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Effects of Sediment Dredging and In-Water Disposal on Fishes in Lower Granite Reservoir, ID - WA.

Completion Report

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ABSTRACT

Sediment deposition in the upper end of Lower Granite Reservoir, Idaho-Washington, is threatening flood control and navigational uses of that system. One alternative under consideration to assure adequate flood protection and maintenance of authorized navigational depths throughout the life of the project is annual dredging and disposal. The impact of proposed dredging and in-water disposal was evaluated by reviewing available literature. Also, we sampled selected physical, chemical and biological components of the Lower Granite system at five shallow and three deep stations. All eight sites were proposed as possible sites for in-water disposal.

We reviewed literature to assess the probable environmental effects of dredging, in-water disposal and the influence of turbidity on fishing success. The literature clearly showed that sediment resuspensions from hydraulic dredging operations are lower than those from mechanical dredges. However, fish entrainment can be a significant form of mortality from hydraulic dredges. Concentrations of suspended solids from dredging generally are lower than those tolerated by aquatic organisms. In contrast, in-water disposal could result in considerably higher suspended solids which could be lethal in the immediate area of disposal. Another adverse affect of in-water disposal could be reduced fishing success with increases in turbidity. Available literature on the relationships between fishing success and turbidity is scanty and difficult to interpret. We analyzed field data (provided by the

Idaho Department of Fish and Game) for steelhead trout (Salmo gairdneri) in North Fork of the Salmon River, Salmon River, and Clearwater River and found no significant correlation ($P > 0.10$) between fishing success and turbidity. Our analysis suggested that factors other than turbidity accounted for a larger variation in catch rates.

To determine the appropriate time and period of dredging and in-water disposal, we looked intensively at anadromous and resident fish activity cycles in Lower Granite Reservoir. During the period from mid March through June, anadromous salmonid smolt activity is high throughout the reservoir. From May through October, resident fishes are spawning and rearing and chinook salmon (Oncorhynchus tschawtscha) are migrating through Lower Granite. In the fall, adult steelhead trout are passing through the reservoir. We found from field sampling and examining dam counts that fish acitvity is lowest in Lower Granite Reservoir from late December through mid March. Therefore, we believe that a 2 to 2.5 month window from late December to mid March would minimize resource conflicts.

We characterized the physical-chemical habitat at proposed shallow and deep disposal sites. Water temperature and dissolved oxygen did not vary among stations when depth was considered. No thermal stratification was found although oxygen levels indicated significant oxygen depletion below 25-30 m. Water velocity was highest at "upriver" stations and varied widely among shallow and deep stations. Also, particle size distributions of substrate varied significantly among stations. Silt particles were most commonly found, while clay ranged from 14-28%. Clay content of the

substrate increased with distance downstream. Water transparency and turbidity were similar among stations.

We collected more than 31,000 fishes representing a maximum of 23 species. Over 96% of these were collected at shallow stations, whereas the remaining 4% were captured at the deep stations. Juvenile and adult salmonid fishes were collected at all stations. Largescale sucker (Catostomus macrocheilus), northern squawfish (Ptychocheilus oregonensis), chiselmouth (Acrocheilus alutaceus) and peamouth (Mylocheilus caurinus) were highly abundant and seasonal means of nongame fish abundance showed a progressive downstream decrease. Larval fish abundance varied among stations and seasonally. Highest abundance was near the Port of Whitman, an area also high in abundance of young-of-year fishes.

To assess the ecological importance of proposed in-water disposal sites to fishes, we sampled stomach contents, enumerated spawning sites and quantified benthos. Mean densities of benthos were highest in the summer and lowest in the spring. No consistent trend in benthos abundance was found among stations. Two shallow stations (SR1S, CR1S) exhibited low benthos abundance but indexes of diversity and evenness generally were higher at these stations. Low density of spawning nests suggested low utilization of shallow stations for reproduction. Juvenile salmonid fishes fed actively on a variety of organisms especially dipterans. Seasonal differences in diets existed although differences between shallow and deep stations were slight. Salmonid fishes were found in stomachs of smallmouth bass (Micropterus salmoides), northern squawfish and possibly yellow perch (Perca flavescens), channel catfish (*Ictalurus punctatus*) and white crappie (*Pomoxis annularis*).

Our results suggest that disposal of dredged material could be conducted at selected sites with low habitat diversity with minimal changes to the biological community. We encourage aquatic resource managers to innovatively examine possibilities to enhance habitat conditions with dredged material.

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INTRODUCTION

The Lower Granite project provides electrical power generation, flood control, slack water navigation and recreation for western Idaho and eastern Washington. Two population centers, Lewiston, Idaho and Clarkston, Washington, are directly affected by this project. A levee system is included in the project which protects industrial, commercial and residential property from inundations by waters impounded behind Lower Granite Dam. Concern has been expressed for the integrity of this project as it may be threatened by sedimentation from upstream sources. High deposition rates of sedimentation in the upstream portion of the project threaten flood control and navigational uses. Recent predictions of sediment deposition rates suggest that by the year 2000, the Lewiston Levee height will be inadequate to pass a standard project flood (about 400,000 cfs). Also, by the year 2000, freeboard has been estimated to be less than 1 meter. By 2035, the standard project flood would overtop the levees by about 2/3 of a meter. More recent predictions, however, suggest that these projections may be overly conservative and could occur sooner than originally estimated.

These predictions of sediment deposition suggest the importance of identifying and evaluating various alternatives to assure adequate flood control protection and maintenance of authorized navigational depths throughout the life of the Lower Granite project. One alternative under consideration is annual dredging and disposal of about 800,000 cubic yards of material.

The possibility of dredging and disposal of material has caused concern among aquatic resource managers because of the potential for impacts to fishery resources. Major concern has been expressed for anadromous fish stocks which use the project area as a corridor for adults migrating upstream to natal streams and juveniles migrating to the Pacific Ocean. With the restoration of anadromous salmonids to the Snake River drainage, significant sports fisheries have developed in areas that could be affected by dredging and in-water disposal. In addition, resident warmwater fisheries are of interest to sportsmen and fisheries managers. The importance of the resident fishery recently has been shown to be significant (Bennett et al. 1983).

The impact of the proposed dredging and in-water disposal on fishery resources needs to be thoroughly evaluated to provide resource managers with adequate information for decision making. As a result, this study was initiated with the following objectives:

Objectives

1) To assess possible effects of dredge types (mechanical vs. hydraulic) on fishes;

2) To assess possible effects of in-water disposal methods (hopper dredge vs. split hull barge) on fishes;

3) To determine the appropriate time and period of dredging and in-water disposal;

4) To assess the effects of dredging and in-water disposal on fishability;

5) To characterize the physical habitat of proposed disposal sites;

6) To determine species composition and relative abundance of adult, juvenile and larval fishes at selected sites proposed for shallow and deep water disposal; and

7) To determine the importance of the proposed in-water disposal sites to resident and anadromous fishes.

Four additional objectives were added to a second phase of this project and will be included as an addendum to this main report. These objectives were:

1) To assess the effects of dredging and the resultant turbidity plume on fishes in Lower Granite Reservoir.

2) To assess the effects of dredging and the resultant turbidity plume on benthics in Lower Granite Reservoir.

3) To collect, analyze and interpret water quality conditions at dredge and disposal sites.

4) To develop a comprehensive literature review on the effects of turbidity from dredging and disposal on aquatic biota.

STUDY AREA

Lower Granite Reservoir, the uppermost reservoir of four in the Lower Snake reservoir chain, extends from Lower Granite Dam at river mile 107.5 in southeastern Washington to the confluence of the Clearwater and Snake rivers in central western Idaho at river mile 139 (Fig. 1). Electrical power generation, flood control, cargo transportation and recreation are major uses of the dam and resulting reservoir.

To assess the effects of sediment dredging and in-water disposal on fishes in Lower Granite Reservoir, eight study stations were selected consisting of five shallow and three deep stations. Comparisons of the physical characteristics at each station demonstrate superficial differences among stations (Table 1). All study stations were designated by Army Corps of Engineers (COE) personnel as possible in-water disposal areas for dredge material. Sediment profiles taken by COE personnel at all stations indicate varying rates of "natural" sedimentation.

One study station was located on the Clearwater River (CR1S). This shallow water station, located directly across from the Port of Lewiston, originally was designed as a barge turn-around area when the levee was constructed (Fig. 1). The shoreline is composed exclusively of large boulders and rubble typically used as rip-rap along the levee system. Consequently, shoreline vegetation is nonexistent at this station.

The uppermost shallow water station (SR4S) on the Snake River is located at the Port of Clarkston (Fig. 1). Shoreline substrate

