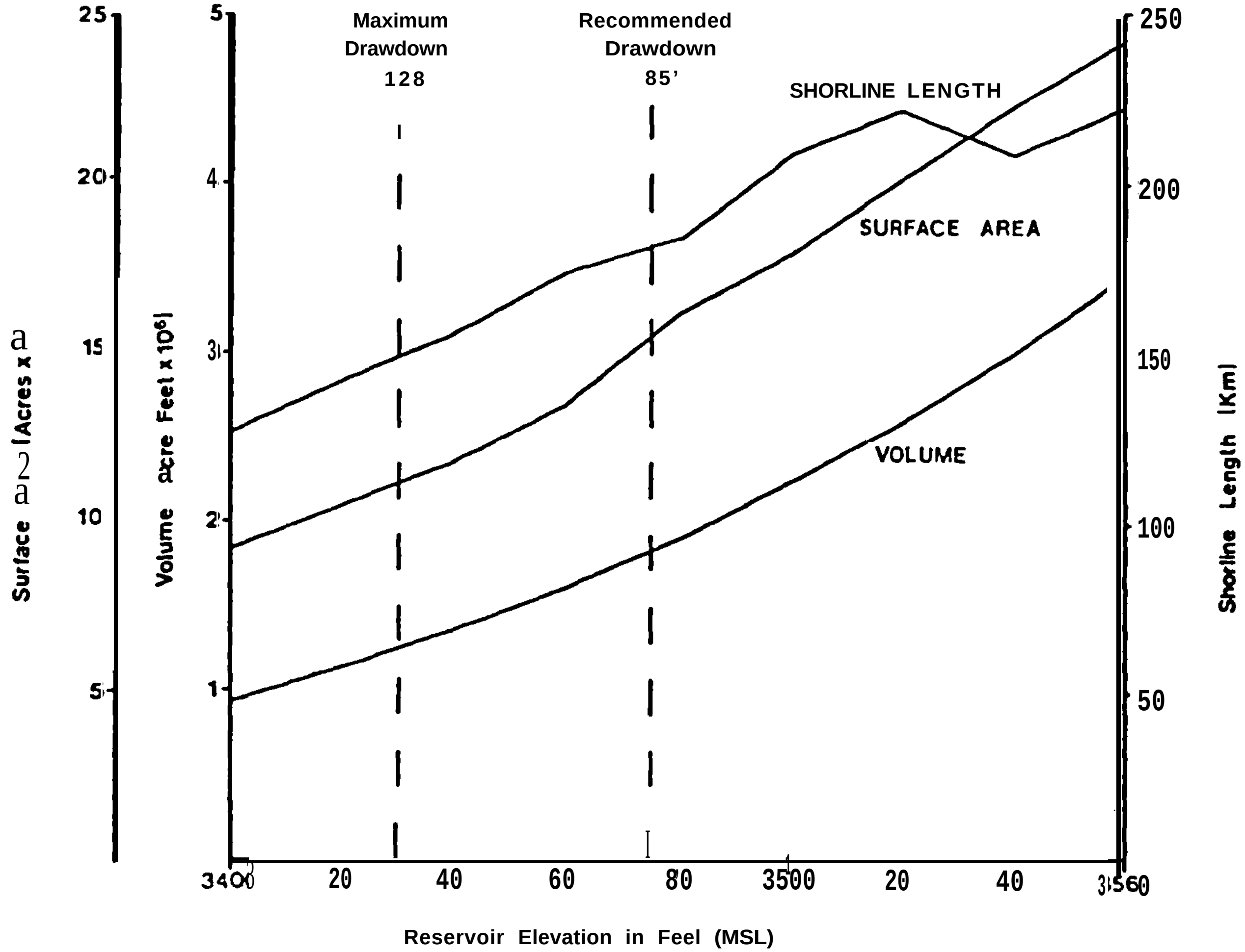


Figure 2. The relationship of reservoir elevation to surface area, volume and shoreline length of Hungry Horse Reservoir.

LONGITUDINAL PROFILE OF HUNGRY HORSE RESERVOIR

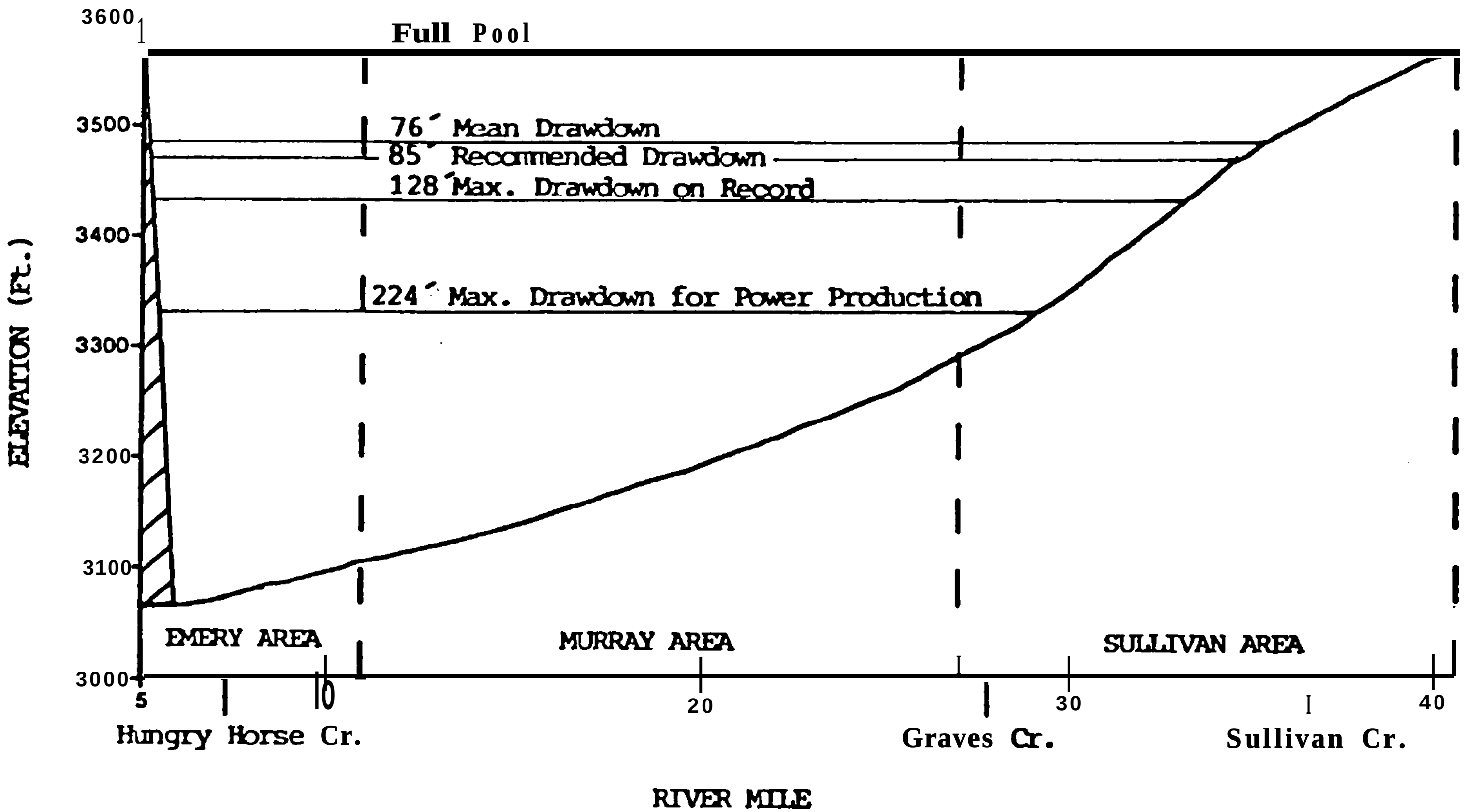


Figure 3,. longitudinal cross-sectional profile of Hungry Horse Reservoir at water surface elevations of 3,560 (full pool), 3,484; 3,475; 3,432 and 3,336.

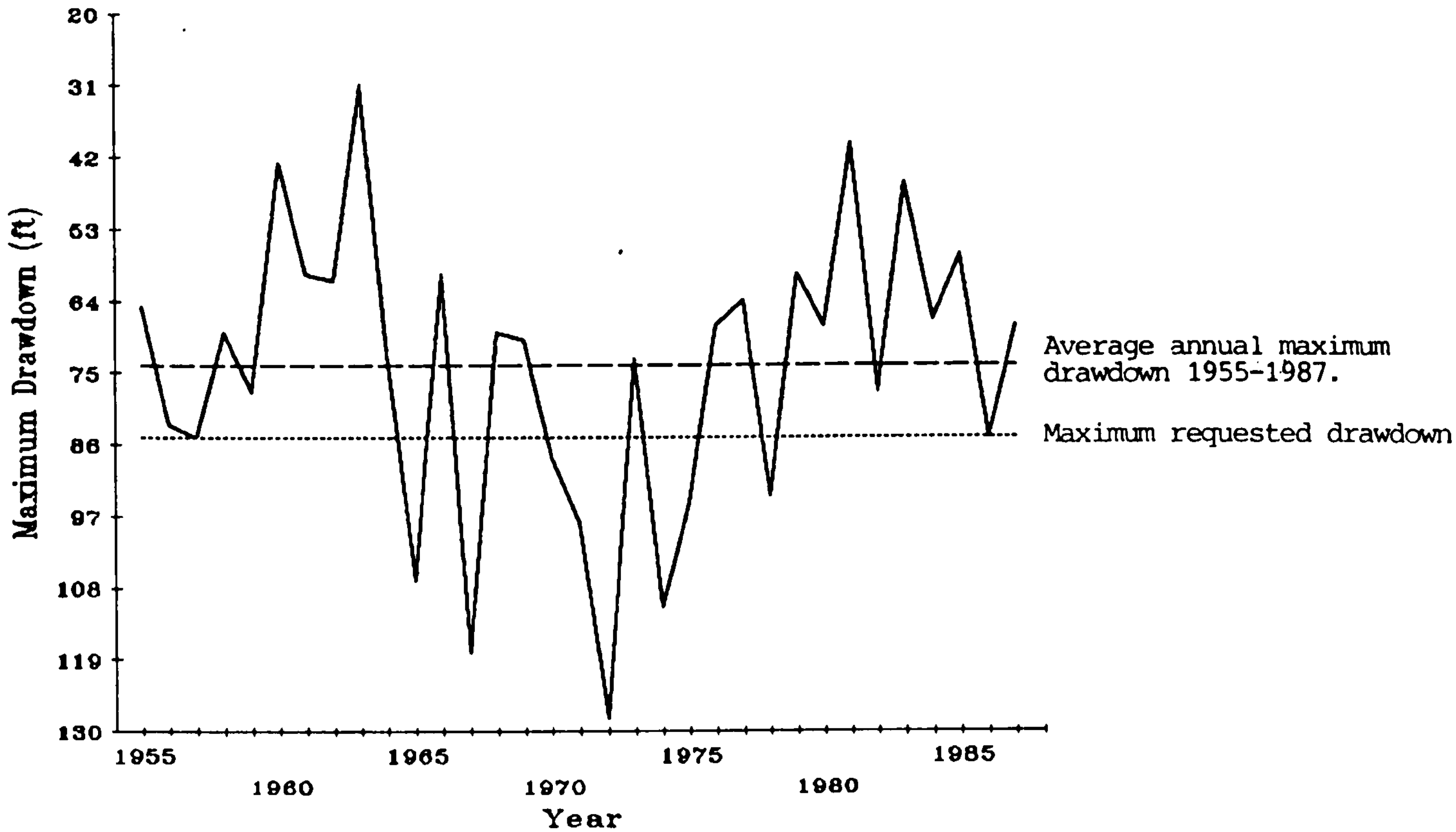


Figure 4. Annual maximum drawdown of Hungry Horse Reservoir from 1955 to 1987.

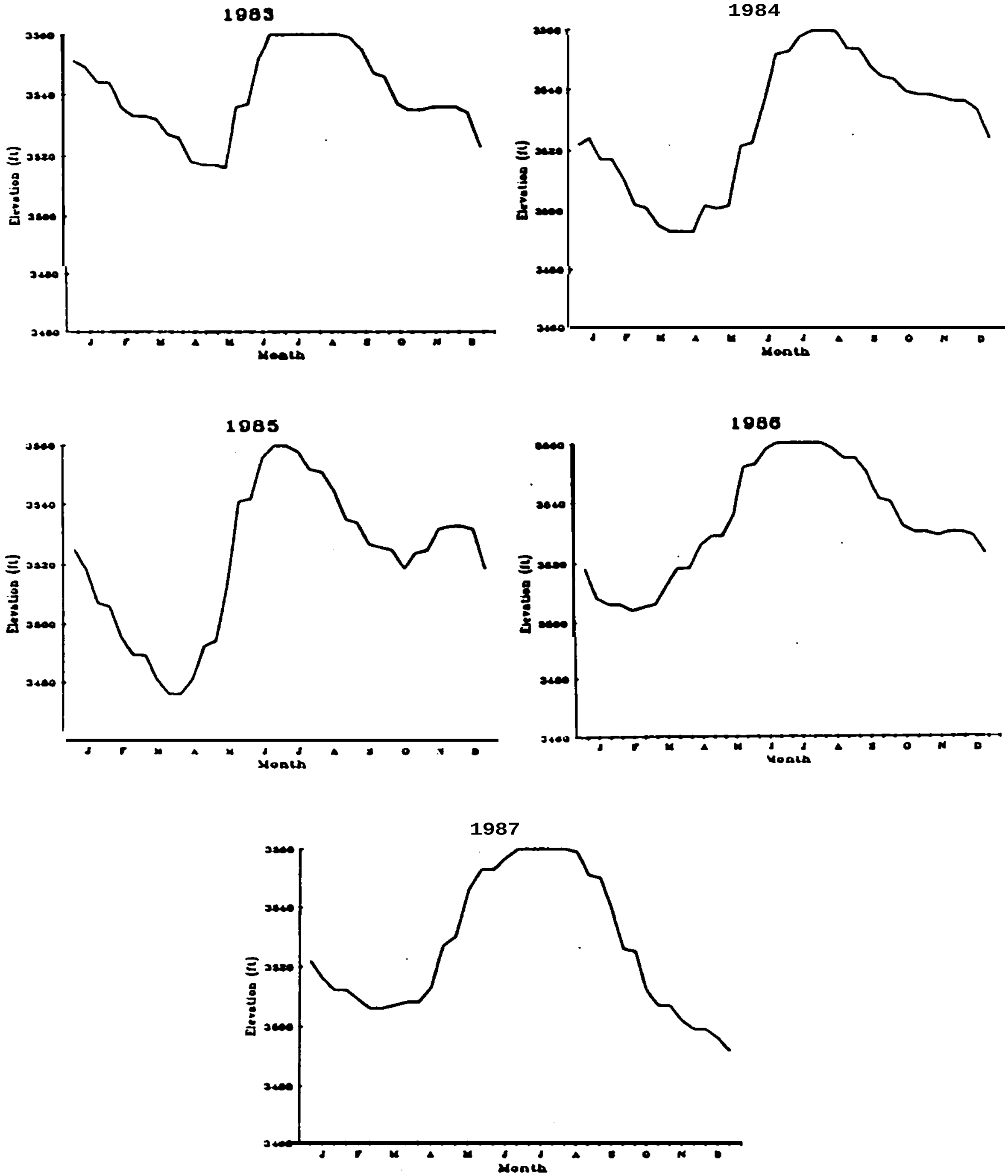


Figure 5.. Reservoir elevation in Hungry Horse Reservoir from 1983 to 1988.

Table 2. Monthly lake-filling and hydraulic-residence times for low (1973), median (1980) and high (1974) water years in Hungry Horse Reservoir and for 1983 to 1987.

Year	Month												Annual mean	Maximum drawdown (ft)	Cumulative discharge (AF)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
							Lake-Filling Time (years)								
1973	3.02	5.75	2.97	1.26	0.33	0.47	2.05	5.29	7.28	5.24	1.65	2.13	3.12	63	1,871,000
1974	1.12	2.37	1.62	0.38	0.22	0.16	0.64	3.03	5.31	6.59	4.20	4.53	2.51	111	3,574,000
1980	5.54	5.47	3.99	0.50	0.30	0.59	1.86	4.47	3.79	5.43	3.08	1.40	3.04	69	2,351,000
1983	3.87	4.88	2.41	1.05	0.35	0.47	0.97	3.67	5.40	4.27	2.57	4.55	2.87	45	2,872,300
1984	1.98	3.50	2.31	0.73	0.37	0.34	1.34	4.60	4.61	3.89	3.58	4.38	2.64	68	2,202,900
1985	5.35	4.67	3.51	0.51	0.22	0.48	2.62	3.86	1.19	1.13	1.11	3.23	2.32	85	2,928,110
1986	3.24	1.89	0.75	0.65	0.36	0.56	2.27	5.76	4.26	3.52	2.53	3.76	2.46	57	2,358,190
1987	4.73	5.08	1.87	0.53	0.41	1.28	2.99	5.37	6.20	6.17	6.06	5.14	3.82	68	2,290,475
							Hydraulic Residence-Time (years)								
1973	0.62	0.57	1.94	1.53	4.14	26.21	1.14	0.87	7.23	0.89	1.54	4.18	4.24		
1974	0.74	0.54	0.36	0.21	0.82	1.47	0.87	2.15	1.15	0.70	0.47	0.57	0.84		
1980	3.92	6.31	11.99	16.81	Ib.37	1.03	2.11	2.19	1.18	1.89	1.25	0.72	5.31		
1983	1.15	0.88	1.03	0.54	0.87	4.92	1.08	2.58	0.80	0.79	3.73	0.71	1.59		
1984	1.02	0.59	0.77	1.92	1.24	3.50	8.99	1.38	1.03	1.27	2.22	0.80	2.06		
1985	0.54	0.53	0.62	3.66	13.00	1.88	0.96	0.58	0.62	0.97	6.41	0.66	2.54		
1986	0.65	1.65	5.46	1.80	1.37	0.91	2.65	1.62	0.69	1.64	2.24	2.17	1.90		
1987	0.82	1.40	2.95	8.13	3.47	4.23	7.U	1.04	0.44	1.03	1.07	1.10	2.73		

WATER QUALITY

Methods

The year was stratified into four seasons based on reservoir operation and surface water temperatures:

1. Winter (mid November through April) - vhen the reservoir is evacuated for flood control and pover production, surface water temperatures are below 8°C and the reservoir is isothermal.

2. Spring (May and June) -when the reservoir is refilled and surface water temperatures are increasing from 8°C to 15°C.

3. Summer (July through mid September) - when the reservoir is near full pool, surface water temperatures are between 16-22°C and the reservoir is thermally stratified;

4. Fall (mid September through mid November) - when drafting of the reservoir begins for power production and surface water temperatures are declining from 15°C to 8°C.

HHR was segregated into Emery, Murray and Sullivan areas, based on reservoir morphometry and the effects of drawdown (Figure 1). Within each of these study areas, a permanent station was selected for vater quality and zooplankton collection. Vertical fish distribution and benthic macroinvertebrate samples were collected near these permanent sites. In addition to the permanent sample sites, ten transects in each study area were established across the reservoir by visual landmarks. At these transects, randomly selected zooplankton, surface insect and purse seine samples vere collected.

The reservoir habitat was further divided into nearshore (littoral) and offshore (limnetic) zones. The littoral zone included the area within the depth of the euphotic zone (approximately 20 m) and less than 100 m from the shoreline.

Water temperature (°C), dissolved oxygen ($m \cdot l^{-1}$), pH and specific conductivity ($umhos \cdot cm^{-1}$) were measured at the permanent sites. Measurements vere taken biweekly from May through November vith a Martek Mark V digital water quality analyzer. Measurements were taken monthly in April and December when access to the reservoir was available. The vertical profile data were collected immediately below the water surface, at one m and every two m down to 15 m. Betveen 15 m and 60 m, data was collected every three m, Data was collected at every five m from 60 m to 100 m or the bottom. Calibration of the Mark V unit vas done in the field from May through October and in the laboratory immediately prior to field measurements from November through April when ambient air temperatures were below freezing.

Light transmittance was measured in foot-candles using a Protomatic photometer. Incident light was measured immediately above the water surface. Light penetration was measured at depths of 90, 60, 30, 15, 5. 1 and 0.1 percent of the incident light. Greeson et al. (1977) defined the lower boundary of the euphotic zone as the depth of 1.0 percent incident light penetration.

Water temperature, dissolved oxygen, pH, conductivity and light transmittance profile data was entered into computer data files and transferred to the U.S. Geological Survey WATSTORE system and the Environmental Protection Agency STORET system. Isopleth diagrams were generated using the USGS program STAMPEDE.

Results and Discussion

Water Temperature

Surface water temperatures have ranged from 0.0° to 23.0° during the study. Ice formation generally began in the upper part of the reservoir in December and the entire reservoir was ice-covered by mid January. Ice-out usually occurred in mid April. The reservoir was typically thermally stratified from approximately the end of May until the first part of October (May and Weaver 1987). The reservoir was then isothermal from about mid November to May. The preferred temperature range of 10-16°C for cutthroat trout (Hickman and Raleigh 1982) is depicted in Figures 6, 7 and 8. The water volume encompassing these temperatures was greatest in the spring and fall in 1987 as in previous years.

Dissolved Oxygen

Dissolved oxygen concentrations in the upper 30 to 50 m of the water column have generally ranged from 8 to 10 $mg \cdot l^{-1}$ (Figures 9, 10 and 11). These concentrations are adequate to sustain healthy aquatic life and are above the minimum required to support fish life. Davis (1975) stated that freshwater salmonids will not exhibit effects of low oxygen vhen concentrations are above 7.8 $mg \cdot l^{-1}$ and temperatures $\leq 15°C$. Hickman and Raleigh (1982) noted that optimal oxygen levels for cutthroat trout are not well documented, but appear to be >7 $mg \cdot l^{-1}$ at temperatures ≤ 15 C. This information indicates that dissolved oxygen levels in HHR are within the tolerance limits of the fish community inhabiting the reservoir and should have little impact on fish distribution.

pH

The pH values tend to increase during periods of high photosynthetic activity and decrease during periods of high respiration. The pH values in HHR in 1987 were similar to previous years (Figures 12, 13 and 14) vith the values in the 7.8 to 8.5 range most common (May and Fraley 1986, May and Weaver

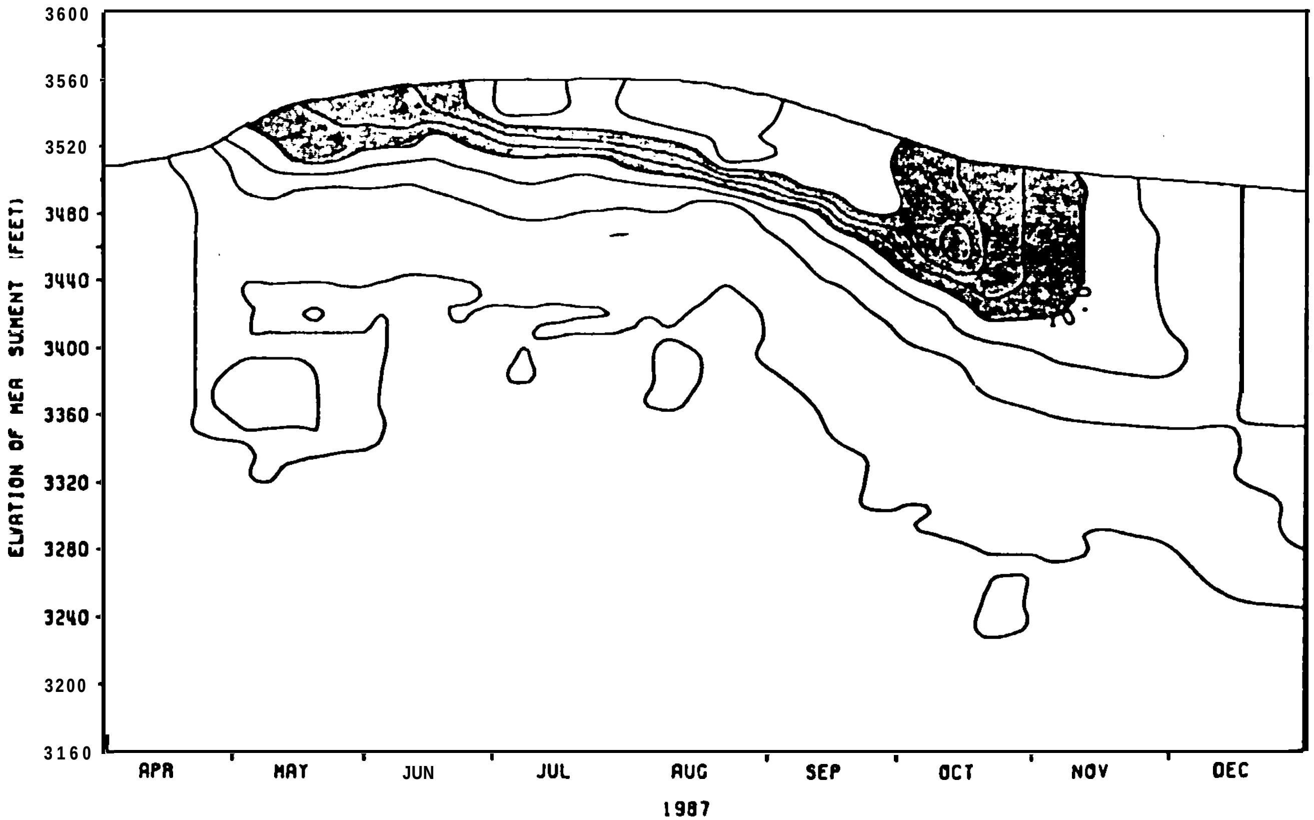


Figure 6. Isopleths of water temperature (2°C) from the Emery station, Hungry Horse Reservoir, 1987. Shaded areas are the preferred temperature strata for cutthroat trout (10°-16°C).

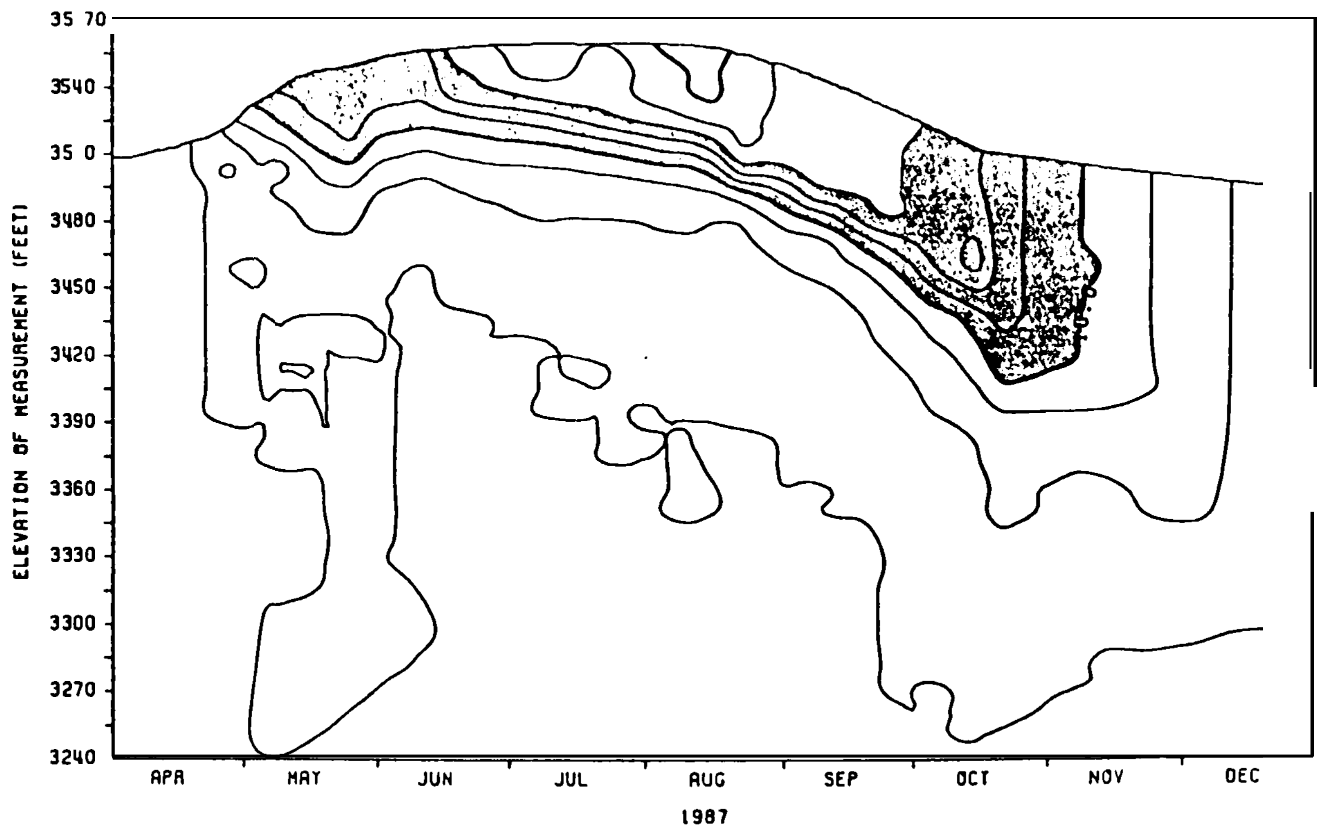


Figure 7. Isopleths of water temperature ($2^{\circ}C$) from the Murray station, Hungry Horse Reservoir, 1987. Shaded areas are the preferred temperature strata for cutthroat trout (10°-$16^{\circ}C$).

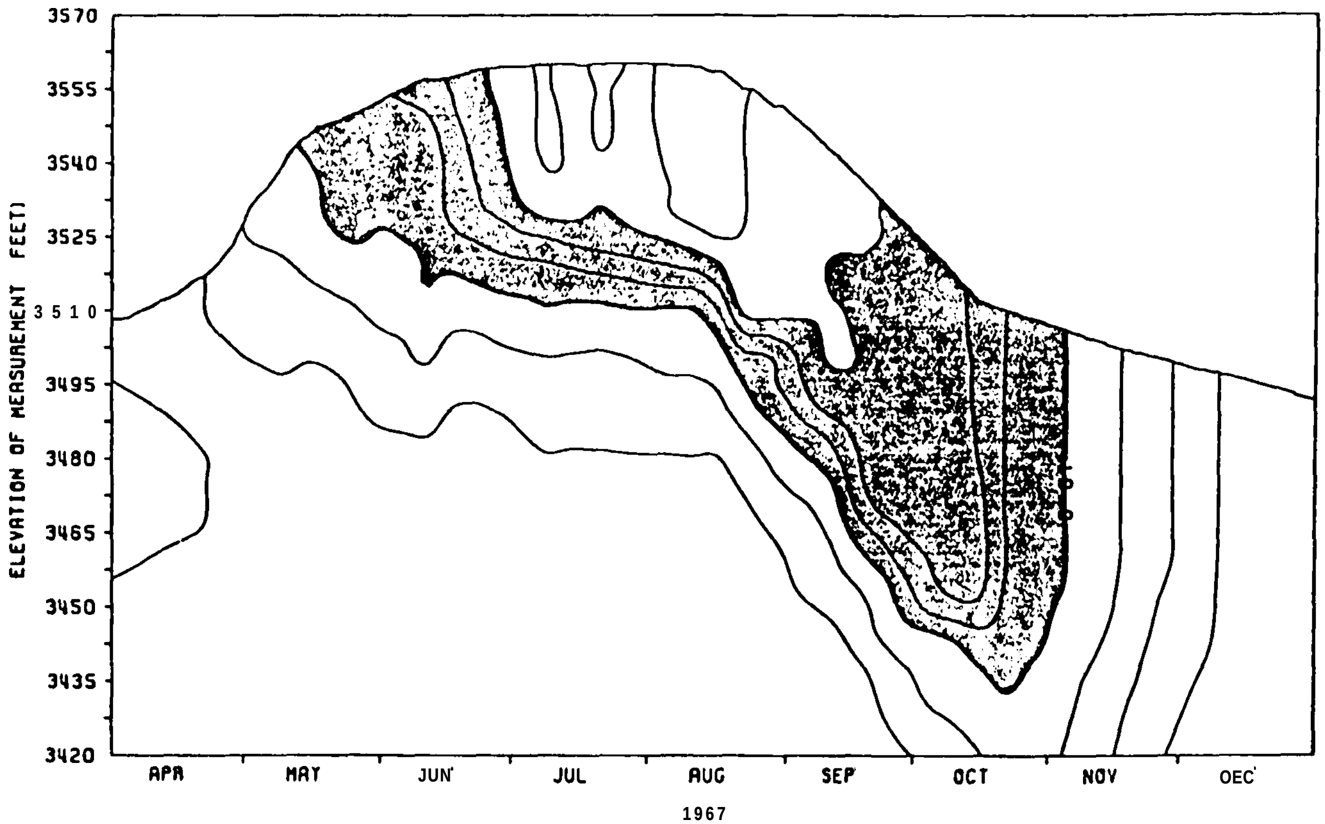


Figure 8. Isopleths of water temperature (2°C) from the Sullivan station, Hungry Horse Reservoir, 1987. Shaded areas are the preferred temperature strata for cutthroat trout (10°-16°C).

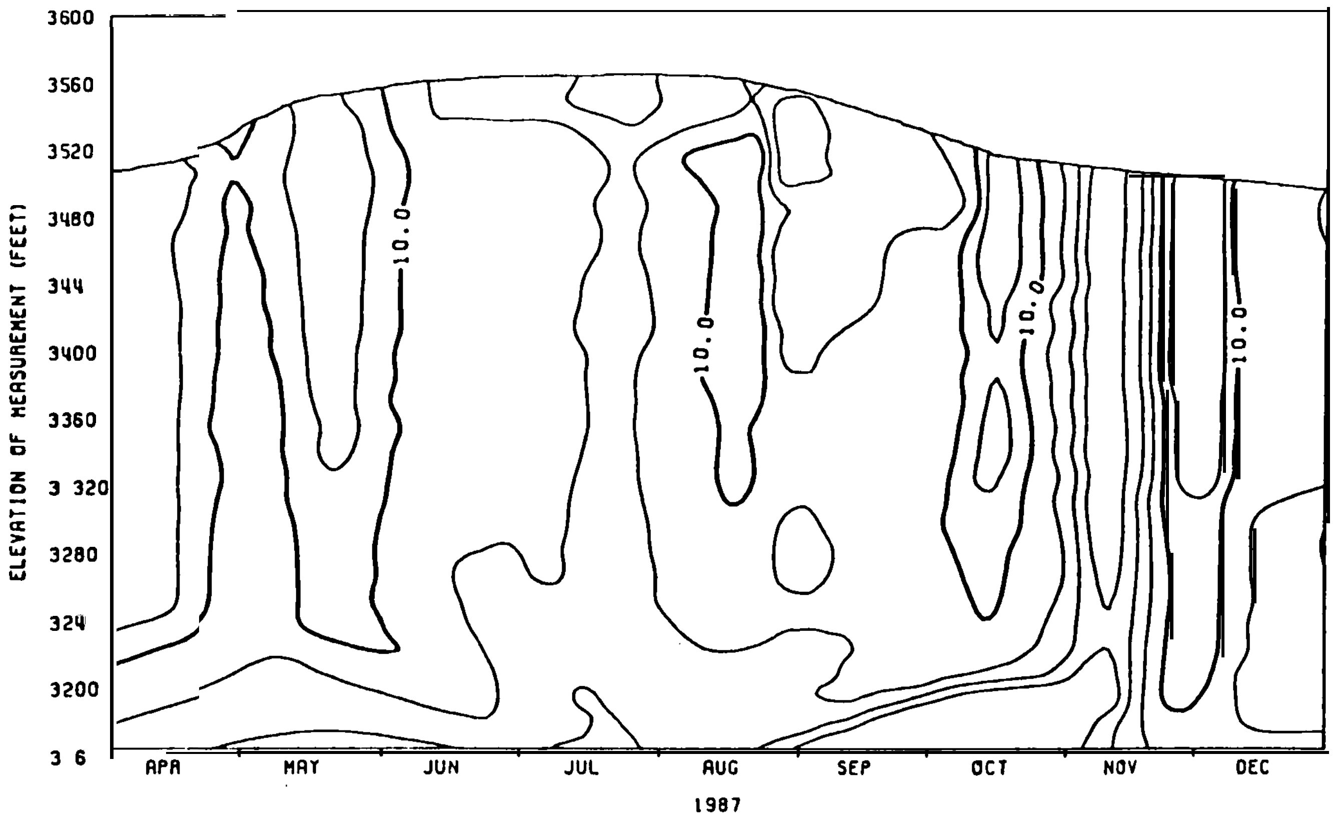


Figure 9. Isopleths of dissolved oxygen ($mg \cdot l^{-1}$) from the Emery station, Hungry Horse Reservoir, 1987.

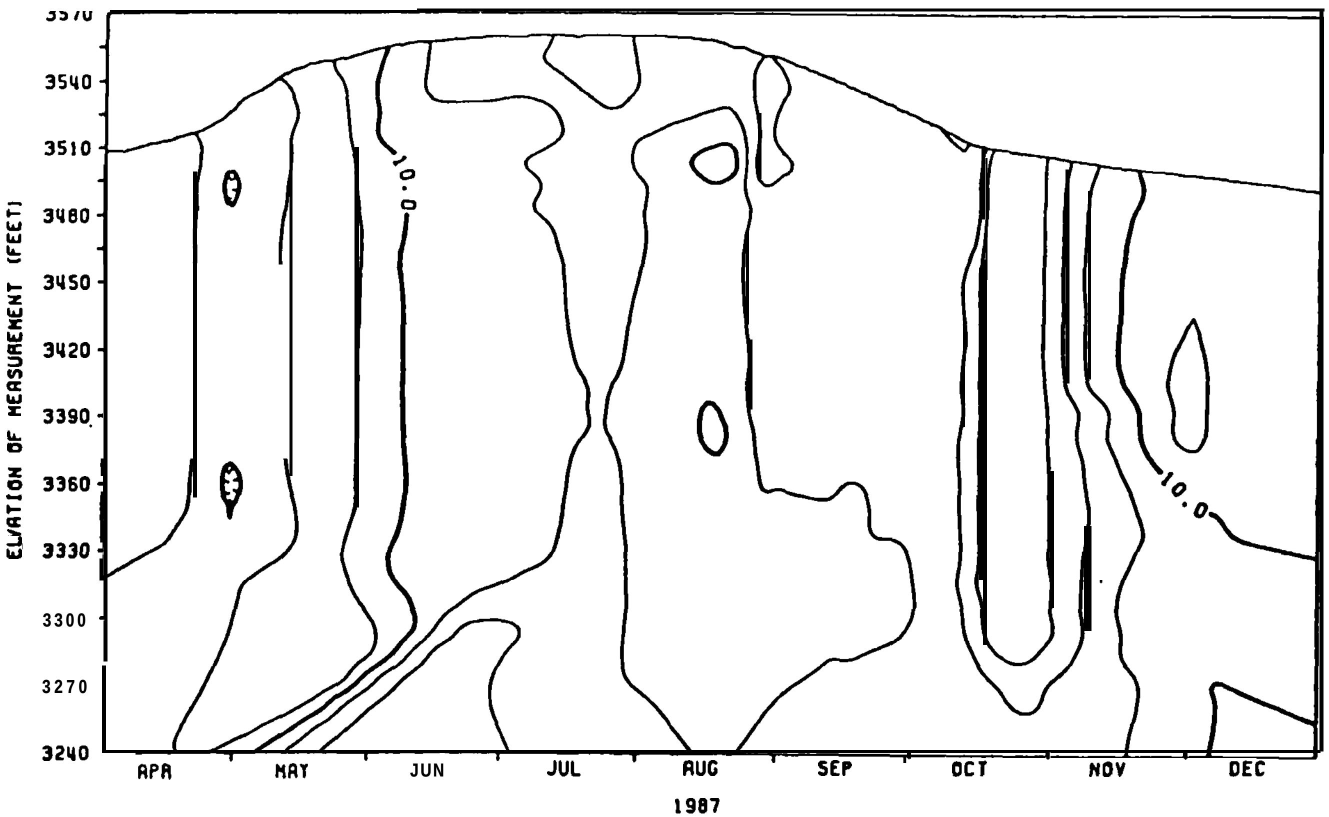


Figure 10. Isopleths of dissolved oxygen (mg·l^{-1}) from the Murray station, Hungry Horse Reservoir, 1987.

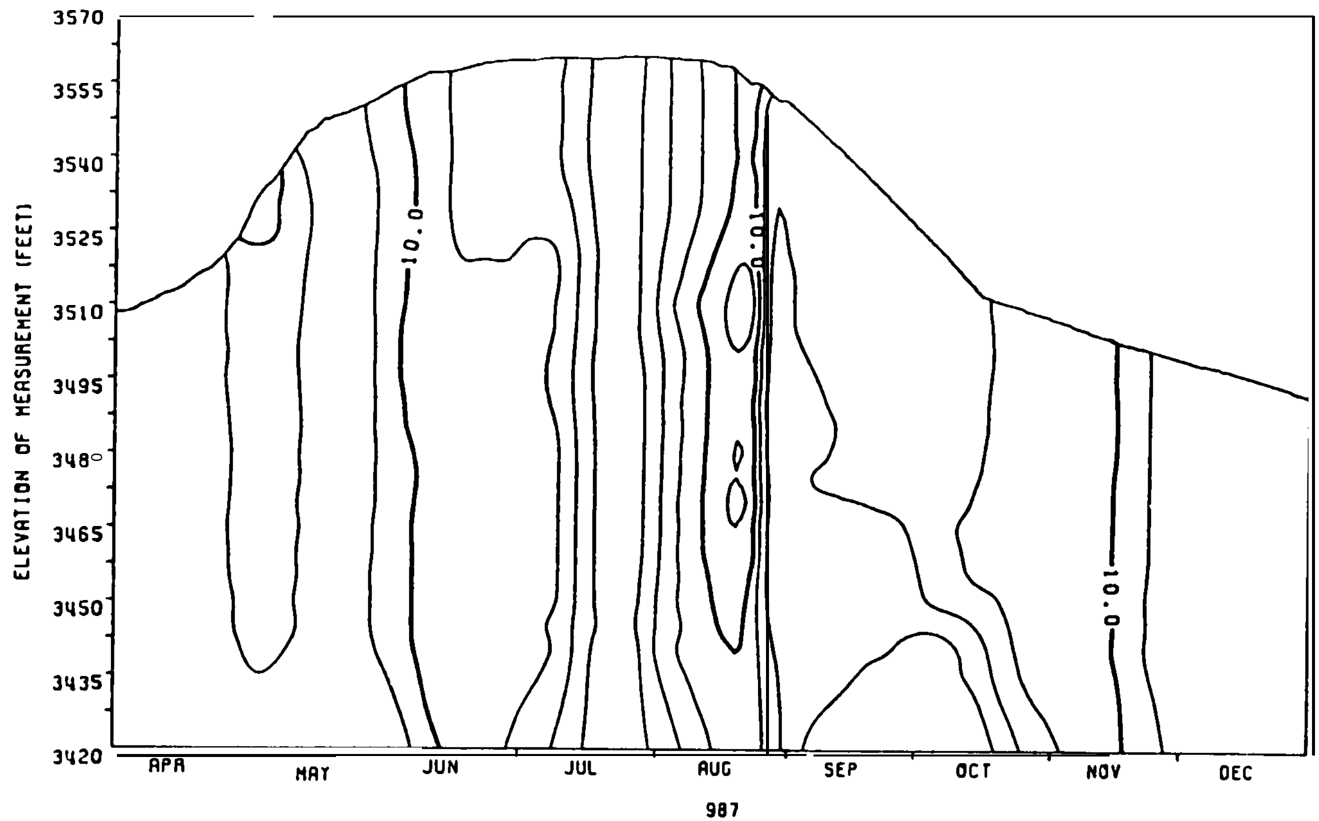


Figure 11. Isopleths of dissolved oxygen ($mg \cdot l^{-1}$) from the Sullivan station, Hungry Horse Reservoir. 1987.