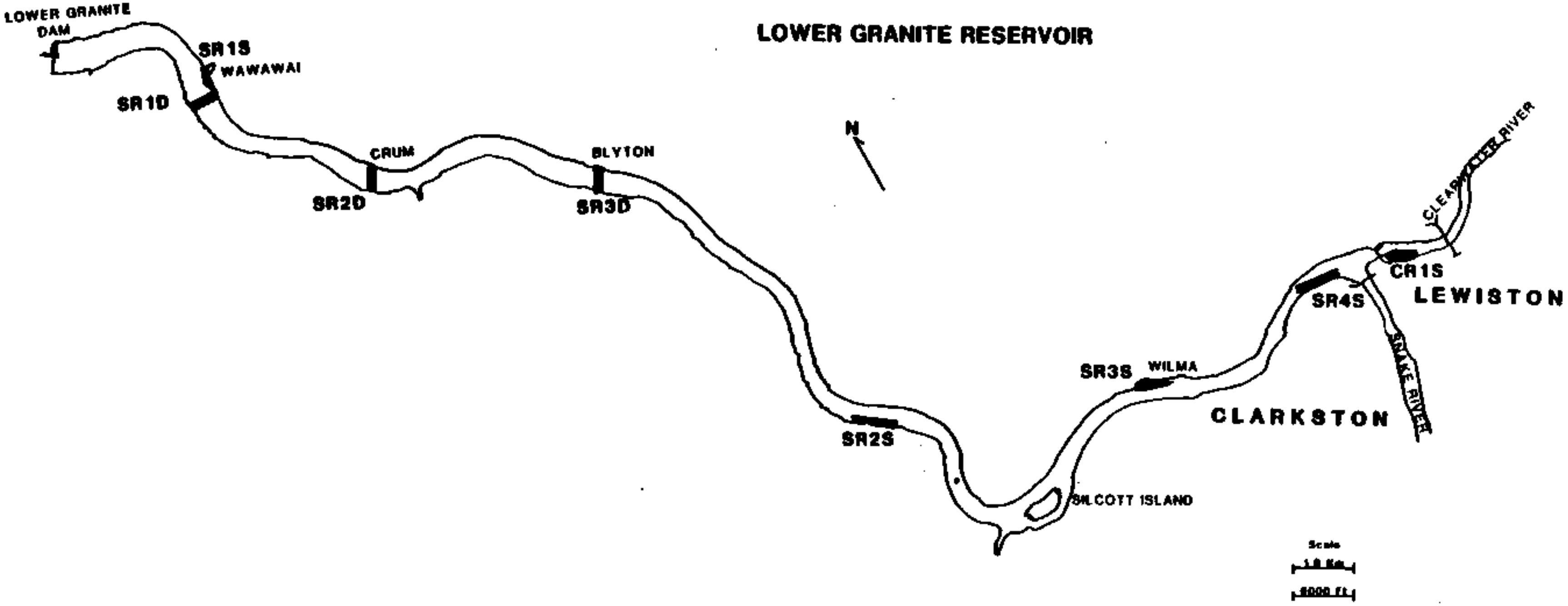


Fig. 1. Eight study sites in Lower Granite Reservoir in Idaho and Washington. Station numbers indicate whether the site is deep water (e.g. SR1D) or shallow water (SR1S).

Table 1. Physical characteristics of sampling stations on Lower Granite Reservoir, Washington and Idaho.

	STATION							
	CR1S	SR4S	SR3S	SR2S	SR1S	SR3D	SR2D	SR1D
River mile	1.0	138.94	133.98	127.63	111.24	119.56	114.0	111.24
Maximum channel width (km)	0.36	0.70	0.92	0.86	0.90	0.75	0.67	0.90
Maximum channel depth (m)	10.0	15.8	22.9	29.3	46.3	32.0	36.3	46.3
Maximum station depth (m)	2.4	4	7	5	10	32.0	36.3	46.3
Aquatic macrophytes	absent	present	present	present	present	absent	absent	present
Substrate	mud, silt, gravel	mud, silt	sand, mud, silt	small rubble, silt	small rubble, silt	mud, silt	mud, silt	mud, silt

ranges from silt and mud to small cobble with a gently sloping profile covered with short grasses and limited shrubs. In addition to the Port of Clarkston, some shoreline development (commercial docks) has occurred at the lower reaches of this station. Our sampling occurred above and below the Port of Clarkston grain terminal.

Moving downstream in Lower Granite Reservoir from SR4S, the next station is SR3S, immediately downstream from the Port of Whitman (Wilma) at river mile 134 (Fig. 1). This station has a diverse shoreline ranging from levee rip-rap to sand beaches. Water depth is shallow (1-3 m) relative to other shallow water stations (Table 1); shoreline substrate is exclusively fine particles. Streamside vegetation consists of short grasses, some willows and cattails (Typha latifolia).

SR2S, the next shallow water station, lies within the canyon portion of the reservoir (Fig. 1). Steep rock banks and several small alluvial fans characterize SR2S. Substrate consists of silt and mud to angular rubble which supports several large beds of pond weed (Potomogeton crispus). Alluvial fans along the canyon walls provide substrate for grasses and shrubs at the shoreline.

Shallow water station SR1S (the Wawawai boat landing) is furthest downstream (Fig. 1). Diverse habitat exists for aquatic life at SR1S as the shoreline ranges from rip-rap along a boat spit to pea gravel, sand beaches and silty backwaters. Extensive beds of P. crispus cover much of the bottom and contribute to habitat diversity.

Deep water stations are generally similar to each other in shoreline and substrate types. The uppermost station, SR3D, at river mile 119.56 is adjacent to the Blyton boat landing (Fig. 1). Open channel substrate is fairly uniform, consisting mostly of fine materials (<0.25 mm). Few aquatic macrophytes were observed along the shoreline. The west shore has submerged trees and stumps. Shoreline vegetation is sparse and consists of few grasses. Canyon walls border the west shore, while the east shore is rip-rapped. The channel narrows at SR2D (Table 1) creating slightly higher water velocities than at other deep stations. Substrate at this station is uniformly fine in open waters. Both east and west shorelines are steep, rocky, and barren of shoreline vegetation; we observed no macrophytes at this station. SR1D, the downstream, deep water station, is similar to SR3D in having a steep-sided western shoreline with submerged trees and a more gently sloping eastern shore consisting mostly of roadside rip-rap. Although SR1D is immediately adjacent to SR1S at Wawawai, the diversity of shoreline and substrate seen at SR1S does not exist at this station.

Objective 1
"To assess possible effects of dredge types (mechanical vs. hydraulic) on fishes."

Dredging methods can be divided into two broad categories, mechanical and hydraulic (Gren 1976). The basic difference between these dredging methods is the amount of water furnished with the dredged material (Mohr 1976). Mechanical dredges are usually bucket, clamshell, orange peel or dragline types. These dredges excavate and elevate bottom materials which are normally loaded into a barge and transported to a disposal site. Mechanical dredges are commonly used for small, localized dredging jobs or where rock deposits occur (Morton 1977). Bottom material production rates are low compared to hydraulic dredges and generally decrease with increasing depth (Raymond 1984). Because of the nature of sediment removal, mechanical dredges minimize interaction between sediments and the water column. Mechanical dredges are commonly employed with bottom materials that have volatile contaminants because less material is lost to resuspension (U.S. Army Corps of Engineers 1984). Also, dredge material is not diluted and it retains its insitu density (Lunz et al. 1984).

Mechanical dredges resuspend sediment in four ways (Barnard 1978): 1) when the bucket impacts on and is pulled off the bottom; 2) when surface material and material adhering to the outside is washed off the bucket; 3) when the bucket breaks the water surface and turbid water spills and/or leaks between the jaws; and, 4) when turbid water overflows in the transportation barge.

In contrast, hydraulic dredges actually remove and transport sediments by suction and pumping. Hydraulic dredges mix large volumes of water with sediments to form a slury which is piped or barged to a disposal area. Some hydraulic dredges use a revolving cutterhead to break bottom materials which facilitates drawing the sediment up the pipe (O'Neal and Sceva 1971). Others employ a water jet to break or loosen bottom materials. Fluid velocities must be maintained at about 3.6 m/second to keep sediments flowing. Dredge material may be piped to a disposal site or loaded into a barge for disposal.

Numerous types of hydraulic dredges have been used. Those more commonly used for larger projects are pipeline dredges, cutterhead and hopper dredges (Barnard 1978). Pipeline dredges must have disposal areas close to the dredging operation. Approximately 15-35% of the material is sediment and the remaining portion is water. Hopper dredges provide dredging and transportation of dredge material in a self-propelled vessel. Hopper dredges employ drag arms which extend down from a hydraulic dredge; dredge materials are raised by large centrifugal pumps, passed through drag pipes and discharged into storage bins or hoppers that can range from small (500-2,000 cubic yards) to large (> 6,000 cubic yards) capacity (U.S. Army Corps of Engineers 1984). Hopper dredges are considered to be the most economical type of dredge where disposal areas are not available within an economically feasible pumping distance. Using hopper dredges, overflow is possible which allows for maximum amount of high density material to fill the hopper (Barnard 1978). Without overflow, 20% of the dredged material is sediments, while the remaining 80% is water (U.S. Army Corps of Engineers 1984).

Aquatic environmental alterations from various dredging methods are a result of several factors. Three significant ones are: sediment resuspension, water quality alteration and organismal entrainment. Sediment resuspension from any method varies among sites, substrates dredged, dredge sizes and capabilities, and operator performance and training (Barnard 1978). Mechanical dredges generate variable amounts of sediment but considerably more than hydraulic dredges. Water-tight buckets can reduce resuspension by 30-70% over that from typical buckets. Comparing mechanical and cutterhead dredge sediment resuspension shows differences at all levels of the water column. Mechanical dredges typically generate more suspended sediments throughout the water column, whereas hydraulic dredges resuspend more near-bottom sediments. Hydraulic dredges typically elevate suspended solids around the cutter as the dredge swings back and forth across the dredging site (Raymond 1984). Sediment concentrations are elevated but highly variable, up to a few tens of grams/liter within about 3 m of the cutter, but decrease exponentially with distance from the cutter to the water surface. Near bottom resuspensions can be elevated to a few hundred milligrams/liter at distances of about 300 m from the cutter. Highest suspended solid concentrations reported by Sustar et al. (1976) from a hopper dredge were 2600 mg/l. As summarized by Raymond (1984), cutterhead and hopper dredges without overflow affect sediment resuspension near the bottom, whereas hopper dredges with overflow and bucket dredges affect the entire water column.

Hopper dredges can be operated to overflow, which is the most economically efficient, or be operated not to overflow (Barnard 1978). Hopper dredges, when overflowing, resuspend more sediment than a cutterhead dredge or hopper dredge without overflow. When overflow is used with a hopper dredge, the nature of the dredged material also affects resuspension. For example, if dredged material were clean sand, the proportion of solids in the overflow is small. If overflow were used, modified discharge ports moved from sides to the bottom of the dredge hull show considerable reduction in sediment resuspension at surface and about 1 m below. A key factor affecting sediment resuspension with hopper dredges is from prop wash in shallow water because of their large size.