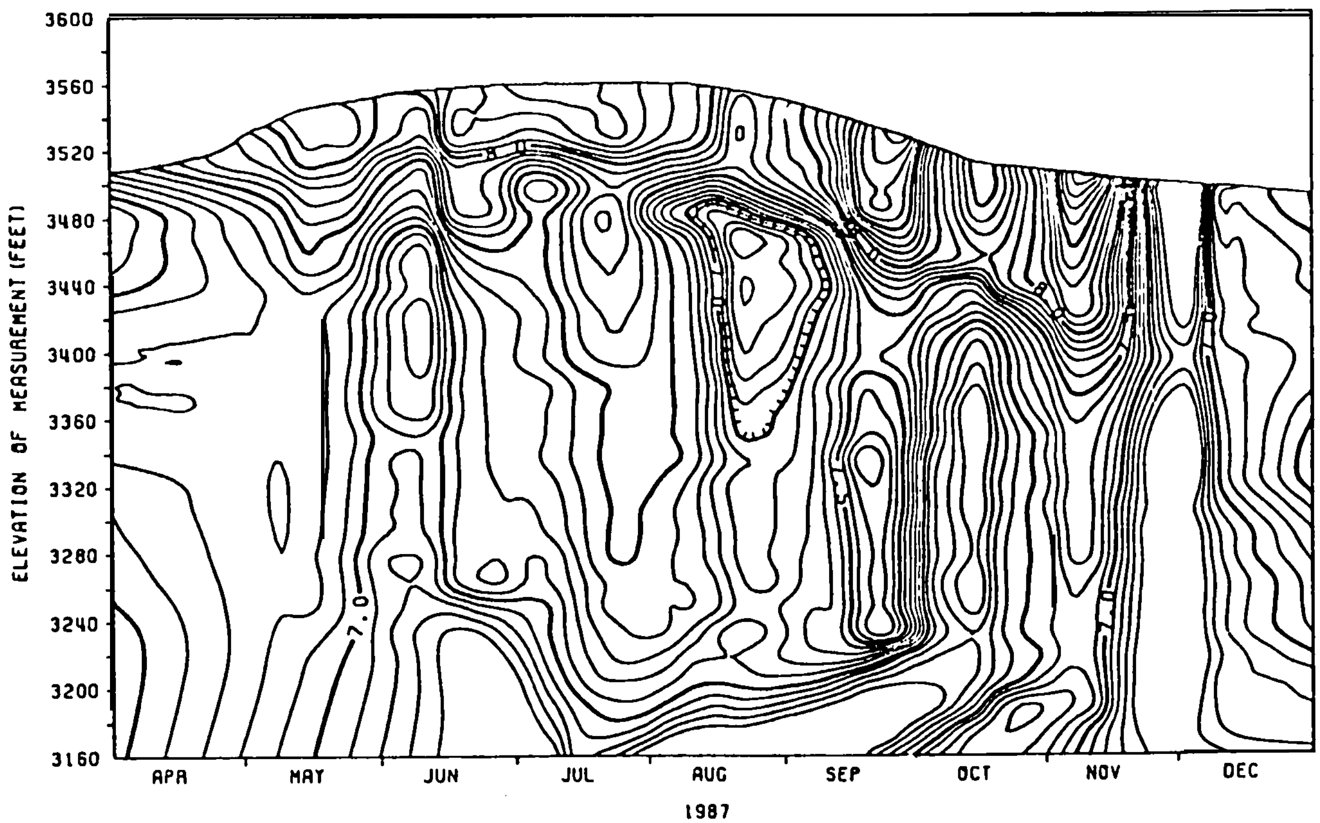


Figure 12. Isopleths of pH standard units (0.1) from the Emery station, Hungry Horse Reservoir. 1987.

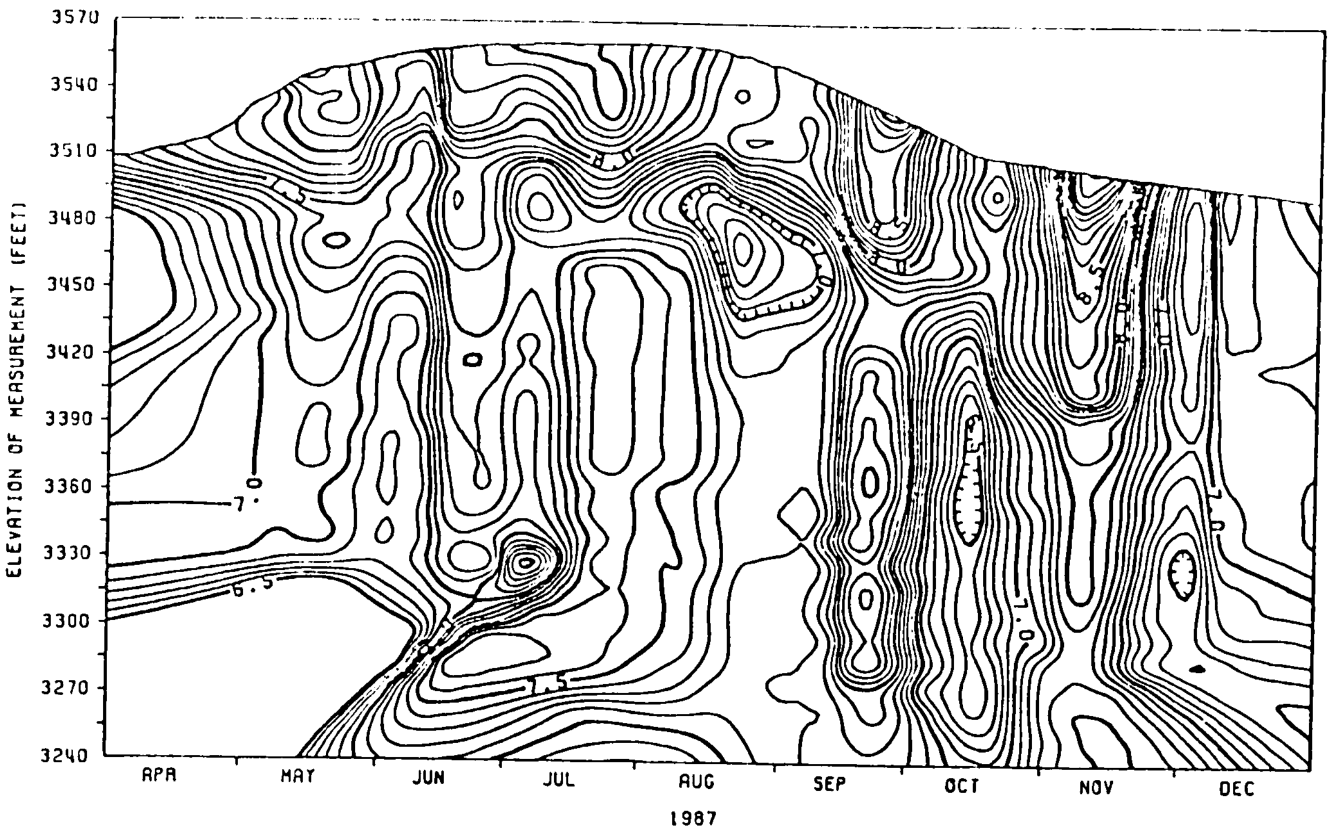


Figure 13. Isopleths of pH standard units (0.1) from the Murray station, Hungry Horse Reservoir, 1987.

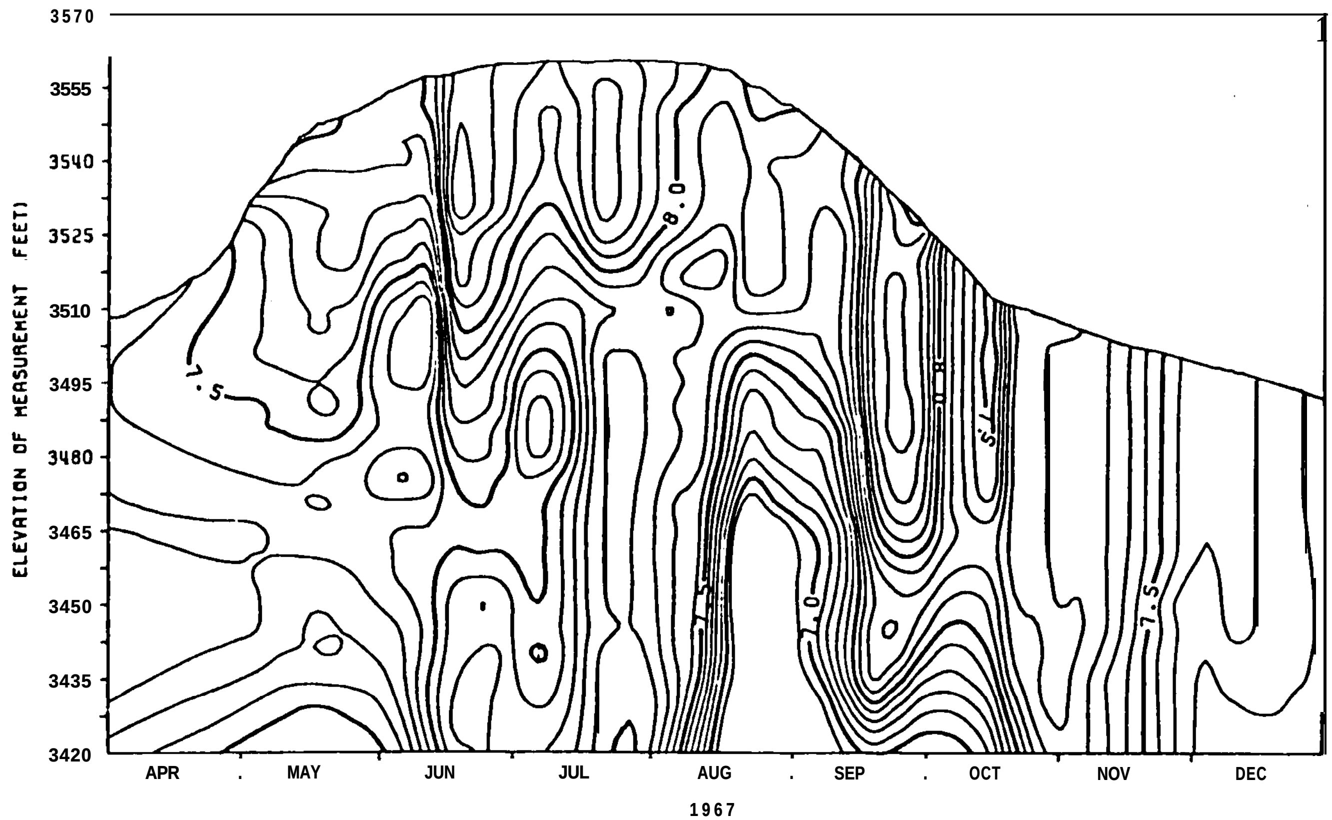


Figure 14. Isopleths of pH standard units (0.1) from the Sullivan station, Hungry Horse Reservoir, 1987.

1987). These values are within the range recommended by the Environmental Protection Agency Red Book (Thurston et al. 1972) for protection of aquatic life. McKee and Wolf (1963) stated that it is generally recognized that the best waters for the support of diversified aquatic life are those with pH values between seven and eight. Most cutthroat trout populations can probably tolerate a pH range of 5.0 to 9.5 With an optimal range of 6.5 to 8.0 (Hickman and Raleigh 1982). Sekulich (1974) reported that pH in three reservoirs containing cutthroat trout ranged from 7.8 to 8.5. Thus, it appears that pH values in Hungry Horse are within the optimum range for aquatic life in general and cutthroat trout in particular.

Specific Conductance

The determination of conductivity is a quick method for measuring the ion concentration of water. Specific conductance measurements in HHR ranged betveen 110 to 160 umhos/cm in 1984-85 (May and Fraley 1986). McKee and Wolf (1963) reported that studies of inland waters indicated that specific conductance of waters supporting a good mixed fish fauna range between 150-500 umhos$\cdot$cm^{-1}. The specific conductivity values in HHR were on the lower end of the productivity scale.

Euphotic Zone

The depth of the euphotic zone in HHR ranged from about 3 to 20.0 m (Figure 15) (May and Fraley 1986). There is considerable variation seasonally and among the geographic areas of the reservoir. Several environmental factors contribute to the wide variability in euphotic zone depths. The reflectivity of light by the water surface is dependent upon the solar height from the zenith. The greater the departure of the angle of the sum from the perpendicular, the greater the reflection (Wetzel 1975). Thus the euphotic zone will vary daily and seasonally due to changes in the amount of incident light reflected at the water surface. The proportion of light reflected is also influenced by wave action. Rapid attenuation of light transmission is caused by dense populations of algae and bacteria which vary seasonally. Similarly, sediment input during spring runoff reduces transmission particularly in the upper part of the reservoir in the Sullivan area.

Euphotic zone depths in HHR tended to be deeper than recorded in Lake Koocanusa vhere the values ranged from 1 to 18 m (Woods and Falter 1982). The greater euphotic zone depths in Hungry Horse appear to be due primarily to lower sediment input and lower primary productivity.

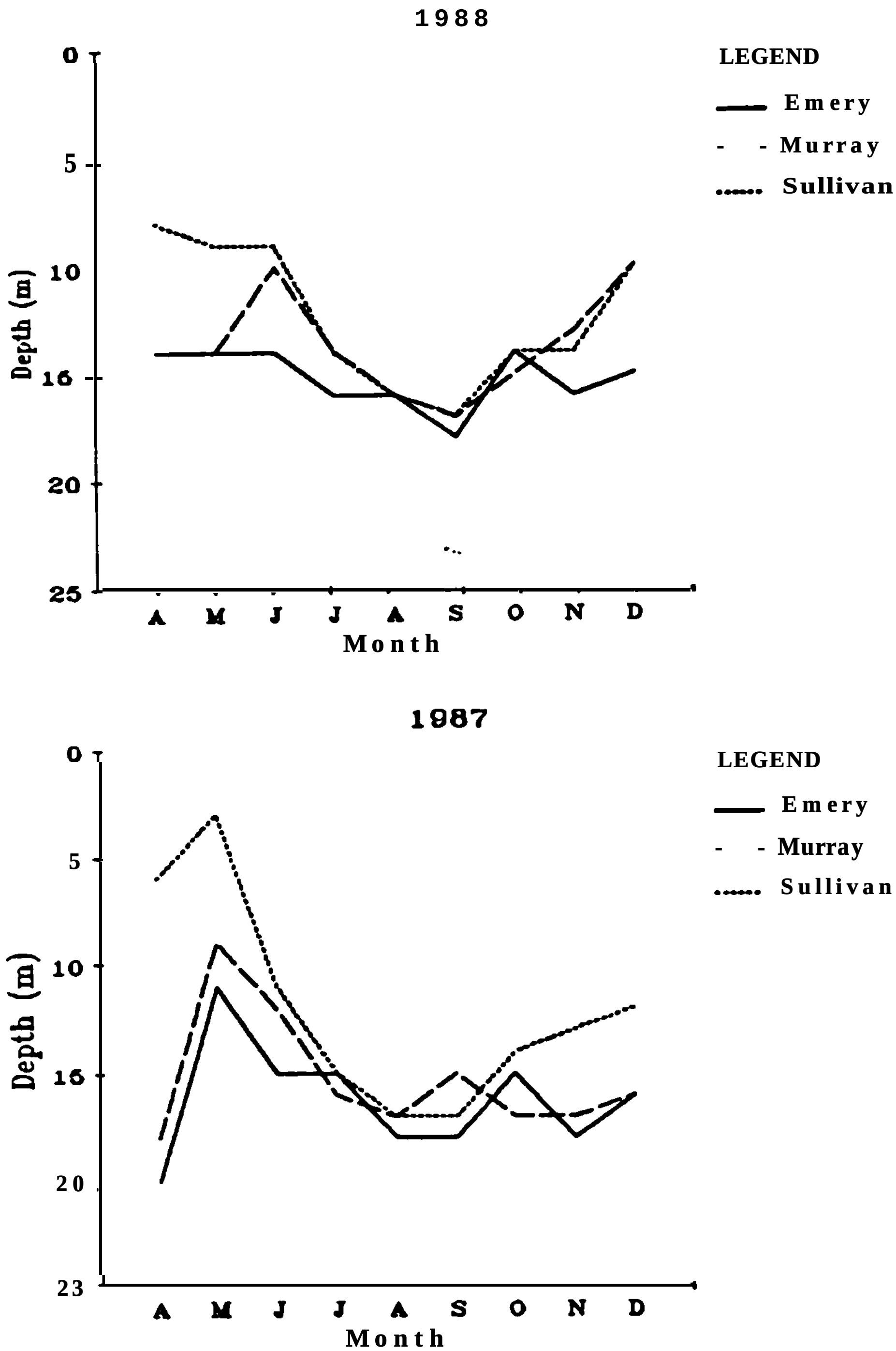


Figure 15. Euphotic zone depth in Hungry Horse Reservoir, 1986 and 1987.

PRIMARY PRODUCTIVITY

Methods

Primary productivity measurements were made at three-week intervals from May to November, 1986, on HHR. Hungry Horse Reservoir was sampled five times from April to September in 1987 (data not yet available).

Primary productivity was measured using ^{14}C radioisotope tracer and the light-dark bottle technique. At each station, water samples were collected at discrete depths (0, 1, 3, 5, 10, 15, 20, and 25 m) and subsamples drawn off into one clear and one opaque bottle. These were inoculated vith ^{14}C and then suspended at the depth of collection and incubated for three to seven hours near midday. The algae from each bottle was then collected by filtration for analysis of ^{14}C uptake by liquid scintillation counting.

Production rates were estimated using the folloving general equation and solving for "^{12}C uptake":

$$\frac{^{12}C\ \text{uptake}}{^{12}C\ \text{available}} = \frac{^{14}C\ \text{uptake}}{^{14}C\ \text{available}}$$

where "^{12}C available" vas estimated from alkalinity measurements, "^{14}C available" was calculated from the specific activity of the $NaH^{14}CO_3$ stock solution and "^{14}C uptake" was measured by liquid scintillation counting of the filtered algae.

Daily, volumetric production rates (mgC/m^3/d) at each station were calculated from the hourly rates measured during the incubation period by normalization to light (total langleys/ langleys during the incubation period). The volumetric rates for each depth sampled were then integrated to give a water-column, or areal, productivity rate (mgC/m^2/d).

Results and Discussion

As the primary productivity components of the reservoir models are as yet incomplete, only very broad, tentative statements can be made regarding the trophic status of the two reservoirs. In particular, it should be noted that the areal productivity rates (Table 3) are not directly comparable as these rates vary with the amount of light available on the sampling day.

With these limitations in mind, based on an initial analysis, Chlorophyll A concentrations (algal biomass) and observed daily, areal productivity rates, HHR would probably be classed as ultraoligotrophic. Throughout the sampling period, production rates were generally two to three times higher in Libby Reservoir than in Hungry Horse.

Table 3. Primary productivity data collected from Hungry Horse Reservoir, 1986. The rates are expressed as Observed, Daily Area Rates $mgC/m^2 \cdot d$).

Date	Primary Productivity $mgC/m^2 \cdot d$		
	Emery Area	Murray Area	Sullivan Area
May 14	131.4	149.1	59.1
June 3	162.3	112.8	121.7
June 28	167.8	153.3	169.0
July 15	227.2	223.5	141.3
August 9	231.8	170.9	124.3
August 26	231.5	229.9	173.6
September 16	176.5	169.3	170.5
October 7	191.8	146.0	120.8
Mean	190.0	169.4	135.0

In terms of crude comparisons, a small, shallow (10 m) lake in the Beartooth Plateau typically has three to ten times the Chlorophyll A concentrations of these two reservoirs (Dr. J. Priscu, Biology Department, MSU pers. comm.). In addition, as reported in Wetzel (1983), maximum daily areal rates in HHR are similar to those reported for Castle Lake, a deep, alpine lake in California, and Lake Superior, the most unproductive of the Great Lakes. Similarly, Libby Reservoir compares favorably with Lake Huron.

Area differences in primary productivity were noticeable with the production highest in the Emery area. intermediate in the Murray area and lowest in the Sullivan area (Table 3). The variances in water temperature, light penetration and nutrients probably account for most of the differences in primary productivity among the areas.

ZOOPLANKTON

Methods

Zooplankton densities in HHR were sampled with a Wisconsin plankton net. A 153-micron mesh conical plankton net having a mouth diameter of 0.115 m was used. Three 30-m vertical tows were made twice a month in the Emery, Murray and Sullivan areas; one tow at the permanent limnological buoy and two tows at randomly selected sites.

The vertical distribution of zooplankton in HHR was assessed with a 30-liter Plexiglas Schindler plankton trap (Schindler 1969). A Schindler trap sample series was conducted monthly at the permanent limnological buoys of each area. The sample series consisted of duplicate samples taken at the reservoir surface and at every 3 m down to 15 m. The series continued from 15 m down to 30 m by 5-m intervals.

Duplicate zooplankton samples were taken biweekly with a drift net below Hungry Horse Dam in the South Fork of The Flathead River. These samples were used to evaluate the loss of HHR zooplankton due to reservoir drafting. The drift net was constructed from 103-micron mesh nitex, its mouth vas 1.0 m by 0.5 m and tapered back to a 10-cm cod end. The net was attached to an angle iron frame and a removable plexiglass bucket with 103-micron mesh nitex panels was attached to the cod end.

The drift nets were anchored in the river (2.5 km downstream from the dam) with iron stakes passing through holes in the net frame and driven into the substrate. Water velocity through the net was recorded along with water depth and temperature. Instantaneous river flows were taken from a USGS gauging station located immediately upstream of the sampling site.

Wisconsin zooplankton samples from the permanent stations were preserved in four percent formalin and 40 $g \cdot l^{-1}$ sucrose. Formalin was used to insure proper zooplankton measurements from these stations which were used to predict biomass estimates for all other zooplankton samples. All other zooplankton samples were preserved in 95 percent ETOH Zooplankton from the Wisconsin samples were identified to genus except for Daphnia pulex using a binocular compound microscope and a 1.0 ml Sedvick Rafter counting cell. Zooplankton from the Schindler and drift samples were identified to genus and counted using a dissecting microscope and a 4-ml zooplankton counting wheel.

In contrast to conventional zooplankton measurement techniques, 1987 zooplankton were projected from the compound microscope onto a monitor where they were measured with electronic calipers. These calipers were coupled to an IBM-AT personal computer and interfaced with a dBase III+ data base through a program called ANGREAD. Not only vere the measurements more accurate (95 percent confidence limits), but the measurements were automatically entered into the data base file. Wisconsin zooplankton counts from all stations were entered directly into the same data base file. This reduced the possibility of error associated with recording data before entering it into the computer. After the counts and measurements were complete, another program (VZREPORT) was used to calculate biomass and density estimates. This procedure saved many hours of lab work, reduced the likelihood of error and gave more accurate zooplankton measurements than conventional methods. The Mann-Whitney non-parametric test was used to check for differences between areas and years.

Results and Discussion

Standing Crop

The zooplankton community was dominated by Cyclops, Diaptomus, Daphnia and Bosmina (Figure 16). They comprised approximately 99 percent of the numbers and biomass of the zooplankton population from 1984 to 1987 (Table 4). Daphnia pulex the primary zooplankter consumed by game fish-accounted for between 7.2 and 17.8 percent of the biomass from 1984 to 1987.

The seasonal progression in zooplankton abundance was typical of many lakes and reservoir (Figure 17). Total zooplankton populations were low in April, peaked in July at approximately $10{,}000 \cdot M^{-3}$, declined during the summer, had another peak in November and declined markedly in December. Cyclops exhibited a slightly different pattern with populations increasing steadily from April to November then declining sharply in December. The seasonal progression of abundance developed more rapidly in 1986 than in other years primarily due to warmer water temperatures (May and Weaver 1987). Surface water temperatures at the end of May, 1986, were 17.5°C in the Murray area as compared to approximately 10 to 12°C in other years. In addition, seasonal

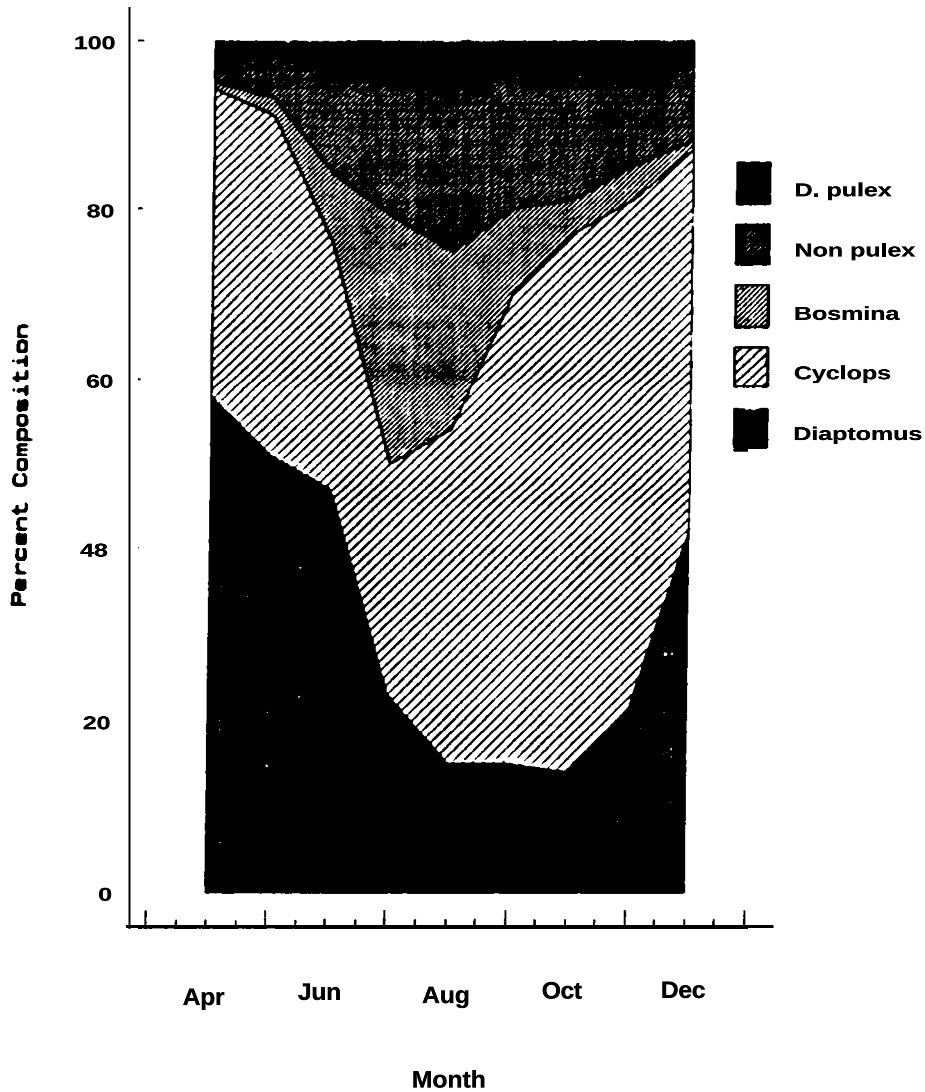


Figure 16. The percent composition of the zooplankton populations in Hungry Horse Reservoir 1984-87. Based on 30-m vertical tows with a Wisconsin plankton net. Daphnia is separated into Daphnia pulex and non pulex (Daphnia SP.).

Table 4. Weighted mean zooplankton densities ($N \cdot M^{-3}$) and weights ($mg \cdot M^{-3}$) estimated from 30m vertical tows during 1987 in Emery Area, Hungry Horse Reservoir.

Month	Number of Samples	Daphnia Pulex	Daphnia Non-pulex	Bosmina	Leptodora	Total Cladocerans	Diaptomus	Cyclops	Epichura	Total Copepods	Total Zooplankton
						Number					
April	3	18	16	30	0	64	4,050	869	0	4,918	4,983
May	6	122	303	124	0	548	3,848	3,612	2	7,462	8,011
June	6	417	859	1,034	0	2,310	3,895	3,393	24	7,312	9,622
July	6	555	1,491	2,861	0	4,908	2,562	3,410	11	5,983	10,891
August	6	150	1,134	2,393	<1	3,676	705	5,505	20	6,230	9,906
September	6	213	1,313	837	<1	2,364	2,165	8,758	18	10,940	13,304
October	6	55	397	113	0	566	525	7,747	5	8,277	8,843
November	6	76	448	25	<1	549	474	6,732	3	7,209	7,757
December	3	41	428	29	0	498	442	3,817	1	4,260	4,758
Year	48	202	771	927	<1	1,900	2,052	5,188	10	7,250	9,151
						Weight					
April	3	2.4	0.7	0.7	0	3.8	240.1	30.5	0	270.6	274.3
May	6	20.7	19.9	1.6	0	42.2	173.8	105.2	0.3	279.3	321.5
June	6	48.3	70.9	11.1	0	130.3	104.0	90.0	6.2	200.3	330.6
July	6	68.9	105.7	34.4	0	209.0	78.1	76.2	3.1	157.4	366.4
August	6	19.1	103.2	21.4	0.4	144.2	12.0	74.2	4.3	90.5	234.7
September	6	27.3	142.8	11.0	0.6	181.8	61.7	109.2	3.1	174.0	355.7
October	6	8.4	53.9	1.3	0	63.5	19.3	122.0	1.2	142.6	206.1
November	6	7.6	29.7	0.3	0.1	37.8	9.8	103.1	0.7	113.6	151.5
December	3	5.2	16.6	0.3	0	22.2	18.1	82.5	0.2	100.8	123.0
Year	48	25.5	66.8	10.2	0.1	102.7	73.5	92.1	2.4	167.9	270.6

Table 4. Continued, Murray Area, 1987.

Month	Number of Samples	Daphnia Pulex	Daphnia Non-pulex	Bosmina	Leptodora	Total Cladocerans	Diaptomus	Cyclops	Epischura	Total Copepods	Total Zooplankton
						Number					
April	3	5	51	19	0	75	1.742	1,303	0	3,045	3,121
May	6	74	157	193	0	425	3,007	3,585	7	6,599	7,024
June	6	170	660	1,605	0	2,435	4,002	3,119	61	7,182	9,617
July	4	406	2,106	4,168	0	6,680	3,667	3,549	12	7,228	13,908
August	6	285	1,317	1,582	<1	3,512	573	4,573	12	5,158	8,671
September	6	199	1,093	616	0	1,909	1,287	6,271	17	7,575	9,484
October	6	98	604	304	0	1,006	497	5,635	5	6,137	7,143
November	6	218	839	54	0	1,111	909	4,831	2	5,742	6,853
December	2	243	493	42	0	778	648	3,260	1	3,910	4,688
Year	45	186	835	954	<1	2,020	1.861	4,282	15	6,139	8,158
						Weight					
April	3	1.1	1.6	0.5	0	3.2	81.7	31.6	0	113.3	116.5
May	6	9.1	6.3	1.8	0	17.2	114.2	76.3	0.8	191.3	208.6
June	6	20.1	54.1	21.5	0	95.7	158.0	97.2	13.4	268.6	364.3
July	4	53.8	162.8	45.8	0	262.3	146.3	62.4	2.8	211.5	473.8
August	6	285.2	1,317.4	1,581.8	0.1	3,512.2	572.8	4,573.3	12.3	5,158.5	8,670.7
September	6	35.0	149.3	5.7	0	190.1	30.4	76.9	2.1	109.4	299.5
October	6	16.1	60.5	3.3	0	79.9	15.8	85.7	0.9	102.4	182.3
November	6	30.0	68.2	1.0	0	99.2	16.6	76.8	0.6	94.0	193.1
December	2	32.8	41.6	0.5	0	74.7	22.7	62.2	0.4	85.2	160.0
Year	45	25.8	83.7	10.0	0	119.6	65.4	73.2	3.0	141.7	261.3

Table 4. Continued, Sullivan Area, 1987.

Month	Number of Samples	Daphnia Pulex	Daphnia Non-pulex	Bosmina	Leptodora	Total Cladocerans	Diaptomus	cyclops	Epischura	Total Copepods	Total Zooplankton
						Number					
April	3	2	11	6	0	19	590	1,826	0	2,416	2,435
May	6	0	0	22	0	22	297	227	13	536	558
June	6	5	62	953	<1	1,020	801	627	75	1,503	2,523
July	6	25	651	2,450	<1	3,126	2,100	1,330	20	3,450	6,577
August	6	55	856	2,349	2	3,263	1,356	2,790	20	4,166	7,429
September	6	20	1,163	947	0	2,130	1,526	4,769	44	6,339	8,469
October	6	28	2,534	536	<1	3,099	1,997	8,882	73	10,953	14,052
November	6	182	2,832	717	0	3,731	3,320	11,285	55	14,661	18.392
December	3	259	2,278	202	0	2,739	9,912	6,096	38	16,046	18.785
Year	48	56	1,155	1,010	<1	2,221	2,081	4,234	40	6,355	8,576
						Weight					
April	3	0.3	0.4	0.1	0	0.8	37.6	62.1	0	99.7	100.5
May	6	0	0	0.3	0	0.3	17.9	10.1	0.7	28.7	29.0
June	6	1.0	4.9	9.5	0.2	15.7	47.2	26.6	9.2	83.0	98.7
July	6	4.2	37.4	23.7	0.4	65.8	66.4	28.0	2.1	96.6	162.3
August	6	6.2	52.2	20.4	3.4	82.3	26.2	41.2	3.8	71.3	153.5
September	6	2.6	101.8	11.9	0	116.3	42.1	72.1	6.6	120.9	237.2
October	6	3.7	439.6	6.2	0.3	449.7	94.2	195.1	20.3	309.7	759.4
November	6	19.9	362.3	9.3	0	391.5	160.0	247.9	16.4	424.3	815.8
December	3	27.3	214.7	2.6	0	244.6	511.6	118.6	10.1	640.3	884.9
Year	48	6.4	138.2	10.3	0.5	155.5	91.1	88.9	8.0	188.0	343.6

Table 4. Continued, Areas combined, 1987.

Month	Number of Samples	Daphnia Pulex	Daphnia Non-pulex	Bosmina	Leptodora	Total Cladocerans	Diaptomus	Cyclops	Epischura	Total Copepods	Total Zooplankton
						Number					
April	9	8	26	18	0	53	2,128	1,332	0	3,460	3,513
May	18	65	153	113	0	332	2,384	2,475	7	4,866	5,198
June	18	197	527	1,197	<1	1,922	2,899	2,380	53	5,332	7,254
July	16	319	1,330	3,034	<1	4,683	2,665	2,665	lb	5,344	10,027
August	18	163	1,102	2,108	<1	3,484	878	4,290	17	5,185	8,669
September	18	144	1,190	800	<1	2,134	1,659	6,599	26	8,285	10,419
October	18	16	1.179	318	<1	1,557	1,006	7,422	27	8,456	10,013
November	18	158	1,373	266	<1	1,797	1,568	7,616	20	9,204	11,001
December	8	173	1,138	97	0	1,409	4,045	4,533	15	8,592	10,001
Year	141	147	922	964	<1	2,048	1,995	4,574	22	6,591	8,638
						Weight					
April	9	1.3	0.9	0.4	0	2.6	119.8	41.4	0	161.2	163.8
May	18	9.9	8.7	1.2	0	19.9	102.0	63.9	0.6	166.4	186.4
June	18	23.1	43.3	14.0	0.1	80.5	103.1	71.3	9.6	184.0	264.5
July	16	40.9	94.3	33.2	0.2	168.6	90.7	54.7	2.7	148.1	316.7
August	18	20.5	107.2	17.6	1.3	146.7	16.0	57.7	3.7	77.4	224.1
September	18	21.6	131.3	9.5	0.2	162.7	44.7	86.1	3.9	134.7	297.4
October	18	9.4	184.7	3.6	0.1	197.7	43.1	134.3	7.5	184.9	382.6
November	18	19.2	153.4	3.5	<0.1	176.2	62.1	142.6	6.0	210.6	386.8
December	8	20.4	97.1	1.2	0	118.7	204.3	91.0	4.0	299.2	418.0
Year	141	19.1	96.5	10.2	0.2	126.1	76.9	85.0	4.5	166.4	292.5

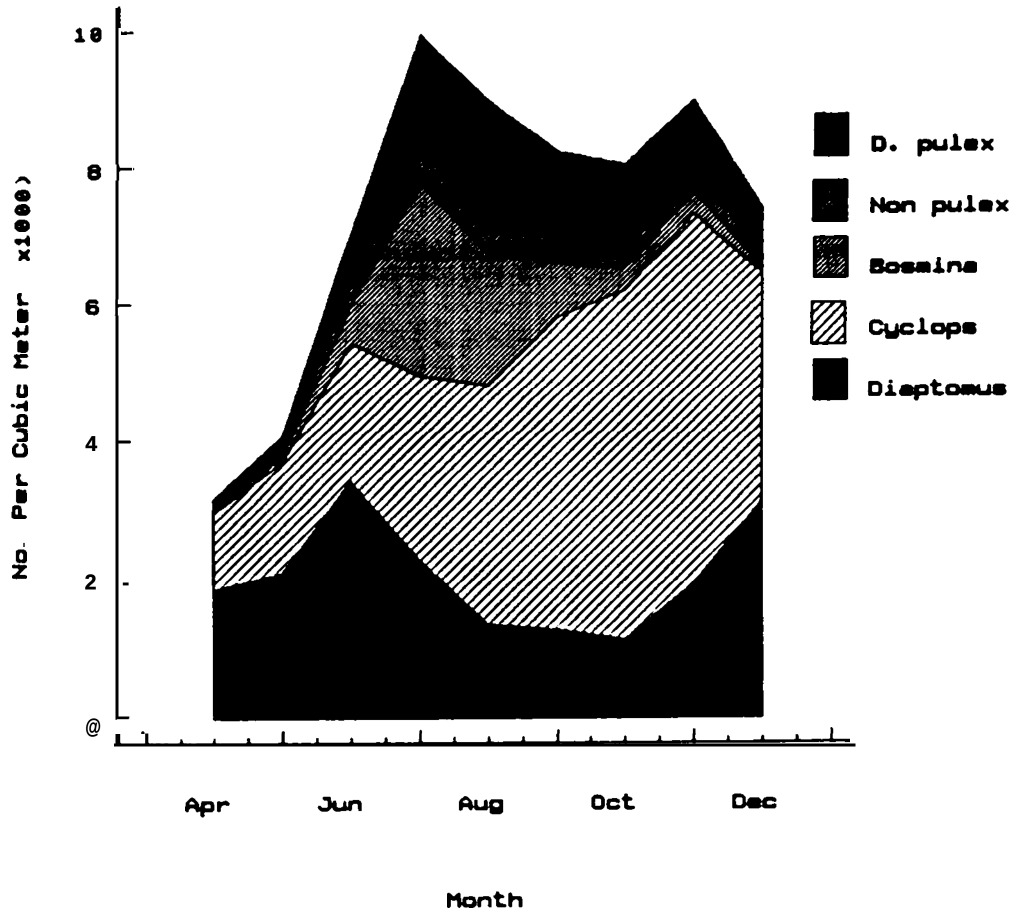


Figure 17. The seasonal abundance ($N \cdot M^{-3}$) of the four most abundant genera of zooplankton in Hungry Horse Reservoir 1984-87. Daphnia is separated into Daphnia pulex and non pulex (Daphnia sp.).

progression in abundance in the Sullivan area tended to lag behind the other two areas due to lower water temperatures and a reduced euphotic zone in spring resulting from turbid inflows from the South Fork of the Flathead River. Martin et al. (1981) found that water temperatures played an important role in influencing the seasonal development of zooplankton populations in reservoirs.

There was a considerable difference in densities of zooplankton among the areas (Table 5). The Emery area had significantly higher standing crops of total zooplankton than the other two areas. In contrast, the populations in the Sullivan area were significantly lower than in the Murray and Emery areas. Daphnia pulex populations were also significantly lower in the Sullivan area than the other two areas. Although in November and December the densities of this species averaged higher in the Sullivan area than in the other two areas (May and Weaver 1987). Primary production was also lowest in the Sullivan area and highest in the Emery area indicating a link betveen phytoplankton abundance and zooplankton densities.

The annual differences in total zooplankton abundance indicated that densities in 1984 were significantly less ($P<.01$) than recorded from 1985 to 1987 (Table 6). Densities in the individual genera exhibited contrasting annual differences. Bosmina densities were not significant among the years, whereas the abundance of Daphnia pulex vas significantly different ($P<.01$) for each annual comparison with the 1984 population the highest, and the 1987 the lowest. The annual variation among the genera is perplexing and not readily understandable in terms of the Variables effecting these differences such as water temperature, primary production, predation and reservoir operation. Understanding gained from the secondary production component of the model should give us insights into the factors influencing zooplankton production

Vertical Distribution

The depth distribution of major zooplankton genera in 1987 (Table 7) vas comparable to previous years. Zooplankton densities vere highest above the 15- to 20-m depths which correspond to the euphotic zone (May and Veaver 1987). Hovever, large numbers were also found below 20 m. Daphnia densities in the fall were highest above 15 m, making this important food item available to westslope cutthroat trout.

Dovnstream Loss

The downstream loss of zooplankton from Hungry Horse Reservoir vas evaluated by sampling in the South Fork of Flathead River downstream from the dam throughout 1987 (Table 8). The mean density for the period April through December, 1987, was approximately 544 zooplankters ($N \cdot M^{-3}$) compared to approximately $378 \cdot M^{-3}$ estimated for the same period in 1986 (May and Weaver

Table 5. A comparison of zooplankton populations (N.H-3) among the Emery. Murray and Sullivan areas collected in Visconsin tovs from 1984 to 1987.

	The mean number of zooplankton (N.M-3)		
Taxon	Emery x Murray	Emery x Sullivan	Murray x Sullivan
Daphnia pulex	344X386	344x257**	386x257**
Daphnia	1,122 x 1,113	1,122 x 1,027*	1,113 x 1,027*
Bosmina	930 x 1,100	930 x 846	1,100 x 846
Cyclops	4,099 x 3,235**	4,099 x 2,978**	3,235 x 2978**
Diaptomus	2,143 x 1,956**	2,143 x 1,675**	1,956 x 1,675**
Total zooplankton	8,649 x 7,810**	8,649 x 6,809**	7,810 x 6,809**

* -significant difference at 0.05 probability level

** - significant difference at 0.01 probability level

Table 6. A comparison of zooplankton populations (N.M-3) among years collected in Wisconsin tows from 1984 to 1987.

Taxon	The mean number of zooplankton ($N \cdot M^{-3}$)					
	1984 x1985	1984x1986	1984x1987	1985x1986	1985 x1987	1986x1987
Daphnia pulex	549 x 378**	549 x 271**	549 x 147*8	378 x 271*	378 x 147**	271x 147**
Daphnia	721 x 1,315**	721 x 1,321**	722x 922	1,315 x 1,321	1,315 x 922**	1,32l x 922**
Bosmina	506 x 1,3ll	506x982	506 x 963	1,311 x 982	1,3ll x 963	982 x 963
Cyclops	2,749 x 2,853	2,749 x 3,436**	2,749 x 4,754**	2,853 x 3,436	2,853 x 4,754**	3,436x 4,754**
Diaptomus	1,749 x 1,936*	1,749 x 2,026	1,749 x 1,994	1,936 x 2,026	1,936 x 1,994	2,026 x 1,994
Totalzooplankton	6,280 x 7,803**	6,280 x 8,052**	6,280 x 8,638**	7,803 x 8,052	7,803 x 8,638*	8,052 x 8,638

* - significant difference at 0.05 probability level
** - significant difference at 0.01 probability level

Table 7. Zooplankton densities (NM^{-3}) estimated from Schindler trap samples taken from Emery area of Hungry Horse Reservoir, 1987.

Taxon	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				One Meter					
Daphnia	17	1,967	250	150	250		67	250	0
Bosmina	0	217	17	0	50		0	0	0
Diaptomus	1.567	6,717	2,200	1,550	450		333	550	0
Cyclops	567	4,017	1,217	2,883	1,233		2,000	II.750	0
Epischura	0	67	17	17	33		0	0	0
				Three Meters					
Daphnia	0	2,700	1,117	2,217	1,100		700	533	483
Bosmina	0	183	150	33	133		17	0	67
Diaptomus	1,900	6.100	4,966	9,417	1,867		717	667	500
Cyclops	667	3,700	3,233	9,583	2.567		4,833	12,400	5,083
Epischura	0	83	17	67	0		0	0	0
				Six Meters					
Daphnia	50	583	783	4,433	2,550		1.867	667	467
Bosmina	0	67	950	100	283		0	0	0
Diaptomus	2,117	2,900	3,300	4,217	2,150		467	467	867
Cyclops	500	1,717	5,033	15,200	7,050	--	9,800	12,933	10,800
Epischura	0	0	33	17	17		0	0	0
				Nine Meters					
Daphnia	133	1,117	0	4,733	2.450		1,333	933	533
Bosmina	0	367	0	117	-667		200	67	0
Diaptomus	2,667	4,083	0	5,367	1.333		200	267	483
Cyclops	833	3.467	0	10,183	7,983		6,800	13,333	4,983
Epischura	0	67	0	67	0		0	0	0
				Twelve Meters					
Daphnia	33	550	2,883	3.500	1.617		1,200	933	417
Bosmina	0	33	1,267	83	-383		0	0	17
Diaptomus	1,550	2,983	2,133	3,817	600		133	533	567
Cyclops	583	1.367	3,950	11,250	5,167		14,600	16,000	4,700
Epischura	0	0	0	17	33		0	0	0
				Fifteen Meters					
Daphnia	17	567	1,217	1,067	1,633	--	417	1,400	883
Bosmina	17	67	217	200	450		0	0	17
Diaptomus	2,400	2,650	900	1,600	250		100	467	367
Cyclops	533	2,150	2,733	15,133	5,050		7,350	12,133	5,750
Epischura	0	33	0	0	50		0	0	0
				Twenty Meters					
Daphnia	67	133	983	2,800	3,967	--	717	1,183	667
Bosmina	0	17	100	800	933		0	50	17
Diaptomus	1,700	1,933	883	1,800	333	--	433	733	583
Cyclops	633	2,333	1,950	9,667	3,317		7,783	15,917	5,450
Epischura	0	17	0	0	0		17	0	0
				Twenty-five Meters					
Daphnia	33	217	617	1,400	1,350		50	400	650
Bosmina	0	50	150	733	483	--	0	67	33
Diaptomus	1,683	3,350	2,050	1,800	383	--	133	800	700
Cyclops	667	2,567	2,167	9,533	4,067		8,000	12,067	6,233
Epischura	0	17	0	0	0	--	0	0	0
				Thirty Meters					
Daphnia	17	550	300	633	333		733	1,500	667
Bosmina	0	117	200	350	217		0	0	17
Diaptomus	1,183	5.817	1,217	967	183	--	267	550	583
Cyclops	617	2,667	1,133	4.733	2,150		9,800	14,350	4,717
Epischura	0	33	0	0	0		0	0	0

Table 7. Continued, Murray area, 1987.

Taxon	Apr	May	Jul	Jul	Aug	Sep	Oct	NW	Dec
				One Meter					
Daphnia	17	100	717	217	500	267	900	1,567	800
Bosmina	0	383	167	133	100	50	133	0	17
Diaptomus	617	5.617	1.317	717	2,150	4.367	500	400	883
Cyclops	150	2,703	617	2,800	3,117	7,383	5.433	5,900	3,000
Epischura	0	117	0	17	0	0	17	17	0
				Three Meters					
Daphnia	17	533	3,117	1.367	4,583	1,400	2,000	1.267	283
Bosmina	0	767	367	100	233	0	467	17	17
Diaptomus	1.633	10,333	6,433	1.333	3,833	6,333	467	717	467
Cyclops	350	8,050	3,150	4,200	8,050	0.333	9,533	6.517	1,600
Epischura	0	217	0	17	33	17	33	0	17
				Six Meters					
Daphnia	50	303	3,150	3,950	4,000	5.733	2,600	1,250	850
Bosmina	50	767	3.467	367	367	0	467	0	33
Diaptomus	2.167	7.617	4.467	850	2,533	4,067	1,400	303	603
Cyclops	933	3,800	3,500	3,200	6,933	11,267	12,733	4,683	2,767
Epischura	0	203	0	17	17	50	33	17	17
				Nine Meters					
Daphnia	117	100	3,650	2,683	2.917	2,533	2,467	2,133	1,117
Bosmina	0	333	3,483	1,583	633	133	400	0	17
Diaptomus	3,033	2,233	5,983	367	1,167	1.667	800	517	703
Cyclops	1.233	1,517	3,617	2,450	6,300	II.333	12,400	5,767	3,283
Epischura	0	17	0	0	0	17	17	0	17
				Twelve Meters					
Daphnia	33	367	1,800	5,267	0	650	2,400	2,100	967
Bosmina	17	833	3,050	2,550	0	50	133	0	33
Diaptomus	2,500	11,233	4,383	03	0	500	1,200	417	1,050
Cyclops	1,083	5,150	2,717	3,183	0	6,600	11,000	6,567	3,983
Epischura	0	150	0	0	0	17	33	0	0
				Fifteen Meters					
Daphnia	67	450	917	1,633	1,700	300	2,733	2,867	1,350
Bosmina	0	400	1,783	4,633	433	50	400	0	17
Diaptomus	1,100	10,000	3,967	267	517	200	600	800	983
Cyclops	800	4,217	3,800	4,117	5.617	4,883	13.933	10,533	4,083
Epischura	0	67	0	33	0	33	33	0	0
				Twenty Meters					
Daphnia	33	183	367	1.333	3,200	1,100	2,267	2,533	1.367
Bosmina	0	300	600	1,100	1,183	367	133	0	33
Diaptomus	1,000	4,667	2,100	900	667	250	733	1,600	1,167
Cyclops	403	2,983	1,950	2,683	5,183	1,783	0.333	7,667	5,633
Epischura	0	117	0	17	0	17	0	0	0
				Twenty-five Meters					
Daphnia	83	117	183	2.817	1,417	500	567	3,333	700
Bosmina	0	350	467	1,350	350	100	50	0	0
Diaptomus	633	3,283	1,717	817	333	283	150	2,533	1,117
Cyclops	417	2,233	1,750	3,283	3,100	2,383	4,500	11,933	4,533
Epischura	0	100	0	0	33	0	0	0	0
				Thirty Meters					
Daphnia	33	183	300	450	633	300	500	2,067	1.317
Bosmina	0	217	583	583	333	83	50	0	17
Diaptomus	883	5,700	1.567	433	283	100	333	2,667	1,483
Cyclops	450	3,250	1,533	1.567	2,033	1,900	4,033	7,867	5,100
Epischura	0	117	0	0	0	0	0	0	0

Table 7. Continued, Sullivan area, 1987.

Taxon	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				One Meter					
Daphnia	17	67	67	283	433	50	867	6,700	233
Bosmina	0	150	167	333	50	0	217	500	03
Diaptomus	167	1,650	367	1,617	1,833	233	467	15,900	2,550
Cyclops	250	333	150	1,567	3,083	367	4,067	15,600	1.467
Epischura	0	100	0	0	0	0	150	67	0
				Three Meters					
Daphnia	67	0	267	667	1,683	2.50	8,600	14,750	3,700
Bosmina	03	67	400	1,250	50	17	867	1,883	200
Diaptomus	2,800	1,550	2,133	6,933	4,867	1,250	1,867	30,250	37,900
Cyclops	4,033	400	583	2,117	6,600	1,833	10,400	22,750	7,900
Epischura	0	150	17	50	83	50	233	300	67
				Six Meters					
Daphnia	50	17	200	3.533	2,733	917	13,800	8,933	4,100
Bosmina	100	67	1,233	1.867	333	50	loo	400	300
Diaptomus	2.667	200	1,133	11,800	1,917	2,033	6,600	25.067	22,500
Cyclops	7,617	67	700	6,800	4.633	3,483	18,000	17,467	4,200
Epischura	0	17	0	67	67	267	217	300	183
				Nine Meters					
Daphnia	33	0	350	3,000	3,717	967	11,400	3,533	1,333
Bosmina	67	17	1,183	667	983	250	1,500	400	0
Diaptomus	1,100	433	800	4.567	1,183	650	6,900	6,200	16,133
Cyclops	2,383	17	550	5,000	4,000	3,383	25,400	8,800	5,667
Epischura	0	50	0	17	50	117	150	333	17
				Twelve Meters					
Daphnia	0	17	67	2.367	1,800	667	8,300	2,933	4,833
Bosmina	0	33	517	2,383	1,150	367	1,100	400	0
Diaptomus	0	517	617	2.767	933	750	6,700	2,667	27,417
Cyclops	0	03	350	2,900	3.633	4,100	20,300	10,333	6,333
Epischura	0	17	0	17	loo	50	183	33	100
				Fifteen Meters					
Daphnia	0	17	167	2,233	1,933	433	1,583	2,933	3,833
Bosmina	17	117	450	7,717	2,133	83	667	200	0
Diaptomus	1,400	1.533	350	1,033	533	283	4,667	6,133	28,917
Cyclops	2,600	350	403	2,133	4,550	2,167	20,500	11,333	4,333
Epischura	0	03	0	0	50	0	117	67	50
				Twenty Meters					
Daphnia	03	17	50	283	1,533	183	1,150	0	0
Bosmina	50	03	403	4,250	1,300	117	750	0	0
Diaptomus	1,717	667	183	1,300	603	300	3,200	0	0
Cyclops	3,183	233	450	900	2,567	2,067	21,750	0	0
Epischura	0	83	0	0	17	17	17	0	0
				Twenty-five Meters					
Daphnia	17	17	150	250	650	300	0	0	0
Bosmina	67	33	503	2,267	367	100	0	0	0
Diaptomus	567	350	250	1,017	367	233	0	0	0
Cyclops	1,517	133	267	700	1,217	2,933	0	0	0
Epischura	0	17	0	17	0	0	0	0	0
				Thirty Meters					
Daphnia	0	17	83	317	383	0	0	0	0
Bosmina	0	0	433	1,033	100	0	0	0	0
Diaptomus	0	333	350	983	300	0	0	0	0
Cyclops	0	100	333	1,417	1.200	0	0	0	0
Epischura	0	17	0	0	0	0	0	0	0

Table 7. Continued, areas combined, 1987.

Taxon	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Standard Deviation
					Oneer						
Daphnia	17	711	344	217	3%	158	611	2.839	344	644	1,328
Bosmina	0	250	117	155	67	25	117	167	33	106	134
Diaptomus	783	4.661	1.295	1,295	1,478	2,300	433	5.617	1,144	2,104	3,273
Cyclops	322	2,378	661	2.417	2,478	3.875	3.833	11,083	1,489	3,144	3,692
Epischura	0	95	6	11	11	0	56	28	0	24	41
					Three Meters						
Daphnia	28	1,078	1,500	1,417	2,455	825	3,767	5.517	1,489	2,054	3,195
Bosmina	28	339	306	461	139	8	450	633	95	283	450
Diaptomus	2,111	5.994	4,511	5,894	3,522	3,792	1,017	lG.544	12,956	5,663	8,892
Cyclops	1,683	4,050	2,322	5,300	5,739	5,083	8,255	13,889	4,861	5,710	4,887
Epischura	0	150	11	44	39	33	89	100	28	56	81
					Six Meters						
Daphnia	50	328	1,378	3,972	3,094	3,325	6,089	3,617	1,806	2,602	3,141
Bosmina	50	300	1,883	778	328	25	189	133	111	437	762
Diaptomus	2.383	3,572	2,967	5,622	2,200	3,050	2,822	8,906	8,017	4.445	6,381
Cyclops	3,017	1.861	3,078	8,400	6,205	7,375	13,511	11,694	5.922	6,762	5,253
Epischura	0	100	11	33	33	158	83	106	67	62	97
					Nine Meters						
Daphnia	94	406	1.333	3,472	3,028	1,750	5,067	2,200	994	2,049	2,357
Bosmina	22	239	1,555	789	761	192	700	156	6	503	766
Diaptomus	2,267	2,250	2.261	3,433	1,228	1,158	2,633	2,328	5,800	2,651	3,458
Cyclops	1,483	1,667	1.389	5,878	6,094	7,356	14,867	9,300	4,644	5,796	5,505
Epischura	0	44	0	28	17	67	56	111	11	36	72
					Twelve Meters						
Daphnia	22	311	1,583	3,711	1,072	658	3,967	1,989	2,072	1,750	1,985
Bosmina	6	300	1,611	1.672	511	208	411	133	17	553	874
Diaptomus	1,350	4,911	2,378	2,222	511	625	2,678	1,206	9.678	2,925	5,575
Cyclops	555	2,200	2.339	5,778	2,933	5,350	15,300	10,967	5,005	5,613	5,327
Epischura	0	56	0	11	44	33	72	11	33	29	50
					Fifteen Meters						
Daphnia	28	344	767	1,644	1.755	367	1,578	2,400	2,022	1.244	1,043
Bosmina	11	194	817	4,183	1,005	67	3%	67	11	772	1,729
Diaptomus	1.633	4,728	1.739	967	433	242	1,789	2,467	10,089	2,770	5,789
Cyclops	1,311	2,235	2,339	7,128	5,072	3.525	13,928	u.333	4,722	5,818	5,109
Epischura	0	61	0	11	33	17	50	22	17	24	33
					Twenty Meters						
Daphnia	61	111	467	1,472	2,900	642	1,378	1,239	678	1,008	1,116
Bosmina	17	133	3%	2,050	1,139	242	294	17	17	167	254
Diaptomus	1,472	2,422	1,055	1.333	561	275	1.455	778	583	1,136	1,042
Cyclops	1.433	1,850	1,450	4,417	3,689	1,925	12,622	7,861	3,694	4,419	5,119
Epischura	0	72	0	6	6	17	11	0	0	12	27
					Twenty-five Meters						
Daphnia	44	117	317	1.489	1,139	400	206	1,244	450	608	847
Bosmina	22	144	400	1,450	400	100	17	22	11	292	510
Diaptomus	961	2.328	1.339	1,211	361	258	94	1,111	606	944	930
Cyclops	867	1,644	1,395	4,505	2.745	2,658	4.167	8,000	3,589	3,315	3,534
Epischura	0	44	0	6	11	0	0	0	0		21
					Thirty Meters						
Daphnia	17	250	228	467	450	150	411	1,189	661	435	511
Bosmina	0	111	405	655	217	42	17	0	11	167	254
Diaptomus	689	3,950	1,044	794	255	50	200	1,139	689	1,015	1,542
Cyclops	3%	2,072	1,000	2.572	1.794	950	4,611	7,406	3,272	2,736	3,449
Epischura	0	56	0	0	0	0	0	0	0	6	24

Table 8. Mean zooplankton densities ($N \cdot M^{-3}$) and weights ($mg \cdot M^{-3}$) estimated from drift net samples taken in the South Fork of the Flathead River approximately 2.5 km downstream from Hungry Horse Dam, 1987. The instantaneous river flow during sampling is given in meters cubed per second ($M^{-3} \cdot S$).

Month	Number of Samples	River Flow ($M^{-3} \cdot S$)	Reservoir Elevation	Zooplankton: Daphnia	Bosmina	Cyclops	Diaptomue	Epischura	Total	Total Zooplankton Emery Area of the Reservoir
					Number					
January	3	115.5	3.515	194	19	430	910	0	1.561	--
February	3	71.9	3,509	55	9	354	1,863	0	2,280	--
March	4	34.9	3,506	16	20	672	2,019	0	2,720	--
April	6	19.2	3,515	0	2	110	391	0	503	4,983
May	4	7.3	3,546	0	0	10	4	0	15	8,011
June	4	5.3	3,558	0	0	6	2	0	8	9,622
July	4	10.2	3,560	3	1	32	11	0	46	10,891
August	4	163.0	3,557	18	1,494	127	23	0	1,663	9,906
September	6	269.2	3,539	39	686	119	4	2	850	13,304
October	4	189.9	3,510	14	23	179	78	<1	294	0.043
November	4	04.5	3,502	5	2	171	1	<1	179	7,757
December	4	145.1	3,496	405	25	843	72	0	1,346	4.750
Year	50	97.1	3,527	56	209	238	391	<1	895	9.151
					Weight					
January	3	115.5	3.515	12.0	0.4	14.6	54.0	0.0	81.0	--
February	3	71.9	3,509	3.4	0.2	11.8	110.4	0.0	125.9	--
March	4	34.9	3,506	1.0	0.5	22.4	119.7	0.0	143.6	—
April	6	19.2	3,515	0.0	<0.1	3.7	23.2	0.0	26.9	274.3
May	4	7.3	3,546	0.0	0.0	0.3	0.2	0.0	0.6	321.5
June	4	5.3	3,558	0.0	0.0	0.2	0.1	0.0	0.3	330.6
July	4	10.2	3,560	0.2	<0.l	0.9	0.4	0.0	1.6	366.4
August	4	163.0	3,557	1.6	12.5	1.6	0.4	0.0	16.1	234.7
September	6	269.2	3,539	4.0	11.7	1.9	0.2	0.4	18.0	355.7
October	4	189.9	3,510	1.8	0.4	2.8	1.9	0.1	6.8	206.1
November	4	04.5	3,502	0.4	<0.1	2.6	<0.1	<0.l	3.2	151.5
December	4	145.1	3,496	25.0	0.4	18.2	2.8	0.0	46.4	123.0
Year	50	97.1	3,527	3.6	2.5	6.2	22.7	<0.1	35.3	270.6

1987). The densities of zooplankton in the river varied from one to 28 percent of the population in the Emery area. The numbers vere generally low from May through October in both years during the period when the reservoir vas thermally stratified. An exception to this pattern occurred in August, 1987, vhen large numbers of Bosmina were flushed through the dam.

The greatest downstream losses occurred in the December through March period vhen the reservoir was isothermal and zooplankton were circulated deep into the water column. Declining pool elevation and large releases from the dam also appeared to increase the downstream loss of zooplankton. Thus, deep drawdowns in the winter should increase the downstream loss of this valuable fish food resource. The magnitude of these losses is amazing considering that the penstock openings are approximately 240 feet below full pool.

MACROINVERTEBRATES

Methods

Benthos samples vere collected monthly from May through November from a permanent transect in each area with a Peterson dredge which sampled .092 m^2 of reservoir bottom. Three replicate samples were taken from each of the folloving depth intervals for a total of nine samples: 1) full pool elevation (3,560 ft) to recommended drawdown elevation of 3,476 ft; 2) recommended to maximum drawdown on record at elevation 3,432 ft; and 3) below elevation 3,432 ft.

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 vas preserved. All macroinvertebrates vere picked from the sample and identified to order or class. Number and total blotted wet weights were determined and densities were expressed as number $\cdot m^{-2}$ and grams·m , respectively.

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 vith 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.

Tvo randomly selected sites in each area were sampled biweekly in 1983 and from May through June, 1984. An additional sample was collected beginning in July 1984. Tvo 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 in a zigzag pattern at approximately 1.0 $m \cdot sec^{-1}$ until $600 \cdot m^{-2}$ vere sampled. A digital knotlog (Signet MK267) was used to determine when a distance of 600 m was traveled. The time of sampling was usually from 1200 to 1800 hours.

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$\cdot$ha^{-1}.

The Mann-Whitney non-parametric test vas used to compare for differences between zones, areas and years.

Emerging dipteran sere sampled sith a square meter emergence trap constructed of l/2-inch thick acrylic (Figure 18). Styrofoam strips were attached to the bottom of the trap for flotation and the trap was anchored to a five-gallon bucket filled with concrete. Holes, approximately 150 mm in diameter, were cut in each side of the trap and the top of the catch basin to allow for evaporation and reduce the condensation problem on the inside surfaces of the trap. The holes were covered with nitex cloth having 102-micron openings. Anti-freeze was used as the preservative in the catch basin.

Five traps vere placed in nearshore areas at water depths from four to ten m below full pool. These areas have been dewatered annually during the study. The other five traps were placed in offshore areas at water depths greater than 30 m below full pool. The traps were checked weekly insects removed and placed in labeled vials. All macroinvertebrates were picked from the sample and identified to order. Number and total wet weights were determined and densities expressed as $N \cdot m^{-2}$ and $G \cdot m$ caught per week.

Results and Discussion

<u>Benthos</u>

Dipteran larvae, pupae and oligochaetes comprised over 99 percent of the benthos community biomass, with dipterans accounting for approximately 80 percent of the weight (Table 9) (May and Weaver 1987). Dipterans vere the only benthic taxon vhich were an important food item of reservoir fish. Therefore, we confined our analysis to this taxonomic group.

The seasonal progression of abundance was similar among the zones with some differences recorded in the Murray area during the fall. In general, densities were low in Hay, increased in June, and peaked in July, with another decreasing trend in August and September, and an increasing trend in October (Figure 19). The pattern was comparable in the Murray area except the numbers increased in September and declined in October. Overall the seasonal abundance was correlated vith peak emergence patterns which occurred in the spring and early fall.

The number of dipteran$\cdot$M^{-2} in depth interval one, which was annually dewatered, was significantly less than in two and three, which were wetted continually during the study (Table 10). In addition, depth interval two had a significantly higher standing

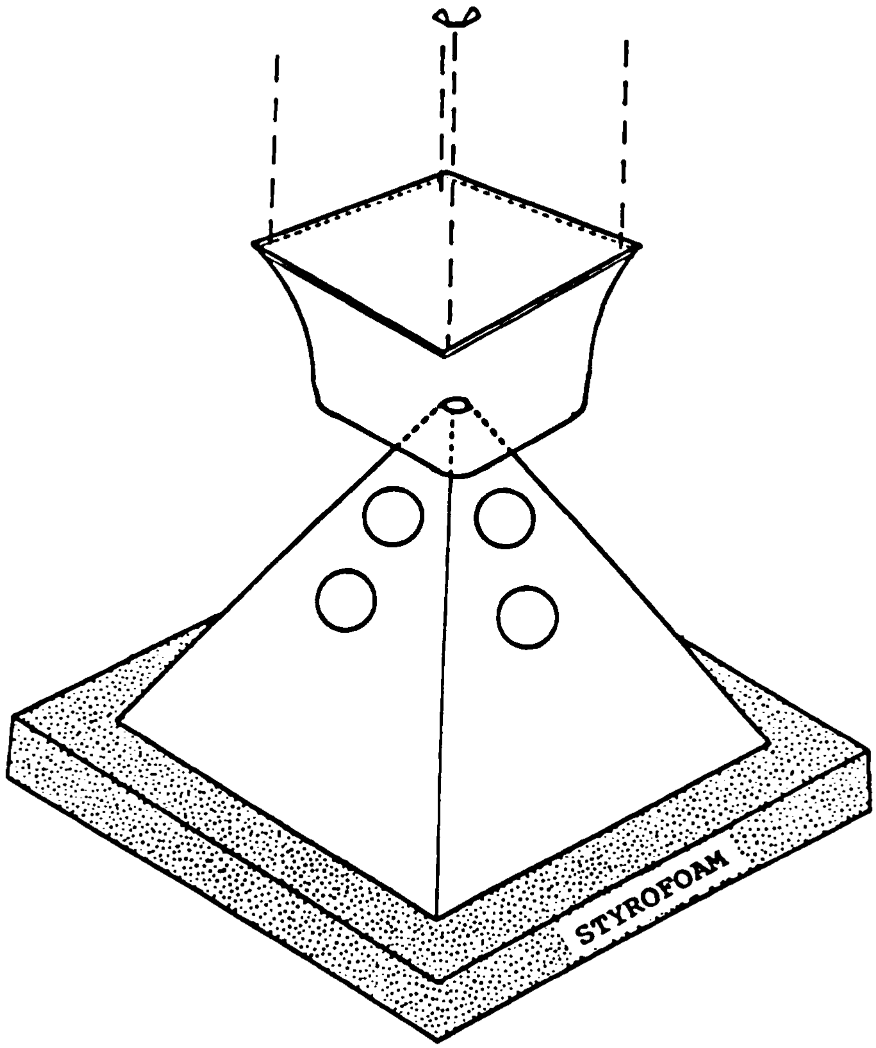


Figure 18. Emergence Trap.

Table 9. The number (N.M-2) and weight (G.M-2) of aquatic macroinvertebrates in benthos samples from Emery, Murray and Sullivan areas of Hungry Horse Reservoir May through November, 1987.

Date	Number of Samples	Depth (m)	Aquatic Dipteran Larvae No.	Larvae Wt.	No.	Wt.	Total No.	Total Wt.	Oligochaeta No.	Oligochaeta Wt.	Other No.	Other Wt.
					Emery Area							
May	3	4.0	143.4	0.040	3.7	0.001	147.0	0.042	229.5	0.001	0.0	0.0
	3	27.7	268.9	0.145	0.0	0.000	268.9	0.145	157.7	0.028	0.0	0.0
	3	69.1	68.9	0.019	3.7	0.001	72.4	0.020	33.8	0.001	0.0	0.0
June	3	2.0	186.4	0.021	0.0	0.000	186.4	0.021	179.2	0.049	0.0	0.0
	3	34.6	351.3	0.198	10.8	0.012	362.1	0.210	828.0	0.206	0.0	0.0
	3	90.9	369.2	0.107	0.0	0.000	369.2	0.107	32.3	0.034	0.0	0.0
July	3	1.0	344.1	0.109	0.0	0.000	344.1	0.109	0.0	0.000	0.0	0.0
	3	42.0	387.1	0.588	0.0	0.000	387.1	0.588	0.0	0.000	0.0	0.0
	3	64.0	423.0	0.314	0.0	0.000	423.0	0.314	39.5	0.031	0.0	0.0
August	3	5.0	297.6	0.158	0.0	0.000	297.6	0.158	7.3	0.017	0.0	0.0
	3	25.7	272.4	0.244	0.0	0.000	272.4	0.244	0.0	0.000	0.0	0.0
	3	48.4	268.9	0.441	0.0	0.000	268.9	0.442	0.0	0.000	0.0	0.0
September	3	7.8	207.9	0.044	0.0	0.000	207.9	0.044	0.0	0.000	0.0	0.0
	3	28.7	1591.5	1.107	0.0	0.000	1591.5	1.107	0.0	0.000	0.0	0.0
	2	63.6	543.1	0.307	0.0	0.000	543.1	0.307	0.0	0.000	0.0	0.0
October	3	16.0	132.7	0.076	0.0	0.000	132.7	0.076	304.7	0.063	0.0	0.0
	3	26.7	1756.3	1.209	0.0	0.000	1756.3	1.209	268.9	0.149	0.0	0.0
	3	43.0	243.8	0.243	0.0	0.000	243.8	0.243	182.8	0.098	0.0	0.0
November	3	18.2	104.0	0.047	0.0	0.000	104.0	0.047	89.6	0.011	0.0	0.0
	3	25.2	358.5	0.282	0.0	0.000	358.5	0.281	61.0	0.039	0.0	0.0
	3	57.4	114.8	0.148	0.0	0.000	114.8	0.148	35.9	0.037	0.0	0.0
Year	`	7.7	202.3	0.071	0.6	0.001	202.8	0.071	115.8	0.021	0.0	0.0
	21	30.1	712.3	0.539	1.6	0.002	713.8	0.541	188.0	0.061	0.0	0.0
	20	62.3	277.6	0.222	0.6	0.001	278.1	0.222	48.7	0.031	0.0	0.0

Table 9. Continued, Murray Area, 1987.

Date	Number of Samples	Mean Depth (m)	Aquatic Dipteran Larvae No.	Larvae Wt.	Pupae No.	Pupae Wt.	Total No.	Total Wt.	Oligochaeta No.	Oligochaeta wt.	Other No.	Other wt.
					Murray Area 1987							
May	3	7.0	25.2	0.006	0.0	0.000	25.2	0.006	71.7	0.016	0.0	0.0
	3	36.3	179.3	0.429	0.0	0.000	179.3	0.483	22.4	0.015	0.0	0.0
	3	73.0	25.1	0.l2l	0.0	0.000	25.1	0.121	89.7	0.038	0.0	0.0
June	3	2.0	14.4	0.005	0.0	0.000	14.4	0.005	82.5	0.046	0.0	0.0
	3	39.0	609.4	0.704	0.0	0.000	609.4	0.704	35.9	0.033	0.0	0.0
	3	79.0	1154.2	0.328	0.0	0.000	l154.2	0.327	71.7	0.030	0.0	0.0
July	3	1.0	57.4	0.031	0.0	0.000	57.4	0.031	3.7	0.224	0.0	0.0
	3	27.0	182.9	0.111	0.0	0.000	182.9	0.111	0.0	0.000	0.0	0.0
	3	72.0	433.7	0.148	0.0	0.000	433.7	0.148	0.0	0.000	0.0	0.0
August	3	4.0	96.8	0.035	0.0	0.000	96.8	0.035	0.0	0.000	0.0	0.0
	3	24.0	240.2	0.187	0.0	0.000	240.2	0.187	82.5	0.023	0.0	0.0
	3	94.0	197.2	0.151	0.0	0.000	197.2	0.151	3.7	0.011	0.0	0.0
September	3	7.8	78.9	0.013	0.0	0.000	78.9	0.013	0.0	0.000	0.0	0.0
	3	37.8	247.4	0.279	0.0	0.000	247.4	0.279	0.0	0.000	0.0	0.0
	2	92.0	134.4									
October	3	15.0	229.4	0.097	0.0	0.000	229.4	0.097	100.4	0.071	0.0	0.0
	3	40.0	541.3	0.447	0.0	0.000	541.3	0.447	89.7	0.068	0.0	0.0
	3	92.0	458.8	0.121	0.0	0.000	458.8	0.l2l	82.5	0.031	0.0	0.0
November	3	18.2	89.7	0.099	0.0	0.000	89.7	0.099	190.0	0.047	0.0	0.0
	3	50.3	172.1	0.335	0.0	0.000	172.1	0.335	71.7	0.044	0.0	0.0
	3	87.8	l14.8	0.0%	0.0	0.000	l14.8	0.096	247.4	0.114	0.0	0.0
Year	21	7.8	84.5	0.041	0.0	0.000	84.5	0.041	64.1	0.058	0.0	0.0
	21	36.3	310.3	0.356	0.0	0.000	310.3	0.305	58.7	0.030	0.0	0.0
	20	83.9	371.0	0.155	0.0	0.000	418.6	0.155	74.3	0.034	0.0	0.0

Table 9. Continued, Sullivan Area, 1987.

Date	Number of Samples	Depth (m)	Aquatic Dipteran: Larvae No.	Larvae Wt. . . .	No.	Wt.	Total No	Total wt.	Oligochaeta No.	Oligochaeta wt.	Other No.	Other wt.
					Sullivan Area 1987							
May	3	3.0	0.0	0.000	0.0	0.000	0.0	0.000	7.3	0.001	0.0	0.0
	3	40.0	344.1	1.177	3.7	0.009	347.7	1.186	319.0	0.227	0.0	0.0
June	3	2.0	179.3	0.050	0.0	0.000	179.3	0.050	0.0	0.000	0.0	0.0
	3	40.0	835.2	0.585	0.0	0.000	835.2	0.585	134.3	0.073	0.0	0.0
July	3		405.1	0.277	0.0	0.000	405.1	0.277	18.0	0.020	0.0	0.0
	3	46.0	526.9	0.434	0.0	0.000	526.9	0.434	0.0	0.000	0.0	0.0
August	3	4.0	892.5	0.709	0.0	0.000	892.5	0.709	0.0	0.000	0.0	0.0
	3	39.0	412.2	0.328	0.0	0.000	412.2	0.328	0.0	0.000	0.0	0.0
September	3	7.8	129.1	0.040	0.0	0.000	129.1	0.040	0.0	0.000	0.0	0.0
	3	37.8	939.1	0.383	0.0	0.000	939.1	0.383	0.0	0.000	0.0	0.0
October	3	15.0	566.4	0.060	0.0	0.000	566.4	0.060	96.8	0.038	0.0	0.0
	2	38.0	666.7	0.431	0.0	0.000	666.7	0.431	53.8	0.050	0.0	0.0
November	3	19.2	261.7	0.175	0.0	0.000	261.7	0.175	853.1	0.166	0.0	0.0
	3	39.0	387.2	0.394	0.0	0.000	387.2	0.394	724.1	0.168	0.0	0.0
Year	21	7.6	347.7	0.187	0.0	0.000	347.7	0.187	139.3	0.033	0.0	0.0
	20	40.1	583.4	0.538	0.6	0.002	583.9	0.540	178.0	0.075	0.0	0.0

Table 9. Continued Areas Combined, 1987.

Date	Number of Samples	Mean Depth (m)	Aquatic Dipteran Larvae No.	Larvae Wt.	Pupae No.	Pupae Wt.	Total No.	Total Wt.	Oligochaeta No.	Oligochaeta wt.	Other No.	Other wt.
					Areas Combined 1987							
May	9	4.7	56.2	0.016	1.3	0.001	57.4	0.016	102.8	0.007	0.0	0.0
	9	34.7	264.1	0.584	1.3	0.003	265.3	0.587	175.7	0.092	0.0	0.0
	6	71.0	47.0	0.070	1.8	0.001	48.8	0.071	61.7	0.021	0.0	0.0
June	9	2.0	126.7	0.025	0.0	0.000	126.7	0.025	87.3	0.032	0.0	0.0
	9	37.9	598.6	0.496	3.7	0.004	602.2	0.500	323.8	0.102	0.0	0.0
	6	84.9	761.7	0.217	0.0	0.000	761.7	0.217	52.0	0.032	0.0	0.0
July	9	1.3	268.9	0.139	0.0	0.000	268.9	0.139	7.3	0.082	0.0	0.0
	9	38.3	365.6	0.378	0.0	0.000	365.6	0.378	0.0	0.000	0.0	0.0
	6	68.0	428.4	0.231	0.0	0.000	428.4	0.231	19.8	0.016	0.0	0.0
August	9	4.3	429.0	0.301	0.0	0.000	429.0	0.301	2.5	0.006	0.0	0.0
	9	29.6	308.3	0.253	0.0	0.000	303.3	0.253	27.6	0.008	0.0	0.0
	6	71.2	233.0	0.297	0.0	0.000	233.0	0.296	1.9	0.006	0.0	0.0
September	9	7.8	138.7	0.032	0.0	0.000	138.7	0.032	0.0	0.000	0.0	0.0
	9	34.8	926.0	0.590	0.0	0.000	926.0	0.590	0.0	0.000	0.0	0.0
	4	77.8	338.7	0.202	0.0	0.000	338.7	0.202	0.0	0.000	0.0	0.0
October	9	15.3	309.5	0.078	0.0	0.000	309.5	0.078	167.3	0.057	0.0	0.0
	8	34.5	1028.3	0.729	0.0	0.000	1028.3	0.729	147.9	0.094	0.0	0.0
	7	63.3	457.8	0.216	0.0	0.000	457.8	0.216	124.5	0.597	0.0	0.0
November	9	18.5	151.8	0.107	0.0	0.000	151.8	0.107	377.6	0.075	0.0	0.0
	9	38.2	305.9	0.337	0.0	0.000	305.9	0.337	285.6	0.084	0.0	0.0
	6	72.6	114.8	0.122	0.0	0.000	114.8	0.122	141.6	0.075	0.0	0.0
Year	63	7.7	211.5	0.100	0.3	0.001	211.7	0.100	106.4	0.037	0.0	0.0
	62	35.4	534.6	0.477	0.8	0.001	535.3	0.478	137.1	0.054	0.0	0.0
	41	72.2	343.1	0.194	0.4	0.001	343.4	0.194	61.8	0.032	0.0	0.0

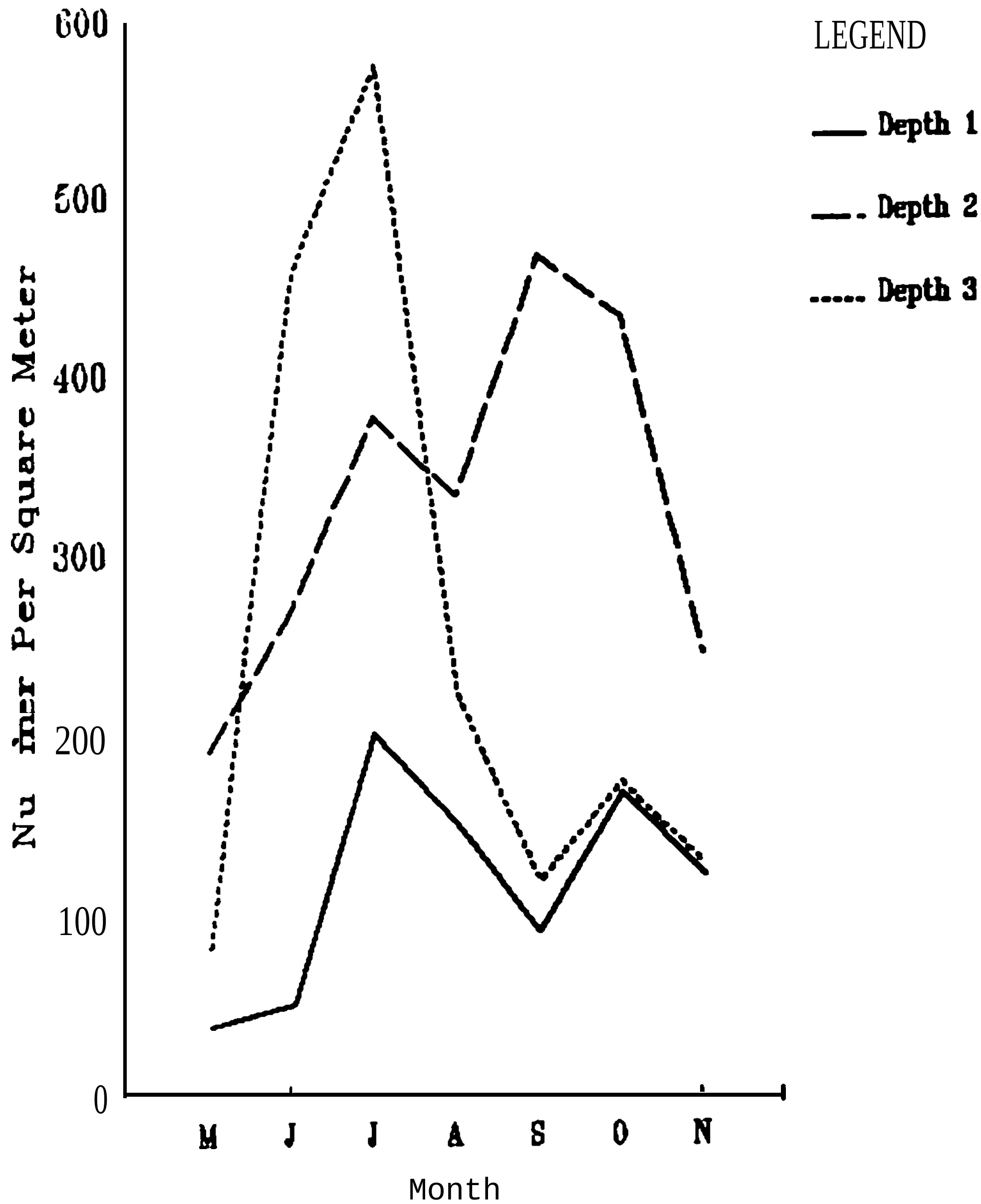


Figure 19. The mean number ($N \cdot M^{-2}$) of aquatic dipteran larvae collected in benthos samples from Hungry Horse Reservoir, 1984-87. Depth 1, represents the reservoir bottom interval less than 26 m below full pool; depth 2, bottom interval from 26-39 m below full pool: and depth 3, greater than 39-m below full pool.

Table 10. A comparison of the number of aquatic dipteran ($N \cdot M^{-2}$) in benthos samples collected from Hungry Horse Reservoir, 1984 to 1987.

The Mean Number of Aquatic Dipteran ($N \cdot M^{-2}$)

Between Depth Intervals[a]

1x2	1x3	2x3
124 x 337**	124x235**	337 x 235**

Between Areas by Depth Interval

Depth Interval	Emery x Murray	Emery x Sullivan	Murray x Sullivan
1	135 x 66*	135 x 172	66 x 172*
2	462 x 299**	462x325	229x325
3	186 x 276		

Between Years by Depth Interval

Depth Interval	1984-85	1984-86	1984-87	1985-86	1985-87	1986-87
1	88x 17**	88x156*	88x212*	17 x 156**	17 x 212**	156 x 212
2	247 x 134	247 x 375*	247 x 535"	134 x 375*	134 x 535**	375 x 535
3	219 x 113	219 x 234	219 x 343	113 x 234	113 x 343**	234 x 343*

[a] Depth interval 1, less than 26.0 m belov full pool; interval 2, betveen 26.0-39 m belov full pool; and interval 3, greater than 39 m belov full pool.

* - significant difference at 0.05 probability level

** - significant difference at 0.01 probability level

crop than three. The mean density in depth interval two of 337 dipteran$\cdot M^{-2}$ was approximately 2.6 times greater than the density in interval one of $124\cdot M^{-2}$, and the mean weight was 6.9 fold greater. This disparity between difference in numbers and weights indicated that the dipteran in interval one were much smaller in size than in interval two, and consequently of less value as fish food due to reduced foraging efficiency. The adverse effects of reservoir drawdown upon benthic macroinvertebrates has been documented by other workers (Filbian 1965, Patterson and Fernando 1969, Benson and Hudson 1975, and Baxter 1977).

The densities of dipteran varied among the areas with the Murray area having significantly less numbers in depth interval one than the Emery and Sullivan areas (Table 10). The Murray area also had significantly lower densities than the Emery area in the depth interval two category. The reason for these differences is unknown.

There was a considerable difference in densities among the years with the numbers in 1984 and 1985 being significantly less than in 1986 and 1987 in depth intervals one and two (Table 10). In addition, the densities in 1984 were significantly higher than in 1985 in depth interval one. The low densities of dipteran in depth interval one in 1985 may be the result of the reservoir being at full pool for only two weeks in 1985. This resulted in less time for recovery of the dipteran populations in depth interval one. In 1984, the reservoir was at full pool for only five weeks and this may partially account for the low benthos densities this year. The differences among the years in depth interval two are not readily understandable because this interval was wetted throughout the study.

Dipteran Emergence

Dipteran emergence was sampled from May through November in 1986 and 1987 (Table 11). The emergence pattern differed between the littoral zone and limnetic zone. The littoral trap catches indicated a peak of emergence in May and September folloved by a rapid decline in activity during October and November (Figure 20). Emergence activity in the limnetic zone showed a gradually increasing trend from May through September, and a rapid decline in October and November. The inshore emergence pattern corresponded to the changes in dipteran abundance found in benthic samples.

There was a highly significant difference ($P<.01$) in the number of emergers caught in the littoral and limnetic traps (Table 12) with littoral traps catching approximately 1.9 to 3.8 fold more insects. This greater production in the area which was annually dewatered, then reflooded, was perplexing at first, but may be explained by the differences in water temperature between the two zones. The limnetic zone had a significantly higher standing crop of dipteran than the littoral, but production was less because of the colder water temperatures which were below

Table 11. The number (NM^{-2} week) and weight (g) of aquatic macroinvertebrates caught in emergence traps in the Murray area of Hungry Horse Reservoir, 1986 to 1987. Standard deviations are given in parentheses.