Based on this review, hydraulic dredges resuspend less sediment than mechanical dredges. Barnard (1978) indicated that the cutterhead dredge had the least effect on sediment resuspensions during dredging followed by a hopper dredge without overflow, followed by the clamshell and hopper dredge during overflow periods. Sustar et al. (1976) concurred in their evaluation of sediment generated by various dredge types with Barnard (1978). An added advantage of hopper dredges is they usually dredge for less than 30 minutes which allows sediment levels to quickly return to ambient in moving water systems.

Effects of suspended sediments on survival of aquatic biota from laboratory studies suggest minimal adverse affects from dredging activities. Peddicord and McFarland (1978) reported that golden shiners (see Appendix A-1 for scientific names of fishes), 4.5-5.5 cm long, were highly tolerant of suspended sediment. They reported that 20% mortality occurred at 20.7 g/l during 21 days of exposure. They also found that rainbow trout fingerlings survived 21 days exposure to suspensions of uncontaminated sediments of 4.3 g/l. Tadpole larvae of the western toad (Bufo boreas) survived suspensions of 2.7 g/l of sediment for at least 13 days. Peddicord and McFarland (1978) also tested larval damselflies (Enallagma sp.) and reported 20% mortality at 2.1 g/l after 21 days. In sharp contrast, Herbert and Merkins (1961) tested 10 cm rainbow trout at concentrations of 0.27 g/l suspended sediment and reported 42% mortality. Herbert and Merkins (1961) were subjecting fish to kaolin clay and diatomaceous earth, whereas Peddicord and McFarland (1978) were using uncontaminated harbor sediment. Comparison of test results suggest differential tolerance by fishes to different particle sizes. Regardless, results of these tests suggest that sediments suspended by dredging, either mechanical or hydraulic, are considerably lower than those that result in mortality and thus, dredging would not create lethal conditions to biota. Even under the most extreme conditions of resuspensions as a result of dredging, short exposures to suspended solids would not result in mortality to most organisms.

A second concern with dredging is in water quality. Water quality considerations are significant when sediments are contaminated and/or associated with organic matter. In general, mechanical dredges have been more commonly employed with bottom materials that have volatile contaminants as less material is lost to resuspension. However, with sediment-bound contaminants, hydraulic dredges are more efficient and more commonly used over mechanical dredges (U.S. Army Corps of Engineers 1984). Dissolved oxygen depressions at a dredging site are related to the biochemical oxygen demand (BOD) of the sediments. Sediments with low organic content usually have low BODs. For example, Smith et al. (1976) found no significant oxygen depression as a result of dredging and disposal of sands from a hopper dredge. Data presented by Dorband (1980) suggest low sediment organic matter (1.1-2.0%) in substrates throughout Lower Granite Reservoir. These low amounts of organic matter should not exert high sediment BOD's or cause oxygen depressions that will be deleterious to aquatic biota.

A third consideration for fishes is entrainment. Fish entrainment mortality is considerably lower with mechanical dredges than hydraulic dredges. Arseneault (1982) reported mortality of 85-98% for organisms entrained in hydraulic dredges, although total losses of chum and pink salmon fry were low (<.0001%). Salmonid fry can be entrained by hydraulic dredges and, as a result, Armstrong et al. (1982) believed all suction dredging should be avoided at the time of their availability. They indicated that clamshell dredges should be given first priority when salmonids are present as mechanical dredges can reduce mortality by 95%. Boyd (1975) reported that fish are attracted to hopper dredges and that even adults can be drawn into the hopper. He stated that suction pumps can attract, capture and transport salmonid fry although only a small proportion of the population actually was extrained. Boyd

(1975) identified seven potentially adverse affects to fishes from dredging:

1) delay upstream migrating salmonids
2) destruction of upstream migration and spawning adults
3) destruction of spawning areas
4) destruction of eggs in spawning areas
5) capture and destruction of juvenile fish migrating downstream or inhabiting river
6) destruction of rearing habitat
7) alteration of current flow patterns

As a result Boyd (1975) recommended that dredging be avoided in the Fraser River when salmonids are migrating and dredging should be avoided in rearing and holding habitat.

Several of the adverse effects listed by Boyd (1975) for the Fraser River generally apply to Lower Granite Reservoir because of its narrow width and importance to salmonid fishes. Proper timing of dredge activities would lessen the potential for adverse affects. Entrainment by hydraulic dredges could be the most significant potential deleterious affect to fishes associated with dredging activities in Lower Granite Reservoir. As indicated earlier, Arseneault (1982) and Boyd (1975) both suggested the potential for mortality from entrainment associated with hydraulic dredging. Based on these studies, hydraulic dredging activities should be avoided at the time of downstream smolt activity. Timing of hydraulic dredging activities should be confined to times (seasonally and temporally) when smolt densities are low . Based on the literature, if dredging must be continued into the smolt run, mechanical dredges should be used until the majority of smolts have moved through Lower Granite Reservoir. The optimum time for dredging and length of the possible dredging "window" are discussed in further detail under Objective 3.

Objective 2
"To assess possible effects of in-water disposal methods (hopper dredge vs. split hull barge) on fishes."

More literature is available on dredge types and their ecological effects than on various means of disposal (Waters and Thorn 1976). In-water disposal generates higher concentrations of suspended solids than dredging. Although solids suspended during dredging return to near ambient conditions within several hundred meters of the dredge, disposal can increase solids as far as 1000 m or more from the disposal site (Sustar et al. 1976). Typically, three means of disposal have been employed: dumping from the bottom of a barge; pumping out via nozzles; and, discharging into the barge wake. Dumping from the bottom of a barge by means of bottom doors is considerably faster (6-12 minutes) vs. dump-pumping which can take up to 2 hours (Welte 1976). A fourth method, sidecasting for beach nourishment, is another disposal system recently used (Krizek et al. 1976).

Disposal and the behavior of the dredged material is affected by a number of factors. One factor is the percent moisture content which varies with the nature of material being dredged, type of dredge, vertical position within the transport vehicle and the time between dredging and disposal. Percent moisture content is low for mechanical dredges and high for hydraulic dredges. The percent moisture content determines the quantity of material that will reach the bottom in a given time interval, the area the dredge material will cover and the direct and immediate impact on pelagic and benthic fauna. Another key factor in turbidity generation during disposal is grain size. Raymond (1984) reported that coarse grained fractions (>0.074 mm) settle rapidly under normal conditions of water turbulence and, as a result, don't contribute significantly to turbidity. Clay and organic components are mainly responsible for turbidity generation. Discharged material dispersed in three ways: coarser materials (clayballs, gravel or sand) settled quickly to bottom and usually accumulated directly beneath the discharge point; finer grained materials in a slurry descended to the bottom and formed a fluid mud mound (Barnard 1978). A small proportion was suspended as a turbidity plume. The characteristics of the plume vary with discharge rate, character of dredged material slurry, water depth discharge configuration and hydrodynamic regime.

Water depth at the disposal site is another factor that determines the fate of the disposed materials. In marine waters less than 50 m deep, a high proportion of the dredged material falls within 200 m of the initial impact (Requegnat 1983). Over 90% will fall within a 120 m radius of where disposal occurred. Smith (1976) monitored disposal of a hopper dredge and found that the sediment cloud arrived later with increasing depth; the surface plume arrived about 10 minutes earlier than the bottom plume which persisted for a longer period of time. However, these studies were conducted in marine waters; in-river disposal may have entirely different currents associated with disposal and may respond considerably different than reported by Requegnat (1983) and Smith (1976).

The basic behavior of dredged material from a hopper dredge was examined by Sustar et al. (1976). They found that sediments pumped through the bottom (> 7 m below surface) start as a discoloration of surface waters. Upon impact with the bottom a density flow or turbidity cloud develops to a few meters in the water column. The suspended sediment concentration ranges from 0.5 - 5% of total sediments in a barge. The bottom plume can move up to 1400 m before decreasing to ambient solids level.

The nature of the discharge can ostensibly affect the turbidity generated at disposal. Submerging the discharge below the surface may reduce slurry dispersion and turbidity (Barnard 1978). Discharge pipes can be extended to allow disposal below the surface to eliminate a visible surface plume. Also, a deflector or splash plate mounted on the end of the discharge pipe may reduce velocity to accelerate settling and generate less water column turbidity. Older hopper dredges had hinged doors, whereas newer dredges have a split hull. Optimum disposal would seemingly be that which would enable the dredge material to fall through the water as a well defined mass of high density fluid that would result in little movement from the point of impact. A split hull disposal would seemingly facilitate this type of disposal as compared to pumping that would increase turbulence in the discharge, increase downstream distribution of a turbidity plume and require considerably more operation time.

According to Raymond (1984), coarse grained materials (>0.074 mm) settle rapidly which provides some insight into the nature of sediment distribution in Lower Granite Reservoir, if in-water disposal were implemented. Dorband (1980) reported that clay (about 10%) particles (<0.005 mm) and organics (1.1 - 2.0%) were not abundant at any of his sampling sites throughout Lower Granite Reservoir. Heavier silt particles (0.020 - 0.062 mm), however, were abundant (about 35%). The remaining substrate composition was that of larger material (>0.062 mm). Using Dorband's (1980) data, we believe that about half of the material would rapidly sink and result in little turbidity. The silts and clays, which constitute about 50% of the potential dredged material, could contribute to a turbidity plume and significantly alter the concentrations of suspended solids downstream of the in-water disposal site. All studies reviewed that examined the behavior of dredged material at the disposal site were conducted in marine waters. Currents through Lower Granite Reservoir would probably transport the turbidity plume and suspended solids further from the disposal site than would occur in marine waters. Sustar et al. (1976) reported a bottom plume up to 1400 m from the disposal site in marine waters. We believe that if in-water disposal were conducted in Lower Granite Reservoir, concentrations of suspended solids could be significantly elevated for several miles downstream. From studies reviewed, it seems possible that the clay component of the dredged material could be suspended through the reservoir and possibly further downstream. Silt particles would probably be moved several miles downstream by currents and possibly into Little Goose Reservoir.

Literature on the tolerance of fishes to suspended solids is weak. Cordone and Kelly (1961) reviewed available literature on the influence of inorganic sediments on aquatic life and concluded that results from carefully controlled experiments were rare. Wallen (1951) reported that individuals of 380 fishes tested survived "turbidities" of more than 100,000 PPM for a week or longer but these same fishes died at turbidities of 175,000 to 225,000 PPM. Wallen (1951) indicated that lethal turbidities resulted in death of fishes within 15 to 120 minutes after the onset of the exposure. Mortality was attributed to clogged gill filaments with silty, clay particles. In another study, Griffin (1938) subjected cutthroat trout to turbidities as high as 3,500 PPM although turbidities were maintained at 360 - 600 PPM. Mortality of cutthroat trout was 44% in the sediment trough. In addition, Griffin (1938) exposed chinook salmon to acute turbidities from 3,100 - 6,500 PPM and continuous turbidities of 300 - 480 PPM and found 12% mortality. Both tests had significant mortalities in control troughs but nevertheless, results suggest fish have high tolerance to acute exposures of sediments. Campbell (1954) exposed rainbow trout to turbidities of 1,000 - 2,500 PPM associated with gold dredging. Trout mortality was 57% over a 20 day period compared to 9.5% in the control. Kemp (1949) considered 3,000 PPM dangerous to fish and mollusks, if maintained for a period of 10 days. These results, although scanty, often inconclusive and somewhat contradictory, do show that fish possess the ability to survive short exposures to relatively high concentrations of suspended inorganic materials. We believe that results from these studies need to be applied with caution as the actual measurement of turbidity (PPM) is not clear in much of the older literature. If turbidity were measured gravimetrically, these results would be equivalent to a measure of suspended solids. However, considering equipment available at the time of these studies, results were probably measured optically and although expressed as PPM were not equivalent to suspended solids. For this reason caution must be exercised in the direct application of results from earlier studies.

Applying results from these studies to potential effects from in-water disposal suggests that localized adverse affects could occur in the immediate area of sediment disposal. Benthic invertebrates would be covered and most would not survive within the disposal site. This mortality would occur in areas receiving the bulk of the dredged material which would be localized at the disposal site. Some fish inhabiting the disposal site could be covered by the dredged material and not survive, but, more likely, fish would move to areas not directly affected by disposal. Concentrations of suspended solids could be sufficiently elevated to result in some mortality to fish if they were unable to migrate to unaffected areas. If suspended solids would range from 0.5 - 5.0% of the barge load in waters immediately surrounding the disposal site, as reported by Sustar et al. (1976), concentrations could exceed the tolerance of fishes for short periods. Studies do suggest, however, that fish would attempt to avoid waters with high suspended solids (Sumner and Smith 1939; Smith 1940) in preference for clear waters. Therefore, if fish could avoid suspended sediments from disposal of dredged material, they would select clearer waters.

Another potential adverse affect of in-water disposal could be in reduced fishing success for steelhead trout. Reservoir fishing for steelhead trout has recently become popular with anglers. Several sites identified for in-water disposal are popular reservoir fishing sites for steelhead trout or are downstream of proposed disposal sites. Increased turbidities could adversely affect fishing success and fishing effort downstream of the in-water disposal activities. A more thorough review of the effects of turbidity on fishing success is included under Objective 4.

Objective 3

"To determine the appropriate time and period of dredging and in-water disposal."

Seasonal restrictions often are applied to dredging projects to protect sensitive life history stages of significant biological resources from physical and chemical alterations of aquatic habitats (Lunz et al. 1984). However, seasonal restrictions may complicate scheduling, funding and contracting, increase project costs, increase the hazards of field operations and may not be supported by technical data. To assess the appropriateness of seasonal restrictions, Lunz et al. (1984) identified five principal issues that should be examined:

1) survival and development of egg and larval stages of fishes, especially anadromous fishes and commercially important flatfishes;
2) survival and development of egg and larval stages of shellfishes, especially oysters and clams;
3) survival and movements of juvenile fishes and shellfishes;
4) survival, growth, and movements of adult and subadult shellfishes in response to siltation and suspended sediments; and,
5) survival and movements of adult and subadult fishes.

If these five issues do not pertain to the project area then seasonal restrictions are not warranted. However, in Lower Granite Reservoir, several issues (1, 3, 5) directly pertain which suggests the need for closer examination of the timing of the proposed dredging project.

Use of Lower Granite Reservoir by anadromous salmonids is the basis for major concern over sediment dredging and disposal activities in the reservoir. Adult salmonid use initiates with early movement in March by steelhead trout (Fig. 2). A slight peak occurs around mid-April and then numbers decrease. Although steelhead trout numbers passing over Lower Granite Dam decrease after mid-April, numbers of adult spring chinook salmon increase until mid-May and then a second smaller peak occurs around late June by summer chinook salmon (Fig. 3). By September, adult fall chinook salmon are migrating through the reservoir until early November. At the same time that numbers of fall chinook salmon are increasing, adult steelhead trout numbers are increasing and peak in mid to late September.

The sports fishery for steelhead in the lower Clearwater River commences in late September, generally peaking in November (Fig. 4) and late February (unpublished data, Idaho Department of Fish and Game, 1984-85 fishery). The winter and early spring fishery is based on the availability of suitable water and weather conditions. Data demonstrate that if conditions were favorable for fishing as in 1984-85, anglers have an interest in the fishery.

Smolt movements through the reservoir are of similar duration (late March - mid July) for both chinook salmon and steelhead trout (Figs. 5 and 6). The peak in the chinook smolt migration occurs from 1-2 weeks earlier, around late April, than that for steelhead trout which occurs in May. As can be seen in Figures 5 and 6, the timing of smolt movement in Lower Granite varies little from year to year. Collectively, smolt movement in the upper reservoir,

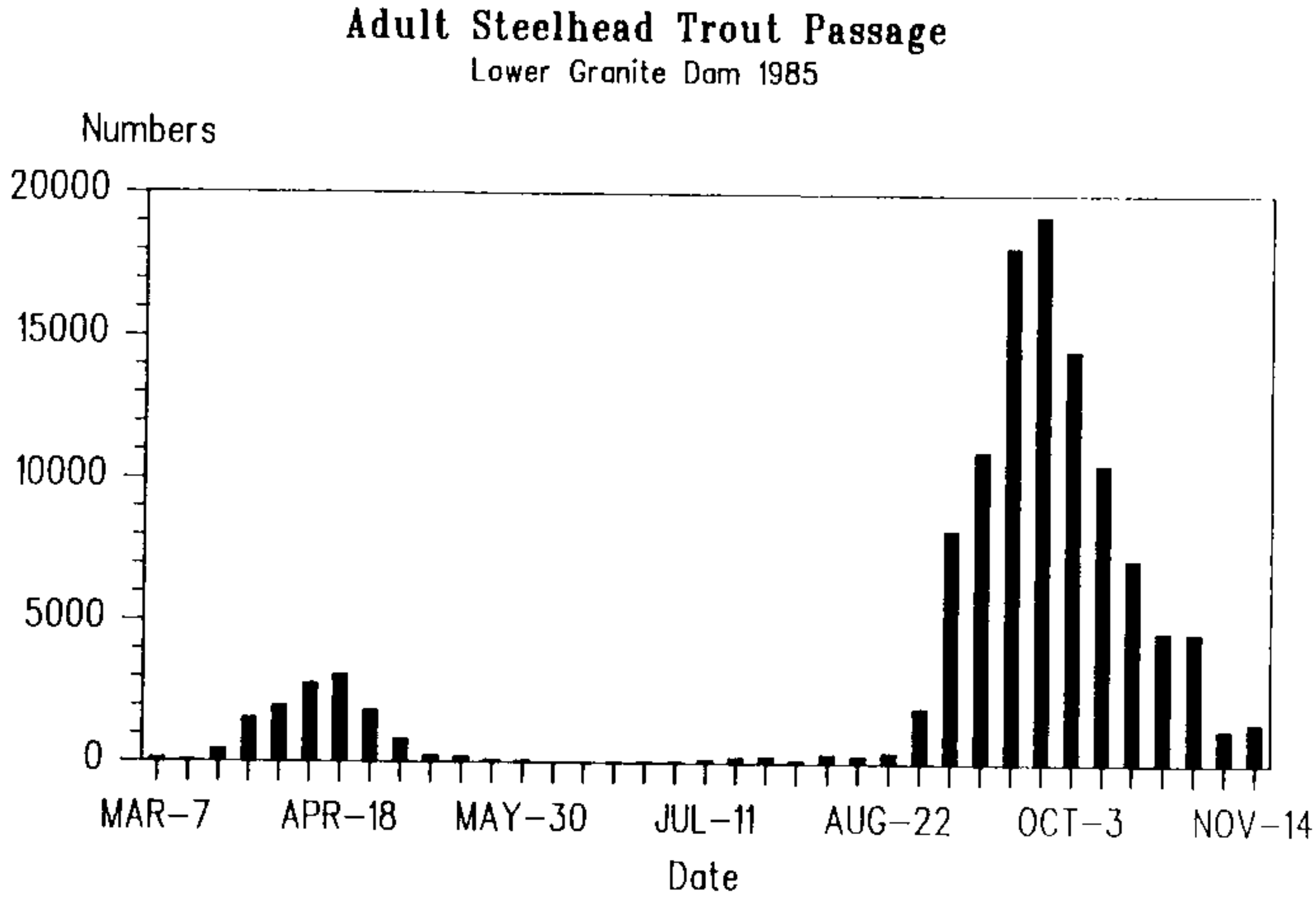


Figure 2. Number of adult steelhead trout passing over Lower Granite Dam during 1985. (Data from U.S. Army Corps of Engineers, Lower Granite Dam, Washington).