Month	Mean Depth (m)	Aquatic Diptera No.	Aquatic Diptera Wt.	Other Aquatic No.	Other Aquatic Wt.	Total Aquatics No.	Total Aquatics Wt.
			1986				
May (Nearshore)	8.7	213.2	0.200	0.0	0.000	213.2	0.200
May (Offshore)	37.0	17.4	0.013	0.0	0.000	17.4	0.013
June	7.8	28.9	0.014	0.0	0.000	28.9	0.014
June	43.4	22.1	0.012	0.0	0.000	22.1	0.012
July	7.7	27.2	0.020	0.6	0.003	27.8	0.023
July	44.9	25.5	0.025	0.0	0.000	25.5	0.025
August	8.3	48.1	0.026	2.4	0.001	50.5	0.027
August	45.5	25.1	0.006	0.0	0.000	25.1	0.006
September	9.7	52.6	0.015	0.4	<0.001	53.0	0.015
September	48.3	31.6	0.012	0.0	0.000	31.6	0.012
October	14.1	23.6	0.005	0.1	0.001	23.7	0.006
October	50.0	7.3	0.003	0.0	0.000	7.3	0.003
November	14.3	0.5	0.001	0.0	0.000	0.5	0.001
November	50.0	0.0	0.000	0.0	0.000	0.0	0.000
Year 1986	9.6	40.7 (72.0)	0.022	0.5 (1.7)	0.001	41.3 (72.2)	0.023 (0.062)
Year 1986	46.3	21.7 (26.3)	0.012	0.0 (0.0)	0.000	21.7 (26.4)	0.012 (0.023)
			1987				
May (Nearshore)	9.3	12.8	0.004	0.0	0.000	12.8	0.004
May (Offshore)	37.4	8.3	0.002	0.0	0.000	8.3	0.002
June	5.2	78.6	0.013	0.1	0.001	78.7	0.014
June	37.4	16.4	0.004	0.0	0.000	16.4	0.004
July	5.3	179.9	0.015	0.2	0.001	180.1	0.016
July	37.2	39.0	0.004	0.0	0.000	39.0	0.004
August	5.2	131.1	0.016	0.4	0.001	131.5	0.017
August	38.1	42.4	0.005	0.0	0.001	42.4	0.005
September	9.2	196.1	0.022	0.4	0.001	196.5	0.023
September	42.0	59.1	0.010	0.0	0.000	59.1	0.010
October	17.0	33.3	0.002	0.0	0.000	33.3	0.002
October	43.4	9.3	0.001	0.0	0.000	9.3	0.001
November	17.0	3.9	0.001	0.0	0.000	3.9	0.001
November	43.4	3.8	0.001	0.0	0.000	3.8	0.001
Year 1987	9.5	97.9 (98.5)	0.011	0.2 (0.6)	0.001	98.1 (98.7)	0.012
Year 1987	39.9	26.0 (29.5)	0.004	0.0	0.000	26.0 (29.5)	0.004

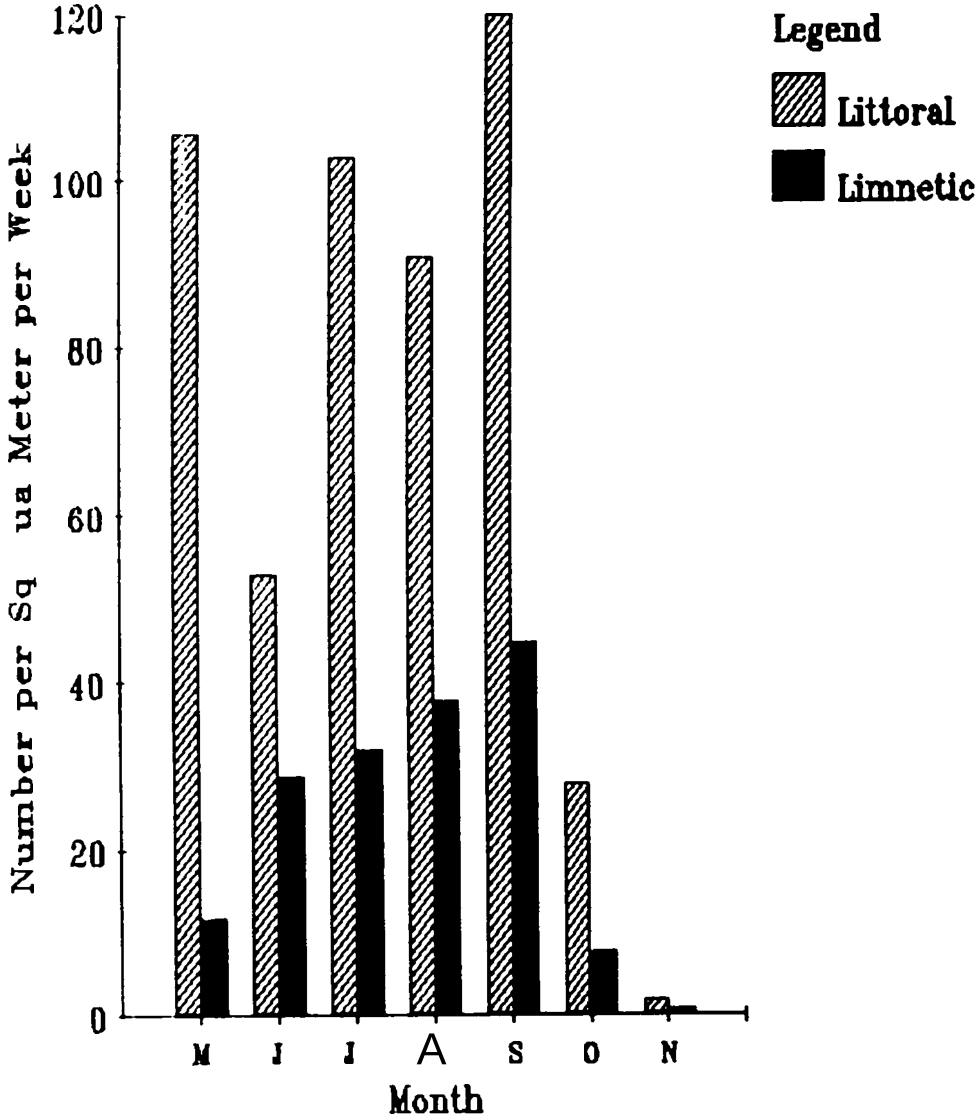


Figure 20. The mean number of aquatic dipteran ($N \cdot M^{-2}$ week) caught in emergence traps in the Murray area of Hungry Horse Reservoir, 1986-87. The littoral zone was dewatered annually and the limnetic zone was permanently wetted during the study.

Table 12. A comparison of the number of aquatic dipteran adults ($N \cdot M^{-2} \cdot week$) caught in the emergence traps in the Murray area of Hungry Horse Reservoir, 1986 to 1987.

The mean number of aquatic dipteran ($N \cdot M^{-2} \cdot week$)	
	Between Zones[a/] by year
Year	Zone 1 x Zone 2
1986	41 x 22**
1987	98 x 26**
	Between Years by Zone
Zone	1986 x 1987
1	41 x 98**
2	22 x 26

a/ Zone 1 is the littoral area which is defined as the area less than 20 m deep and less than 100 m from the shoreline. Zone 2 is the limnetic area which is deeper than 20 m and greater than 100 m from the shoreline.

* - significant difference at 0.05 probability level

** - significant difference at 0.01 probability level

7.0°C year-round. In contrast, water temperatures in the littoral area which was above the thermocline ranged from 10 to 19°C during the growing season from May through October. In addition, littoral areas generally are more productive than the deep colder areas of a lake.

The production of aquatic insects in the littoral zone is much lower than its potential due to the drawdown. Since the reservoir is at full pool for only two to eight weeks during the growing season, much of the productive littoral zone is dewatered during this critical period. The overwinter mortality in the dewatered areas is approximately 90 percent (Patterson and Fernando 1969). Thus, when this area is reflooded in the spring the insect populations are at extremely low levels initially. The drawdown precludes the development of aquatic vegetation in the littoral zone, an important food source for aquatic insects in lakes and most importantly alters the species complex of the system. Nillson (1961) found that trout growth was adversely effected by lake regulation because important insect species had disappeared or been essentially thinned out in the littoral zone.

There was a highly significant difference in the number of dipteran caught in the littoral traps between 1986 ($41 \cdot M^{-2}$) and 1987 ($98 \cdot M^{-2}$) but catches in the limnetic zone were comparable (Table 12). Reservoir operation was similar between the two years, so this variable doesn't appear to have influenced the larger number of emergers in 1987. Water temperatures above the thermocline were also similar between the two years averaging 13.4°C in 1986 as compared to 13.9°C in 1987. The difference between the years appears to have no obvious causative factor.

Surface Insects

The distribution of terrestrial insects on the surface film was extremely patchy both spatially and temporally in 1987 and in previous years (May and Fraley 1986, and May and Weaver 1987). The standard deviation for the mean annual catches were generally tvo to five times greater than the mean (Table 13). Terrestrial insects are deposited on the water as a result of wind-induced or rain-induced movements (Hunt 1975) or by passive transport once they are airborne by raising air masses over a lake and subsequent passive descent to the lake surface as air masses are cooled (Norlin 1967). Rates of deposition on lake surfaces can also vary markedly from year to year depending upon population densities on the adjacent land.

The terrestrial insects collected from the surface film of HHR were in decreasing order of abundance: hymenopterans, homopterans, hemipterans and coleopterans (Table 13). Terrestrial numbers vere extremely low in the spring and early summer, reaching a maximum number of about $1{,}600 \cdot ha^{-1}$ in August then gradually declining to low numbers again in November (Figure 21). These seasonal trends are comparable to those found in other lakes and reservoir (Hunt 1975).

Table 13. The mean number and weight (g) of surface insects per hectare captured in surface insect tows from Hungry Horse Reservoir, May-December, 1987. Samples were taken nearshore (<100 m) and offshore (>100 m).

Month (N)	Insect Group	Emery Nearshore Number	Emery Nearshore Weight	Emery Offshore Number	Emery Offshore Weight	Murray Nearshore Number	Murray Nearshore Weight	Murray Offshore Number	Murray Offshore Weight	Sullivan Nearshore Number	Sullivan Nearshore Weight	Sullivan Offshore Number	Sullivan Offshore Weight	Areas Combined Nearshore Number	Areas Combined Nearshore Weight	Areas Combined Offshore Number	Areas Combined Offshore Weight
May (17)	Coleopterans	10.0	0.08	25.0	0.21	25.0	0.18	19.5	0.13	8.5	0.06	41.5	0.62	14.8	0.11	28.[illegible]	0.32
	Hemipterans	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Homopterans	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	13.8	0.02	0.0	0.00	4.9	<0.01	0.0	0.00
	Hymenopterans	6.8	0.04	11.2	0.04	8.3	0.06	8.3	0.02	16.7	0.12	38.8	0.23	10.8	0.08	19.4	0.10
	Other	0.0	0.00	2.8	0.02	2.8	0.01	0.0	0.00	2.8	0.03	5.5	0.04	2.0	0.01	2.8	0.02
	Total																
	Terrestrials	16.8	0.12	38.0	0.27	36.2	0.24	27.8	0.14	41.7	0.22	86.0	0.88	32.4	0.20	50.9	0.43
	Aquatic																
	Dipterans	33.4	0.03	16.7	0.02	111.0	0.28	55.7	0.14	72.0	0.10	36.0	0.08	74.4	0.14	36.1	0.08
	Other Aquatics	6.8	0.02	5.5	0.08	0.0	0.00	0.0	0.00	0.0	0.00	19.5	0.06	2.0	0.01	8.3	0.05
	Total Aquatics	40.2	0.05	22.2	0.10	111.0	0.28	55.7	0.14	72.0	0.10	55.5	0.14	76.4	0.15	44.4	0.12
	TOTAL INSECTS	56.8	0.17	61.2	0.37	147.2	0.52	83.2	0.28	113.8	0.33	141.5	1.02	108.8	0.35	95.3	0.56

Month (N)	Insect Group	Emery Nearshore Number	Emery Nearshore Weight	Emery Offshore Number	Emery Offshore Weight	Murray Nearshore Number	Murray Nearshore Weight	Murray Offshore Number	Murray Offshore Weight	Sullivan Nearshore Number	Sullivan Nearshore Weight	Sullivan Offshore Number	Sullivan Offshore Weight	Areas Combined Nearshore Number	Areas Combined Nearshore Weight	Areas Combined Offshore Number	Areas Combined Offshore Weight
June (17)	Coleopterans	8.5	0.08	0.0	0.00	5.7	0.07	13.4	0.52	8.5	0.00	8.3	0.19	7.6	0.07	6.9	0.22
	Hemipterans	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	5.6	0.06	0.0	0.00	2.0	0.02
	Homopterans	2.8	<0.01	0.0	0.00	25.2	0.22	3.4	0.03	5.7	0.00	0.0	0.00	11.2	0.09	1.0	0.01
	Hymenopterans	2.8	0.04	0.0	0.00	5.7	0.02	6.6	0.06	2.8	0.00	11.2	0.12	3.8	0.05	5.9	0.06
	Other	16.5	0.15	5.7	0.01	5.7	0.03	6.8	0.07	0.0	0.00	0.0	0.00	7.4	0.06	4.0	0.02
	Total																
	Terrestrials	30.5	0.27	5.7	0.01	41.7	0.34	30.0	0.68	16.8	0.17	25.2	0.36	29.7	0.26	19.7	0.33
	Aquatic																
	Dipterans	19.5	0.02	27.8	0.00	69.3	0.06	53.2	0.01	41.5	0.07	39.0	0.06	43.4	0.05	39.2	0.04
	Other Aquatics	0.0	0.00	0.0	0.00	2.8	0.66	0.0	0.00	0.0	0.00	0.0	0.00	0.9	0.22	0.0	0.00
	Total Aquatics	19.5	0.02	27.8	0.00	72.2	0.72	53.2	0.01	41.5	0.07	39.0	0.06	44.4	0.27	39.2	0.04
	TOTAL INSECTS	50.0	0.29	33.3	0.07	114.0	1.06	83.2	0.68	58.3	0.24	63.8	0.43	74.1	0.53	58.8	0.38

Table 13. Continued.

Month (N)	Insect Group	Areas: Emery Nearshore Number	Weight	Emery Offshore Number	Weight	Murray Nearshore Number	Weight	Murray Offshore Number	Weight	Sullivan Nearshore Number	Weight	Sullivan Offshore Number	Weight	Areas Combined Nearshore Number	Weight	Areas Combined Offshore Number	Weight
July (18)	Coleopterans	8.3	0.05	2.8	0.03	2.8	0.08	0.0	0.00	0.0	0.00	0.0	0.00	3.5	0.04	0.9	0.01
	Hemipterans													1.7	0.01	0.9	<0.01
	Homopterans	0.0 5.5	0.04 0.00	2.6 0.0	0.00	0.0 0.0	0.00 0.00	11.02	0.05	0.0 0.0	0.00	0.0 0.0	0.00	0.0	0.00	3.7	0.02
	Hymenopterans	36.0	1.00	8.5	0.14	2.6	0.02	2.6	0.02	0.0	0.00	0.0	0.00	u.3	0.32	3.8	0.0s
	Other	0.0	0.00	2.6	0.04	2.8	<0.01	0.0	0.00	0.0	0.00	0.0	0.00	0.89	<0.01	0.9	0.01
	Total																
	Terrestrials	50.0	1.10	16.6	0.21	8.5	0.1	14.0	0.07	0.0	0.00	0.0	0.00	lB.4	0.38	10.3	0.09
	Aquatic																
	Dipterans	91.7	0.12	55.5	0.06	139.0	0.18	19.5	<0.01	2S.2	0.02	19.5	0.04	99.2	0.12	31.5	0.03
	Other Aquatics	2.13	<0.01	2.8	0.01	0.0	0.00	2S.0	<0.01	169.S	0.32	0.0	0.00	s4.4	0.10	9.3	<0.01
	Total Aquatics	94.3	0.12	58.3	0.06	139.0	0.18	44.s	0.01	194.7	0.34	19.5	0.04	153.6	0.23	40.8	0.04
	TOTAL INSECTS	144.5	1.22	7s.o	0.27	147.3	0.28	58.5	0.07	194.7	0.34	19.5	0.04	172.0	0.60	51.0	0.13

Month (N)	Insect Group	Areas: Emery Nearshore Number	Weight	Emery Offshore Number	Weight	Murray Nearshore Number	Weight	Murray Offshore Number	Weight	Sullivan Nearshore Number	Weight	Sullivan Offshore Number	Weight	Areas Combined Nearshore Number	Weight	Areas Combined Offshore Number	Weight
August (17)	Coleopterans	8.3	0.11	5.5	0.11	0.0	0.00	5.5	0.02	3.4	0.01	5.5	0.04	3.9	0.04	5.5	0.06
	Hemipterans	0.0	0.00	0.0	0.00	2.4	0.04	0.0	0.00	0.0	0.00	0.0	0.00	1.0	0.02	0.0	0.00
	Homopterans	5791.5	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Hymenopterans		17.0	8947.5	11.28	4361.9	3.69	13441.6	29.37	SW.2	58.8	24SIl.0	60.2	3985.2	24.19	W33.4	33.61
	Other	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Total																
	Terrestrials	5799.8	17.14	8953.0	Ll.39	4364.3	3.93	13447.3	29.39	5216.6	58.8	24516.5	60.24	3990.1	24.2s	15636.4	33.67
	Aquatic																
	Dipterans	14.0	0.04	36.2	0.08	7.3	0.11	8.3	0.01	43.2	0.12	5s.s	0.08	20.6	0.09	33.3	0.06
	Other Aquatics	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Total Aquatics	14.0	0.04	36.2	0.08	7.3	0.11	8.3	0.01	43.2	0.12	55.5	0.08	20.6	0.09	33.3	0.06
	TOTAL INSECTS	5813.8	17.18	8988.8	11.47	4371.4	4.04	13455.7	29.40	5260.0	S6.9	24572.0	60.32	4010.8	24.3	15672.2	33.73

Table 13. Continued.

Month (N)	Insect Group	Emery Nearshore Number	Emery Nearshore Weight	Emery Offshore Number	Emery Offshore Weight	Murray Nearshore Number	Murray Nearshore Weight	Murray Offshore Number	Murray Offshore Weight	Sullivan Nearshore Number	Sullivan Nearshore Weight	Sullivan Offshore Number	Sullivan Offshore Weight	Areas Combined Nearshore Number	Areas Combined Nearshore Weight	Areas Combined Offshore Number	Areas Combined Offshore Weight
September (17)	Coleopterans	8.3	0.29	0.0	0.00	26.6	0.15	5.5	<.01	8.3	0.03	8.5	0.10	13.7	0.16	4.7	0.04
	Hemipterans	94.3	0.05	30.5	0.01	240.0	0.05	50.0	0.04	0.0	0.00	11.2	0.01	103.9	0.03	30.6	0.02
	Homopterans	66.7	0.04	100.0	0.06	50.0	0.03	8.3	<0.01	119.5	0.02	0.0	0.00	80.4	0.03	36.1	0.02
	Hymenopterans	2.8	0.03	75.0	0.05	236.6	0.40	141.7	0.22	172.0	0.18	63.8	0.07	131.3	0.19	93.5	0.11
	Other	0.0	0.00	0.0	0.00	13.4	<0.01	8.3	0.03	0.0	0.00	0.0	0.00	3.9	<0.01	2.8	0.01
	Total																
	Terrestrials	172.2	0.42	205.5	0.11	566.6	0.63	214.0	0.30	299.8	0.23	83.3	0.18	333.2	0.41	167.6	0.20
	Aquatic																
	Dipterans	133.2	0.14	263.8	0.12	396.6	0.12	255.7	0.11	247.3	0.23	144.5	0.12	250.9	0.16	221.3	0.11
	Other Aquatics	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	2.8	a.01	0.0	0.00	0.9	<0.01
	Total Aquatics	133.2	0.14	263.8	0.12	396.6	0.12	255.7	0.11	247.3	0.23	147.2	0.12	250.9	0.16	222.2	0.12
	TOTAL INSECTS	305.5	0.55	469.5	0.23	963.2	0.75	469.5	0.40	547.2	0.46	230.5	0.29	584.2	0.58	389.8	0.31

Month (N)	Insect Group	Emery Nearshore Number	Emery Nearshore Weight	Emery Offshore Number	Emery Offshore Weight	Murray Nearshore Number	Murray Nearshore Weight	Murray Offshore Number	Murray Offshore Weight	Sullivan Nearshore Number	Sullivan Nearshore Weight	Sullivan Offshore Number	Sullivan Offshore Weight	Areas Combined Nearshore Number	Areas Combined Nearshore Weight	Areas Combined Offshore Number	Areas Combined Offshore Weight
October (17)	Coleopterans	25.0	0.30	2.8	0.06	14.0	0.12	11.2	0.10	0.0	0.00	0.0	0.00	13.8	0.14	4.7	0.05
	Hemipterans	27.8	0.09	0.0	0.00	113.8	0.12	22.2	0.12	6.8	0.04	10.0	0.06	52.0	0.08	11.1	0.06
	Homopterans	36.2	0.06	41.7	0.08	422.3	0.21	566.7	0.25	6.6	0.02	63.2	0.05	163.8	0.10	220.3	0.13
	Hymenopterans	74.8	0.13	19.3	0.04	33.5	0.05	2.8	0.01	0.0	0.00	0.0	0.00	38.2	0.06	7.4	0.01
	Other	2.8	<0.01	2.8	0.01	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	1.0	al.01	0.9	<0.01
	Total																
	Terrestrials	166.5	0.58	66.7	0.20	583.3	0.50	602.8	0.48	13.4	0.06	73.2	0.11	268.6	0.40	244.4	0.26
	Aquatic																
	Dipterans	566.8	0.14	400.2	0.11	313.8	0.08	58.3	0.06	103.4	0.13	46.6	0.02	341.2	0.12	167.6	0.06
	Other Aquatics	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Total Aquatics	566.8	0.14	400.2	0.11	31.3.8	0.08	58.3	0.06	103.4	0.13	46.6	0.02	341.2	0.12	167.6	0.06
	TOTAL INSECTS	733.3	0.73	466.5	0.31	897.2	0.58	661.2	0.53	116.8	0.19	120.0	0.13	609.8	0.52	412.0	0.32

Table 13. Continued.

Month (N)	Insect Group	Emery Nearshore Number	Emery Nearshore Weight	Emery Offshore Number	Emery Offshore Weight	Murray Nearshore Number	Murray Nearshore Weight	Murray Offshore Number	Murray Offshore Weight	Sullivan Nearshore Number	Sullivan Nearshore Weight	Sullivan Offshore Number	Sullivan Offshore Weight	Areas Combined Nearshore Number	Areas Combined Nearshore Weight	Areas Combined Offshore Number	Areas Combined Offshore Weight
November (17)	Coleopterans	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Hemipterans	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Homopterans	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Hymenopterans	3.4	0.04	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	1.0	0.01	0.0	0.00
	Other	0.0	0.00	0.0	0.00	0.0	0.00	2.8	0.02	0.0	0.00	0.0	0.00	0.0	0.00	4.1	0.01
	Total																
	Terrestrials	3.4	0.04	0.0	0.00	0.0	0.00	2.8	0.02	0.0	0.00	0.0	0.00	1.0	0.01	1.0	0.01
	Aquatic																
	Dipterans	0.0	0.00	0.0	0.00	5.5	0.02	2.8	0.01	0.0	0.00	0.0	0.00	1.9	0.01	1.0	<0.01
	Other Aquatics	0.0	0.00	0.0	0.00	0.0	0.00	2.8	<0.01	0.0	0.00	0.0	0.00	0.0	0.00	1.0	<0.01
	Total Aquatics	0.0	0.00	0.0	0.00	5.5	0.02	5.7	0.02	0.0	0.00	0.0	0.00	1.9	0.01	2.0	0.01
	TOTAL INSECTS	3.4	0.04	0.0	0.00	5.5	0.02	8.3	0.04	0.0	0.00	0.0	0.00	2.9	0.02	2.9	0.01

Month (N)	Insect Group	Emery Nearshore Number	Emery Nearshore Weight	Emery Offshore Number	Emery Offshore Weight	Murray Nearshore Number	Murray Nearshore Weight	Murray Offshore Number	Murray Offshore Weight	Sullivan Nearshore Number	Sullivan Nearshore Weight	Sullivan Offshore Number	Sullivan Offshore Weight	Areas Combined Nearshore Number	Areas Combined Nearshore Weight	Areas Combined Offshore Number	Areas Combined Offshore Weight
December (6)	Coleopterans	--	--	--	--	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Hemipterans	--	--	--	--	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Homopterans	--	--	--	--	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Hymenopterans	--	--	--	--	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Other	--	--	--	--	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Total																
	Terrestrials	--	--	--	--	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Aquatic																
	Dipterans	--	-	-	--	0.0	0.00	5.7	0.04	0.0	0.00	0.0	0.00	0.0	0.00	2.8	0.02
	Other Aquatics	--	--	-	--	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
	Total Aquatics	-	-	--	--	0.0	0.00	5.7	0.04	0.0	0.00	0.0	0.00	0.0	0.00	2.8	0.02
	TOTAL INSECTS	--	--	--		0.0	0.00	5.7	0.04	0.0	0.00	0.0	0.00	0.0	0.00	2.8	0.02

Table 13. Continued.

Month (N)	Insect Group	Areas: Emery Nearshore Number	Emery Nearshore Weight	Emery Offshore Number	Emery Offshore Weight	Murray Nearshore Number	Murray Nearshore Weight	Murray Offshore Number	Murray Offshore Weight	Sullivan Nearshore Number	Sullivan Nearshore Weight	Sullivan Offshore Number	Sullivan Offshore Weight	Areas Combined Nearshore Number	Areas Combined Nearshore Weight	Areas Combined Offshore Number	Areas Combined Offshore Weight
Annual																	
Grand Mean (129)	Coleopterans	10.0	0.13	5.2	0.06	8.9	0.07	6.6	0.09	3.9	0.02	8.7	0.13	7.7	0.08	7.0	0.09
	Hemipterans	19.2	0.03	4.8	<0.01	40.4	0.03	9.0	0.02	0.8	<0.01	3.8	0.02	21.1	0.02	6.2	0.01
	Homopterans	15.8	0.02	20.2	0.02	62.4	0.06	73.6	0.06	20.2	0.01	7.2	0.01	34.6	0.03	36.1	0.02
	Hymenopterans	887.5	2.75	1294.5	1.65	683.4	0.64	1700.4	3.49	632.9	6.89	3357.9	8.27	555.7	3.31	21B2.6	4.70
	Other	2.9	0.02	2.0	0.01	2.9	<0.01	2.1	0.01	0.4	a.01	0.8	<0.01	2.1	0.01	1.7	0.01
	Total Terrestrials	935.4	2.95	1326.6	1.74	797.9	0.81	1791.7	3.65	658.1	6.93	3378.4	8.42	621.2	3.45	2233.6	4.84
														[2725.2]	[25.78]	[10469.6]	[24.55]
	Aquatic Dipterans	127.9	0.07	l14.3	0.06	U9.8	0.11	60.8	0.06	70.9	0.09	46.2	0.05	112.4	0.10	73.2	0.05
	Other Aquatics	1.3	0.01	1.2	0.01	0.4	0.08	3.5	a.01	23.6	0.04	3.0	0.01	8.5	0.05	2.7	0.01
	Total Aquatics	129.2	0.07	115.5	0.07	130.1	0.20	64.3	0.06	94.6	0.1.3	49.2	0.06	120.8	0.14	75.9	0.06
														[225.0]	[0.41]	[197.4]	[0.11]
	TOTAL INSECTS	1064.6	3.02	1442.0	1.82	928.0	1.01	1855.9	3.71	752.7	7.06	3427.6	8.49	742.1	3.59	2309.5	4.90
														[2718.2]	[25.77]	[10462.5]	[24.54]

a/ Standard deviations are given in brackets.

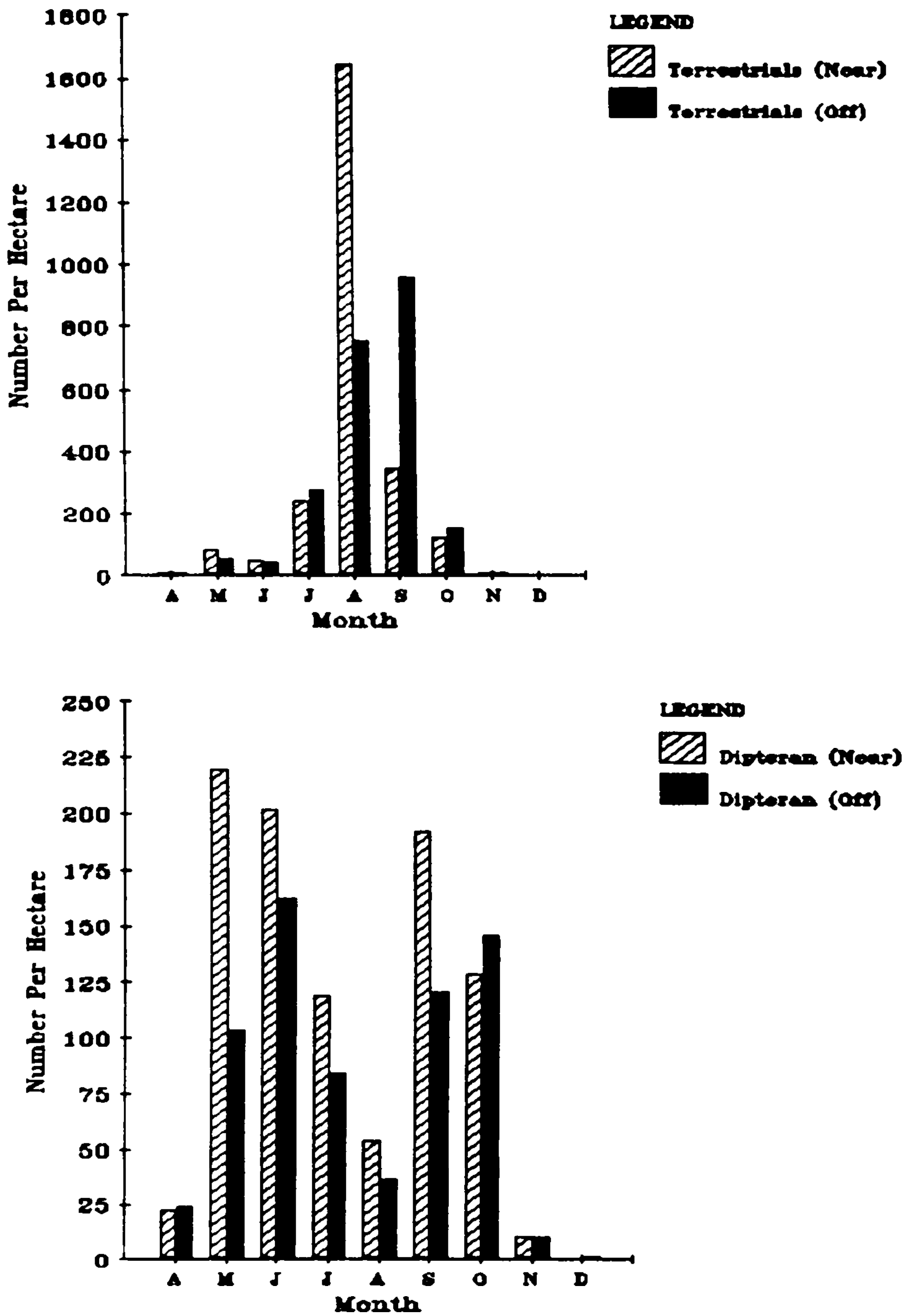


Figure 21. The number per hectare of terrestrial insects and aquatic dipteran collected in surface insect tows from Hungry Horse Reservoir, 1984-87. The near and off samples were collected within and further than 100 m from the shoreline, respectively.

There was no significant difference in numbers between the littoral and limnetic zones (Table 14). The Emery area had significantly higher ($P<.05$) populations of terrestrial insects than the other two areas for no clearly understood reason. The number of terrestrials collected in 1986 was significantly lower than in the other three years of the study. Again, the reasons for this difference is not understood. Reservoir operation in 1986 was comparable to the other years of the study. Norlin (1967) stated that drawdown can influence the recruitment of terrestrial insects to a reservoir in a negative vay. The bare zone or dewatered land area can reduce the spreading of insects from vegetated regions near the shore to the water and the rising thermal air currents originating above such bare regions form a barrier to air-borne transport tovard the water. Since the drawdown from 1983 to 1987 has only varied betveen 60 to 85 ft, we probably have not had a sufficient range of conditions to ascertain the drawdown effects upon terrestrial insect recruitment to the reservoir.

Aquatic insect variances were also high during the study primarily due to emergence patterns and wind and wave action (Table 13). Aquatic insects were represented almost entirely by dipterans. The abundance of dipteran adults on the surface varied seasonally with peaks occurring in May and June, then again in September and October (Figure 21). The densities of dipteran which peaked at almost $225 \cdot ha^{-2}$ were much less than the peaks recorded in the emergence traps vhich were approximately 150,000 to $170,000 \cdot ha^{-1}$. The probable causes for this disparity were the mesh size in the tow net was too large to capture the smaller dipteran and, most importantly, dipterans emerge and fly away almost immediately upon reaching the water surface (Oliver 1971).

The number of aquatic dipteran adults caught in the littoral area was significantly higher ($P<.05$) than captured in the limnetic zone (Table 14). This abundance pattern is similar to the one recorded in the emergence traps and probably results from the greater production of dipterans in the littoral zone.

There was no significant difference betveen the numbers of dipteran caught in the littoral zone in the three reservoir areas. In contrast, the Sullivan area had significantly ($P<.05$) larger numbers of dipterans on the surface film in the limnetic zone than the other tvo areas (Table l4). It is interesting to note that although the mean $number \cdot ha^{-1}$ of 78 in Sullivan was lower than the mean of 141 in the Emery area, the non-parametric test indicated that the Sullivan numbers were indeed significantly higher than in the Emery area. This apparent contradiction is due to the distribution of the catch. The Emery area having a few samples with large numbers of dipteran which biased the average catch upward.

There was little difference in numbers in the littoral zone among the years sampled, except the 1984 mean catch was significantly higher than the 1986 catch (Table 14). In the limnetic zone the catches recorded in 1985 were significantly

Table 14. A comparison of the number of surface insects per hectare collected in tows from Hungry Horse Reservoir, 1984 to 1987.

The mean number of terrestrial and aquatic insects per hectare

Terrestrials Between Zones[a]

Zone 1 x Zone 2
389 x 344

Terrestrials Between Areas

Emery x Murray	Emery x Sullivan	Murray x Sullivan
519[b] x 248*	519 x 372*	248 x 372

Terrestrials Between Years

1984 x 1985	1984 x 1986	1984 x 1987	1985 x 1986	1985 x 1987	1986 x 1987
556 x 547	556 x 211**	556 x 417*	347 x 211**	347 x 417	211 x 417*

Aquatics Between Zones

Zone 1 x Zone 2
136 x 93*

Aquatics Between Areas by Zone

Zone	Emery x Murray	Emery x Sullivan	Murray x Sullivan
1	168 x 116	168 x 129	116 x 129
2	141 x 70	141 x 78*	70 x 78**

Aquatics Between Years by Zone

Zone	1984 x 1985	1984 x 1986	1984 x 1987	1985 x 1986	1985 x 1987	1986 x 1987
1	79 x 174	79 x 144**	79 x 121	174 x 144	174 x 121	144 x 120
2	58 x 114*	58 x 116	58 x 76	114 x 111**	114 x 76*	111 x 76

a/ Zone 1 corresponds to the littoral area which extends approximately from the shoreline out 100 meters whereas zone 2 includes the part deeper than the euphotic zone and greater than 100 meters from the shoreline.

b/ The underlined number is the one that had the highest rank in the Mann-Whitney test.

* - significant difference at 0.05 probability level

** - significant difference at 0.01 probability level

higher ($P<.05$) than in the other years. The limnetic zone vas continually wetted throughout the study and the difference in numbers is probably due to climatic variation or sampling error.

FOOD HABITS

Methods

The year was stratified into four seasons based on reservoir operation and surface water temperatures.

1. Winter (mid November through April) -when the reservoir is evacuated for flood control and power production, surface water temperatures are below 8.0°C and the reservoir is isothermal;

2. Spring (May and June) - when the reservoir is refilled and surface water temperatures are between 10 to 15°C; and increasing;

3. Summer (July through mid September) - when the reservoir is near full pool and surface water temperatures are between 16 to 22°C and the reservoir is thermally stratified.

4. Fall (mid September through mid November) - when drafting of the reservoir begins for power production and surface water temperatures are between 10 to 15°C and declining.

Fish samples for the food habits study were collected with gill nets from each area of the reservoir during the seasonal gill net series. Fish were picked from gill nets and immediately placed on ice. Stomach contents vere removed the same day and placed in labeled vials with a formalin preservative.

Approximately 20 of each westslope cutthroat trout, bull trout and northern squawfish along with ten mountain whitefish were collected from each area seasonally. Cutthroat and squawfish under 300 mm in total length were classified as juveniles, whereas 350 mm was the criteria used to separate juvenile and adult bull trout.

The number and weight of each taxonomic food group from each stomach were recorded. Wet weights of food categories were weighed to the nearest 0.00l g after removing excess water with paper towels.

Zooplankton in the stomachs were identified to genus and carapace lengths of Daphnia determined from the relationship betveen the length of the post-abdominal claw if the carapaces vere too digested to measure them directly. The regression formula is:

$$Y = 0.0553 + 11.74x$$

Where: Y = carapace length;
X = post-abdominal claw length; and
$R = .962$.

The weight of zooplankton was calculated using length - weight regressions in Bottrell et al. (1976).

Daphnia $LnW = 5.9115 + 2.7166\ LnL$

Copepoda $LnW = 1.9526 + 2.3990\ LnL$

Where: Ln = natural log;
W = dry veight (ug); and
L = length of zooplankton in mm.

An index of relative importance (IRI) was calculated to estimate the importance of a particular food item in the diet (George and Hadley 1979). The IRI incorporates the number, frequency of occurrence and volume of a food item in the diet. It is the arithmetic mean of these parameters (all expressed as percentages) and ranges from zero to 100, with the latter value indicating exclusive use of a food item. The IRI values overestimated the importance of other food items as compared to fish for the piscivorous fish species. Thus, wet weight of food ingested was used to evaluate the food habits of bull trout and northern squawfish.

The Schoener overlap index (Schoener 1970) was used to determine the degree of diet overlap between four fish species:

$$a = 1 - 0.5 \left(\sum_{i=1}^{n} Pxi - Pyi \right)$$

Where: a = Schoener overlap index:
Pxi = proportion of food category i; in the diet of fish species x; and
Pyi = proportion of food category i in the diet of fish species y.

The value for this index can range betveen zero and 1.0. A low value indicates a small degree of diet overlap vhereas a value approaching 1.0 indicates a high degree of diet overlap between the two fish species.

Results and Discussion

Westslope Cutthroat Trout

The food habits of westslope cutthroat trout in HHR were determined by examining a total of 434 stomachs collected from August, 1983 through November 1985 (Table 15). Approximately 86 percent of the stomachs contained food. The biomass of food in the stomachs was highest from June through September when the cutthroat were feeding primarily on terrestrial and aquatic

Table 15. Number of fish stomachs collected in Hungry Horse Reservoir from 1983 to 1985. Number of stomachs with food in parentheses.

Date	Westslope Cutthroat Trout	Bull Trout	Mountain Whitefish	Northern Squawfish
		1983		
Aug	18 (17)	9 (7)	12 (12)	22 (8)
Sep	65 (57)	32 (18)	21 (17)	18 (8)
Nov	36 (30)	17 (13)	36 (34)	12 (5)
YEAR	119(104)	56 (38)	69 (63)	52 (21)
		1984		
Jun	60 (58)	58 (49)	20 (20)	58 (35)
Aug	23 (15)	36 (18)	21 (13)	55 (19)
Oct	32 (31)	41 (13)	15 (12)	20 (7)
Dec	48 (25)	-- --	-- --	-- --
YEAR	163 (129)	135 (80)	56 (45)	133 (61)
		1985		
May	55 (52)	54 (42)	17 (16)	35 (21)
Aug	38 (34)	49 (46)	19 (15)	36 (17)
Nov	59 (55)	65 (37)	16 (13)	26 (13)
YEAR	152 (141)	168 (125)	52 (44)	97 (51)
TOTAL	434 (374)	359 (243)	177 (152)	282 (133)

insects adults and lowest in the late fall and winter when they are primarily zooplankton (Table 16).

The diet of cutthroat was similar annually, and there was little difference between the food habits of juvenile and adult fish. Terrestrial insects comprised most of the food eaten, folloved by aquatic insects and zooplankton (Figure 22). Eiymenoptera were the most important terrestrial insect consumed and aquatic dipterans comprised almost all of the aquatics ingested. Cutthroat selected Daphnia pulex almost exclusively when feeding on zooplankton, apparently due to its larger size. Cutthroat fed on Daphnia over 1.8 mm in length (Table 17). Koening (1983) found that rainbow trout selected Daphnia over 1.5 mm in length in two lakes in southeast Alaska.

The diet of cutthroat trout varied seasonally in response to food availability (May and Weaver 1987). In May, aquatic insects with an IRI value of 72 vere the most important food item eaten followed by terrestrial insects. From June through October terrestrial insects dominated the diet vith IRI values of between 50 to 95. During this period, aquatic dipteran were also an important component of the diet vith IRI values usually from 20 to 30. When terrestrial insects vere no longer available in November and December the cutthroat switched to feeding primarily on Daphnia pulex, although aquatic dipteran were still an important part of the diet.

The food habits of cutthroat trout in lakes are highly variable and are influenced by the availability of food items, subspecies of cutthroat trout and species composition of the fish community. Westslope cutthroat trout food habits in HHR were nearly identical to those recorded for the same subspecies in Flathead Lake (Leathe and Graham 1982). Cutthroat trout in Lake Koocanusa utilized more Daphnia than cutthroat from Hungry Horse (McMullin 1979). Westslope cutthroat from a number of northern Idaho lakes fed almost entirely on terrestrial and aquatic insects (Bjornn 1957, Jeppson and Platts 1959).

Bull Trout

The stomachs from 359 bull trout were examined to determine the diet of this species (Table 15). Approximately 32 percent of the stomachs were empty. Fish was the principal component of the bull trout diet comprising over 99 percent of the biomass (Figure 23). In 1984, juveniles ate primarily northern squawfish and mountain whitefish while adults ate suckers, northern squawfish and mountain whitefish. The adults collected in 1984 fed on suckers, mountain whitefish, northern squawfish and cutthroat trout, whereas the juveniles consumed cutthroat trout, suckers, squawfish and mountain whitefish. Overall, the juveniles and adults had similar food habits, except the adults consistently ate more suckers than the juveniles. The food habits were similar among the years, except more cutthroat were consumed in the spring of 1985 than in the other years (May and Weaver 1987).

Table 16. Mean weight (g) of food items in the stomachs of westslope cutthroat trout, bull trout, mountain whitefish and northern squawfish, collected from Hungry Horse Reservoir, 1983 to 1985.