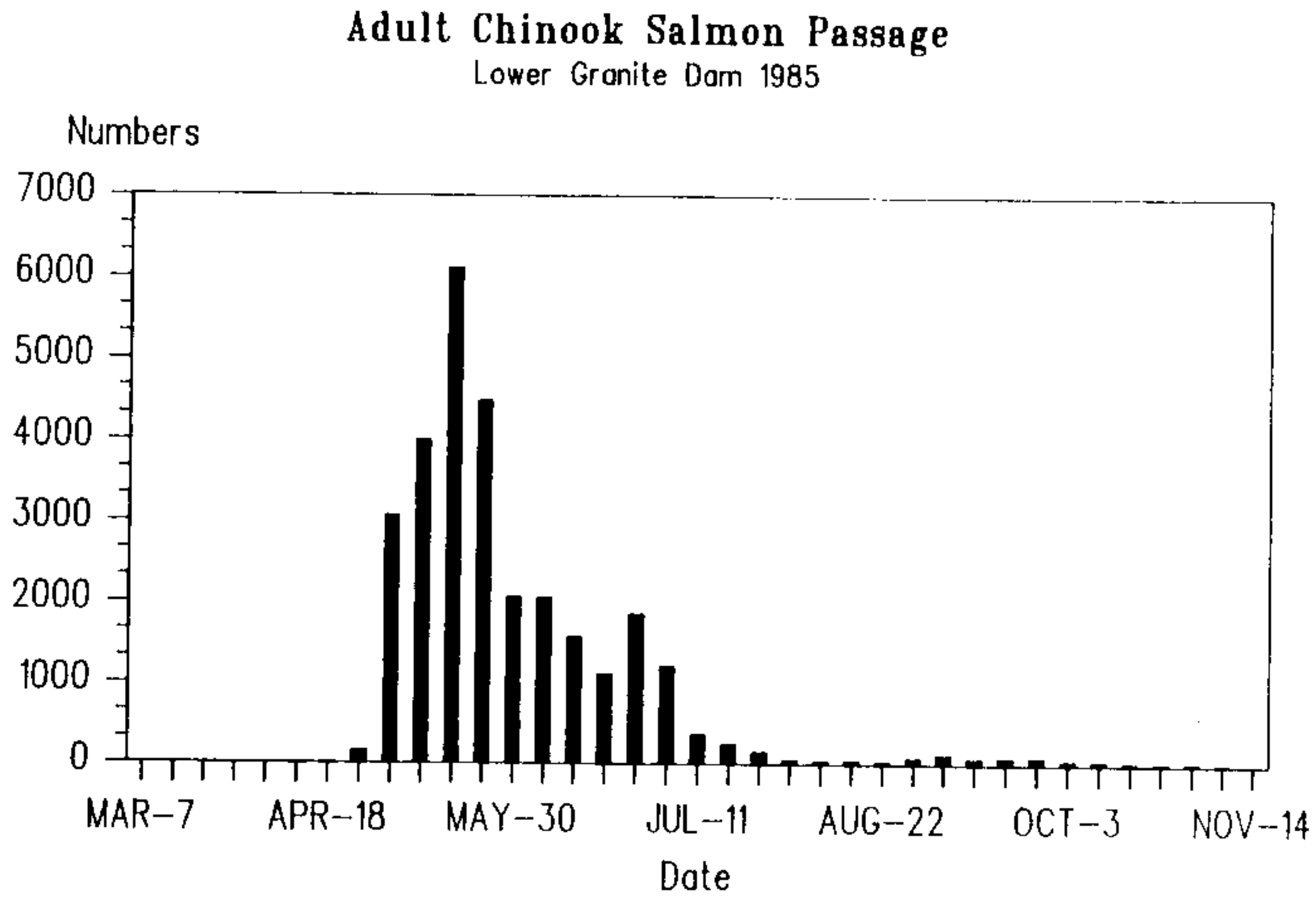


Figure 3. Number of adult chinook salmon passing over Lower Granite Dam during 1985. (Data from U.S. Army Corps of Engineers, Lower Granite Dam, Washington).

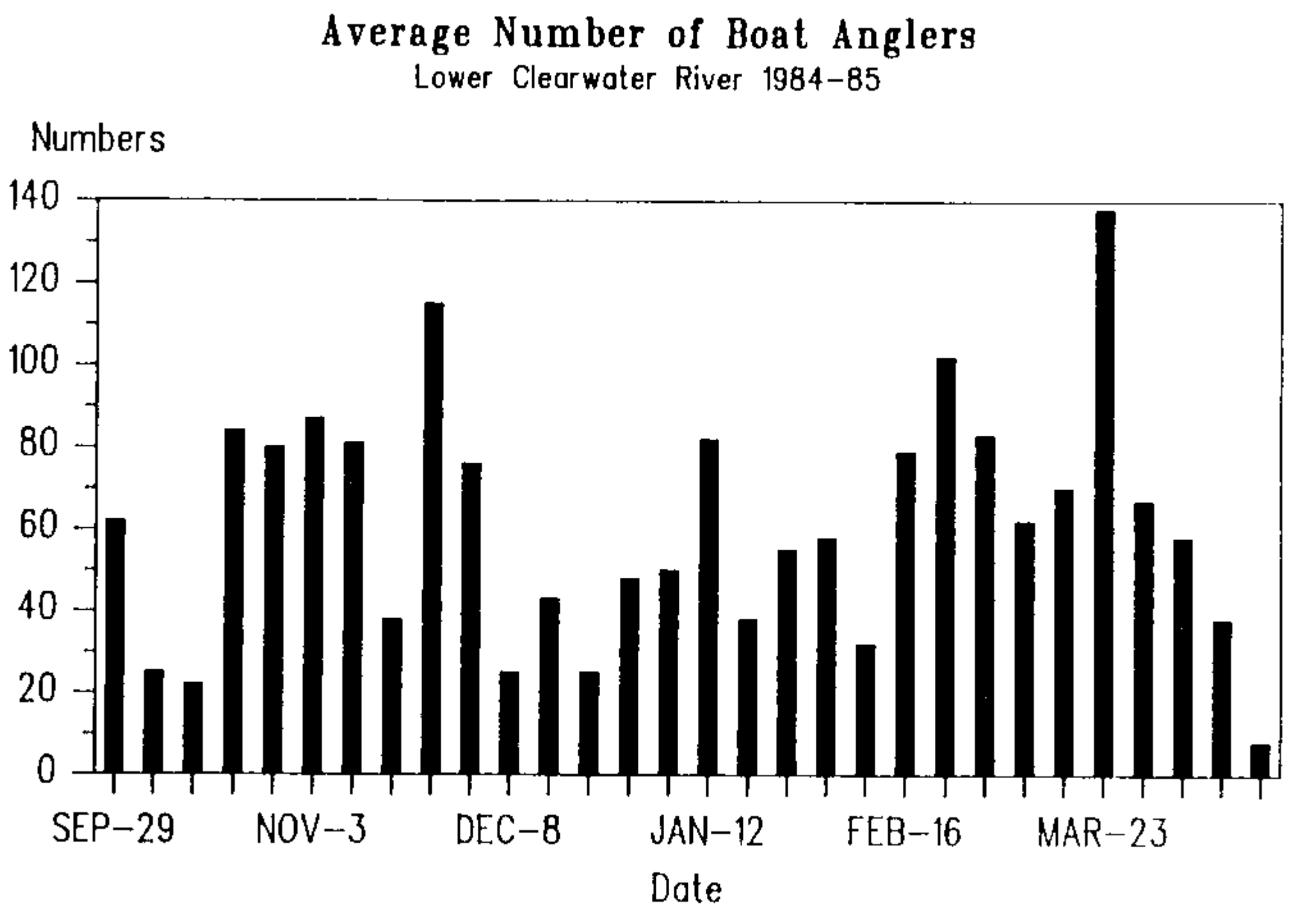


Figure 4. Average number of boat anglers counted during the 1984-85 fishing season on the Clearwater River, Idaho. (Data from Idaho Department of Fish and Game). This figure covers the entire lower Clearwater River from the North Fork to the mouth.