	Mean wet weight of stomach contents in grams						
Species	**May**	**Jun**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
WCT	0.67	3.21	1.82	9.21	0.48	0.14	0.36
DV	2.26	4.94	11.42	10.37	6.87	12.38	--
MWF	0.01	0.24	0.11	0.11	0.29	0.31	--
NSQ	5.07	2.17	0.33	0.13	1.09	0.19	--

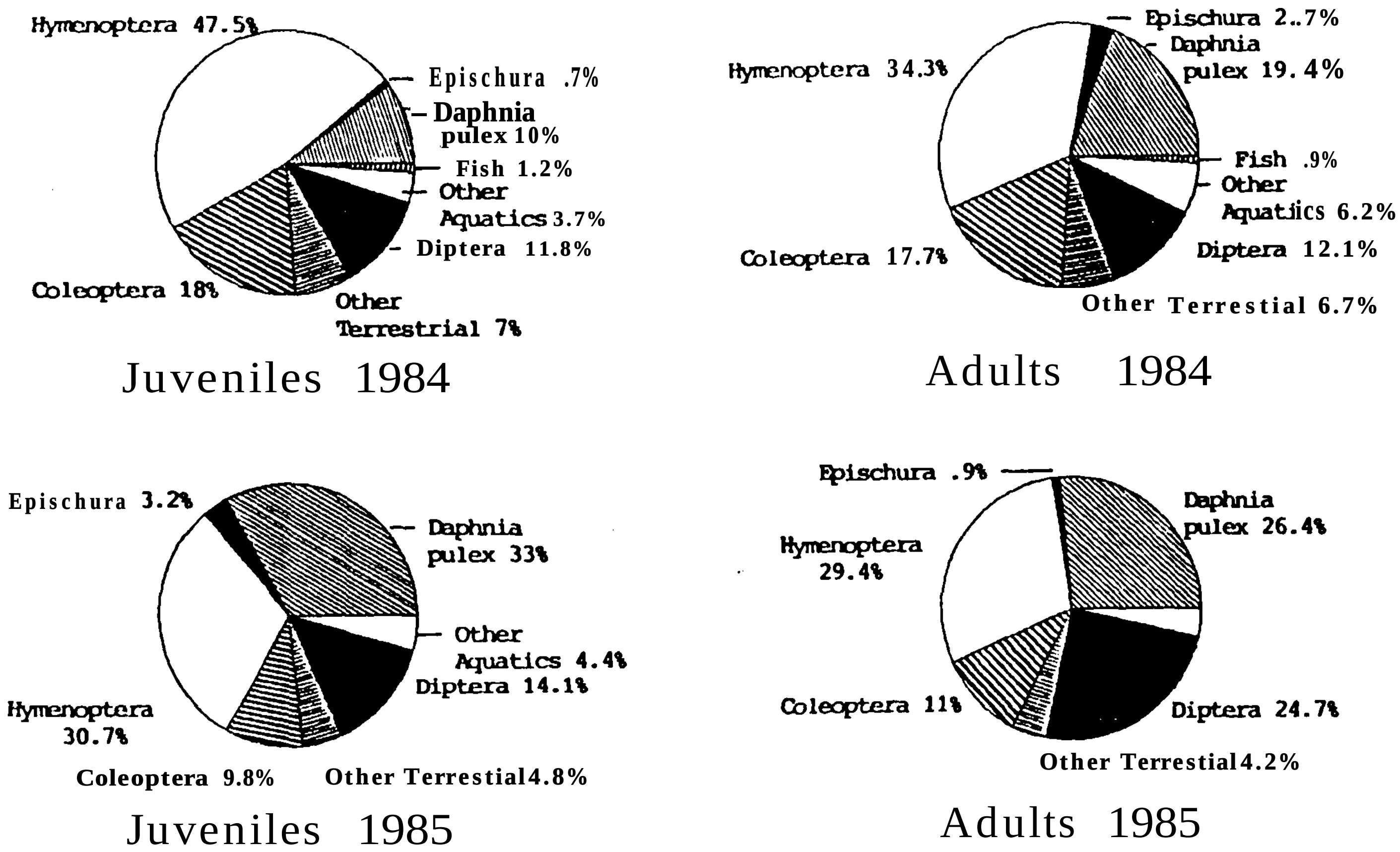


Figure 22. Percent indices of relative importance (IRI) for westslope cutthroat trout juveniles and adults collected in Hungry Horse Reservoir, 1984-85.

Table 17. Length group frequencies and mean lengths of *Daphnia* from Wisconsin tow samples and eaten by vestslope cutthroat trout in Hungry Horse Reservoir, 1983 to 1985.

	Wisconsin Tow Samples					
	Length Group Frequencies of Daphnia				Mean Length	WCT, Stomach Mean Length
Date	0.0-0.99	1.0-1.49	1.50-1.99	2.0-2.49		
Nov, 1983	29.9	46.8	20.0	3.3	1.18	1.95 (0.075[a/]
Dec. 1984	31.2	11.8	28.0	29.0	1.44	1.96 (0.014)
Nov, 1985	34.5	40.5	15.0	10.0	1.15	1.91 (0.063)

a/ Standard deviation

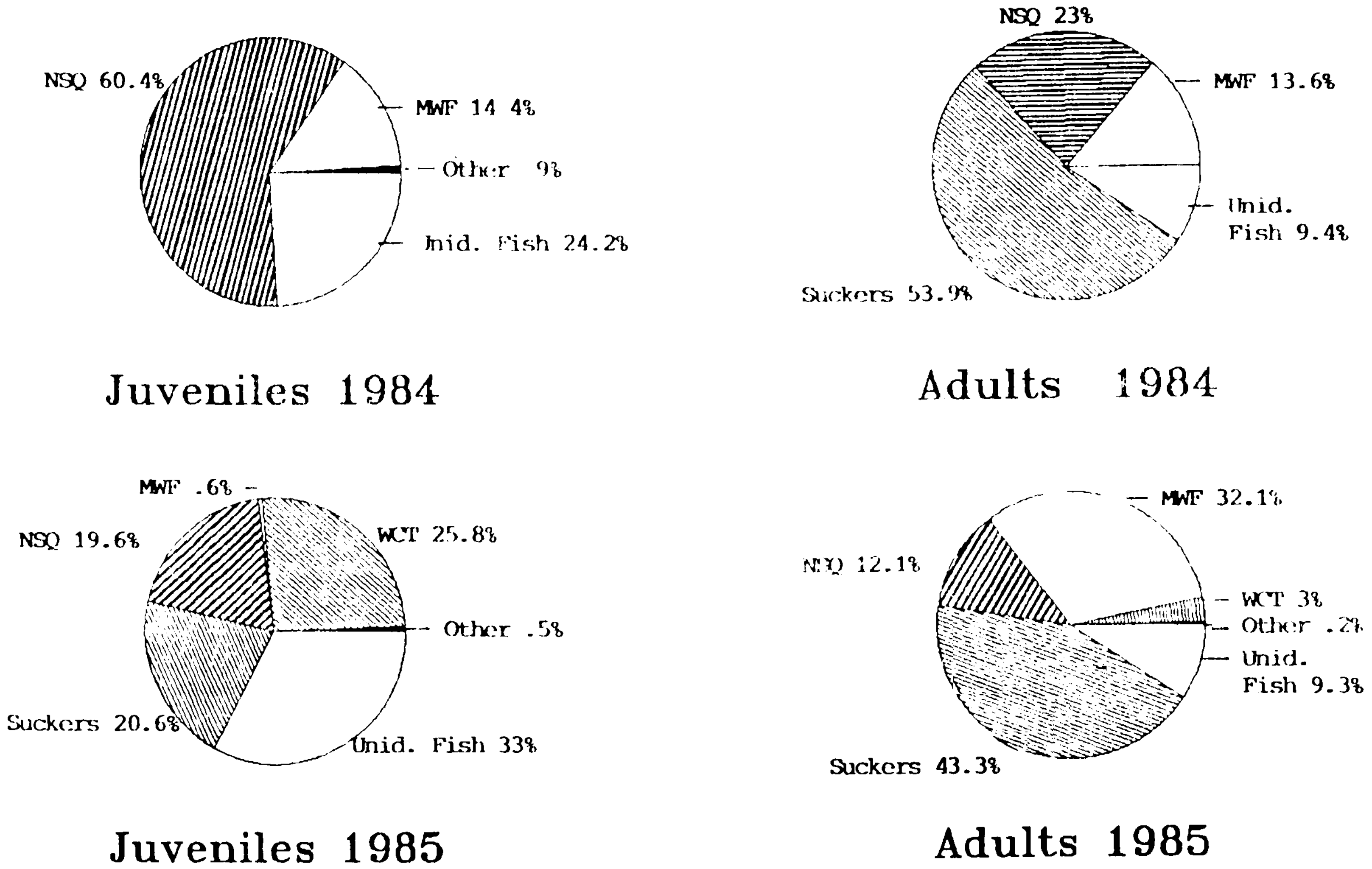


Figure 23. Percent wet weight of food items consumed by juvenile and adult bull trout from Hungry Horse Reservoir, 1984-85.

Other food habits studies of bull trout have shovn them to be piscivorous, feeding almost entirely on fish. Leathe and Graham (1982) found that bull trout in Flathead Lake fed almost entirely on fish as did bull trout in Libby Reservoir. Bull trout in northern Idaho lake consumed mostly fish (Jeppson and Platts 1959, and Bjomn 1957). Hovever, mysids became an important component of the diet in Priest Lake following the decline of the kokanee population (Rieman and Lukens 1979).

Mountain Whitefish

Approximately 177 stomachs were examined to assess the diet of mountain whitefish. Mountain whitefish ate primarily Daphnia pulex folloved by aquatic dipteran, Epischura and terrestrial insects (Figure 24). The diet was uniform vith little seasonal variation, except for the May, 1985 collection when aquatic dipteran comprised most of the diet. Daphnia pulex had an average IRI value of 77 as compared to 12 for aquatic dipteran.

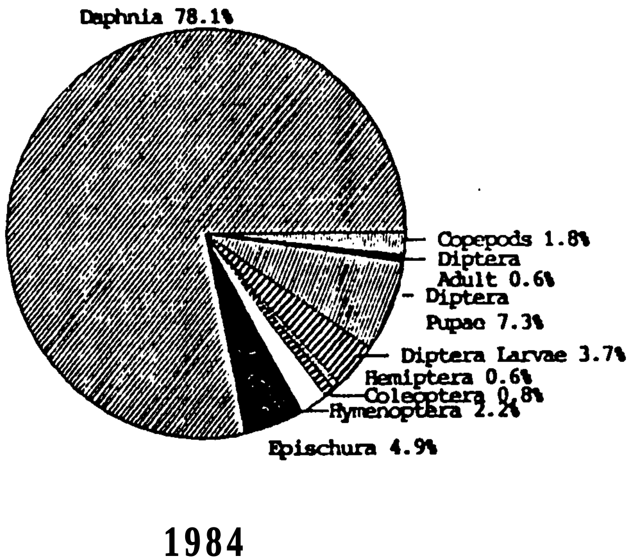
The mountain whitefish is typically a bottom feeder consuming primarily aquatic insect larvae. Hovever, when bottom fauna are scarce, they will eat mid water zooplankton and surface insects (Scott and Crossman 1973). Mountain whitefish fed mostly on Daphnia in Flathead Lake (Leathe and Graham 1982).

Northern Squawfish

Assessing the food habits of northern squawfish was difficult because of the high frequency of regurgitation of their stomach contents when the fish vere caught in gill nets. Only 47 percent of 282 stomachs examined contained food items (Table 15). In addition, the biomass found in stomachs with food was low (Table 16).

Fish were the principal component of the squawfish's diet comprising over 90 percent of the annual biomass consumed (Figure 25). There was variation among the years in the relative importance of the various species eaten due primarily to the low number of food items found in the stomachs. A total of only 14 fish were identified from the stomachs of squawfish. The species eaten in order of abundance were bull trout, mountain whitefish, northern squawfish, suckers and westslope cutthroat trout. Juvenile squawfish did eat more zooplankton and insects than adults. Squawfish predation on bull trout did not appear to have a major effect on the abundance of bull trout. The effect of squawfish predation on westslope cutthroat trout was not ascertained. Habitat separation in HHR appears to reduce predation of squawfish on cutthroat trout.

Northern squawfish eat the young of salmon and trout and have been shown to be serious predators on salmonids (Ricker 1941, Jeppson and Platts 1959. and Thompson and Tufts 1967). Uremovich



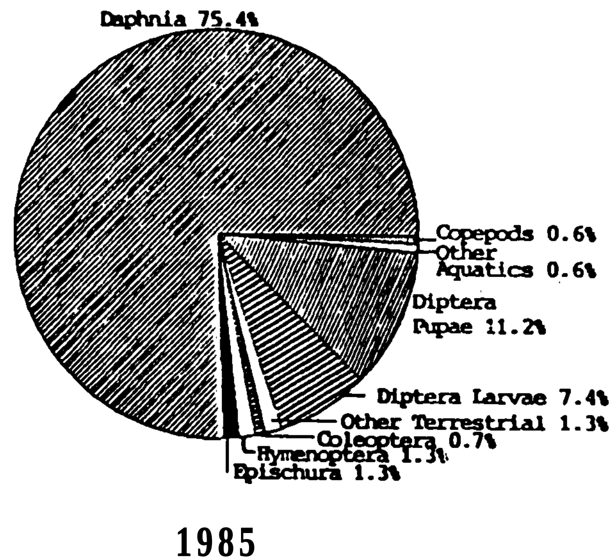


Figure 24: Percent indices of relative importance (IRI) for mountain whitefish from Hungry Horse Reservoir.

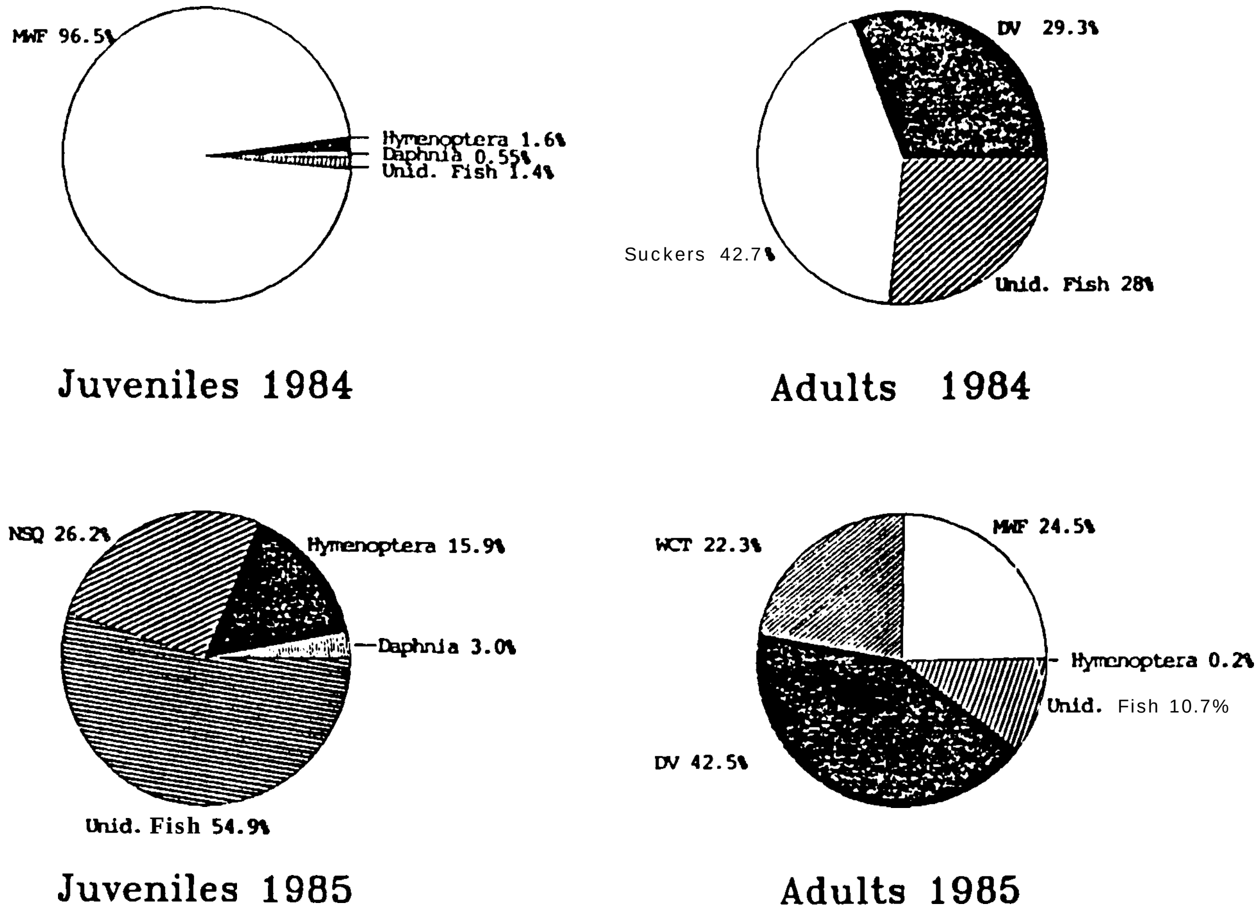


Figure 25. Percent indices of relative importance (IRI) for northern squawfish from Hungry Horse Reservoir, 1984-85.

et al. (1980) estimated that northern squawfish ate 3.8 million juvenile salmonids in summer, 1980 in the forebay of Bonneville Dam.

Diet Overlap

Diet overlap was determined for four species of fish from HHR collected from May through December in 1984 and 1985. This time span comprised the main growing season for these fishes. Diet overlap measurement can be useful to describe fish community structure and possible competitive interactions.

There was little diet overlap among the four species, except between bull trout and northern squawfish (Table 18). Both of these species are piscivorous and fish accounted for over 90 percent of the food biomass consumed. Although the Schoener index of 0.99 indicated a high degree of overlap, there may be relatively little competition for food resources between bull trout and squawfish. Both species are abundant in HHR and have good growth rates.

GILL NET CATCHES

Methods

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 square mesh. Floating nets sampled from the surface down to 1.8 m and sinking nets sampled from the bottom up 1.8 m. A floating net set consisted of two floating nets tied end to end (double floater) and fished perpendicular from shore. A sinking net consisted of a single net fished perpendicular from shore. In each area seven double floaters and five sinkers were set in the evening and retrieved the next morning (Figure 1). The netting series were done monthly from July through November 1983 and from April through June 1984 and seasonally through May 1987. Nets were set two nights in each area during the seasonal netting.

All fish were removed from the nets, identified to species, with length (mm) and veight (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. Otoliths were collected from westslope cutthroat trout beginning in December, 1984.

Horizontal gill nets were effective in sampling for all fish species vhen they were distributed in inshore areas, except for pygmy whitefish and sculpins (Cottus sp.). Gill net data was analyzed using catch per single net night by species. The Mann-Whitney non-parametric ranking test was used to compare catches betveen years and among areas.

Table 18. Schoener diet overlap index values for four species of fish collected from Hungry Horse Reservoir, 1984 to 1985.

	WCT	DV	MWF	NSQ
		1984		
VCT	--	0.03	0.10	0.06
DV	0.03	--	0.01	0.99
MWF	0.10	0.01	--	0.01
NSQ	0.06	0.99	0.01	--
		1985		
VCT	--	0.01	0.15	0.01
DV	0.01	--	0.01	0.99
MWF	0.15	0.01	--	0.01
NSQ	0.01	0.99	0.01	--

Estimation of fish abundance by the relative index method requires that gill net sampling be done at similar locations and times each year. It is especially critical that water temperatures and reservoir elevation be standardized. Vith this sampling design, the complex interrelation of factors influencing catch are minimized and catch per unit of effort is proportional to relative species abundance. Indexes derived from catch-effort data can be used to determine year to year changes in population size, species composition and other vital statistics (Walburg 1969).

Results and Discussion

The reservoir elevations, surface water temperatures and euphotic zone parameters were generally more stable during the summer netting in August than in the spring and fall net series (Table 19). Surface water temperatures during the seasonal netting in May and late October usually varied within ±2°C of 9.0°C (Table 19). Reservoir elevations averaged about 30 feet below full pool during the spring netting series as compared to 25 feet for the fall series.

A total of 11,783 fish vere caught in sinking and floating gill nets during the study. Westslope cutthroat trout dominated the catch in floating nets comprising from 42 to 60 percent of the fish caught (Table 20). Northern squawfish were also an important component of the floating net catch, making up 16 to 46 percent of the sample. The most abundant species in the sinking net catches was mountain whitefish which comprised 27 to 40 percent of the catch folloved by northern squawfish, longnose suckers, bull trout, largescale suckers and pygmy whitefish. Most of the pygmy whitefish were caught in the fall gill net series in 1986.

The variance in catch of individual species by net type indicated that cutthroat trout were concentrated primarily in the upper part of the water column when in the littoral zone. In contrast, mountain whitefish, suckers and bull trout were more closely associated with the reservoir bottom. Northern squawfish were more generally dispersed throughout the water column in the nearshore habitat.

Westslope Cutthroat Trout

The catch of westslope cutthroat trout in floating gill nets has varied considerably among the seasons of the year (Figure 26 and Table 21). In general, catches were highest in the spring, intermediate in the fall and lowest in the summer, ranging from a maximum of 4.8 fish per net in April to a minimum 0.2 in August. Water temperature, water transparency and reservoir elevation difference account for most of the catch variability. Shoreline floating net catches of cutthroat also varied seasonally in Flathead Lake (Leathe and Graham 1982).

Table 19. Reservoir elevations surface water temperatures and water transparency for gill net sampling dates in Hungry Horse Reservoir, 1983 to 1987.

Date	Reservoir Elevation (ft)	Surface water temperature (°C)			Depth euphotic zone (m)		
		Emery	Murray	Sullivan	Emery	Murray	Sullivan
			1983				
07/26-28	3,560	16.6	17.8	17.2	--	--	--
08/23-25	3,560	20.6	20.6	20.0	18.3	19.1	18.9
09/27-29	3,547-49	14.7	14.8	13.9	26.0	18.5	20.5
10/31-11/2	3,534	8.6	8.4	8.0	23.0	16.5	19.3
11/29-30	3,536	7.1	6.5	--	20.5	14.0	--
12/14-16	3,534			4.3	20.3	16.5	19.1
			1984				
04/24-27	3,500	4.2	5.6	5.7	15.1	10.3	5.2
05/30-31	3,519-23	10.5	9.9	8.6	14.5	13.0	5.8
06/26-28	3,549-51	17.0	19.6	18.4	17.8	14.3	8.3
08/13-22	3,557-59	20.0	21.0	20.0	18.3	16.7	16.3
10/11-15	3,540-41	--	12.6	12.1	17.8	19.6	14.6
			1985				
05/14-21	3,512-22	7.2	8.1	7.1	12.0	7.5	3.9
08/14-20	3,544-45	20.1	18.3	20.1	15.8	14.0	17.0
10/31-11/4	3,524-27	7.9	8.3	8.0	13.6	14.8	11.4
			1986				
05/16-22	3,536-39	7.9	10.0	7.9	16.0	15.1	15.0
08/12-20	3,557-59	20.1	20.0	19.9	17.7	15.5	15.4
10/30-11/7	3,530	9.4	9.7	9.7	17.5	11.5	15.2
			1987				
05/12-20	3,543-48	12.3	12.6	10.3	13.5	10.7	4.7

Table 20. Percent composition by species and net type for gill net catches from Hungry Horse Reservoir, 1983 to 1987.

Species	Percent of Catch									
	Floating Nets					Sinking Nets				
	1983	1984	1985	1986	1987	1983	1984	1985	1986	1987
Westslope cutthroat trout (WCT)	43.9	41.8	54.1	42.1	59.4	2.3	1.4	0.8	1.4	1.3
Bull trout (DV)	3.4	5.8	8.4	7.9	16.8	9.4	14.0	16.5	18.0	19.7
Mountain whitefish (MFW)	11.5	4.2	8.4	10.3	5.5	40.4	36.7	38.3	40.1	27.2
Northern squawfish (NSQ)	39.6	45.7	26.6	37.4	14.7	22.8	22.8	23.1	16.6	13.7
Largescale suckers (CSU)	1.4	2.2	2.4	1.7	1.8	10.1	9.1	8.7	9.1	Il.2
Longnose sucker (LNSU)	0.2	0.3	0.1	0.6	1.8	15.0	15.9	12.5	13.1	26.9
Pygmy Whitefish (PW)	--	--	--	--	--	<0.1	<0.1	<0.1	1.7	--
Total fish caught	712	1,147	711	828	453	963	2,110	1,772	2,132	960

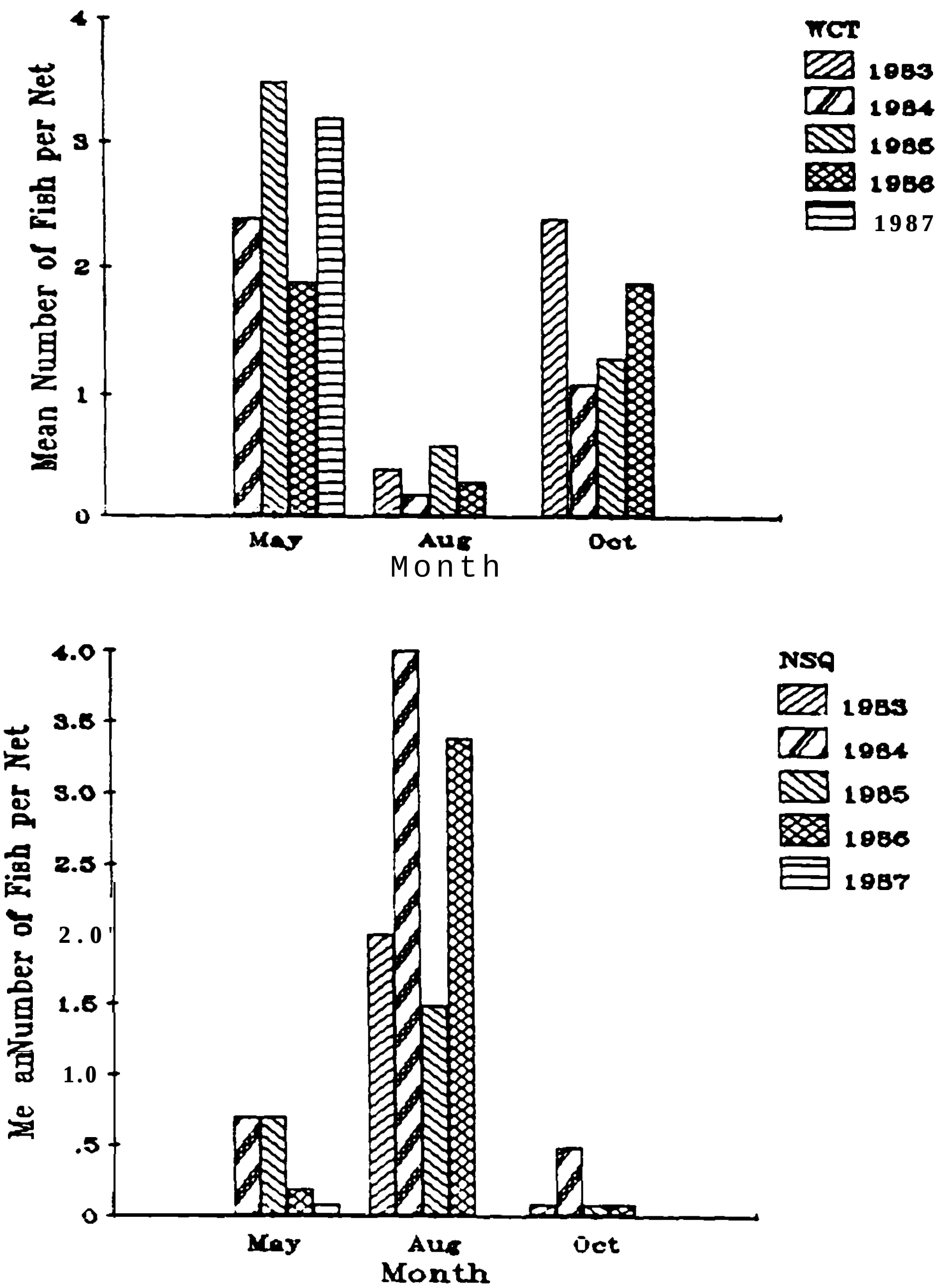


Figure 26. Seasonal catches of westslope cutthroat trout (WCT) and northern squawfish (NSQ) in floating gill net sets in Hungry Horse Reservoir 1983-87.

Table 21. Average catch in floating and sinking nets for fish species from HungryHorse Reservoir, 1983 to 1987.

DATE	Number of nets/area[a] E	M	S	Emery WCT	DV	MWF	NSQ	CSU	LNSU	Murray WCT	DV	MWF	NSQ	CSU	LNSU	Sullivan WCT	DV	MWF	NSQ	CSU	LNSU	Areas Combined WCT	DV	MWF	NSQ	CSU	LNSU
07/26-28/83	16	16	14	1.2	0.1	0.1	2.9	0.0	0.0	0.7	0.1	0.0	1.7	0.0	0.0	1.4	0.1	0.0	0.6	0.1	0.0	1.1	0.0	1.7	0.1	0.0	12.0
07/26-28/83	16	14	14	1.2	0.1	0.1	2.9	0.0	0.0	0.7	0.1	0.0	1.7	0.0	0.0	1.4	0.1	0.0	0.6	0.1	0.0	1.1	0.1	0.0	1.7	0.1	0.0
08/23-25/83	14	14	14	0.2	0.1	0.0	2.7	0.0	0.0	0.2	0.1	0.0	1.9	0.1	0.1	0.9	0.0	0.0	1.5	0.1	0.1	0.4	0.1	0.0	2.0	0.1	0.0
09/27-29/83	14	14	14	2.0	0.2	1.7	6.6	0.0	0.0	3.0	0.3	1.9	3.3	0.3	0.0	3.5	0.1	0.3	1.1	0.0	0.0	2.8	0.2	1.3	2.9	0.1	0.1
11/01-03/83	14	16	14	2.6	0.2	0.5	0.1	0.0	0.0	1.2	0.1	0.6	0.0	0.0	0.0	3.3	0.1	0.9	0.1	0.1	0.0	2.4	0.2	0.6	0.1	0.0	0.0
11/29-12/03/83	16	14	14	0.5	0.1	0.1	0.0	0.0	0.0	0.8	0.0	0.1	0.0	0.0	0.0	0.7	0.1	0.0	0.0	0.0	0.0	0.7	0.1	0.1	0.0	0.0	0.0
04/24-27/84	14	14	14	2.2	0.0	0.1	0.1	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	9.1	1.2	0.1	0.1	0.0	0.0	4.8	0.4	0.0	0.0	0.0	0.1
05/30-31/84	14	16	12	1.6	1.4	0.5	0.9	0.4	0.1	3.4	0.6	0.3	0.4	0.1	0.1	2.1	1.0	0.3	0.8	0.1	0.0	2.4	0.6	0.4	0.7	0.2	0.1
06/26-28/84	14	16	16	1.1	0.7	0.2	5.0	0.3	0.0	2.3	0.2	0.2	2.2	0.2	0.1	4.3	0.6	0.1	1.3	0.2	0.0	2.6	0.5	0.2	2.9	0.2	0.1
08/13-22/84	28	28	28	0.1	0.1	0.1	5.3	0.0	0.0	0.2	0.0	0.1	5.4	0.1	0.0	0.5	0.0	0.1	1.7	0.0	0.0	0.2	0.1	0.1	4.1	0.1	0.0
10/11-15/84	--	28	26	--	--	--	--	--	--	0.4	0.1	0.6	0.8	0.2	0.0	1.8	0.1	0.0	0.2	0.0	0.0	1.1	0.1	0.3	0.5	0.1	0.0
05/14-21/85	14	28	28	4.8	0.5	0.1	1.9	0.2	0.0	2.6	0.4	0.2	0.2	0.1	0.0	3.7	0.9	0.2	0.7	0.0	0.0	3.5	0.6	0.2	0.7	0.1	0.0
08/14-20/85	28	26	30	0.7	0.1	0.7	1.7	0.0	0.1	0.1	0.1	0.4	1.3	0.1	0.0	1.1	0.0	0.1	1.6	0.1	0.0	0.6	0.1	0.4	1.5	0.1	0.1
10/31-11/06/85	28	26	16	0.8	0.4	0.1	0.2	0.1	0.0	1.2	0.1	0.3	0.0	0.1	0.0	2.6	0.1	0.2	0.1	0.0	0.0	1.3	0.2	0.2	0.1	0.1	0.0
05/15-22/86	28	28	28	2.4	0.3	0.2	0.2	0.1	0.0	1.7	0.4	0.1	0.3	0.1	0.1	1.7	0.4	0.1	0.2	0.0	0.1	1.9	0.3	0.1	0.2	0.1	0.1
08/12-20/86	28	28	28	0.1	0.0	0.1	8.0	0.1	0.1	0.3	0.1	0.2	1.9	0.1	0.0	0.5	0.0	0.1	0.1	0.1	0.0	0.3	0.1	0.1	3.4	0.1	0.1
11/01-07/86	28	28	28	1.9	0.4	0.8	0.1	0.0	0.0	1.2	0.3	0.6	0.1	0.0	0.0	2.8	0.6	1.0	0.2	0.0	0.0	1.9	0.6	0.1	0.8	0.0	0.0
05/13-20/87	28	28	28	3.7	0.8	0.3	1.2	0.1	0.1	2.8	0.8	0.2	0.6	0.2	0.1	3.0	1.0	0.3	0.7	0.1	0.0	3.2	0.9	0.3	0.8	0.1	0.1
Sinking Nets																											
07/26-28/83	2	2	2	0.0	1.0	1.0	13.5	3.5	18.5	0.0	4.0	1.5	7.5	6.0	7.5	0.0	2.0	2.0	3.0	4.0	10.0	0.0	2.3	1.5	7.0	3.8	12.0
08/23-25/83	3	3	3	0.3	1.3	2.0	8.7	3.3	11.3	0.0	0.3	1.3	10.3	6.3	6.0	0.0	0.7	0.7	6.0	5.7	6.0	0.1	0.8	1.3	8.3	4.1	7.8
09/27-29/83	3	3	3	0.0	4.7	15.0	14.7	4.7	0.3	1.0	3.3	38.0	5.3	1.3	0.0	2.3	3.7	22.0	3.3	0.3	0.0	1.1	3.9	25.0	7.8	2.1	0.1
11/01-03/83	3	3	3	0.3	1.3	9.0	2.3	1.0	0.3	0.0	3.0	7.3	0.7	1.0	0.0	0.3	2.3	13.7	3.7	0.7	0.0	0.3	2.2	10.0	2.2	0.9	0.1
11/29-12/03/83	3	3	3	1.3	1.7	3.0	0.7	0.3	0.0	1.3	1.3	7.7	1.3	0.0	0.0	0.3	2.0	6.7	0.3	0.0	0.0	1.0	1.7	5.9	0.8	0.7	0.0
04/24-27/84	6	6	6	1.5	4.3	11.5	1.3	1.0	0.3	1.5	2.5	11.0	0.3	0.3	0.3	0.0	8.0	16.8	2.0	1.5	2.5	1.0	4.9	13.1	1.2	0.9	1.0
05/30-31/84	6	6	6	0.0	6.5	7.3	3.5	1.0	6.8	1.0	7.0	7.5	4.0	1.5	2.8	0.3	2.3	4.5	4.3	0.8	1.8	0.4	5.3	6.4	3.9	1.1	3.8
06/26-28/84	6	6	6	0.8	3.5	7.0	7.5	4.8	6.8	0.3	5.0	3.0	5.5	2.5	7.0	0.3	5.8	7.5	4.0	3.8	9.0	0.4	4.8	5.8	5.7	3.7	7.6
08/13-22/84	10	10	10	0.0	1.1	3.6	12.8	2.8	8.0	0.1	1.8	1.9	10.8	6.6	5.9	0.2	0.7	3.7	3.8	3.7	4.3	0.1	1.4	3.1	9.1	3.7	6.1
10/11-15/84	--	10	7	--	--	--	--	--	--	0.0	3.6	21.6	3.8	0.5	0.3	0.7	5.6	23.3	5.9	1.1	0.3	0.3	4.4	22.3	4.6	0.8	0.3
05/14-21/85	5	10	10	0.0	4.6	11.2	2.4	1.2	4.0	0.0	3.8	13.8	1.4	1.8	3.8	0.2	5.6	13.3	2.5	1.9	1.9	0.1	4.7	13.1	2.0	1.7	3.1
08/14-20/85	10	10	10	0.6	3.3	9.5	11.2	1.7	4.7	0.0	1.4	4.0	10.8	2.7	2.8	0.2	3.3	4.7	8.1	4.3	6.2	0.3	2.7	6.1	10.0	2.9	4.6
10/31-11/06/85	10	10	5	0.0	3.9	6.8	2.8	1.0	0.6	0.1	2.2	4.3	2.3	1.0	0.1	0.6	4.2	11.8	1.2	1.2	0.4	0.2	3.8	6.8	2.3	1.0	0.3
05/15-22/86	10	10	10	0.3	4.1	16.2	1.1	1.4	2.9	0.0	4.5	11.0	2.2	2.9	3.6	0.5	8.7	9.8	2.6	1.2	4.3	0.3	5.8	12.3	2.0	1.8	3.6
08/12-20/86	10	10	10	0.0	3.4	5.0	7.0	1.3	7.4	0.8	1.4	2.1	10.3	4.2	4.0	0.2	1.9	2.8	5.7	4.8	5.5	0.3	2.2	3.4	7.7	3.4	5.6
11/01-07/86	10	10	10	0.6	5.1	10.3	1.7	1.6	0.2	0.6	2.6	6.5	2.2	1.0	0.0	0.2	6.6	21.5	2.4	1.1	0.1	0.6	4.8	12.8	2.1	1.2	0.1 (1.2)[b] PW
05/13-20/87	10	10	10	0.7	5.6	9.6	4.6	3.3	6.9	0.2	6.5	8.8	6.6	2.9	10.9	0.2	6.8	7.8	3.9	4.6	8.1	0.4	6.3	8.7	4.4	3.6	8.6

[a] E - Emery area, M - Murray area, S - Sullivan area
[b] Pygmy whitefish

The relative abundance of cutthroat trout varied little from 1983 to 1987 (Table 20). There was no discernible trends with significant difference in catches occurring in four of 12 paired tests (Table 22). The catch of 1.9 fish per net in May. 1986 was significantly lower (P<.01) than the mean catches in 1985 and 1987. The euphotic zone depth in May, 1986 was much greater than in the other years. High water transparency reduces floating gill net catches because the nets are more visible and fish avoid them.

There was little difference in floating net catches recorded for the May sampling period among the three geographical areas of the reservoir (Table 23). However, catches of cutthroat trout in the fall sampling period were significantly higher in the Sullivan area than in the Emery and Murray areas. This higher concentration of cutthroat in the fall in the Sullivan appears to be the result of the Sullivan area having a much more extensive littoral zone than the other two areas. Terrestrial and aquatic insects are more available to the surface-oriented cutthroat in the shallow littoral zones than in the deeper off-shore waters. Cutthroat also occurred and fed mostly near the surface in littoral zones in British Columbia Lakes (Andrusak and Northcote 1971), and Flathead Lake (Leathe and Graham 1982). The dewatering of the littoral zone and subsequent reduction of benthic production and cutthroat habitat reduces the reservoir carrying capacity for cutthroat.

There appeared to be little relationship between westslope cutthroat trout densities in shoreline areas and substrate and cover types. Distribution of cutthroat in Lake Koocanusa was determined to a large degree by temperature and food availability (McMullin 1979). Neils and Magnuson (1974) found that percid fishes partitioned time between an environment with preferred temperature and an environment with food, but either warmer or cooler than preferred temperature. The fish made forays for food into water vith extreme temperatures, but feeding behavior did not override thermoregulatory behavior. This behavior pattern appears to be regulating the distribution of cutthroat trout and other fish species in HHR.

The length-frequency distribution of cutthroat caught in the spring and fall gill net samples are given in Figure 27. Cutthroat caught in the spring ranged in length from 165 to 505 mm as compared to 172 to 426 mm for the fall sample. The mean length of cutthroat collected in the spring series of 327 mm was greater than the mean length of 308 mm from the fall sample. The recruitment of juveniles from tributaries during the summer and spawning mortalities account for the differences in mean lengths betveen spring and fall samples. The sex ratio of mature cutthroat in net catches varied from 2.0 to 4.3 females per male.

The gill net catches consisted primarily of age IV and V fish which comprised 70 to 81 percent of the catch (Table 24). This age structure is not indicative of age composition of the population due to the size selectivity of the gillnets. Fish weren't fully recruited to the gill net catch until they were

Table 22. A comparison of gill net catches from Hungry Horse Reservoir from 1983 to 1987 using the Mann-Vhitney test. The westslope cutthroat trout catches vere recorded from floating gill nets vhereas the other species catches vere from sinking gill nets.

Species	The mean catch of fish in gillnets between years					
	84x85	84X86	84x87	85X&5	85X87	86X87
			May			
WCT	2.4:3.5	2.4:1.9	2.4:3.2	3.5:1.9*	3.5:3.2	1.9:3.2*
DV	5.3:4.7	5.3:5.8	5.3:6.3	4.7:5.8	4.7:6.3	5.8:6.3
MWF	6.4:13.1	6.4:12.3	6.4:8.7	l3.1:12.3	l3.1:8.7	12.3:8.7
			October-November			
	83X84	83X85	83X86	84X85	84X86	85X86
WCT	1.6:1.1	1.6:1.3	1.6:1.9	1.1:1.3	1.1:1.9*	1.3:1.9*
DV	2.0:4.4	2.0:3.8	2.0:4.8*	4.4:3.8	4.4:4.8	3.8:4.8
MWF	8.0:22.3	8.0:6.8	8.0:12.8	22.3:6.8	22.3:12.8	6.8:12.8
			August			
NSQ	8.3:9.1	8.3:10.0	8.3:7.7	9.1:10.0	9.1:7.7	l0.0:7.7
CSU	4.1:3.7	4.1:2.9	4.1:3.4	3.7:2.9	3.7:3.4	2.9:3.4
LNSU	7.8:6.1	7.8:4.6	7.8:5.6	6.1:4.6	6.1:5.6	4.6:5.6

* - significant difference at 0.01 probability level

Table 23. A comparison of gill net catches using the Mann-Vhitney test from the Emery area (1). Murray area (2). and Sullivan area (3) of Hungry Horse Reservoir, 1983 to 1987. The westslope cutthroat trout catches were recorded from floating gill nets, whereas the other species catches were from sinking gill nets.