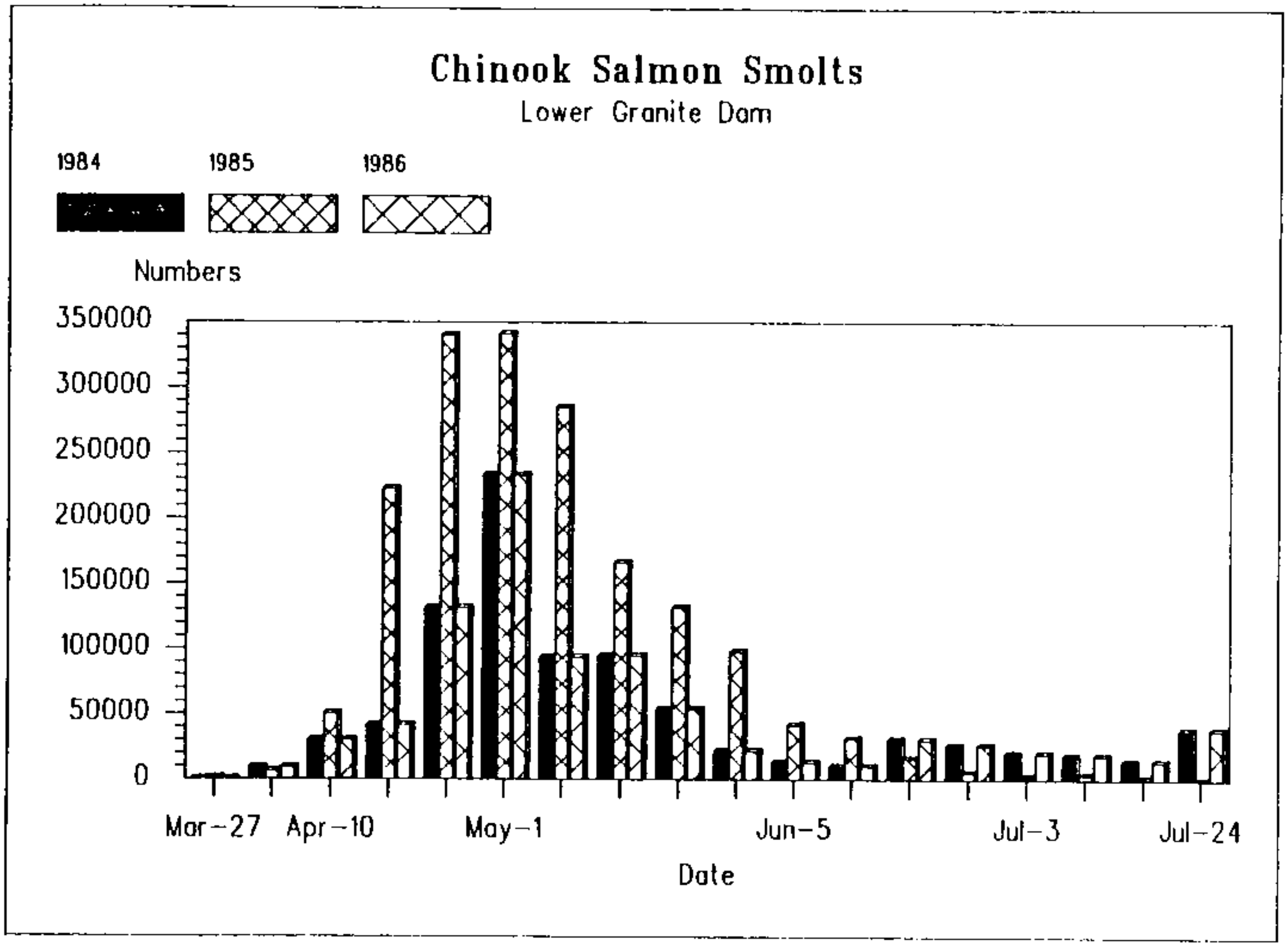


Figure 5. Chinook salmon smolt movement through Lower Granite Reservoir during 1984, 1985 and 1986. (Data from U.S. Army Corps of Engineers, Lower Granite Dam, Washington).

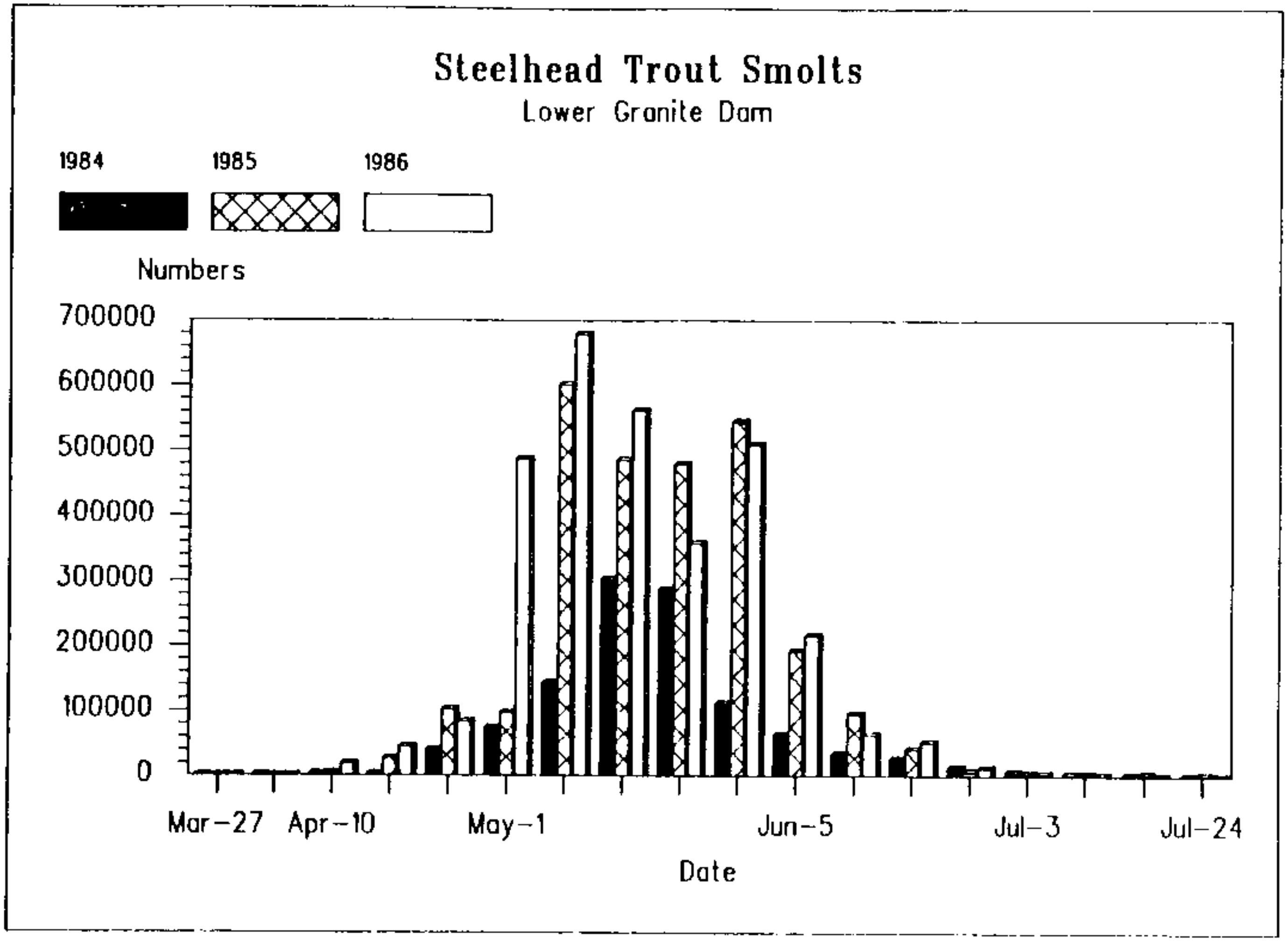


Figure 6. Steelhead trout smolt movement through Lower Granite Reservoir during 1984, 1985 and 1986. (Data from U.S. Army Corps of Engineers, Lower Granite Dam, Washington).

based on captures at the Idaho Department of Fish and Game trap near Lewiston, Idaho, shows most activity from late March through June (Fig. 7). Data collected during this study (Objective 6) showed the presence of juvenile salmonids in Lower Granite Reservoir from October through June although numbers are comparatively lower than in April and May when smolts are actively moving through the system.

The potential impacts of dredging and disposal on resident fishes also is a concern. For most resident fishes, periods of active spawning and rearing generally occur in late spring to late summer. Survival and development of egg and larval stages of fishes, expressed by Lunz et al. (1984; issue #1), should be a concern for shallow water spawners. Based on our sampling (Objective 7) and previous research in the lower Snake Reservoirs (Bennett et al. 1983), spawning of fishes in Lower Granite Reservoir probably occurs from early April through August. Earliest spawning fishes are suckers and yellow perch followed by centrarchid, cyprinid and ictalurid fishes. Our sampling in Lower Granite did not show yellow perch to be high in overall abundance. Spawning and early life history development of other game species probably occurs between late June through August (Table 2). Survival and movements of juvenile fishes and shellfishes (Lunz et al, 1984; issue #3), is especially germane to maintenance of sport fishes in Lower Granite Reservoir. Therefore, the period from late spring to late fall is important for resident fishes in Lower Granite Reservoir. Our sampling has indicated that reduced fish activity occurs at all sites for most resident fishes from late