Species	The mean catch in gill nets between areas					
	Area 1 x Area 2		Area 1 x Area 3		Area 2 x Area 3	
			May			
VCT	3.1	2.5	3.1	2.7	2.5	2.7
DV	5.0	5.2	5.0	6.5	5.2	6.5
MWF	11.8	10.8	11.8	9.6	10.8	9.6
			October-November			
VCT	1.4	0.9	1.4	2.3*	0.9	2.3*
DV	3.8	2.7	3.8	5.0	2.7	5.0*
MWF	8.0	10.2	8.0	17.8*	10.2	17.8*
			August			
NSQ	10.2	10.6	10.2	5.9	10.6	5.9*
CSU	2.1	4.1*	2.1	4.4*	4.1	4.4
LNSU	7.1	4.4	7.1	5.4	4.4	5.4

* - significant difference at 0.01 probability level

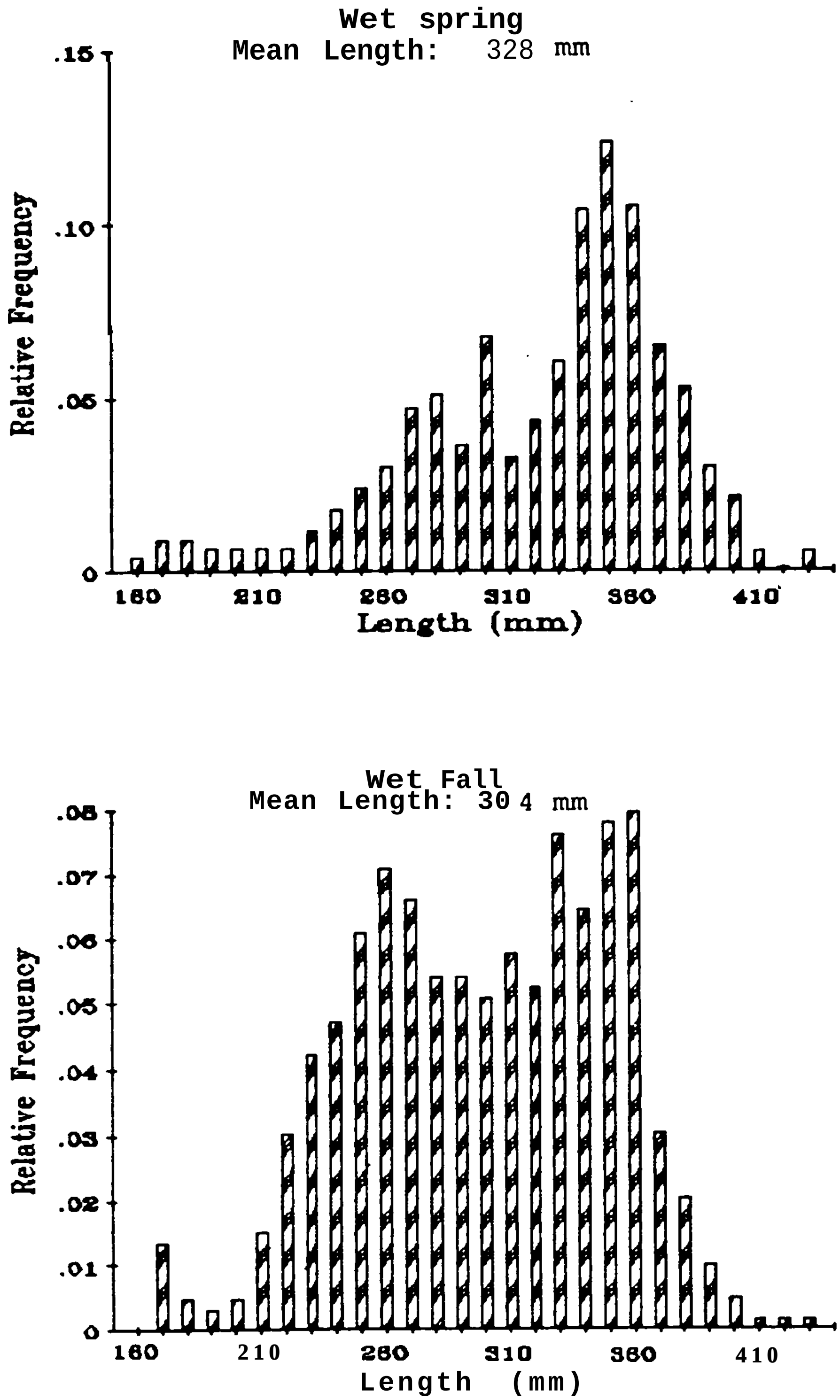


Figure 27. Length frequency diagrams of westslope cutthroat trout caught in spring and fall floating gill net sets in Hungry Horse Reservoir, 1983-87.

Table 24. Percent age and migration class composition of westslope cutthroat trout caught in gill nets set in Hungry Horse Reservoir, spring 1984 to 1987. The number aged is in parentheses.

Migration	Percent of Catch at age						
Class	II	III	IV	V	VI	VII	Total
				1984			
1	--	1.3 (2)	--	1.3 (2)	--	--	2.5 (4)
2	0.6 (1)	3.2 (5)	10.2 (16)	6.4 (10)	0.6 (1)	--	21.0 (33)
3	--	10.1 (16)	29.3 (46)	22.9 (36)	0.6 (1)	1.3 (2)	64.3 (101)
4	--	--	4.4 (7)	7.2 (11)	0.6 (1)	--	12.2 (19)
Combined	0.6 (1)	14.6 (23)	43.9 (69)	37.8 (59)	1.9 (3)	1.3 (2)	(157)
				1985			
1	--	--	--	0.6 (1)	--	--	0.6 (1)
2	--	5.1 (8)	7.7 (12)	7.1 (11)	1.3 (2)	--	21.2 (33)
3	--	1.3 (2)	17.9 (28)	40.4 (63)	10.3 (16)	1.3 (2)	71.2 (111)
4	--	--	--	3.8 (6)	2.5 (4)	0.6 (1)	7.0 (11)
Combined	--	6.4 (10)	25.6 (40)	51.9 (81)	14.1 (22)	2.0 (3)	(156)
				1986			
1	--	--	0.9 (1)	--	--	--	0.9 (1)
2	--	5.4 (6)	9.9 (ll)	8.1 (9)	0.9 (1)	--	24.3 (27)
3	--	--	18.0 (20)	46.8 (52)	5.4 (6)	--	70.3 (78)
4	--	--	--	1.8 (2)	2.7 (3)	--	4.5 (5)
Combined	--	5.4 (6)	28.8 (32)	56.6 (63)	9.2 (10)		(111)
				1987			
1	--	0.9 (1)	--	--	--	--	0.9 (1)
2	--	16.1 (17)	17.0 (18)	4.7 (5)	--	--	37.7 (40)
3	--	--	14.1 (15)	41.5 (44)	2.9 (3)	--	58.5 (62)
4	--	--	--	1.9 (2)	0.9 (1)	--	2.9 (3)
Combined	--	17.0 (18)	31.1 (33)	48.1 (51)	3.8 (4)	--	(106)
				Years Combined			
1	--	0.6 (3)	0.2 (1)	0.6 (3)	--	--	1.3 (7)
2	0.2 (1)	6.8 (36)	10.8 (57)	6.6 (35)	0.7 (4)	--	25.1 (133)
3	--	3.4 (18)	20.8 (109)	36.8 (195)	4.9 (26)	0.7 (4)	66.4 (352)
4	--	--	(7)	4.0 (21)	1.8 (9)	0.2 (1)	7.2 (38)
Combined	0.2 (1)	10.8 (57)	32.8 (174)	47.9 (254)	7.4 (39)	0.9 (5)	(530)

greater than 325 mm in total length. Thus, the younger age groups were not adequately represented in the gill net catches. Migration class two and three fish comprised a mean of 91.5 percent of the catch from 1984-87.

The monthly catch of westslope cutthroat trout and northern squawfish in floating gill nets indicated a considerable degree of temporal and spatial separation between the two species. Cutthroat trout catches were high in the spring from April through June and in the fall from late September through November. In contrast northern squawfish catches were highest during the summer period from late June to late September. This difference in seasonal catch between the two species was primarily a result of dissimilar temperature preferences. Cutthroat trout are a cold water species which prefer water temperatures between 10-16°C (Hickman and Raleigh 1982). Dvyer and Kramer (1975) noted that cutthroat trout scope of activity is highest at 15°C. When water temperatures in the upper part of the water column are above 17°C cutthroat trout move into deeper offshore waters. On the other hand, squawfish prefer warmer water temperatures, becoming more active and inhabiting the littoral zone when water temperatures are above 12-15°C. Squawfish become less active and move into deeper offshore waters in the fall and winter when water temperatures decline (Scott and Crossman, 1973). This habitat separation betveen the two species reduces potential competition for food and space and limits predation on juvenile cutthroat by northern squawfish. Indeed, analysis of squawfish stomachs indicated that juvenile cutthroat were eaten infrequently. Behnke (1979) noted that competition and/or predation by squawfish have not been responsible for the decline in abundance of westslope cutthroat trout. Habitat degradation and competition from nonnative trout have been the causative agents of the westslope decline.

Bull Trout

Bull trout catches in sinking nets varied monthly and seasonally in a pattern similar to cutthroat (Figure 28). The mean catches were highest in the spring, intermediate in the fall and lowest in the summer. The mean catches ranged from 4.7 to 6.3 fish per net in the May samples and from 2.0 to 4.8 fish per net in the fall collections. There was no discernible trend in abundance and no significant differences in mean catches except between the 1983 and 1986 mean catches recorded in the fall (Table 22). The water transparency in the fall of 1983 was considerably higher than in the other fall netting periods (Table 19). Overall catch rates were similar to those obtained in HHR in the early 1970's (Huston 1972. 1974 and 1975), but greater than those from Flathead Lake (Leathe and Graham 1982) and Libby Reservoir (Huston et al. 1984).

The mean catches in the Sullivan area were consistently higher than in the other two areas although a significant difference ($P<.01$) in catch occurred only between the Sullivan area and

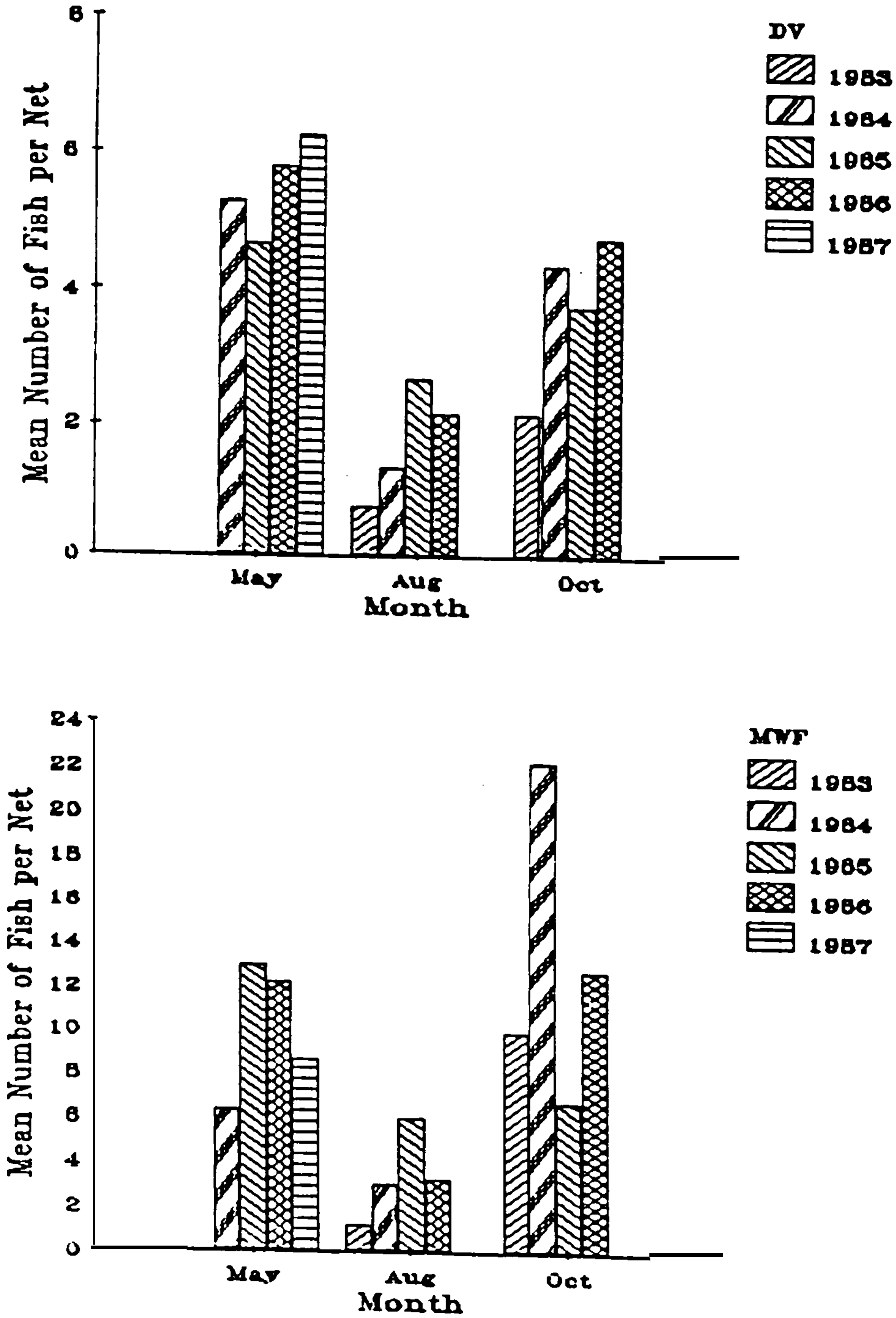


Figure 28. Seasonal catches of bull trout (DV) and mountain whitefish (MWF) in sinking gill net sets in Hungry Horse Reservoir, 1983-87.

Murray area in the fall collection (Table 23). Catches of mountain whitefish, an important food item of bull trout, were significantly higher (P<.01) in the Sullivan area than in the other two areas. The most important spawning and rearing tributaries for bull trout drain into the upper part of the reservoir and the South Fork River above the reservoir.

Bull trout caught during this study ranged in length from 170 to 910 mm with the largest fish weighing 7,249 grams (Figure 29). The mean length of fish caught in the spring netting series was 386 mm, identical to the mean length captured during the fall series.

Mountain Whitefish

Mountain whitefish have dominated the catch in sinking nets comprising between 27 to 41 percent of the annual catches (Table 20). The catch of whitefish varied seasonally. The catch was highest in the spring and fall ranging from 6.4 to 22.3 fish per net and lowest in the summer when 1.3 to 5.8 fish per net were caught (Figure 28). There were no significant differences in catches between the years either in the spring or fall series (Table 22). Mountain whitefish have similar temperature and depth preferences to bull trout which accounts for whitefish being an important item in the diet of bull trout.

The catch of mountain whitefish in the fall net series was significantly higher (P<.01) in the Sullivan area than in the other two areas. This difference in catch was probably related to pre-spawning movements by whitefish coupled with food availability.

The mean length of mountain whitefish in the spring net series was 279 mm versus 295 mm in the fall series (Figure 30).

Northern Squawfish

Northern squawfish catches were substantial in both sinking and floating gill nets, with the highest catches recorded in the summer (Figures 26 and 31). The summer catch in sinking nets averaged about 8.8 fish per net while the catch in floating nets was 2.7 fish per net. Spring and fall catches were much lower as squawfish became less active and more offshore when water temperatures were below l0-12°C. There were no significant differences in catch among the years (Table 22) indicating little fluctuation in abundance of the population during the study.

The catch of northern squawfish was greater in the Emery and Murray areas than in the Sullivan areas with differences between the Sullivan and Murray area being significant (P<.01) (Table 23). The apparent lover numbers of squawfish in the Sullivan area may be related to poor spawning habitat. Northern squawfish in lakes spawn over clean talus and gravel areas (Patten and Rodman 1969).

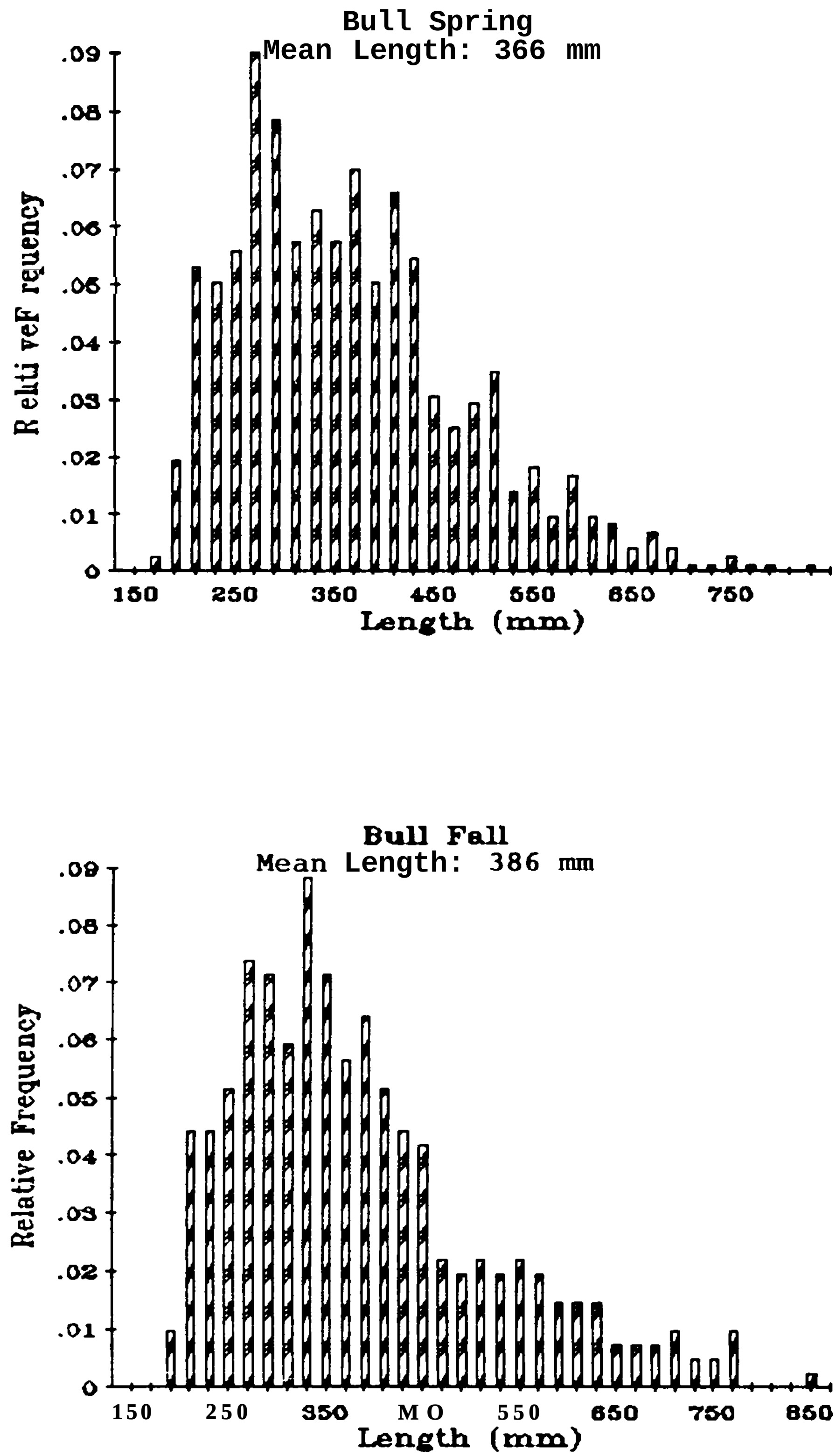
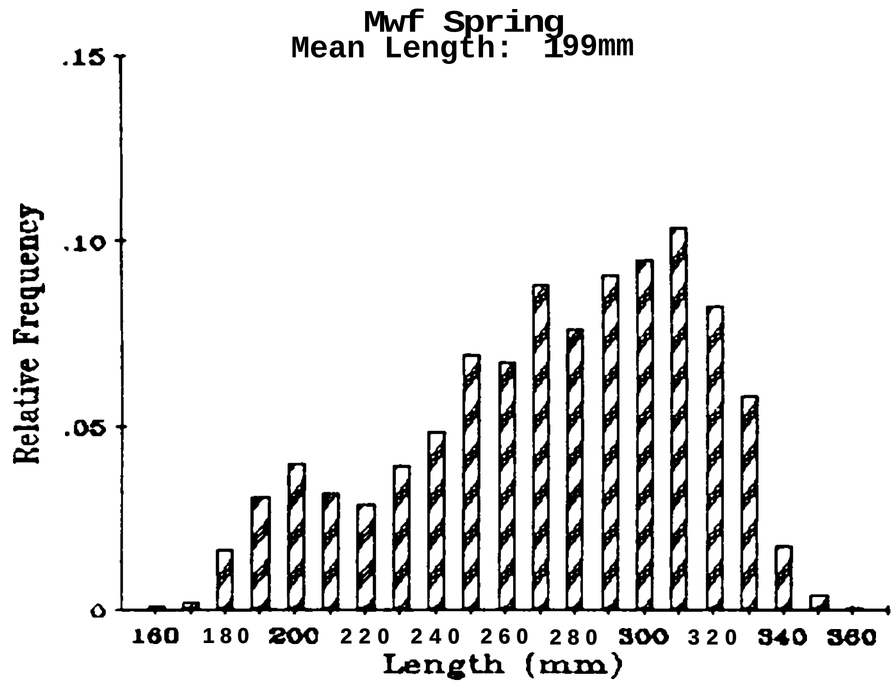


Figure 29. Length frequency diagrams of bull trout caught in spring and fall sinking gill net sets in Hungry Horse Reservoir 1983-87.



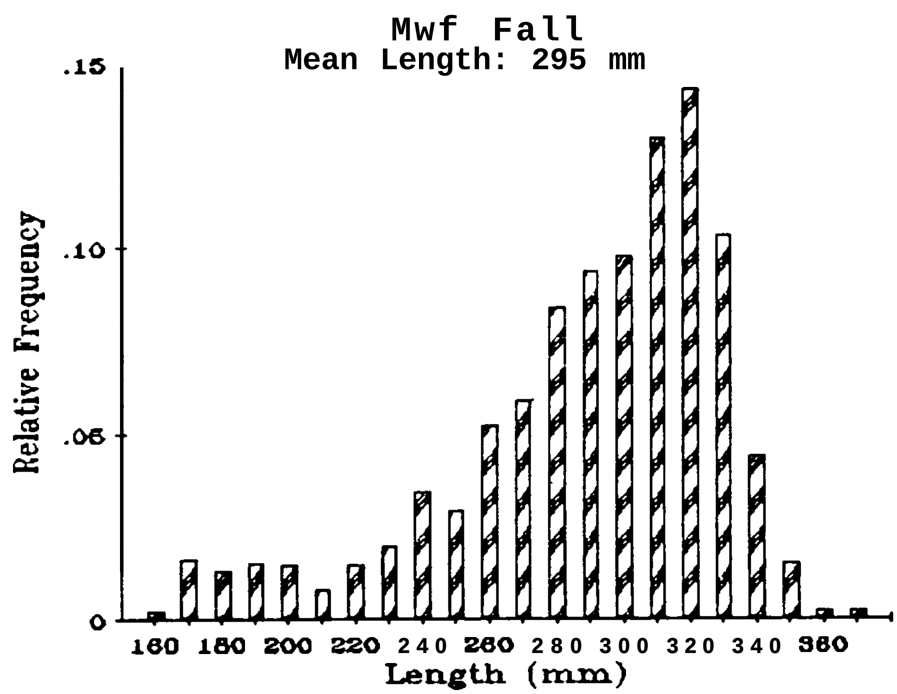


Figure 30. Length frequency diagrams of mountain whitefish caught in spring and fall sinking gill net sets in Hungry Horse Reservoir, 1983-87.

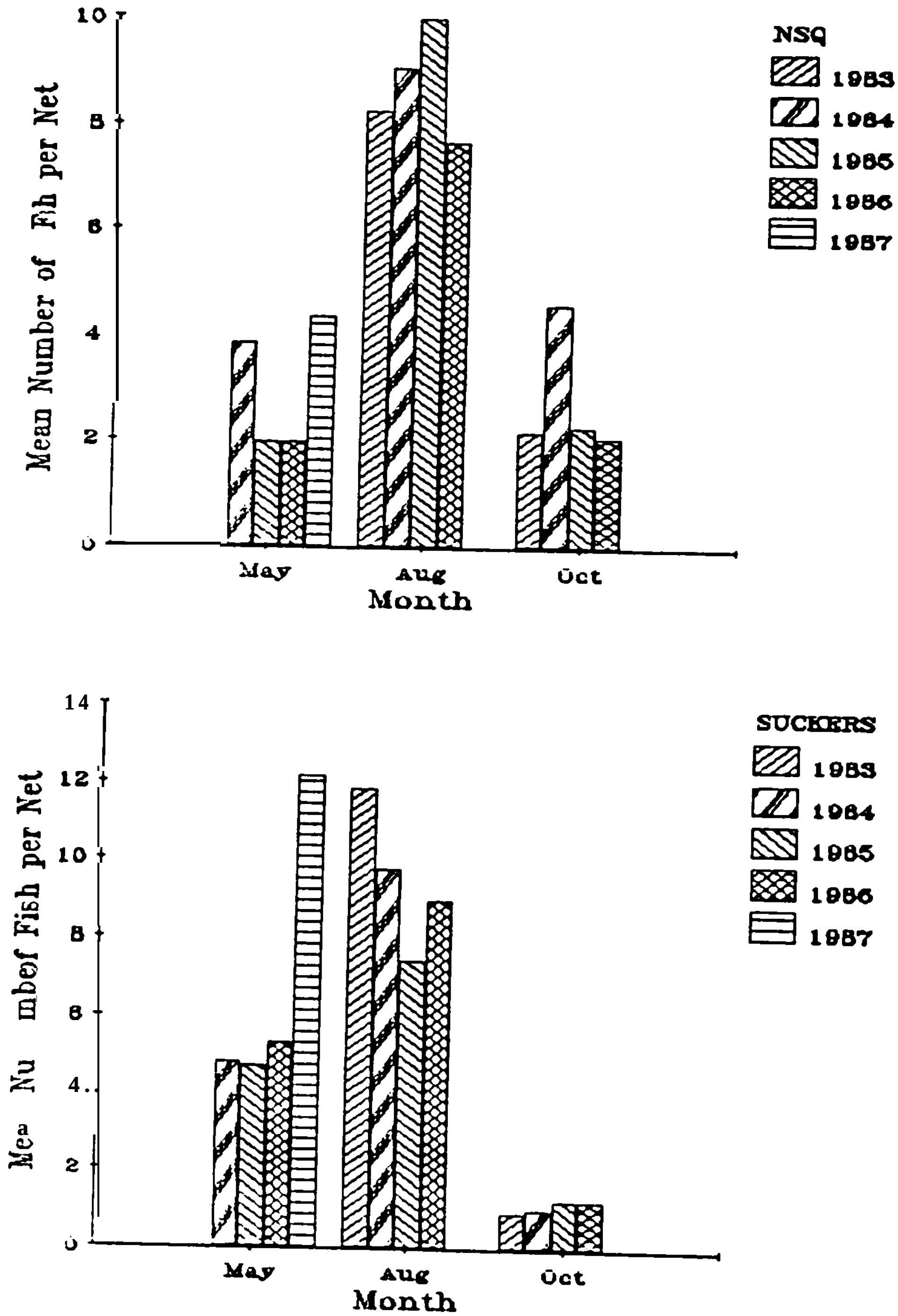


Figure 31. Seasonal catches of northern squawfish (NSQ) and suckers (longnose and largescale) in sinking gill net sets in Hungry Horse Reservoir, 1983-87.

Eggs are dermesal and adhesive, attaching themselves to the substrate. A thin layer of silt from the inflow of the South Fork covers most of the rubble and gravel in the Sullivan area, reducing their suitability as spawning habitat for squawfish.

Northern squawfish caught in gill nets ranged in length from 74 mm to 542 mm (Figure 32). The mean size of the catch was 227 mm.

Suckers

Suckers comprised an important part of the sinking gill net catch with catches generally highest in the summer, intermediate in the spring and lowest in the fall (Table 21 and Figure 31). Largescale sucker catches in the summer ranged from 2.9 to 4.1 fish per net as compared to 4.6 to 7.8 fish per net for longnose suckers. There was little differences in catch among the years for both species (Table 22). Largescale sucker catches were significantly higher ($P<.0l$) in the Sullivan and Murray areas than in the Emery area, whereas the longnose sucker catches were not significantly different among the areas (Table 23). Length-frequency distributions from the summer net series are shown in Figure 33.

FISH TRAPPING

Methods

A velocity barrier, upstream trap and Wolfe type downstream trap were installed in Hungry Horse Creek in the fall, 1983. Traps were operated May through September annually, 1984 through 1987. Traps were checked twice daily and all fish removed, anesthetized, measured and weighed. Adult spawners caught in the upstream trap were marked with a left pelvic punch and passed upstream. Spent adults caught in the dovnstream trap were inspected for marks and tagged with numbered anchor tags.

The total number of fish in the spawning run was estimated using the formulas taken from Vincent (1971):

$$N= \frac{(M+1)\quad(C+l)}{(R=l)} -1 \quad \text{where:}$$

N = Population estimate;
M = Number of fish marked (upstream trap catch):
C = Number of fish in catch sample (dovnstream trap catch); and
R = Number of marked fish in recapture sample (C).

$$\text{Variance} = \frac{N^2\ (C-R)}{(C+l)\quad(R+2)}$$

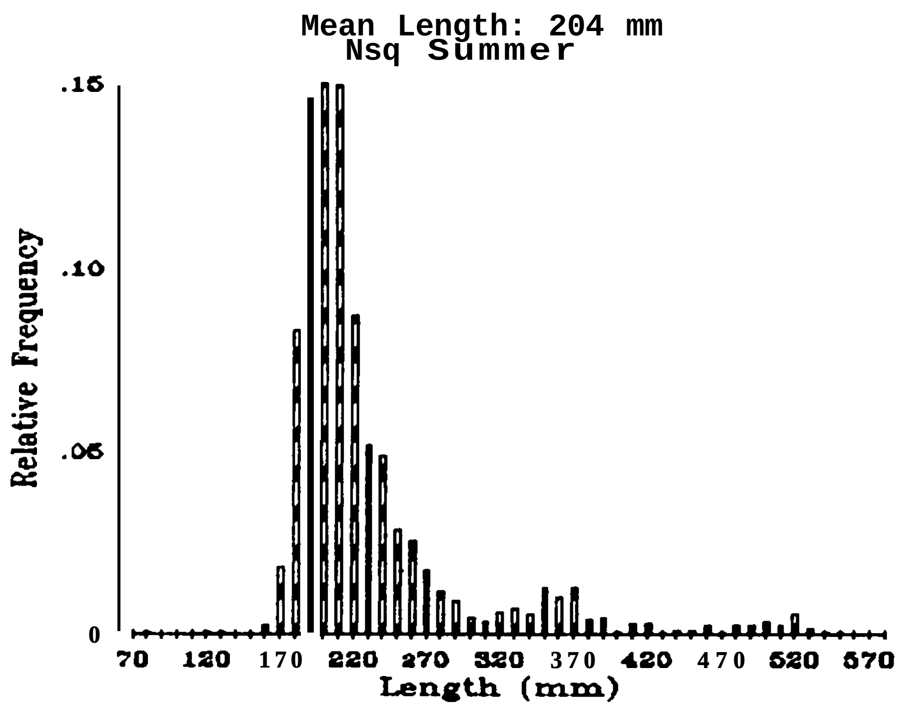
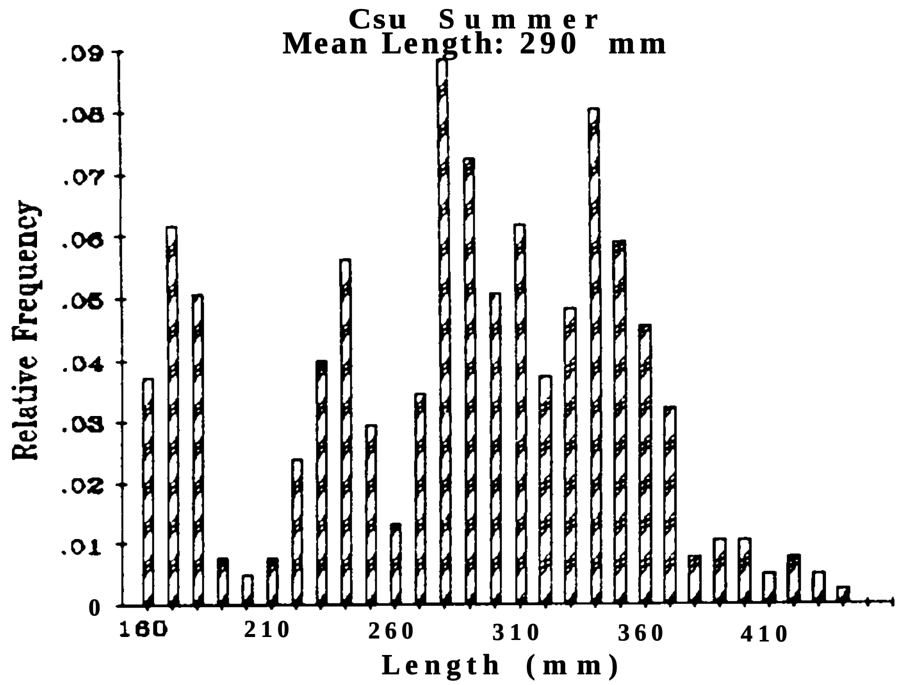


Figure 32. Length frequency diagram of northern squawfish caught in summer gill net sets in Hungry Horse Reservoir, 1983-87.



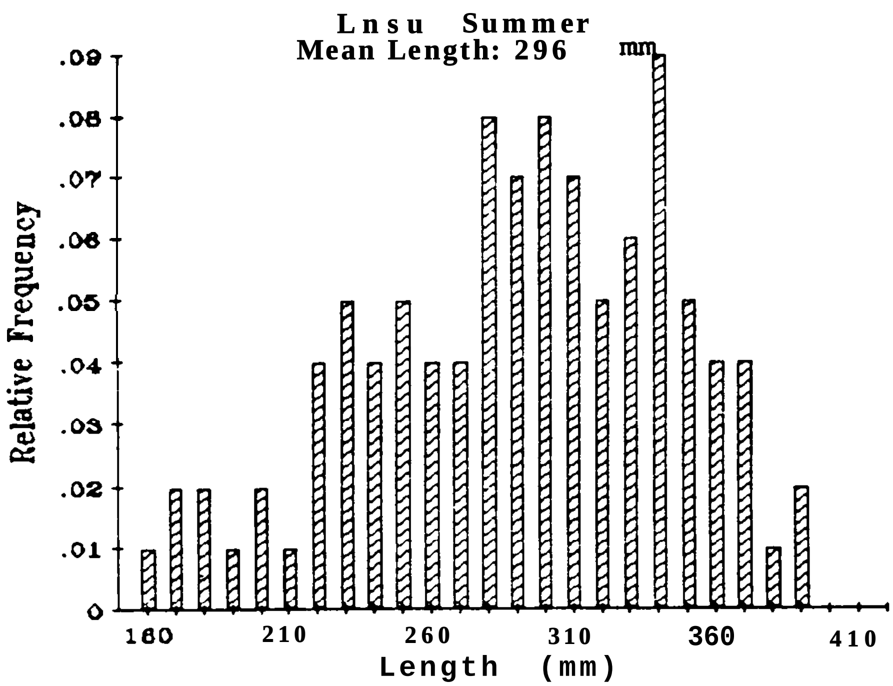


Figure 33. Length frequency diagrams of largescale and longnose suckers in summer sinking gill net sets in Hungry Horse Reservoir, 1983-87.

Juvenile emigrants caught in the downstream trap in 1984 and 1985 were tagged with numbered dangler tags. In 1986, the juveniles were not tagged and in 1987 the juveniles were marked using the cold brand technique. Fish <100 mm in length were brandedwvith |-- |; 100 to 160 mm, V; 160 to 250 mm, H; >250 mm, T. Trap efficiencies for juvenile cutthroat were determined in 1985 and 1987 by marking approximately 20 to 30 juveniles per two-veek period placing them above the trap and recording the number of recaptures in the downstream trap. This trap efficiency coefficient (number captured/number marked) was divided into the number caught per two-veek period to estimate total recruitment.

$$R = \sum_{i-l}^{N} \frac{VCTi}{EFi}$$

where: **EF** = efficiency coefficient per two-week period;
VCT = number of cutthroat juveniles caught per two-week period:
N = number of periods: and
R = number of juveniles recruited to the reservoir.

Results and Discussion

Spawning Runs

Vestslope cutthroat trout spawners usually ascend Hungry Horse Creek from approximately mid May to the first veek of July, with the peak of the run occurring the first two to three weeks in June. Spent spawners begin moving downstream in late June and by the end of July most fish have migrated dovnstream (May and Weaver 1986). In 1987, the first spawner was trapped on May 13 and the last on June 17. A total of 89 spawners were caught during the upstream run with 67 spent adults trapped as they moved downstream. The mean length of the spawners, 1987, was less than recorded in previous years, indicating a reduction in the number of older fish in the run. The length-frequency distribution of males was bimodal vith few fish in the 300 to 400 mm length interval (Figure 34). The estimated run in 1987 was only 111 fish which is much lower than the 322 spawners recorded in 1986 (Table 25). Initial trapping results from 1988 indicate that the spavning run rebounded to between 400 to 500 cutthroat.

The decline in the 1987 run was probably due to a combination of factors. The removal of juveniles in 1983 and 1984 to rehabilitate the Murray Springs Hatchery stock resulted in reduced recruitment to HHR. The loss of 1,150 juveniles in 1983 and 650 in 1984 should have caused a decline of approximately 100 adults to the 1987 run. In addition, the early drawdovn in 1985 may have adversely effected the survival of juveniles that fall. The reservoir was at full pool for only one week in 1985 and the elevation at the end of October vas 62 ft below full pool (Figure 5).

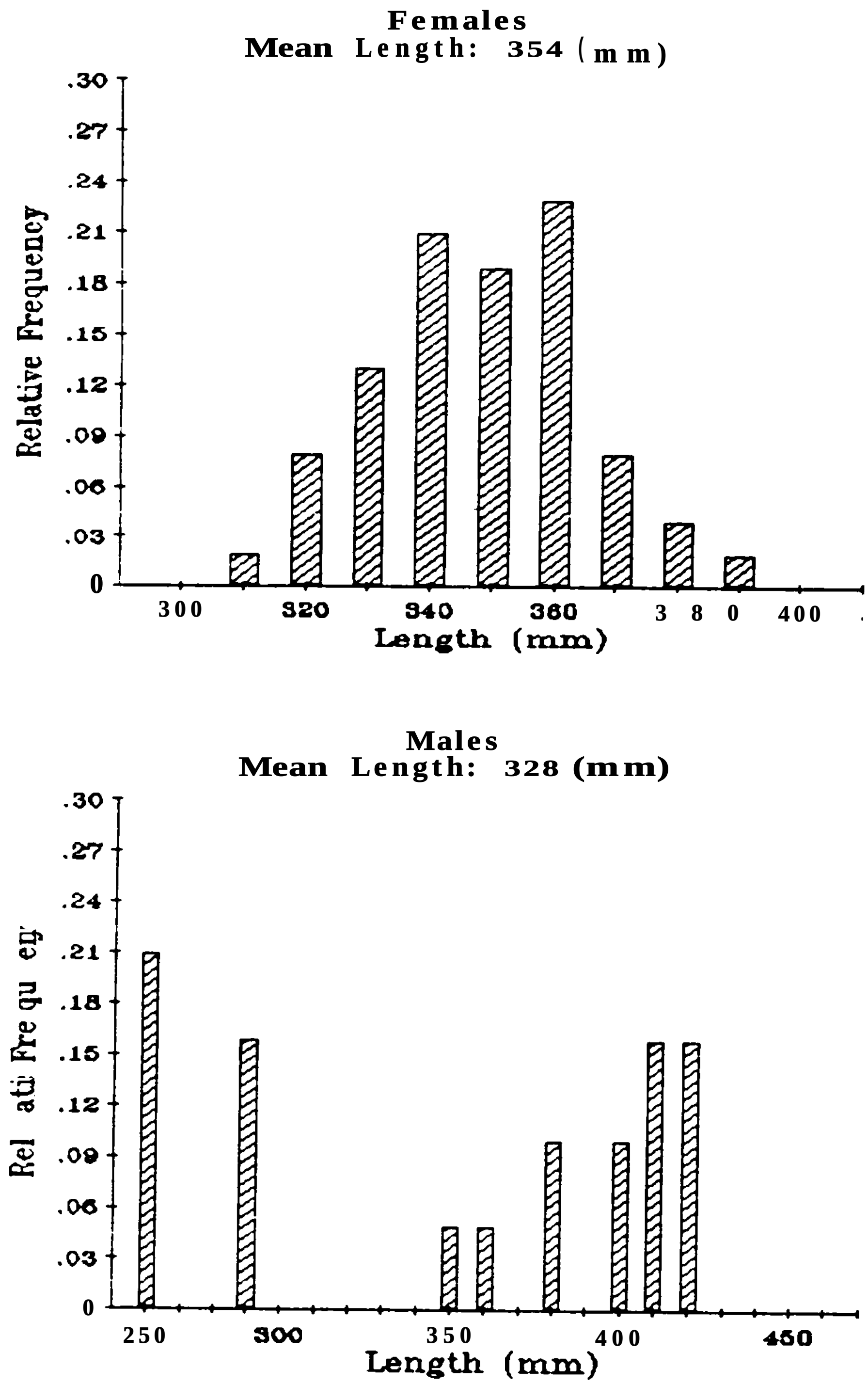


Figure 34. Length frequency diagrams of westslope cutthroat trout spawners from Hungry Horse Creek, 1987.

Table 25. Estimated number of spavners and outmigrant juvenile westslope cutthroat trout in Hungry Horse Creek, 1965 to 1987. The 95 percent confidence limits for the spavning run is given in parentheses as percent of the point estimate.

Year	Estimated Run		Mean Length (mm) Male	Female	Sex Ratio Male:Female	Number Outmigrant Total Caught	Juvenile Estimated
1965	1,200		368	366	1.0 :3.2	--	--
1966	1,200		371	373	1.0 :3.3	--	--
1967	--		368	363	1.0 :3.3	--	--
1968	1,160		373	368	1.0 :3.7	2,110	--
1969	1,050	(3.7)	368	371	1.0 :5.3	2,680	--
1970	1,001	(3.9)	358	361	1.0 :5.6	2,040	--
197l	702	(3.2)	350	350	1.0 :6.2	1,951	--
1972	590	(3.6)	371	358	1.0 :4.0	--	--
1984	388	(13.8)	375	370	-- :--	980	--
1985	370	(14.8)	374	374	1.0 :5.7	1,212	1,865
1986	322	(29.1)	370	369	1.0 :8.3	1,870	2,403
1987	111	(13.3)	326	354	1.0 :8.3	1,270	1,703

The late summer-fall drawdown appeared to reduce survival of juvenile cutthroat in HHR beginning in 1967. Prior to this time, the reservoir was held at full pool from July until approximately the first part of December. The cutthroat spawning runs from 1965 to 1968, which averaged 1,200 fish (Huston 1970) resulted from the conditions in the reservoir prior to 1967 when there was no fall drawdown (Figure 35). By 1972, the run had declined to 590 fish. The fall drawdown from 1967-70 appeared to reduce the survival of juveniles in their first year in the reservoir.

The spavning runs continued to decline from 590 fish in 1972 to 388 in 1984. The mean fall drawdown during this period was 24 ft. The mean maximum drawdown vas 73 ft vhich vas 17 ft less than prior to the 1966-1970 period. Thus, even though the maximum drawdown in the winter was less, the runs continued to decline from 1971-84. This indicates that the summer-fall drawdown may influence survival of cutthroat juveniles more than the maximum drawdown in the winter. Drawdown during the growing season dewaters the preferred littoral habitat of fish and reduces food availability and concentrates the fish thereby making them more susceptible to predation (Wegener and Williams 1975, Noble 1981, Plosky 1986).

The migration class composition of the run appears to be different in recent years than prior to 1967. The spawning runs from 1984 to 1987 vere comprised primarily of migration class III fish which made up 80.0 percent of the run followed by migration class four and migration class II fish (Table 26). In contrast, from 1964 to 1967, the spawning runs consisted of about 75 percent migration class II fish and 25 percent migration class three fish (Huston 1969). Some of this difference is probably due to different aging techniques. Prior to 1980, missing annuli were not identified, consequently, some fish would have been assigned an age at migration that was incorrect. Approximately 63 and 61 percent of the Hungry Horse Creek spawners and juveniles, respectiveiy, were assigned a missing annulus from 1984 to 1987.

There appeared to be higher mortalities of migration class I and II fish in the reservoir as compared to migration class III and IV fish. Migration class II fish comprised 37 percent of the recruits to the reservoir, yet only 9.6 percent of the spawning run (Table 27). On the other hand, migration class III and IV fish vhich made up 59 percent of the recruitment contributed 90 percent of the adults to the spawning runs. Drawdown may have influenced this selection process by increasing competition for food and space, and predation. Thereby providing a competitive edge to the older and larger fish which were better able to survive the intense competition caused by the shrinking reservoir habitat.

A decline in angier catch rates of cutthroat trout from 1961-1969 to 1985-1986 also indicated a declining reservoir population. From 1961 to 1969, the mean catch rate per hour of effort in

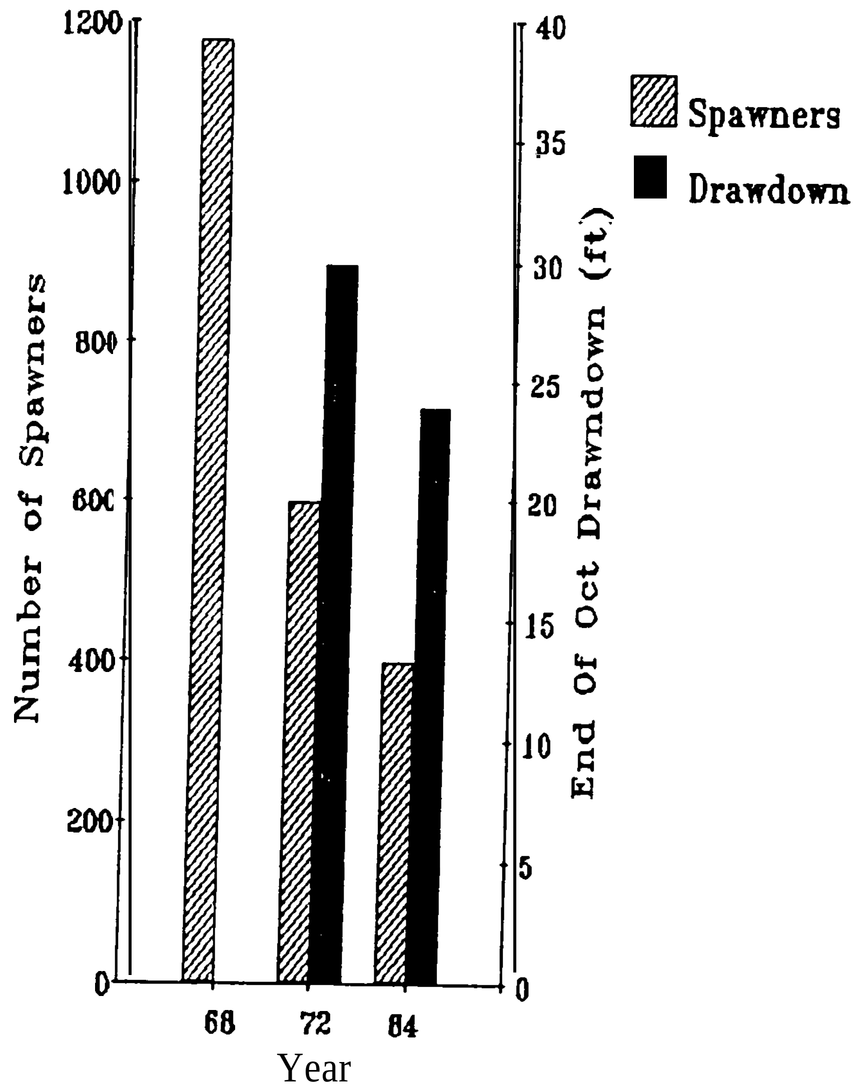


Figure 35. The spawning runs of westslope cutthroat trout in Hungry Horse Creek in relationship to fall drawdown patterns. The 1972 drawdown is the mean of the end of October elevations from 1967-70 and the 1984 elevation represents the mean 1971-1982 end of October elevations.

Table 26. Percent age and migration class composition of vestslope cutthroat trout spavning runs into Hungry Horse Creek, 1984 to 1987. The number aged is in parentheses.

Migration Class	Percent of run at age				
	IV	V	VI	VII	Total
			1984		
1	1.6 (1)	1.6 (1)	--	--	3.2 (2)
2	1.6 (1)	9.5 (6)	1.6 (1)	--	12.7 (8)
3	12.7 (8)	54.0 (34)	11.1 (7)	1.6 (1)	79.4 (50)
4	--	3.2 (2)	1.6 (1)	--	4.7 (3)
Combined	15.8 (10)	68.3 (43)	14.3 (9)	1.6 (1)	(63)
			1985		
1	--	--	--	--	--
2	--	8.0 (7)	2.3 (2)	--	10.3 (9)
3	6.9 (6)	23.0 (20)	41.4 (36)	2.3 (2)	73.6 (64)
4	--	5.7 (5)	8.0 (7)	2.3 (2)	16.1 (14)
Combined	6.9 (6)	36.8 (32)	51.7 (45)	4.6 (4)	(87)
			1986		
1	--	--	--	--	--
2	3.6 (2)	1.8 (1)	--	--	5.4 (3)
3	10.7 (6)	69.7 (39)	8.8 (5)	--	89.2 (50)
4	--	1.8 (1)	3.6 (2)	--	5.4 (3)
Combined	14.3 (8)	73.2 (41)	12.5 (7)	--	(56)
			1987		
1	--	--	--	--	--
2	4.5 (3)	3.0 (2)	1.5 (1)	--	9.1 (6)
3	16.7 (11	45.4 (30)	16.7 (11)	--	78.8 (52)
4	--	6.1 (4)	6.1 (4)	--	32.1 (8)
Combined	21.2 (14)	54.5 (36)	24.3 (16)	--	(66)
			Years Combined		
1	0.4 (1)	0.4 (1)	--	--	0.7 (2)
2	2.2 (6)	5.9 (16)	1.5 (4)	--	9.6 (26)
3	11.4 (31)	45.2 (123)	21.7 (59)	1.1 (3)	80.0 (216)
4	--	4.4 (12)	5.1 (14)	0.7 (2)	9.7 (28)
Combined	14.0 (38)	55.9 (152)	28.3 (77)	1.8 (5)	(272)

Table 27. Percent age composition of juvenile westslope cutthroat trout caught in Hungry Horse Creek downstream fish trap, 1984 to 1986.

Age	Year 1984	1985	1986	Combined
1	7.9	2.4	0.4	3.6
2	21.8	50.0	39.4	37.1
3	68.1	46.6	58.4	57.3
4	2.2	2.0	1.8	2.0

October and November was 0.67 cutthroat trout (Huston 1971) as compared to a mean of 0.31 cutthroat in October of 1985 and 1986 (May and Weaver 1987).

The sex ratio of the spawning runs has varied considerably through time (Table 25). Prior to 1968, the sex ratio averaged approximately 1.0 male to 3.3 females. The sex ratio in 1986 and 1987 of 1.0 male to 8.3 females was extremely skewed. In 1984 and 1985, the sex ratio of mature cutthroat trout caught in gill nets was 1.0 male to 2.1 females while the 1987 sex ratio was 1.0 male to 3.4 females. The sex ratio of the spawning run in 1988 of about 1.0 male to 2.5 females was comparable to that recorded in the gill nets.

Juvenile Emigration

Downstream movement of juveniles from Hungry Horse Creek usually begins in mid June and continues through July (May and Weaver 1987). A few fish continue to emigrate in the summer and fall. In 1987, approximately 99 percent of the outmigration occurred in June and July. The total number of juveniles trapped was 1,270, and the estimated number of emigrants was 1,703 (Table 25). The juveniles ranged in size from 60 to 220 mm with the larger fish emigrating in June (Figure 36).

The number of juveniles caught in the downstream trap has indicated a general declining trend through the time. From 1968 to 1971, the number of outmigrants trapped averaged 2,195 fish as compared to a mean of 1,333 juveniles caught from 1984 to 1987. This apparent decline in recruits is probably due to a combination of factors including habitat degradation from logging and road building in the watershed, and different trap efficiency.

The age composition of emigrating juvenile westslope cutthroat trout varied among the years but was dominated by age two and three fish (Table 27). As noted previously, the age structure was altered in the reservoir with fish migration class three and four fish appearing to have better survival rates than the younger fish.

EGG INCUBATION

Methods

For the second consecutive year, substrate samples were collected in known adfluvial westslope cutthroat trout spawning areas in the Hungry Horse Creek drainage, documenting trends in sediment deposition and fry production potential. Stream sections where high redd densities were observed during 1986 cutthroat trout spawning site inventories were sampled using a standard hollow core sampler (McNeil and Ahnell 1964) and procedures outlined by Shepard and Graham (1982). Tvelve core samples were collected from each sampling area again this year.

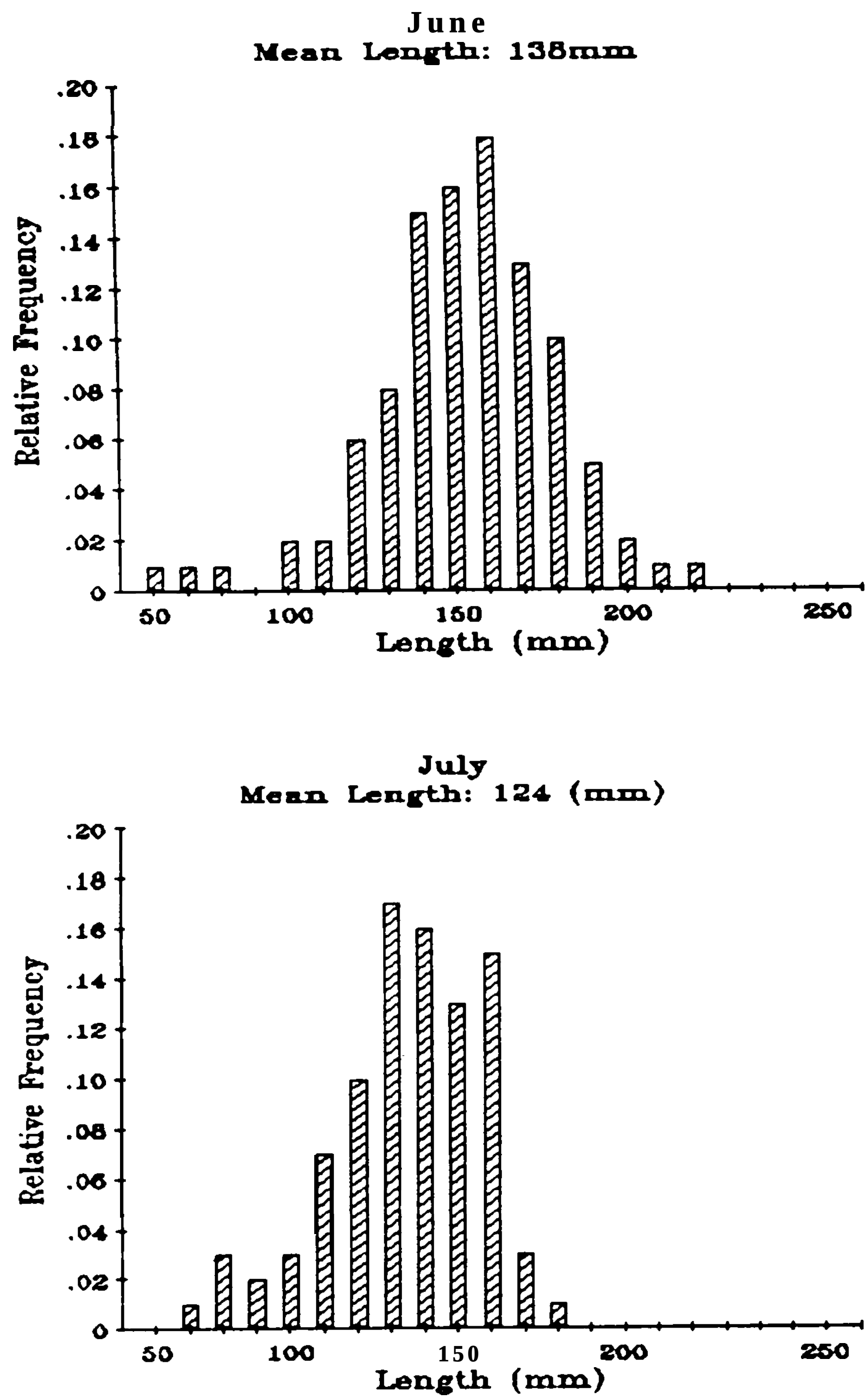


Figure 36. Length frequency diagrams of westslope cutthroat trout juveniles caught in the downstream trap in Hungry Horse Creek, 1987.

Two areas were sampled in Hungry Horse Creek. The downstream area (loeer Hungry Horse) was just above the mouth of Margaret Creek at stream kilometer 2.1. The upstream area (upper Hungry Horse) was above the mouth of Lost Mare Creek at stream kilometer 4.8. The sampling area in Margaret Creek was below the old crossing at stream kilometer 1.6 and Tiger Creek was sampled just above the east side road crossing at stream kilometer 0.3.

Natural adfluvial westslope cutthroat trout redds were present in sampling areas and were actually sampled to compare sites "worked" by fish with undisturbed gravel. Although unquantified, an increase in embryo mortality probably occurs from the mechanical disturbance of core sampling in redds during the incubation period. In light of decreasing estimates of spawner escapement and this potential for increased mortality, we reduced sampling effort in natural redds. Only four natural redds were core sampled this year.

Samples were placed in labeled bags and transported to the Flathead National Forest Soils Lab in Kalispell for drying and sieve analysis. After drying, each core sample was passed through the following sieve series:

76.10 mm	(3.00 inch)
50.80 mm	(2.00 inch)
25.40 mm	(1.00 inch)
18.80 mm	(0.74 inch)
12.70 mm	(0.50 inch)
9.52 mm	(0.38 inch)
6.35 mm	(0.25 inch)
4.76 mm	(0.19 inch)
2.36 mm	(0.09 inch)
1.70 mm	(0.07 inch)
0.85 mm	(0.03 inch)
0.42 mm	(0.016 inch)
0.063 mm	(0.002 inch)
Pan	(<0.002 inch)

All material retained on each sieve was weighed and the percent dry weight in each size class was calculated. Fine material suspended in the water inside the corer was sampled using a 1.0-l Imhoff settling cone following procedures described by Shepard and Graham (1982). This amount was added to the material passing through the smallest sieve into the pan to obtain the total amount smaller than 0.063 mm.

Westslope cutthroat trout spawning gravel quality in the Hungry Horse Creek drainage was assessed using the technique developed by Tappel (1981) and later reported by Tappel and Bjornn (1983). By plotting the 1986 substrate data on log-probability paper, we found particle size distributions appearing close to lognormal. An average coefficient of determination (r^2) close to 1.0 was obtained, indicating that selection of any two points corresponding to sieve sizes allowed description of the entire range of spawning gravel (May and Weaver 1987). We selected the percentage of material smaller than 1.70 and 6.35 mm as the points used because this is the size range of material typically generated from land management activities and these sizes are prevalent in the literature.

Gravel composition was expressed as cumulative percentages smaller than each sieve size. Mean percentages smaller than 1.70 and 6.35 mm in each spawning area were compared with information from 1986. Further analyses of changes in spawning and gravel quality were completed using a two-tailed Mann-Whitney test comparing annual median percentages smaller than 1.70 and 6.35 mm during the 1986 and 1987 samplings.

Cutthroat embryo survival to emergence was predicted using the following laboratory-developed relationship reported by Irving and Bjornn (1984):

$$\text{PercentSurvival} = 106.10029 - 0.4460803(S_{6.35}) - 7.7660173(S_{1.70}) + 0.1694598(S_{1.70})^2$$

where : $(S_{6.35})$ = percent smaller than 6.35 mm;
$(S_{1.70})$ = percent smaller than 1.70 mm;
$(S_{1.70})^2$ = percent smaller than 1.70 mm squared: and

Results of the 12 predictions from each spawning area were averaged, obtaining the mean predicted survival to emergence for each area.

Since relationships developed during laboratory studies often do not adequately simulate conditions in the field, we constructed and planted five artificial redds in lower Hungry Horse Creek. Redd construction and egg handling procedures outlined by Weaver and White (1985) were used. Twenty-two bags each containing 50 eggs were planted on June 10, 1987. Approximately 1,300 eggs were incubated in a hatchery tray to provide control data on fertilization success and development.

Our intent was to excavate half the egg bags during the developmental period and to place emergence traps on the remaining bags quantifying emergence success. Hovever, stream flows dropped rapidly to extremely low levels and four of the five artificial redds dewatered by July 6. 1987. Emergence traps (Weaver and White 1985) were placed over the remaining egg bags on July 27. when emergence ended, the traps were removed and egg bags were excavated along with a hollow core sample from the exact location of each bag. These samples were sieve analyzed as previously described and the percentages smaller than 1.70 and 6.35 mm observed were used to predict survival to emergence.

Fry emergence success was expressed as the mean percentage of viable embryos which successfully emerged. The number viable was considered equal to survival to hatch among the control eggs in the hatchery. After this adjustment was made, observed fry emergence success was compared to emergence predicted using the laboratory relationship reported earlier.

Successful incubation of salmonid embryos requires gravels that are relatively free of fine material. Researchers have reported negative relationships between fine sediment and incubation success of many salmonid species including cutthroat trout. Results of these studies have recently been summarized by Chapman and McLeod (1987).

High levels of fine sediment impact embryo survival in several ways. Decreased gravel permeability cuts down water exchange around incubating embryos, resulting in reduced oxygen delivery to and metabolic waste removal from the incubation environment. Entombment of fry attempting emergence occurs when high levels of fine sediment fill interstitial spaces in gravels. Clogging of these interstices creates a physical barrier to emergence. Cooper (1965) suggested that embryos may be crushed when the weight of overlaying material is transferred directly to alevins by high levels of fine material. Mortality during incubation may also result from abrasion of developing embryos by fine sediments (Phillips 1971). These reductions in incubation success result in loss of recruitment and decreased production.

Results and Discussion

The mean cumulative percentage of material smaller than 1.70 and 6.35 mm increased in all four sampling areas between 1986 and 1987 samplings (Table 28). The change was similar for material in both size classes and represented an increase of approximately 20 percent at the two Hungry Horse Creek sites and in Margaret Creek, while the Tiger Creek site showed an increase in fine material of approximately 30 percent. The overall range of material smaller than 1.70 mm was from 4.6 to 22.7 percent during 1986 and from 4.6 to 23.8 percent in 1987. Material smaller than 6.35 mm ranged from 17.2 to 44.2 percent during 1986 and from 23.9 to 54.5 percent in 1987 (Table 28). Reiser and Bjornn (1979) reported salmonid embryo survival drops sharply when spawning gravel is comprised of more than 20 to 25 percent material smaller than 6.35 mm. During 1986 and 1987, approximately 56 and 93 percent of the undisturbed sites sampled exceeded 25 percent smaller than 6.35 mm respectively.

Results of the Mann-Whitney tests indicated the increase in material smaller than 1.70 mm in Margaret Creek was not significant ($P<.1$) at the .l0 level while material smaller than 6.35 mm did increase significantly at this level between 1986 and 1987 (Table 29). Conversely, the median percentage smaller than 1.70 mm increased significantly ($P<.1$) in the upper Hungry Horse Creek spawning area while the increase in the less than 6.35 mm size class was not significant at this site. Median percentages smaller than both 1.70 and 6.35 mm increased significantly at the .l0 level in the lower Hungry Horse Creek spawning area and the increase observed in both size classes was significant at the .05 level in the Tiger Creek spawning are (Table 29). All observed increases resulted from unidentified sources and it is possible

Table 28. Summary of annual mean cumulative percentages of substrate material smaller than 1.70 and 6.35 mm in diameter and mean predicted embryo survival to emergence from core sampling of undisturbed gravel in known westslope cutthroat trout spavning areas during the springs of 1986 and 1987.

Spawning area	Year	n	$\bar{x}$ % <1.70 mm (range)	$\bar{x}$ % <6.35 mm (range)	$\bar{x}$ Predicted Survival (%) (range)
Hungry Horse Cr.					
Lower	1986	8	10 (5.0-16.1)	27 (17.2-44.2)	35 (5-64)
	1987	11	13 (7.5-18.3)	34 (23.9-40.2)	19 (4-42)
Upper	1986	8	12 (7.8-19.0)	30 (22.4-38.8)	28 (0-57)
	1987	12	15 (7.8-19.7)	36 (26.2-47.6)	15 (0-43)
Margaret Cr.	1986	9	8 (4.6-11.2)	28 (21.1-34.4)	41 (23-60)
	1987	9	10 (6.8-13.9)	34 (27.8-41.2)	31 (9-48)
Tiger Creek	1986	9	10 (4.9-22.7)	25 (18.6-38.0)	34 (0-63)
	1987	12	14 (4.6-23.8)	38 (24.2-54.5)	19 (0-63)

Table 29. Results of Mann-Whitney tests for annual changes in median percentages of substrate material smaller than 1.70 and 6.35 mm from core sampling of undisturbed gravel in known westslope cutthroat trout spawning areas in the Hungry Horse Creek drainage between the springs of 1986 and 1987.

Spavning Area	<1.70 mm	<6.35 mm
Hungry Horse Creek		
Lower	* ↑	* ↑
Upper	* ↑	N.S.
Margaret Creek	N.S.	* ↑
Tiger Creek	** ↑	** ↑

N.S. - not significant
* - significant at the .l0 level
** - significant at the .05 level
↑ - increase
↓ - decrease

that extremely low spring flows during the last tvo years may have resulted in less flushing action and increased retention of fine materials.

The decreases in mean predicted survival for all spawning areas reflected the higher level of fine materials present during the 1987 sampling (Table 28). Similar declines of approximately 45 percent were observed in both the Hungry Horse Creek spawning areas and the Tiger Creek spawning area while mean predicted survival in Margaret Creek declined 25 percent during this period. Average predicted survival during 1987 was lowest for upper Hungry Horse Creek and highest for Margaret Creek, the identical pattern observed during 1986. Currently, in both the Hungry Horse Creek spawning areas and the Tiger Creek spawning area, average embryo survival to emergence predictions were less than 20 percent. Predicted survival for Margaret Creek during 1987 averaged approximately 30 percent (Table 28). In a laboratory study, Irving and Bjornn (1984) reported mean adjusted cutthroat embryo survival to emergence of from 95 percent where no material smaller than 6.35 mm was present down to less than five percent when more than 30 percent of the gravel was smaller than 6.35 mm.

Comparison of core samples collected from the tailspills of natural westslope cutthroat trout redds during 1986 and 1987 with samples from undisturbed streambed gravel surrounding redds showed no significant difference in the percentage of material smaller than 1.70 or 6.35 mm (Table 30). Average survival predictions were also quite similar. This suggests that a sampling scheme based on coring undisturbed gravel may be adequate for assessing spawning gravel quality. Hovever, natural redds should be sampled occasionally to confirm this. Sac fry were observed in cores collected in 10 of the 18 natural redds sampled during the past tvo years (56 percent). Average predicted survival to emergence for these 10 samples vas 30 percent.

In natural stream channels, factors other than fine sediment play important roles in embryo survival (Reiser and Bjornn 1979, Sovden and Pover 1985, Chapman and McLeod 1987). Natural variability in dissolved oxygen content, permeability or apparent velocity and temperature of upwelling groundwater has not been adequately simulated in laboratory experiments like the one in which the predictive equiation we used was developed. Consequently, we attempted to verify the relationship with an insitu experiment in Hungry Horse Creek.

Survival to hatch among the control eggs maintained in the hatchery vas 57 percent. After applying the adjustment factor of 0.57 to the four egg bags which remained wetted, a total of 114 emergent fry were possible. Mean adjusted survival to emergence observed from this artificial redd was approximately 14 percent and ranged from 0 to 32 percent. Although this figure is similar to the mean predicted survival value for lower Hungry Horse Creek during 1987 (19 percent), extreme effects of low flow conditions may have influenced the survival to emergence in our test.

Table 30. Comparison of mean cumulative percentages of material smaller than 1.70 and 6.35 mm and average predicted survival to emergence for core samples collected from natural vestslope cutthroat trout redds and from undisturbed gravel surrounding redds in the Hungry Horse Creek drainage during 1986 and 1987.

Class	n	$\bar{x}$ I <1.70 mm (range)	$\bar{x}$ % <6.35 mm (range)	$\bar{x}$ predicted survival (%) (range)
Natural Redds	18	11.8 (6.0-18.0)	30.4 (10.6-49.7)	27.0 (0.0-60.9)
Undisturbed	78	11.9 (4.6-23.8)	32.0 (17.2-54.5)	26.2 (0.0-63.2)

RECRUITMENT

Methods

Estimating the annual recruitment of westslope cutthroat trout to HHR was a difficult task, because of the number of tributary streams and the complex life cycles of the cutthroat. Although adfluvial juveniles live primarily in stream sections of less than six percent gradient, some resident juveniles are sympatric with them.

Spawning of adfluvial cutthroat from HER has been documented in many drainages to the reservoir and in the South Fork Flathead River upstream to Bunker Creek. Adfluvial cutthroat tagged in HHR have not been caught above Bunker Creek, nor have cutthroat tagged above Bunker Creek in the South Fork been caught downstream in HHR. Consequently, there is insufficient data to determine the magnitude of the spawning from HHR into the South Fork Flathead River above Bunker Creek and subsequent recruitment of juveniles. Because of these problems, we have estimated recruitment to HHR only from stream sections below Bunker Creek vith gradients of less than six percent.

We estimated standing crops of juvenile cutthroat by using methodology developed by Zubik and Fraley (1987). This method categorizes the stream habitat by stream order and gradient and then utilizes the mean population estimates from sections with similar habitat characteristic6 in the Flathead drainage to estimate standing crops of juveniles (Table 31).

Results and Discussion

Using these criteria, we estimated the standing crop of adfluvial juveniles >75 mm in length in HHR tributaries to be 43,125, and in tributaries to the South Fork from HHR to Bunker Creek to be 38,821 for a total of 81,946 fish (Table 32).

The annual recruitment to the reservoir is the percent of the standing crop of juveniles which emigrates from the tributaries each year. Based on data from Young Creek, a tributary to Lake Koocanusa (Huston et al. 1984) and the current Hungry Horse study, it appears that approximately 25 to 30 percent of the adfluvial juveniles emigrate from the tributary streams each year. Applying the higher value to the standing crop figure, we calculated an annual recruitment of approximately 24,600 cutthroat juveniles to HHR. This figure is a minimum estimate because if does not include streams above Bunker Creek.

Table 31. Estimated number of cutthroat trout juveniles by stream order and gradient categories (for gradients less than six percent) in tributary reaches to the South, Middle and North forks of the Flathead River (from Zubik and Fraley 1987).

Stream Order	Gradient6 (%)	Number Reaches	Mean Number/ 100 m
2	0.4 - 1.8	1	22.7
2	2.2 - 2.6	4	56.9
2	2.8 - 3.8	7	77.6
2	3.9 - 5.9	32	31.6
3	0.7 - 1.0	2	22.3
3	1.1 - 1.4	2	38.9
3	1.7 - 2.2	8	62.9
3	2.6 - 4.0	20	25.4
3	4.1 - 5.9	20	43.4
4	0.3 - 0.6	8	5.2
4	1.1 - 1.3	5	24.0
4	1.7 - 4.8	13	13.5
5	0.6 - 0.8	3	14.3
TOTAL		125	

Table 32. Estimated number of cutthroat trout juveniles >75 mm in tributaries to Hungry Horse Reservoir and South Fork of the Flathead River upstream from the reservoir to Bunker Creek.

Stream	Stream Order	Reach	Gradient Percent Slope	Length (meters)	Number WCT >75 mm
			Tributaries to Hungry Horse Reservoir		
Emery	3	1	2.0	10,000	6,290
Emery	2	1	5.8	261	82
Emery Loop	2	1	2.2	1.624	924
Emery Loop	2	1	5.9	1,501	474
Emery Loop	2	2	2.2	684	389
Strife	2	1	5.4	424	134
Hungry Horse	3	1	1.7	6,264	3,940
Hungry Horse	3	1	4.4	415	180
Hungry Horse	2	2	4.5	2,150	679
Margaret	2	1	4.1	2,700	853
Lost Mare	2	1	5.7	1.199	379
Tiger	2	1	3.5	2,882	2,231
Tent	3	1	3.2	7l7	182
Dudley	2	1	4.3	2,659	840
Riverside	3	1	5.9	1.237	537
McInernie	2	1	4.6	1,864	589
Logan	2	1	4.8	2,499	790
S.F. Logan	2	1	6.3	2,900	916
Baptiste	2	1	5.4	1,399	442
Peters	2	2	3.9	620	196
Doris	3	1	3.5	2,100	533
Doris	3	2	5.8	340	148
Lost Johnny	3	1	4.1	1,000	434
Wounded Buck	4	1	2.1	4,789	636
Wounded Buck	3	2	3.9	2,512	1,090
Quintonkon	3	1	3.3	5,200	1,321
Clark	2	1	3.9	2.500	790
Sullivan	4	1	1.2	10,800	2,592
Sullivan	3	2	2.2	8,346	5,250
Slide	2	1	5.5	2,100	664
Connor	3	1	3.3	4,800	1,219
Connor	2	1	5.5	4,721	1,492
Branch	3	1	5.3	1,542	669
Branch	2	2	3.6	2,261	1,745
Wheeler	3	1	2.8	1,700	432
Wheeler	3	2	2.6	8,300	2,108
Forest	2	1	6.7	2,200	955
				106,930	43,125

Table 32. Continued.

Stream	Stream Order	Reach	Gradient Percent Slope	Length (meters)	Number WCT >75 mm
			Tributaries to South Fork Downstream from Bunker Creek		
Soldier	2	1	6.4	6,539	2,066
Lower Twin	3	1	2.2	6,736	4,237
Twin	4	1	1.3	6,807	1,634
Tin	3	1	4.0	1,494	379
Spotted Bear River	5	1	0.8	29,485	4,216
Spotted Bear River	4	2	2.0	3,503	473
Bent	2	1	4.0	1,542	487
Bent	2	2	4.8	3,849	1,216
Bent	2	3	2.9	2,083	1,616
Sergeant	3	1	4.4	4,704	2,042
Sergeant	2	1	4.4	1,353	428
Sergeant	2	2	4.0	686	217
Milk	2	1	5.0	245	77
Silvertip	3	1	4.8	1,814	787
Dean	4	1	4.8	3,893	526
Dean	3	2	3.0	3,206	814
Dean	2	3	2.3	5,749	4,086
Addition	4	1	4.2	2,639	356
Harrison	4	1	3.8	5,486	741
Harrison	3	2	5.9	1,897	823
Corporal	2	1	3.8	2,189	1,699
Bunker	5	1	0.6	8,170	1,168
Bunker	4	2	4.6	529	71
Gorge	4	1	2.1	5,656	764
Gorge	3	1	2.1	893	562
Gorge	3	2	1.3	7,357	2,862
Gorge	2	4	1.5	877	199
Stadium	4	1	3.4	4,433	598
Stadium	3	2	5.8	1,844	800
Cannon	3	1	5.0	6,630	2,877
				132,288	38,821

SURVIVAL

Methods

Model 1 from Brownie et al. (1985) was used to estimate annual fishing mortality and survival rates of westslope cutthroat trout greater than 250 mm in total length in Hungry Horse Reservoir. The model uses the number of individuals tagged each year and subsequent tag returns by anglers each succeeding year to estimate harvest and survival rates. It is assumed that rate parameters are age independent and that survival, fishing and reporting rates are year-specific but independent of the year of banding.

Two estimates of exploitation and survival were made. One estimate assumed no tag loss and that all tags were returned by anglers. The other estimate assumed 10 percent tag loss and a 70 percent return of tags by anglers. Studies on the loss of floy anchor tags have indicated highly variable rates ranging from 5.0 to over 25.0 percent (Carline and Bryneldson 1972, Ebner 1982, and Kratt 1985). Non-reporting of tags by sport anglers is difficult to determine without specific studies. Anglers on the Madison River in Montana returned approximately 70 percent of tags caught (Vincent 1971) and tag loss was estimated at about 5 to 10 percent.

Results and Discussion

The exploitation rates for the no tag loss estimates ranged from 5.1 to 8.6 percent as compared to 7.9 to 13.6 percent for the 10 percent tag loss estimate (Table 33). Survival rates for adult cutthroat varied little betveen the two estimates ranging from 49 to 64 percent among the individual years. The estimates which are based on a 10 percent tag loss and a 70 percent return of tags by adults are probably the most realistic.

Huston et al. (1984) noted that the mean annual survival rate in Libby Reservoir for westslope cutthroat trout was 49 percent. This rate included the time span from recruitment to the reservoir as juveniles to their return to spawn two years later. The mean annual survival rate for adult cutthroat in HHR vas 56 percent. Survival of juveniles their first year in the reservoir would undoubtedly be less.

The confidence limits for the exploitation rates varied between ±28-40 percent of the point estimates. Survival estimates had wider confidence limits ranging from ±39 percent of the point estimate in 1984 to ±120 percent of the point estimate in 1986, indicating that the latter estimate was unreliable.

Table 33. Estimates of annual exploitation and survival rates of adult westslope cutthroat trout in Hungry Horse Reservoir from 1984 to 1987. The 95 percent confidence limits are given in parentheses.

Year Tagged	Number Tagged	Recovery Year for Tags 1984	1985	1986	1987	Estimated Percent Exploitation	Survival
				Estimate 1[a/]			
1984	297	15	13	6	--	5.1	50.8
1985	325	--	13	25	2	5.4	62.5
1986	299	--	--	21	11	8.6	49.2
1987	68	--	--	--	2	--	--
				Estimate 2[b/]			
1984	267	21	19	9	--	7.9 (±3.2)	52.3 (±21.9)
1985	292	--	19	36	3	8.8 (±2.9)	63.6 (±25.2)
1986	269	--	--	30	16	13.6 (±3.8)	53.4 (±64.2)
1987	61	--	--	--	3	--	--

a/ Based on no tag loss and all tags returned by angler.

b/ Based on ten percent tag loss and 70 percent tag return by angler.

POPULATION ESTIMATES

Methods

Population estimates for the number of adult cutthroat trout were calculated using three different methods. In the first method, the Peterson Estimator was used to calculate cutthroat populations in 1985 and 1986. Adult cutthroat were marked with floy anchor tags in the reservoir and as spent spawners migrating out of tributary streams. They were recaptured in gill nets and by anglers contacted by a creel census.

The second method involved determining the adult population from the annual recruitment estimates by multiplying the mean annual survival rates by times the recruitment estimate for four successive years and summing the results.

$$N = \sum_{i-l}^{4} Ri(S)$$

Where: N = Number of adults in reservoir;
R = Number of recruits surviving each successive year; and
S = Annual survival rate.

The third method was based on dividing the annual exploitation rate in 1984 and 1985 into the total harvest of adult westslope cutthroat for each year, respectively.

Results and Discussion

The population estimates for adult westslope cutthroat trout ranged from 9,859 to 16,352 with an average of 12,800 (Table 34). The confidence limits for the mark-recapture estimates indicated that the actual population could vary considerably from the point estimate. Nevertheless, the estimates from the three methods are within a surprisingly narrov range considering the variability of the data.

These estimates should be vieved as a starting point and certainly need more validation. Approximately 4,000 cutthroat, 200 to 250 mm in length, will be released into the reservoir in September, 1989. An intensive trapping effort will be used to catch sufficient cutthroat in order to calculate a population estimate with narrow confidence limits.

GROWTH

Methods

Total body length of cutthroat, bull trout and mountain whitefish collected during the study was measured to the nearest millimeter. Body weight was determined to the nearest gram for

Table 34. Population estimates of adult westslope cutthroat trout in Hungry Horse Reservoir.

Year	Method	Estimate	95% Confidence Limits
1984	1	12,036	$\pm$8,828
1985	1	9,859	$\pm$5,488
1984-86 Combined	2	11,400	--
1985	3	16,352	--
1986	3	14,352	--

fish weighing 500 g or less and to the nearest 45 g (0.1 pound) for fish weighing more than 500 g. Scales were taken from an area just above the lateral line along an imaginary line between the posterior insertion of the dorsal fin and the anterior insertion of the anal fin. Otolith bones were removed from cutthroat trout and stored in scale envelopes in a dry state and sent to Dr. Ed Brothers.

Cellulose acetate impressions of scales were examined using microfiche readers. Distances from the focus to annuli were measured to the nearest millimeter using transparent plastic rule6 and recorded directly onto computer coding sheets.

Age and growth information was analyzed using a modified FIRE 1 computer program described by Hesse (1977) and the program6 developed by MDFWP personnel. Body length-scale radius relationships are most accurately described using log-log plot6 constructed from pooled samples of tributary and lake fish.

The error caused by back-calculating growth at young ages was reduced by using the back-calculated growth to the first annulis only for cutthroat collected in the reservoir. Stream growth was obtained from back calculation of growth from scales taken from juvenile cutthroat emigrating to the reservoir. Juvenile bull trout growth data was not available so bull trout lengths at young ages were back-calculated from fish collected in the reservoir.

Mortality estimates will be cross-checked using a variety of additional methods including catch curves and mark-recapture data from Hungry Horse trap operation.

Otolith samples were taken from westslope cutthroat trout collected during the spring and fall gill net series. Mounting and analysis of otoliths was contracted to Dr. Ed Brothers, Cornell University. A total of 406 otoliths were mounted and aged. The analysis of monthly grovth increments was based on cutthroat that had been in the reservoir for one year or less. This enabled us to determine the monthly growth increments of cutthroat during their first year of life in the reservoir when growth is most rapid.

Trout otoliths were prepared in the following manner. Pairs of sagittae from each fish were placed in a silicon rubber embedding mold. The molds are imprinted with identification numbers and these were recorded for future reference. Use of these numbers also allowed for "blind" readings of fish age and other measurements. The otoliths were positioned at either end of the individual wells with their sulcal surfaces facing up.

The embedding material (Spurr's) was poured into each well and the material was cured overnight at 70°C. The blocks were removed from the mold and then prepared for microscopic examination. The embedded otoliths were primarily ground on the sulcal surface until a mid sagittal section was achieved. Specimens were repeatedly inspected during the grinding process to carefully control the amount of material removed. From some of the larger, more opaque otoliths, some grinding was also done on the distal otolith face. Grinding was done with the aid of electrically powered and water-bathed vheels. Rough cutting was with 180-grit, followed by 600-grit. Samples were also polished with 1 um diamond compound. Age determinations and measurements were done with the specimens in oil (mineral) and viewed vith transmitted light and a compound microscope (100-1000x). Criteria for annual marks and emigration marks were as described in the earlier study.

Otoliths were measured along a single axis called the "dorsal radius." This line extends from a central primordium to the dorsal otolith margin. Distances to otolith annuli and incremental widths were also measured along this axis if possible. For cases when incremental measurements were easier along another axis, the total axis was first measured and subsequent increment dimensions were then scaled to the dorsal axis.

Back-calculation of fish lengths and growth was accomplished by the same method as used previously. Both linear and curvilinear dorsal radius X fish TL relationship (x-intercept) was then used in a Lee back-calculation procedure. Since the curvilinear otolith regressions gave slightly better fits (especially at smaller fish sizes), the following equation form was used:

$$\text{In } Lt = C + Ot/\ln OT\ (1n\ LT - C)$$

vhere: C = x-intercept of the natural log transformation plot of dorsal radius X TL;
Lt = TL at time t (mm);
LT = TL at capture (mm);
Ot = otolith radius at time t (um);
OT = otolith radius at capture (um); and
Ln = .6995 x Ln + 3.1593 . . . .*

For cutthroat collected in the fall, increments were counted and measured back from the otolith margin -- usually for three or four months. For spring-collected fishes, back-calculation of monthly growth was achieved vith a modified method. Increments were counted and measured back from the last winter zone or check (very close to the margin). Increments could not be seen for the late fall and winter and this area was limped into an "End" zone. when increments became visible it was assumed to be October and then counting and measurement proceeded as for the fall-collected fish.

Results and Discussion

Westslope Cutthroat Trout

Age determination and scale measurements were made on a total of 1896 westslope cutthroat trout collected from HHR and its tributaries from 1983 to 1987. Cutthroat were collected in gill nets, fish traps and by angling.

A logarithmic body-scale relationship was used to back-calculate fish length at previous annuli. A significant relationship ($P<.05$) was obtained from 1,502 fish ($r-0.93$). The slope vas 0.697 and the intercept 13.41. Fraley et al. (1981) noted that slopes for individual tributaries from the Flathead River varied from 0.604 to 0.754. The Y intercepts varied from 7.79 to 19.01.

The migration class composition of the fish from Hungry Horse Reservoir (Table 24) vas similar to that found in Flathead Lake (Leathe and Graham 1982) and Priest Lake (Averett and MacPhee 1971). In these lakes, migration class III comprised 50 to 58 percent of the populations followed by age tvo fish (25 to 42 percent) and age 1 (four to six percent).

The back-calculated grovth of westslope cutthroat trout in HHR and its tributaries is presented in Table 35. Migration class II cutthroat averaged 307 mm in total length at age four and 348 mm at age five. Migration class III fish had a mean length of 348 mm at age five and 365 mm at age six. Grovth from 1984 to 1987 vas less than recorded from 1962 to 1968. During the latter period, migration class tvo fish averaged 370 mm at age five and migration class three fish averaged 350 mm at the same age (Huston 1969). Cutthroat from Hungry Horse Reservoir averaged approximately 25 mm longer in length at age four and five than cutthroat from Flathead Lake (Leathe and Graham 1982).

The mean grovth increments of westslope cutthroat vere largest the first year of life in the reservoir ranging from 117 to 188 mm (Tables 36 and 37). The mean annual grovth increments of 151 mm for these fish vas 22 mm larger than the mean increment calculated for otolith aged fish (Table 38). Grovth increments declined to a mean of 55 mm the second year in the reservoir and 26 mm the third year. The mean grovth increments the first year in the reservoir varied among the years vith the largest increment in 1986 and the smallest in 1983. Second year mean increments vere characterized by their stability, ranging from 57 to 58 mm.

The body length-otolith relationship vas best described by a curvilinear regression using natural logarithms. The slope of this equation vas .6995 vith an intercept of 3.1593 and an r value of 0.92.

Grovth increments for cutthroat varied considerably among the months. The juveniles grev approximately 32 mm prior to migrating to the reservoir (Table 38). Grovth increments vere highest in July averaging approximately 29 mm and gradually declined to about 18 mm in October. Total grovth from Hay through September ranged from 104 to 122 mm and the annual grovth increment ranged from 126 to 131 mm. As noted previously, grovth sloved markedly after the first year in the reservoir.

Table 35. Back-calculated growth[a/] (mm) of westslope cutthroat trout collected from Hungry Horse Reservoir and its tributaries, 1984 to 1987. Number of fish aged is in parenthesis.