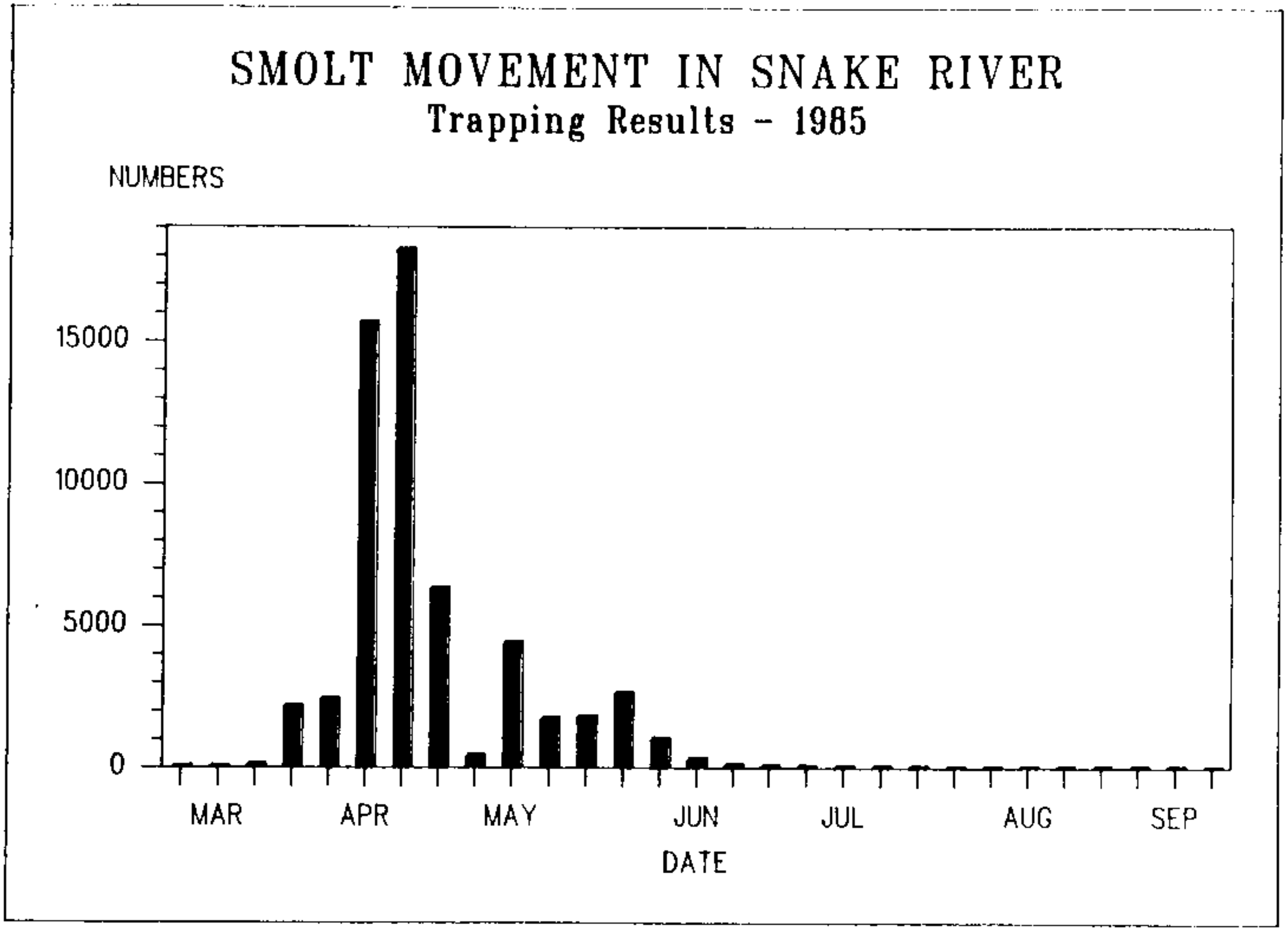
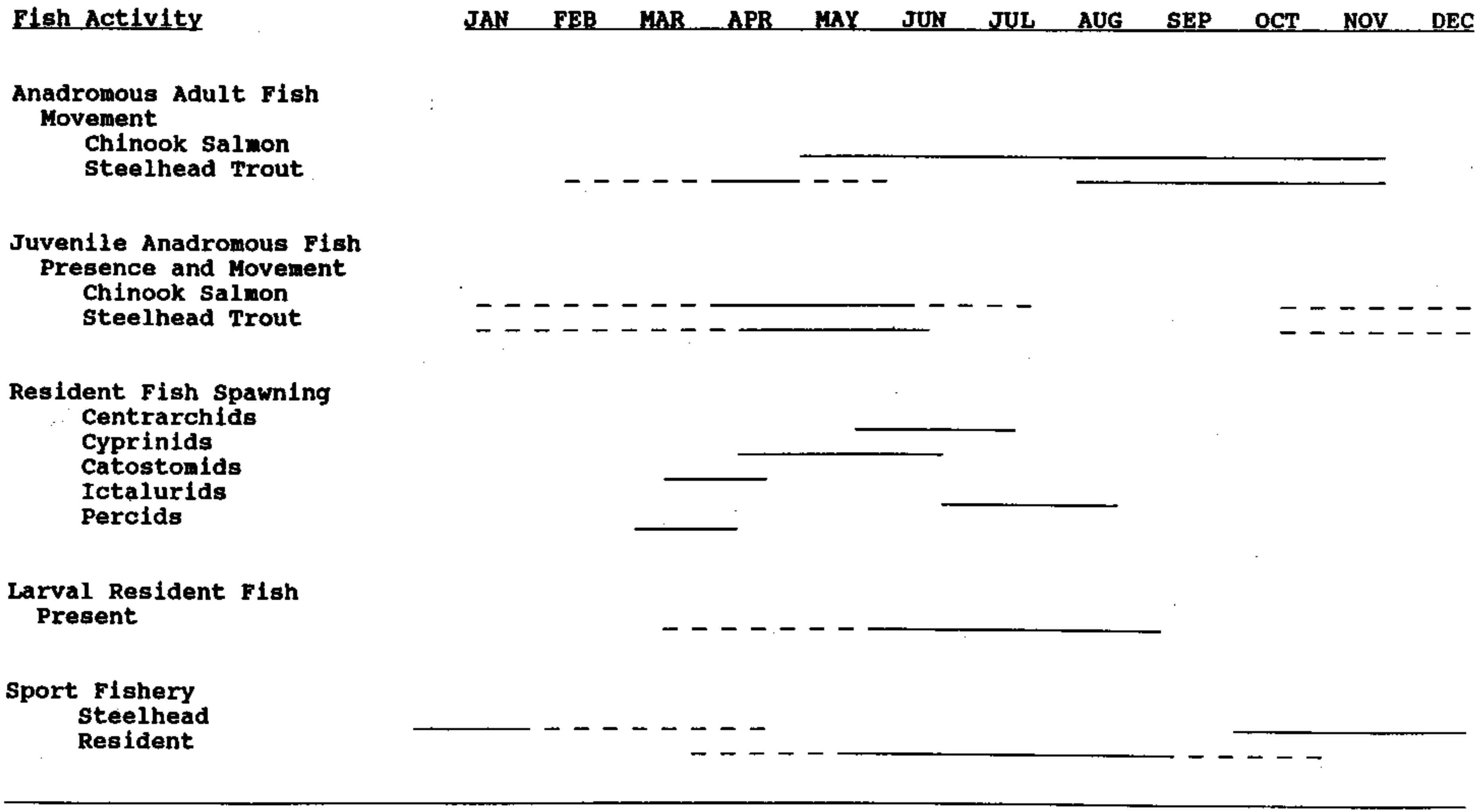


Figure 7. Salmonid smolt movement in Snake River near Lewiston, Idaho during 1985. (Data from Bonneville Power Administration, Portland, Oregon).

Table 2. Timetable of fish activity in Lower Granite Reservoir, Idaho and Washington. Anadromous fish results based on fish counts at Lower Granite Dam. Resident fish spawning times based on Bennett et al. (1983). Dashed lines indicate presence while solid lines indicate time of abundance or a high level of activity.



fall until late winter (Objective 6) especially at shallow stations.

Combining fisheries activity information provides a clearer picture of times when reduced interactions from dredging and disposal would occur (Table 2). With the exception of the sports fishery for steelhead trout, the period from December through mid-March probably would result in the fewest resource conflicts. Since most of the dredging and disposal operations are scheduled to occur downstream from the bulk of the fishery, this period may be more acceptable to resource managers than other times that could have deleterious affects on various life history stages.

Aspects of dredging and disposal necessitate use of a window to minimize resource conflicts. Entrainment appears to be the major adverse affect that could occur from hydraulic dredging although increased turbidities localized immediately downstream of the dredge could result in reduced fishing success for steelhead trout. In addition, in-water disposal operations could result in high turbidities and suspended solids considerable distances from the disposal site. We believe that fishing success and angler use in the lower reservoir will decrease as a result of increased turbidities. Suspended solids from disposal could exceed those tolerated by fish in areas immediately surrounding the disposal site. Our fishery data (Objective 6) suggest that the winter period would be the time for reduced fish activity. Other than decreased water turbidity and increased suspended solids, no other chemical changes are expected in water quality.

Based on fisheries information (Table 2), concerns expressed by Boyd (1975) over possible entrainment and potentially adverse concentrations of suspended solids during disposal, we believe that the period from late December through mid March would result in fewest resource conflicts. Therefore, a winter window, of 2 to 2.5 months duration would minimize resource conflicts.

Objective 4
"To assess the effects of dredging and in-water disposal on fishability."

A concern of fisheries managers is that turbidity generated by dredging and/or disposal will alter the catchability of sport fishes, especially steelhead trout. Although managers and anglers have inferred that sport fishing success declines with increasing turbidity, little data are available to support or refute this inference. In fact, little data are available that relate turbidity to fishing success. In Oklahoma, Buck (1956) compared two impoundments for sport fishing success, Heyburn Reservoir (1070 acres) with Upper Spavinaw (3192 acre) Reservoir. Heyburn Reservoir was classified as a turbid reservoir, while Upper Spavinaw was considered clear. Creel census provided data on fishing success in the two reservoirs. Buck reported that fishing success in Heyburn Reservoir was 0.25 fish/hour as compared to 0.94 fish/hour in Spavinaw. Also, higher catches of largemouth bass in the clear Spavinaw Reservoir were reported. A number of factors could affect fishing success in the two reservoirs. The main factor was that Heyburn Reservoir supported 66% of the biomass (117 lbs/ac) supported by Spavinaw Reservoir (177 lbs/ac). Buck (1956) concluded, however, that "the clear reservoir attracted more anglers and yielded greater returns per unit of fishing effort, as well as desirable species."

In Minnesota, Lux and Smith (1960) evaluated factors which influenced seasonal changes in angler catch. They concluded that food supply was inversely related to catch rates and the principal factor causing seasonal fluctuations in angler success. Turbidity, one of the physical factors examined, exerted little or no measurable influence on angler catch rates except as it may have influenced food abundance.

Studies that relate fishing success of migratory fishes to turbidity also are limited. In Oregon, on the Rogue River, fishing success for chinook salmon and steelhead trout generally declined when the turbidity ranged from 1 to 23 NTU. However, McPherson and Cramer (1982) and Cramer and McPherson (1980) could not significantly correlate turbidity with catch rates. The authors reported that other factors (flow and temperature), confounded the relationship. Only during a single year of this study could Cramer and McPherson (1980) significantly correlate winter steelhead trout catches and turbidity. Little difference in angler effort was observed up to 5 NTUs of turbidity but effort decreased above 5 NTU (McPherson and Cramer 1982). Their study showed the most deleterious effect of turbidity in the 1-10 NTU range was a decrease in angler effort.

In 1984, personnel of the Idaho Department of Fish and Game initiated collecting turbidity data, fishing success and angler use. These data probably represent the largest data set collected to date on this subject. Data were collected on three systems: the North Fork of the Salmon River, the Salmon River and the Clearwater River. Pearson product moment correlations demonstrated no significant association between fishing success (hours/fish) and turbidity for the North Fork ($r = -0.131$; $n = 20$) and the Salmon River ($r = -0.37$; $n = 15$). Although not significant, both correlations were negative which suggested that as turbidity increased, hours required to catch a fish decreased. The largest data set was for the Clearwater River where turbidity and sport fishing information were collected from late September 1984 (9/29/84) through mid-April 1985 (4/14/85). Although correlations were positive (hours to catch a fish increase with increases in turbidity), they were not significant for the entire data set ($r = 0.15$; $n = 79$) or for weekly means ($r = 0.04$; $n = 25$). Statistical transformations, to normalize the data, did not account for a higher proportion of variation between fishing success and turbidity.