Year class	Back-calculated Length (mm) at Annulus I		II		III		IV		V		VI		VII	
	Migration Class 2													
1981	63	(74)	123	(74)	240	(3)	307	(12)	347	(10)	394	(1)	--	
1982	50	(33)	92	(33)	241	(4)	304	(13)	349	(7)	--		--	
1983	54	(44)	95	(44)	238	(5)	310	(21)	--		--		--	
1984	62	(21)	106	(21)	241	(12)	--		--		--		--	
Combined	57	(172)	104	(172)	240	(24)	307	(46)	346	(17)	394	(1)	--	
	Migration Class 3													
1980	56	(33)	108	(33)	147	(33)	288	(54)	347	(83)	365	(11)	400	(4)
1981	54	(57)	98	(57)	146	(57)	282	(33)	358	(91)	365	(14)	--	
1982	57	(99)	101	(99)	144	(99)	296	(26)	346	(74)	--		--	
1983	53	(66)	95	(66)	137	(66)	309	(26)	--				--	
Combined	55	(255)	100	(255)	144	(255)	294	(139)	348	(248)	365	(25)	400	(4)
	Migration Class 4													
1979	48	(11)	99	(11)	132	(11)	160	(11)	317	(13)	366	(11)	385	(3)
1980	46	(3)	93	(3)	133	(3)	170	(3)	329	(11)	371	(5)	--	
1981	48	(14)	90	(14)	127	(14)	161	(14)	322	(3)	370	(5)	--	
1982	47	(3)	77	(3)	119	(3)	147	(3)	335	(6)	--		--	
Combined	47	(31)	90	(31)	128	(31)	160	(31)	326	(25)	369	(21)	385	(3)
	Migration Classes Combined													
Combined	53	(458)	98	(458)	171	(310)	254	(216)	341	(2%)	376	(47)	392	(7)

a/ The adult fish were back-calculated only to the outer annulus to reduce error caused by back-calculating earlier ages. Stream growth was determined from juvenile emigrants caught in the Hungry Horse Creek fish trap.

Table 36. Annual growth increments (mm) for westslope cutthroat trout collected from Hungry Horse Reservoir and its tributaries from 1983 to 1987.

Year Class	Growth increment (mm) to Annulus						
	I S[a]	II S	III R[b]	IV R	V R	VI R	VII R
	Migration Class 2						
	I S[a]	II S	III R[b]	IV R	V R	VI R	VII R
1981	63	60	117	67	40	47	--
1982	50	42	149	63	45	--	--
1983	54	41	143	72	--	--	--
1984	62	44	135	--	--	--	--
Combined	57	47	136	67	41	47	--
	Migration Class 3						
	I S[a]	II S	III R[b]	IV R	V R	VI R	VII R
1980	56	52	39	141	59	18	35
1981	54	44	48	136	68	15	--
1982	57	44	43	152	50	--	--
1983	53	42	42	172	--	--	--
Combined	55	45	44	150	54	17	35
	Migration Class 4						
	I S[a]	II S	III R[b]	IV R	V R	VI R	VII R
1979	48	51	33	28	157	49	19
1980	46	47	40	37	159	42	--
1981	48	42	37	34	161	48	--
1982	47	40	42	28	188	--	--
Combined	47	45	38	32	166	43	19

a/ S = Stream growth

b/ R = Reservoir growth

S a/ II S III R b/ IV R V R VI R VII R

Table 37. Annual growth increments for westslope cutthroat trout in Hungry Horse Reservoir from 1983 to 1986.

	1983	1984	1985	1986	Mean
		Migration Class 2			
First year	117	149	143	135	136
Second year	--	67	63	72	67
Third year	--	--	40	45	42
		Migration Class 3			
First year	141	136	152	172	150
Second year	--	59	68	50	54
Third year	--	--	18	15	17
		Migration Class 4			
First year	157	159	161	188	166
Second year	--	49	42	48	43
Third year	--	--	--	19	19
		Migration Classes Combined			
First year	138	148	152	165	151
Second year	--	58	58	57	55
Third year	--	--	29	26	26

Table 36. Annual growth increments (mm) for westslope cutthroat trout collected from Hungry Horse Reservoir and its tributaries from 1983 to 1987.

Year Class	Growth increment (mm) to Annulus						
	I S[a]	II S	III R[b]	IV R	V R	VI R	VII R
			Migration Class 2				
	I S[a]	II S	III R[b]	IV R	V R	VI R	VII R
1981	63	60	117	67	40	47	--
1982	50	42	149	63	45	--	--
1983	54	41	143	72	--	--	--
1984	62	44	135	--	--	--	--
Combined	57	47	136	67	41	47	--
			Migration Class 3				
	I S[a]	II S	III R[b]	IV R	V R	VI R	VII R
1980	56	52	39	141	59	18	35
1981	54	44	48	136	68	15	--
1982	57	44	43	152	50	--	--
1983	53	42	42	172	--	--	--
Combined	55	45	44	150	54	17	35
			Migration Class 4				
	I S[a]	II S	III R[b]	IV R	V R	VI R	VII R
1979	48	51	33	28	157	49	19
1980	46	47	40	37	159	42	--
1981	48	42	37	34	161	48	--
1982	47	40	42	28	188	--	--
Combined	47	45	38	32	166	43	19

a/ S = Stream growth

b/ R = Reservoir growth

S a/ II S III R b/ IV R V R VI R VII R

Growth of cutthroat in weight was more evenly distributed among the months with biomass increase the largest from August through October ranging from 32 to 35 g per month (Table 38). In addition, approximately 19 grams of biomass was accrued after October. Nearly all of this increment probably occurred in November because water temperatures were generally too cold after November for efficient metabolism, less than 5.0°C. In addition, food availability was very low in December.

Growth in the late summer and fall is very important for the juvenile cutthroat their first year in the reservoir. From August through November, juveniles obtained a mean of 55 percent (70 mm) of their growth in length and 68 percent (118 g) of their growth in weight. Growth from September through November is also important when 48 percent of the annual growth in veight is accrued.

During the late summer-fall period, food resources are abundant and water temperatures are in the preferred range for growth of westslope cutthroat trout. Drawdown during this period should reduce trout growth by increasing competition for space and available food resources. In 1985, the weight increment from August through November was 68 g as compared to about 88 g in 1986. The reservoir was at full pool for only seven days in 1985 and the pool began to decline on July 5 as compared to about August 7 in 1986. By the end of October the pool elevation in 1985 was 3,524 as compared to 3,530 in 1986. The reservoir was drafted more rapidly in 1987 after mid October than in 1985 and 1986. Hovever, growth increment data is not available for the October and November period in 1987.

Bull Trout

Age determinations were made on 718 scales from bull trout collected in gill nets from Hungry Horse Reservoir, 1983 through 1987. A significant logarithmic total body length to scale radius was calculated for the bull trout from HHR. The line had a slope of 0.991, an intercept of 5.13, and an r- value of 0.91. This body-scale relationship vas comparable to the one calculated by Leathe and Graham (1982) for Flathead Lake which had a slope of 1.020.

Migration class III comprised approximately 59 percent of the catch (Table 39) in gill nets followed by migration class II (29 percent), class IV (7.0 percent) and class one (4.3 percent). Age at migration was more difficult to discern in bull trout than in cutthroat trout because the bull trout did not exhibit a large increase in growth during their first year of life in the reservoir.

The age structure of the bull trout captured in gill nets was comprised primarily of age three and four fish which accounted for approximately 75 percent of the catch. Age six and older bull trout comprised 13 percent of the catch. The age structure of the

Table 39. The percent age and migration class composition of bull trout collected from Hungry Horse Reservoir. 1984 to 1987. Number of fish aged is in parentheses.

Migration class	Percent of Catch at Age							
	II	III	IV	V	VI	VII	VIII	Total
				1984				
1	--	--	1.1 (1)	1.1 (1)	--	--	--	2.2 (2)
2	--	4.4 (4)	8.8 (8)	6.6 (6)	3.3 (3)	--	--	23.0 (2l)
3	--	4.4 (4)	24.2 (22)	28.6 (26)	8.8 (8)	1.1(1)	--	67.0 (61)
4	--	--	--	5.5 (5)	2.2 (2)	--	--	7.8 (7)
Combined	--	8.8 (8)	34.1 (31)	41.8 (38)	14.3 (13)	1.1(1)		(91)
				1985				
1	0.9 (1)	1.8 (2)	3.5 (4)	--	0.9 (1)	--	--	7.1 (8)
2	--	ll.4 (13)	9.7 (11)	9.7 (ll)	1.8 (2)	0.9 (1)	--	33.6 (38)
3	--	2.7 (3)	33.3 (15)	20.4 (23)	10.6 (12)	1.8 (2)	--	48.7 (55)
4	--	--	3.5 (4)	3.5 (4)	2.7 (3)	--	0.9 (1)	10.6 (12)
Combined	0.9 (1)	15.9 (18)	30.1 (34)	33.6 (38)	15.9 (18)	2.7 (3)	0.9 (1)	(113)
				1986				
1	--	--	1.7 (2)	0.9 (1)	--	--	--	2.6 (3)
2	--	6.0 (7)	13.8 (16)	9.5 (11)	2.6 (3)	--	--	31.9 (37)
3	--	1.7 (2)	36.2 (42)	19.8 (23)	2.6 (3)	0.9 (1)	--	61.2 (7l)
4	--	--	--	3.4 (4)	--	0.9 (1)	--	4.3 (5)
Combined	--	7.7 (9)	51.7 (60)	33.6 (39)	5.2 (6)	1.7 (2)	--	(116)
				1987				
1	--	1.4 (1)	4.2 (3)	--	--	--	--	5.6 (4)
2	--	8.5 (6)	14.1 (10)	4.2 (3)	--	--	--	26.8 (19)
3	--	5.6 (4)	39.4 (28)	ll.3 (8)	5.6 (4)	1.4 (1)	--	63.4 (45)
4	--	--	1.4 (1)	--	2.8 (2)	--	--	4.2 (3)
Combined	--	15.5 (ll)	59.2 (42)	15.5 (ll)	8.5 (6)	1.4 (1)	--	c m
				Years Combined				
1	0.3 (1)	0.8 (3)	2.6 (10)	0.5 (2)	0.3 (1)	--	--	4.3 (17)
2	--	7.7 (30)	ll.5 (45)	7.9 (31)	2.0 (8)	0.3 (1)	--	29.4 (115)
3	--	3.3 (13)	27.4 (107)	20.5 (80)	6.9 (27)	1.3 (5)	--	59.3 (232)
4	--	--	1.3 (5)	3.3 (13)	1.8 (7)	0.3 (1)	0.3 (1)	7.0 (27)
Combined	0.3 (1)	ll.8 (46)	42.7 (167)	32.2 (126)	11.0 (43)	1.8 (7)	0.3 (1)	(391)

HHR bull trout populations was similar to that recorded for bull trout from Flathead Lake in 1981 (Leathe and Graham 1982) except that age six and older fish in Flathead Lake comprised almost 30 percent of the catch.

Growth of the 1978 to 1983 bull trout year classes from Hungry Horse Reservoir was comparable to growth in previous years and from other waters (Table 40). The mean length of 388 mm at age five was almost identical to the 390 mm recorded for bull trout collected from HHR in 1982, 1976 and 1980 (Huston 1982). The mean length at age six of 499 mm was about 22 mm larger than the length of age six fish from previous years. The lengths achieved by bull trout in HHR at age five and six were comparable to those calculated for bull trout from Flathead Lake and Lake Koocanusa (Leathe and Graham 1982). The relatively good growth achieved by bull trout in HHR indicated that they have an adequate forage base.

The largest growth increments of 90 and 95 mm were achieved by bull trout during their fifth and sixth years of life, respectively (Table 41). Leathe and Graham (1982) noted that bull trout in Flathead Lake had their maximum growth increment of 95 mm at age seven with the next largest increment of 92 mm achieved during the fifth year.

Growth increments among the years was quite variable (Table 41). For example, the increment at age five varied from 71 mm in 1984, to 103 mm in 1985. The growth increment for age five bull trout was highest in 1985 when the reservoir was drafted earlier than normal. The age four increment for 1985 was above average but the increment for age six fish was below average. The age six increment was based on only two fish and therefore was probably biased. The overall growth increment of 184 mm for age four and five reservoir fish was higher in 1985 than in other years. This may be related to the drawdown in 1985 as the reduction in volume should concentrate the fish and make prey species more available to predators.

MOVEMENT

Methods

Westslope cutthroat trout adults were tagged with floy anchor tags and the juveniles were tagged with floy dangler tags. Fish were captured vith electrofishing gear, purse seine and gill nets in the reservoir. Fish traps and angling were used to collect cutthroat in reservoir tributaries and the South Fork of the Flathead River. Tag returns were provided by voluntary angler returns, creel census intervievs and fish sampling activities in the reservoir and tributary streams.

Table 40. Back-calculated growth (mm) of bull trout collected from Hungry Horse Reservoir, 1984 to 1987. Number of fish aged is in parentheses.

Year Class	**Back-calculated Length (mm) at Annulus**						
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**
				Migration Class 2			
1979	79 (8)	140 (8)	211 (8)	285 (8)	370 (8)	369 (2)	--
1980	82 (22)	147 (22)	221 (22)	301 (22)	381 (11)	515 (3)	--
1981	81 (26)	138 (26)	220 (26)	299 (22)	395 (11)	--	--
1982	82 (27)	142 (27)	223 (27)	303 (14)	371 (3)	--	--
1983	80 (17)	131 (17)	208 (17)	272 (10)			
Combined	81 (100)	140 (100)	217 (100)	292 (76)	379 (33)	442 (5)	--
				Migration Class 3			
1978	87 (9)	145 (9)	224 (9)	309 (9)	398 (9)	504 (19)	600 (12)
1979	80 (39)	145 (39)	220 (39)	309 (39)	391 (39)	480 (13)	721 (1)
1980	77 (49)	139 (49)	204 (49)	282 (49)	354 (27)	465 (4)	471 (1)
1981	80 (35)	141 (35)	215 (35)	308 (31)	395 (27)	562 (4)	
1982	85 (53)	136 (53)	211 (53)	291 (50)	386 (8)	--	
1983	78 (30)	134 (30)	204 (30)	284 (28)	--	--	
Combined	81 (215)	140 (215)	213 (215)	297 (206)	385 (110)	503 (40)	597 (4)
				Migration Classes Combined(1, 2, 3, 4)			
1978	88 (17)	148 (17)	238 (17)	319 (17)	406 (17)	490 (17)	583 (4)
1979	81 (64)	145 (64)	221 (64)	307 (64)	392 (64)	468 (21)	674 (2)
1980	80 (90)	141 (90)	214 (90)	286 (90)	357 (48)	469 (8)	454 (2)
1981	80 (99)	139 (99)	215 (99)	299 (84)	402 (47)	569 (6)	
1982	80 (101)	138 (101)	213 (101)	294 (73)	382 (11)	--	
1983	79 (75)	133 (75)	205 (74)	284 (45)	--	--	
Years Combined	81 (446)	141 (446)	218 (445)	298 (373)	388 (187)	499 (52)	570 (8)

Table 41. Annual growth increments of bull trout collected from Hungry Horse Reservoir, 1984 to 1987.

Growth Year	Growth Increment at Age					
	I	II	III	IV	V	VI
Migration Class 2						
1979	79					
1980	82	61				
1981	81	65	71			
1982	82	57	74	74		
1983	80	60	82	80	85	--
1984	--	51	81	79	80	-1
1985	--	--	77	80	96	--
1986	--	--	--	64	68	134
Combined	81	59	77	75	87	53
Migration Class 3						
1978	87	--	--	--	--	--
1979	80	58	--	--	--	--
1980	77	65	79	--	--	--
1981	80	62	75	85	--	--
1982	85	61	65	89	89	--
1983	78	51	74	78	82	96
1984	--	56	75	93	72	141
1985	--	--	68	80	87	6
1986	--	--	--	80	95	--
Combined	81	59	73	84	88	94
Migration Classes Combined (1, 2, 3, 4)						
1978	88	--	--	--	--	--
1979	81	66	--	--	--	--
1980	80	64	80	--	--	--
1981	80	61	76	81	--	--
1982	80	59	70	86	87	--
1983	79	58	76	72	85	93
1984	--	54	75	84	71	106
1985	--	--	72	81	103	85
1986	--	--	--	79	92	--
Years Combined	81	60	77	80	90	95

Results and Discussion

Westslope Cutthroat Trout

A total of 5,217 juveniles and 1,085 adult westslope cutthroat vere tagged in HHR and its tributaries from 1983 to 1987 (Table 42). Movement information vas obtained on 36 juvenile and 128 adult cutthroat cutthroat from angler return and of tags from tagged fish captured in gill nets (Table 43).

Tagged fish vere caught throughout the reservoir and the lover South Fork vith 45 percent of the adults and 31 percent of the juveniles caught vithin one km of their tagging location. Approximately 37 percent of the adults moved upstream as compared to 18 percent which moved dovnstream. The longest upstream and dovnstream movements of adult fish vere 54.4 and 52.3 km, respectively (Table 44). The fish which moved farthest upstream vere tagged in Hungry Horse Creek in June, 1986, and recaptured at the head of the reservoir in July, 1987 (Table 45). The record dovnstream movement vas recorded by an adult cutthroat tagged in Lover Tvin Creek on August, 1983. and recaptured one year later near Lid Creek (May and Fraley 1986). Adult cutthroat trout tagged in the Emery area appeared to travel more than cutthroat from the Sullivan area vith 37 and 16 percent of the fish tagged in these areas, respectively recaptured more than one km from tagging location (Table 45).

Juvenile fish exhibited a propensity for dovnstream movement vith 50 percent caught dovnstream from tagging location and only 19 percent upstream. In addition, no juveniles moved upstream more than 10 km or dovnstream more than 20 km.

The dovnstream movement of cutthroat trout vas influenced by the devatering of the upper reservoir which forced fish to relocate. Upstream movement vas influenced by spawning runs and littoral habitat availability. Large numbers of adult westslope cutthroat trout moved up-reservoir in the spring to spavn in tributaries located in the upper part of the reservoir and in the lover South Fork of the Flathead River. The upper part of the reservoir contains most of the littoral habitat in the reservoir and as noted earlier, this littoral habitat is preferred by cutthroat trout.

Cutthroat trout tagged in the upper south Fork of the Flathead River above Meadow Creek Gorge exhibited comparatively little movement from 1985 to 1987 (Table 46). Movement data on 81 adult fish vere collected during this period. Approximately 76 percent of these fish moved less than one km. Five fish vere recaptured more than one km upstream from vhere they vere tagged vith the maximum distance moved about 35 km. The remaining 16 fish moved dovnstream. One cutthroat tagged at the confluence of Youngs Creek and Danaher Creek in July, 1986, vas recaptured at Gorge Creek in Hay. 1987; a dovnstream movement of 66.3 km. A total of three fish tagged in the upper South Fork vere later recaptured in the Meadow Creek Gorge area. Altogether, 18 percent of the tags

Table 42. The number of westslope cutthroat trout tagged in Hungry Horse Reservoir, the lower South Fork of the Flathead River from HHR to Meadow Creek (37 km), and the upper South Fork from Meadow Creek to Youngs Creek (69 km upstream from Meadow Creek).

	Location Tagged				
	Hungry Horse Reservoir			Flathead River	
	Emery area	Murray area	Sullivan area	Lower South Fork area	Upper South Fork area
			1983		
Juveniles	755	402	637	374	--
Adults	34	37	25	27	--
			1984		
Juveniles	858	0	920	12	--
Adults	204	0	93	6	--
			1985		
Juveniles	1,413	0	242	0	712
Adults	256	0	69	36	319
			1986		
Juveniles	0	0	0	0	78
Adults	181	9	109	2	597
			1987		
Juveniles	0	0	0	0	0
Adults	52	11	5	0	166
Totals					
Juveniles	3,026	402	1,789	386	790
Adults	727	57	301	71	1,082

Table 43. Movement of vestslope cutthroat trout tagged in Hungry Horse Reservoir and recaptured by anglers and gill nets, 1983 to 1987. Fish which moved less than one kilometer are given in the upstream movement column.

	Upstream Movement (km)						
	<1	l-10	11-20	21-30	31-40	41-50	51-60
			1983				
Juveniles	8	1	0	0	0	O	0
Adults	2	1	0	1	0	1	0
			1984				
Juveniles	3	6	0	0	0	O	0
Adults	13	1	0	0	0	O	0
			1985				
Juveniles	0	0	0	0	0	0	0
Adults	14	3	5	4	1	3	0
			1986				
Juveniles	0	0	0	0	0	0	0
Adults	24	2	10	2	4	1	0
			1987				
Juveniles	0	0	0	O	0	0	O
Adults	4	2	2	2	1	0	1
			TOTAL				
Juveniles	11	7	0	O	0	0	O
Adults	57	9	17	9	6	5	1

	Downstream Movement (km)						
	<1	l-10	11-20	21-30	31-40	41-50	51-60
			1983				
Juveniles	--	4	1	1	0	0	0
Adults	--	2	1	0	0	0	0
			1984				
Juveniles	--	7	0	1	0	O	0
Adults	--	2	2	1	0	1	0
			1985				
Juveniles	--	1	0	O	O	O	0
Adults	--	1	0	2	1	1	0
			1986				
Juveniles	--	0	0	O	O	O	0
Adults	--	0	2	2	2	2	0
			1987				
Juveniles	--	0	0	O	0	0	0
Adults	--	1	0	O	0	0	0
			TOTAL				
Juveniles	--	12	1	2	0	0	0
Adults	--	6	5	5	3	4	0

Table 44. The movement of westslope cutthroat trout tagged in the South Fork of the Flathead River in the Bob Marshall Wilderness area and recaptured by anglers, 1985 to 1987. Fish which moved less than one kilometer are given in the upstream movement column.

	Upstream Movement (km)						
	<1	**l-10**	**11-20**	**21-30**	**31-40**	**41-50**	**>50**
				1985			
Juveniles	6	3	0	0	1	0	0
Adults	9	0	0	0	1	0	0
				1986			
Juveniles	7	0	0	0	0	0	0
Adults	32	0	1	1	0	0	0
				1987			
Juveniles	0	0	0	0	0	0	0
Adults	19	1	0	1	0	0	0
				TOTAL			
Juveniles	13	3	0	0	1	0	0
Adults	60	1	1	2	1	0	0

	Downstream Movement (km)						
	<1	**l-10**	**11-20**	**21-30**	**31-40**	**41-50**	**>50**
				1985			
Juveniles	--	1	0	0	0	0	0
Adults	--	1	0	0	0	0	0
				1986			
Juveniles	--	0	0	0	0	0	0
Adults	--	2	3	2	1	0	0
				1987			
Juveniles	--	0	0	0	0	0	0
Adults	--	2	2	1	0	1	1
				TOTAL			
Juveniles	--	1	0	0	0	0	0
Adults	--	5	5	3	1	1	1

Table 45. Tagging and return information for westslope cutthroat trout recaptured in 1987 from Hungry Horse Reservoir and its tributaries.

Tagging Data			Return Data			
Date	Location	Length (mm)	Date	Location	Length (mm)	Distance Moved
06-29-85	H.H. trap[a]	358	05-15-87	H.H.R. - ?	~360	
07-16-85	H.H. trap	356	06-??-87	H.H.R - Wounded Buck	--	+7.9
06-12-86	H.H. trap	373	05-05-87	H.H.R. - Fire Island	~406	+9.5
06-13-86	H.H. trap	318	05-21-87	H.H.R. - Graves Creek	~300	+33.8
06-15-86	H.H. trap	370	07-28-87	H.H.R. - ?	~356	?
06-15-86	H.H. trap	384	05-13-87	H.H.R. - Deep Creek	~356	+23.8
06-16-86	H.H. trap	380	05-10-87	H.H.R. - Flossie Creek	~380	+16.0
06-18-86	H.H. trap	358	05-26-87	H.H. Creek	~356	0
06-18-86	H.H. trap	298	??-??-87	Emery Creek	~380	-0.5
06-20-86	H.H. trap	370	07-10-87	H.H.R. - mouth of S. Fk.	~330	+54.4
06-21-86	H.H. trap	375	05-14-87	H.H.R. - Deep Creek	~356	+23.8
06-24-86	H.H. trap	353	10-??-87	H.H.R. - ?	~370	
07-06-86	H.H. trap	407	04-25-87	Emery Creek	~406	-0.5
04-28-86	H.H.R. - Peters Creek	335	06-20-87	H.H.R. - Inlet of S. Fk.	~406	+0.6
06-11-86	H.H.R. - Peters Creek	398	05-16-87	Sullivan Creek	~406	-3.8
06-11-86	H.H.R. - Peters Creek	340	05-10-87	Upper Twin	~356	+10.6
08-06-87	S. Fk. - Harrison Creek	249	09-04-87	S. Fk. - Bunker Creek	~250	+5.3
08-06-87	S. Fk. - Harrison Creek	300	09-07-87	s. Fk. - Bunker Creek	~300	+5.3

a/ Fish trap near mouth of Hungry Horse Creek.

Table 46. Tagging and return information for westslope cutthroat trout tagged in the South Fork of the Flathead River in the Bob Marshall Wilderness area and recaptured by anglers, 1987.

Tagging Data			Return Data			
Date	Location River Mile	Length (mm)	Date	Location River Mile	Length (mm)	Distance Moved
07-31-87	68.6	335	08-16-87	68.6	~313	0
07-16-85	70.8	236	09-16-87	70.8	~356	0
07-17-85	70.8	239	07-30-87	70.8	~340	0
07-15-86	70.8	--	06-20-87	63.4 Gorge Creek	--	-17.4
07-15-86	70.8	270	07-22-87	70.8	~300	0
07-30-87	80.8	322	09-07-87	80.8	~300	0
07-14-86	82.9	330	07-10-87	82.9	~370	0
07-15-86	82.9	330	06-24-87	82.9	~330	0
07-15-86	82.9	315	07-18-87	82.9	~410	0
07-15-86	82.9	275	07-20-87	97.6	~406	+23.6
07-15-86	82.9	320	07-28-87	82.9	~315	0
07-14-86	84.9	300	07-29-87	84.9	--	0
07-19-85	88.0	268	09-01-87	82.9	~292	-9.8
07-19-85	88.0	315	07-29-87	88.0	~330	0
07-29-87	88.0	316	08-05-87	88.0	~356	0
07-29-87	97.6	388	09-02-87	97.6	~380	0
07-12-86	98.5	303	09-01-87	100.3	~460	+8.0
07-10-86	100.3	305	09-02-87	82.9	~380	-25.9
07-30-87	104.0	240	09-15-87	104.0	~240	0
07-15-86	104.6	295	06-12-87	97.6	~300	-11.2
07-15-86	104.6	288	07-28-87	104.6	~310	0
07-14-86	104.6	234	05-24-87	63.4 Gorge Creek	~300	-66.3
07-27-87	104.6	315	08-08-87	104.6	~280	0
07-16-86	105.0	300	06-26-87	105.00	--	0
07-28-87	105.0	294	08-08-87	105.0	~300	0
07-29-87	105.0	270	08-04-87	100.3	~260	-6.9
06-15-87	109.6	325	06-28-87	109.6	--	0
06-15-87	109.6	385	07-19-82	80.8	~380	-46.3

returned from adults indicated a movement of more than 10 km. Only 18 of 790 tags from juvenile trout were returned. Approximately 72 percent of these fish exhibited movement of less than one km and only one was returned downstream from where it was tagged. Thus, it appears that most cutthroat tagged and recaptured were resident fluvial fish which moved only short distances in the South Fork.

The recapture of three adult cutthroat in the gorge area indicated that there is probably some movement between the upper and lower South Fork River by cutthroat. Hovever, the significance of the upper South Fork as a spawning and rearing area for cutthroat trout from the reservoir is still uncertain.

MODEL DEVELOPMENT

The data collected during this study was used to develop the trophic level model. Our modeling strategy entails the use of several component models corresponding specifically to the hypothesized mechanisms of the effects of dam operation upon the reservoir’s biota. The component models, by virtue of their simplicity, are less likely to generate inappropriate predictions and are more accessible to assessment of reliability, than a complex full system model. The model will use particulate carbon to track energy flow through the trophic levels, identify limiting factors and include a sensitivity analysis. It will indicate the direction of change caused by reservoir operation in production of organisms in the various trophic levels.

PHYSICAL FRAMEWORK

Evaluation of the consequences of the various reservoir management options requires a common physical framework within which the submodels can operate. This framework is a three-dimensional representation of the reservoir basin, coupled to a day-by-day representation of the inflow, turbidity, solar radiation and air temperature. The model has a provision for specifying the annual schedule of water withdrawals.

The effect of reservoir operation upon thermal regimes within the reservoir will be evaluated using the predictive thermal model. The model will enable us to hold environmental variables (volume of inflow, temperature of inflow and solar radiation) constant, while determining impacts of operational variables (discharge volume, depth of discharge and timing of discharge) on the thermal regime in the reservoir. We can evaluate the effect of these predicted thermal regimes on primary productivity, secondary productivity and fish growth by incorporating them into the physical framework model.

PRIMARY PRODUCTION

The primary production submodel includes area, stratification and washout effects. The area component predicts the annual

schedule of primary productivity for the entire lake by area. Particulate carbon will be used to track energy flow through the trophic levels.

The stratification component uses a physical framevork to generate a description of profiles of temperature and light with passive distribution of nutrients. Diatom biomass is assigned to the mixed layer and primary production is calculated from light, temperature, and nutrients. the output is an annual schedule of primary productivity.

The "washout effect' part of the model computes net biomass loss to washout and incorporates this annual primary production model. The final output is a schedule of primary production as affected by washout loss.

SECONDARY PRODUCTION

The benthos submodel uses a life history model of aquatic dipteran to obtain the rate of production of emergers by date. This rate is calibrated against the observed standing stock of emergers. The output will be a schedule of incremental dipteran production for the entire lake over the course of the year. The results should be reliable and readily interpreted.

The zooplankton model will produce a schedule of zooplankton production by area and month as influenced by primary production, nutrients, living space, and temperature. The effect of downstream loss of zooplankton on zooplankton production in the reservoir will be determined.

FISH COMMUNITY

A growth model will produce a trajectory of differential growth for the salmonid stocks in the reservoir. Fish stocks will be allowed to grow in response to food availability and to place proportionate demands on food resources as indicated by food habits data. Treating the competition between the salmonids as resource-based scramble competition only should lead to reasonable predictions with respect to grovth for a period of one growing season

We will also use a population simulation model developed for adfluvial rainbow trout (Serchuk et al. 1980). This is an age-structured simulation model of the growth and population dynamics of a migratory rainbov trout population. It includes all principal life-history intervals and incorporates food-density and temperature relationships of salmonid growth efficiency. The core of the simulation involves individual fish growth rather than growth of the population. Factors directly affecting the growth processes of trout such as food availability, water temperature, and intraspecific competition have been incorporated. Population size, mean weight and biomass are estimated monthly in age, sex and location categories. A variety of environmental and biological parameters are utilized in the simulation which can be altered as a user option. the utility of this model will be dependent upon sufficient data to allow us to alter the parameters to represent local conditions.

RECOMMENDATIONS

1. The effects of the deep drawdown in 1988 should be thoroughly studied to determine its impact upon the reservoir's biota.

2. The model should be verified with data collected from 1988 through 1990. This will greatly increase its predictive capability.

3. Continue to monitor substrate composition of spawning areas in Hungry Horse Creek.

4. Continue work on development of a model predicting cutthroat embryo survival to emergence under field conditions.

5. Estimate populations of westslope cutthroat trout in HHR and their survival rates by an intensive mark and recapture study. Approximately 4,000 marked ten-inch cutthroat should be planted into the reservoir in September, 1989, and recaptured with trap nets and gill nets in October, 1989, April, 1990, and October, 1990.

LITERATURE CITED

Andrusak, H. and T.G., Northcote. 1971. Segregation between adult cutthroat trout (Salmo clarki) and dolly varden (Salvelinus malma) in small coastal British Columbia Lakes. Journal of the Fisheries Research Board Canada 28:1259-1268.

Arbrett, R.C. and C. MacPhee. 1971. Distribution and growth of indigenous fluvial and adfluvial cutthroat trout Salmo clarki, St. Joe River, Idaho. Northwest Science 45:38-47.

Bachman, R.A. 1984. Foraging behavior of free-ranging wild and hatchery brown trout in a stream. Transactions of the American Fisheries Society 113(1):1-33.

Baxter, R.M. 1977. Environmental effects of dams and impoundments. Annual Review of Ecology and Systematics 8:25S-83.

Behnke, R.J. 1979. Monograph of the native trouts of the genus Salmo of western North America. Colorado Springs, Colorado.

Benson, N.G. and P.L. Hudson. 197s. Effects of a reduced fall drawdown on benthos abundance in Lake Frances Case. Transactions of the American Fisheries Society 104:526-528.

Bjornn, T.C. 1957. A survey of the fishery resources of Priest and Upper Priest Lake and their tributaries. Idaho Department of Fish and Game, Completion Report No. F-24-R, 176 pp.

Bottrell, H.H., A. Duncan, Z.M. Gliwicz, E. Gyrgierek, A. Herzig, A. Hillbricht-Ilkowska, H. Kurasawa, P. Larsson and T. Weglenska. 1976. A review of some problems in zooplankton production studies. Norwegian Journal of Zoology 24:419-456.

Brounie, C., D.R. Anderson, K.P. Burnham and D.S. Robson. 1985. Statistical inference from land recovery data -- A handbook. United States Department of the Interior. Fish and Wildlife Service. Resource Publication No. 156. Washington, D.C.

Carline, R.E. and O.M. Bryneldson. 1972. Effects of the floy anchor tag on the growth and survival of brook trout, Salvelinus fontinalis. Journal of the Fisheries Research Board of Canada 29:458-460.

Chapman, D.W. and K.P McLeod. 1987. Development of criteria for fine sediment in the northern rockies ecoregion. Final Report. Work Assignment 2-73, Dattelle Columbus Laboratory. EPA Contract Number 68-01-6986. Contractor Don Chapman Consultants Inc., 3180 Airport Way, Boise, ID 83705. 279 pp.

Cooper, A.C. 1965. The effect of transported stream sediments on survival of sockeye and pink salmon eggs and alevin. Int. Pac. Sal. Fish. Comm. Bull. 18. 71 PP.

Davis, J.C. 197S. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: a review. Journal of the Fisheries Research Board of Canada. 32(12):229S-2332.

Dwyer, W.P. and R.H. Kramer. 1975. The influence of temperature on scope for activity in cutthroat trout (Salmo clarki). Transactions of the American Fisheries Society 104:552-555.

Ebener, M.P. and F.A. Copes. 1982. Loss of floy anchor tags from Lake Whitefish. North American Journal of Fisheries Management 2:90-93.

Fillion, D.B. 1967. The abundance and distribution of benthic fauna in three mountain reservoirs on the Kananskis River in Alberta. Journal of Applied Ecology. 4:1-11.

Fraley, J.J., D. Read and P.J. Graham. 1981. Flathead River fisheries study. Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

George, E.L. and W.F. Hadley. 1979. Food and habitat partitioning between rock bass (Ambloplites rupestris) and smallmouth bass (Micropterus dolomieui) young-of-the-year. Transactions of the American Fisheries Society 108:253-261.

Graham, P., W. Fredenberg and J. Huston. 1982. Supplements to recommendations for a fish and wildlife program. Submitted to: Pacific Northwest Power Planning Council by Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

Greson, P.E., T.A. Ehlke, G.A. Irvin, B.W. Lium and K.V. Slack. 1977. Methods for collection and analysis of aquatic biological and microbiological samples. U.S. Geological Survey Techniques of Water-Resources Investigation, book 5, Chapter A4. 332 pp.

Hesse, L. 1977. FIRE I, a computer program for the computation of fishery statistics. Nebraska Tech. Ser. No. 1, Nebraska Game and Parks Commission. Project No. F-10-R.

Hickman, T. and R.F. Raleigh. 1982. Habitat suitability index model: cutthroat trout. United States Department of Interior, Fish and Wildlife Service. FWS/OBS-82/10-5. Fort Collins, Colorado.

Hunt, R.L. 1975. Food relations and behavior of salmonid fishes. Coupling of land and water systems. Spurger, Verlag Berlin, Heidelberg, Nev York.

Huston, J.E. 1969. Hungry Horse Reservoir study. Montana Department of Fish and Game. Job Progress Report. Project No. F-34-R-2, Job II. Kalispell, MT.

Huston, J.E. 1970. Hungry Horse Reservoir study. Montana Department of Fish and Game. Job Progress Report. Project No. F-34-R-3. Job II. Kalispell. MT.

Huston, J.E. 1971. Hungry Horse Reservoir Study. Montana Department of Fish and Game. Job Progress Report. Project No. F-34-R-4, Job II-a. Kalispell, MT.

Huston, J.E. 1982. Hungry Horse Reservoir Study. Montana Department of Fish, Wildlife and Parks. Job progress report, project number F-34-R-15, Job II-a, Kalispell, MT.

Huston, J.E. P. Hamlin and B. May. 1984. Lake Koocanusa investigations final report. Montana Department of Fish, Wildlife and Parks, Helena. MT.

Irving, J.S. and T.C. Bjornn. 1984. Effects of substrate core composition on survival of kokanee salmon and cutthroat and rainbow trout. Technical Report 84-6, Idaho Cooperative Fishery Research Unit, Moscov, Idaho.

Jenkins, R.M. 1970. The influence of engineering design and operation and other environmental factors on reservoir fishery resources. Water Resources Bulletin. Journal of the American Water Resources Association 6:110-119.

Jeppson, P.W. and W.S. Platts. 1959. Ecology and control of the Columbia River squawfish in northern Idaho lakes. Transactions of the American Fisheries Society. 88(3):197-203.

Koenigs, J.P. 1983. Southeast lake fertilization project progress report: Limnology investigations at Bakewell Lake (1982). Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement, and Development, Juneau, AK.

Kratt, L.F. 1985. Long-term retention of floy tags by arctic grayling, Thymallus arcticus. Canadian Field Naturalist 99(4)545-546.

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

Martin, D.B., L.L. Mengel. J.F. Novotny and C.H. Walburg. 1981. Spring and summer water levels in a Missouri River reservoir: Effects on age-0 fish and zooplankton. Transactions of the American Fisheries Society 110:370-381.

May, B. and R.J. Zubik. 1985. Quantification of Hungry Horse Reservoir water levels needed to maintain or enhance reservoir fisheries. Prepared for Bonneville Power Administration, project no. 83-465, by Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

May, B. and J.J. Fraley. 1986. Quantification of Hungry Horse Reservoir water levels needed to maintain or enhance reservoir fisheries. Prepared for Bonneville Power Administration, project no. 83-465 by Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

May, B. and T.M. Weaver. 1987. Quantification of Hungry Horse Reservoir water levels needed to maintain or enhance reservoir fisheries. Prepared for Bonneville Power Administration, project no. 83-465 by Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

Mayhew, J. 1977. The effects of flood management regimes on larval fish and fish food organisms at Lake Rathbun. Iowa Conservation Commission. Technical Series 77-2, Des Moines, Iowa.

McKee, J.E. and H.H. Wolf. 1963. Water quality criteria. California Water Quality Control Board, Sacramento, CA. Publication No. 3-A.

McMullin, S.L. 1979. The food habits and distribution of rainbow and cutthroat trout in Lake Koocanusa, MT. M.S. Thesis, University of Idaho, Moscow, ID.

McNeil, W.J. and W.H. Ahnell. 1964. Success of pink salmon spawning relative to size of spawning bed materials. U.S. Fish and Wildlife Service, Special Scientific Report.

Neils, W.H. and J.J. Magnuson. 1974. Distributional ecology and behavioral thermoregulation of Fishes in relation to heated effluent from a power plant at Lake Monona, Wisconsin. Transactions of the American Fisheries Society 103(4)663-711.

Noble, R.L. 1981. Management of forage fishes in impoundments of the southern United States. Transactions of the American Fisheries Society 110:738-750.

Norlin, A. 1967. Terrestrial insects in lake surfaces. Their availability and importance as fish food. Institute of Freshwater Research, Drottningholm, Sveden. Report no, 47.

Oliver, D.R. 1971. Life history of the chironomidae. Annual Review of Entomology. 16:211-230.

Paterson, C.G. and C.H. Fernando. 1969. The effect of winter drainage on reservoir benthic fauna. Canadian Journal of Zoology. 47:589-595.

Phillips, R.W. 1971. Effects of sediment on the gravel environment and fish production. In Forest Land Uses and Stream Environment. Oregon State Univ. 1970.

Plosky, G.R. 1986. Effects of water-level changes on reservoir ecosystems with implications for fisheries management. In Reservoir Fisheries Management: Strategies for the 80's. Editors G.E. Hall and J.U. VanDen Avyll.

Ricker, W.E. 1941. The consumption of small sockeye salmon by predaceous fish. Journal of the Fisheries Research Board Canada 5:293-313.

Rieman, B.E. and J.R. Lukens. 1979. Lake and reservoir investigations: Priest Lake creel census. Job Completion Report, Idaho Department of Fish and Game. Project no. F-73-R-1, Subproject III, Study I, Job I.

Reiser, D.W. and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. U.S.D.A. Forest Service, General Technical Report DNW-96. Pacific Northvest Forest and Range Experiment Station. Portland, OR.

Schindler, D.W. 1969. Two useful devices for vertical plankton and water sampling. Journal of the Fisheries Research Board of Canada 26:1948-1955.

Schoener. T.W. 1970. Non-synchronous overlap of lizards in patchy habitats. Ecology 51:408-418.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184. Fisheries Research Board of Canada. Ottowa, Canada.

Sekulich. P.T. 1974. Role of the Snake River cutthroat trout (Salmo clarki spp.) in fishery management. M.S. thesis, Colorado State University, Fort Collins, CO.

Shepard. B. and P. Graham. 1982. Monitoring spawning bed material used by bull trout on the Glacier Viev District, Flathead National Forest. Montana Department of Fish, Wildlife and Parks, Kalispell, MT.

Sowden, T.K. and G. Power. 1985. Prediction of rainbow trout embryo survival in relation to groundwater seepage and particle size of spawning substrates. Transactions of the American Fisheries Society 114:804-812.

Tappel, P.D. 1981. A nev method of relating spawning gravel size composition to salmonid embryo survival. M.S. thesis, University of Idaho, Moscow, ID.

Tappel, P.D. and T.C. Bjornn. 1983. A new method of relating size of spawning gravel to salmonid embryo survival. North American Journal of Fisheries Management 3:123-135.

Thompson, R.B. and D.F. Tufts. 1967. Predation by dolly varden and northern squawfish on hatchery-reared sockeye salmon in Lake Wenatchee, Washington. Transactions of the American Fisheries Society 96(4):424-427.

Thurston, R.V., R.C. Russo, C.M. Fetterolf, Jr., T.A. Edsall and Y.M. Barber, Jr., (Eds.). 1972. A review of the EPA Red Book: quality criteria for water. Water Quality Section, American Fisheries Society, Bethesda, MD.

Uremovich, B.L., S.P. Cramer, C.F. Willis and C.O. Junge. 1980. Passage of juvenile salmonids through the ice-trash sluicing and squawfish predation at Bonneville Dam, 1980. Annual report to the United States Army Corps of Engineers. Oregon Department of Fish and Wildlife, Clackamas, OR.

Vincent, E.R. 1971. Electrofishing and fish population estimates. The Progressive Fish Culturist 33:(3)163-169.

Vincent, E.R. 1971. Evaluation of river fish populations. Montana Department of Fish and Game. Job Progress Report. Project no. F-9-R-19. Job no. III-a, Bozeman. MT.

Weaver, T.M. and R.G. White. 1985. Coal Creek fisheries monitoring study number III. Final Report. Montana Cooperative Fisheries Research Unit, Bozeman, MT.

Wegener. W. and V. Williams. 1975. Fish population responses to improved lake habitat utilizing an extreme drawdown. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners. 28:144-160.

Wetzel, Robert G. 1975. Limnology. W.B. Saunders Company, Philadelphia, PA.

Woods, P.F. and C.M. Falter. 1982. Limnological investigations: Lake Koocanusa, Montana, Part 4: Factors controlling primary productivity: Hanover, New Hampshire, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory Special Report.

Woods, P.F. 1982. Annual nutrient loadings, primary productivity, and trophic state of Lake Koocanusa, Montana and British Columbia, 1972-80. Geological Survey Professional Paper 1283. Washington, D.C.

Zubik, R.J. and J.J. Fraley. 1987. Determination of fishery losses in the Flathead system resulting from the construction of Hungry Horse Dam. Prepared for Bonneville Power Administration, project no. 85-23 by the Department of Fish, Wildlife and Parks, Kalispell, MT.