Two important factors that could confound the relationship between turbidity and fishing success were weekends vs. weekdays and the number of anglers. Associations between angler numbers and fishing success also were not significant for the Clearwater River fishery ($r = -0.01$; $n = 79$), the North Fork ($r = -0.01$; $n = 20$) and the Salmon River ($r = 0.52$; $n = 15$). These analyses indicate no relationship between fishing success and the number of anglers. To examine this further, we tested using analysis of covariance the influence of weekends vs. weekday on fishing success as numerous people believe that fishing success was higher on weekdays. The adjusted means were not significant ($P > 0.10$) as the adjusted catch rates were nearly identical (26.5 vs. 25.4 hours per fish). The last comparison between fishing success for steelhead trout and different turbidity classes further corroborated results of our previous analyses. Although sample sizes were small, the relationship shows few differences in catchability among turbidity classes to > 20 NTU (Fig. 8). In fact, the mean number of hours to

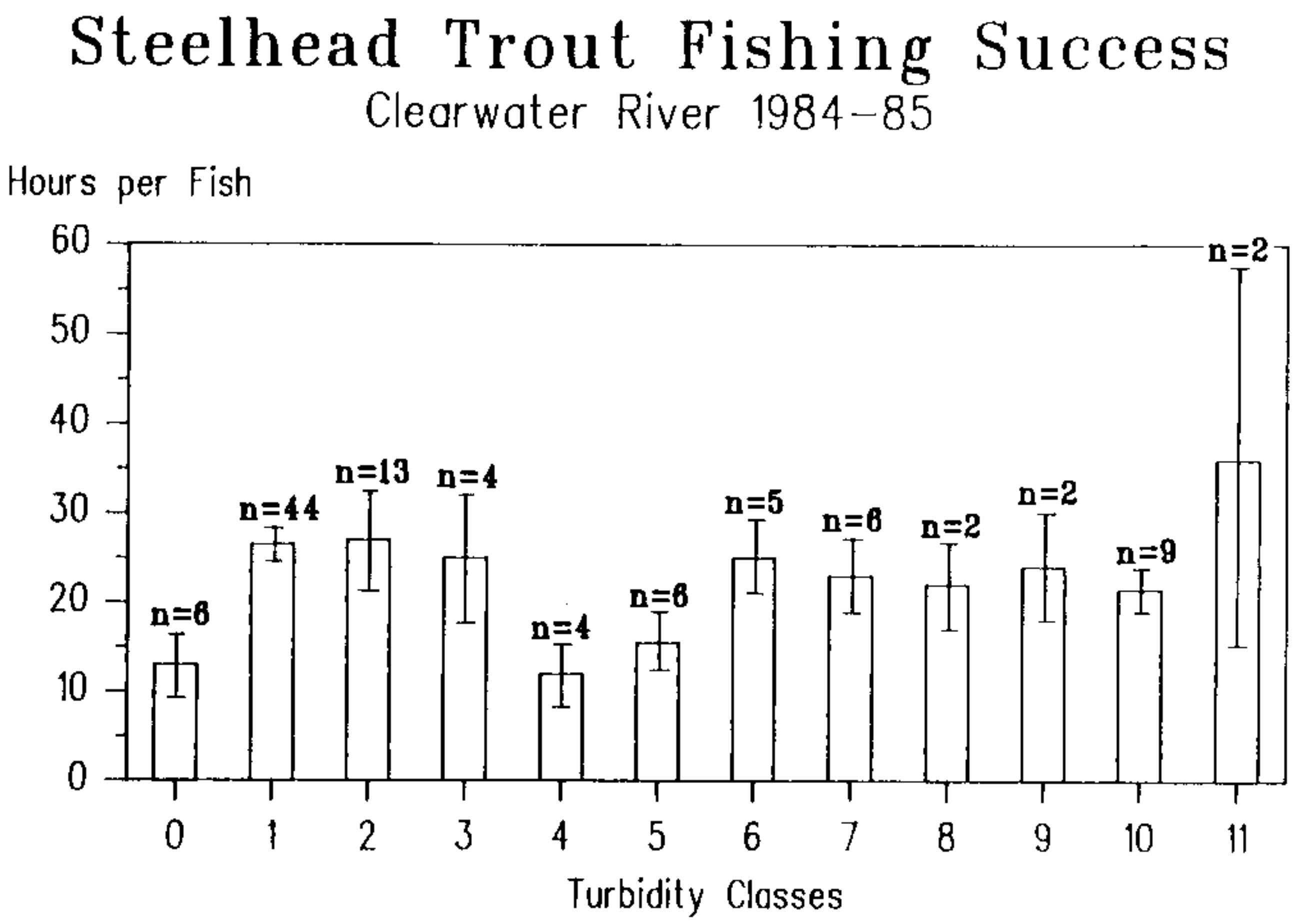


Figure 8. Mean fishing success (hours per fish) for steelhead trout as related to turbidity classes (0 = < 1 NTU; 1 = 1.0 - 1.9 NTU; 2 = 2.0 - 2.9 NTU; 3 = 3.0 - 3.9 NTU; 4 = 4.0 - 4.9 NTU; 5 = 5.0 - 5.9 NTU; 6 = 6.0 - 6.9 NTU; 7 = 7.0 - 7.9 NTU; 8 = 8.0 - 8.9 NTU; 9 = 9.0 - 9.9 NTU; 10 = 10.0 - 19.9 NTU; 11 = ≥ 20.0 NTU) for the Clearwater River, Idaho. Also shown are sample sizes (n) and ± standard error.

catch a fish was lowest at 4 NTUs followed by turbidities < 1.0 NTU although standard errors overlapped.

In summary, the relationship between fishing success and turbidity is poorly defined in the literature. Buck's (1956) results suggest that turbidity can influence sport fishing success and fish production. The study by Lux and Smith (1960) suggests that turbidity has little measurable influence on fishing success. Because of contradictions in available data, the influence of turbidity on fishing success in resident fishes is unclear and only speculation is possible. Our analysis of the steelhead trout fishing success data set suggests that a number of other factors account for a high proportion of variation in fishing success for steelhead trout, at least in the Salmon, North Fork of Salmon and Clearwater rivers. The limited data available indicate that on the average, slight increases in turbidity are probably not going to directly adversely affect fishing success for steelhead trout. As indicated by McPherson and Cramer (1982), however, angling effort may decline. To date, available data suggests that other physio-chemical and biological factors have an equal or possibly more significant impact on fishing success than low levels of turbidity.

Objective 5
"To characterize the physical habitat of proposed disposal sites."

Limnological data were collected seasonally on Lower Granite Reservoir from April, 1985 to March, 1986. Limited substrate sampling also was conducted in September 1986. Seasonal periods were spring (April - June), summer (July - Sept.), fall (Oct. - Dec.) in 1985 and winter (Jan. - Mar.) in 1986. Data collection occurred within a 5-week period during each season.

METHODS

Limnological sampling occurred over a 3 day period near the end of each season. Water velocity, temperature, and dissolved oxygen profiles were taken at each station along with benthic and sediment samples and water transparencies. Dissolved oxygen (mg/l) and temperature (C) were measured using a Yellow Springs Model 57 dissolved oxygen meter. To measure water velocity (feet/second), a Swoffer Model 2100-A2 digital electronic current meter was used. Water velocities were then converted to metric units (m/sec). At shallow stations, profile measurements were recorded every 1/2 m in depth, whereas measurements at deep stations were taken at 1/2 m intervals for the first 2 m, 2 m intervals for the next 10 m, and 5 m intervals thereafter (C. M. Falter, University of Idaho, Moscow, Idaho, personal communication).

Water transparency and turbidity were sampled at each of the eight stations. Water transparency was measured to the nearest 0.1

m using a standard 20 cm secchi disc. Water samples, collected in 1 liter plastic bottles, were transported to the University of Idaho laboratory for turbidity analysis. Turbidity levels were measured to the nearest 0.10 nephelometric turbidity unit (NTU) using a Hach turbidimeter.

Three measurements of temperature, velocity, and turbidity and three each of benthic and sediment grabs were made at each of eight stations. At deep water stations, the channel width was divided into approximately 1/3 intervals for sampling, whereas at shallow sites, an upper, lower and median location, about one-half the distance to shore, was randomly selected for sampling. In addition, temperature, turbidity, and transparency (time of day permitting) were taken every time a sampling station was visited.

We collected sediment samples by Ponar dredge (239.25 cm^2). Samples were transferred into covered plastic buckets and later washed through a series of sieves. Initial sieving was conducted at 76.2, 50.8, 9.5, 6.3, 4.75, 3.35, 2.00, 1.70, 1.00, 0.833, 0.500, and 0.250 mm. The volume of material in each sieve was measured by volumetric displacement and the quantity associated with each particle size recorded as a percent of the total volume. Because of the limited information that this method provided for smaller particle sizes, we took three additional sediment grab samples with a Ponar dredge to refine our substrate analysis at each of six study stations (not CR1S or SR4S) in September 1986. As before, we wet sieved from 76.2 mm to 2.00 mm for analysis of larger particle sizes and assessed their proportional contribution to the total sample. For analysis of the smaller particles we took

100 g subsamples of each of the three samples and oven dried them at 105 C. We then sieved these samples to remove particles larger than 2.00 mm and excluded these from the analysis. We then followed the Bouyoucos procedure using the hydrometer method for analysis of the percent sand, silt and clay (Day 1965). Since three samples were taken, we averaged the composition for each station.

RESULTS

Temperature

Temperature profiles at shallow and deep water stations show little variation within shallow and deep sites but differences were found between them. Little layering was found at shallow stations in the spring and summer although a small temperature differential existed between the surface and bottom. Late fall temperatures were nearly isothermic (4 C) at all stations. Water temperatures in the Clearwater River (CR1S) generally were 2 to 4 C cooler than those at the Snake River stations throughout the study (Appendix A-2). Deep water stations experienced little temperature differences among stations. Thermal layering was evident during the summer sampling period (Fig. 9).

Weekly average temperatures collected at various times throughout the study show the overall annual temperature cycle (Appendix A-2). Fall water temperatures were considerably lower in 1985 than those reported for 1979-80 for Little Goose Reservoir (Bennett et al. 1983).

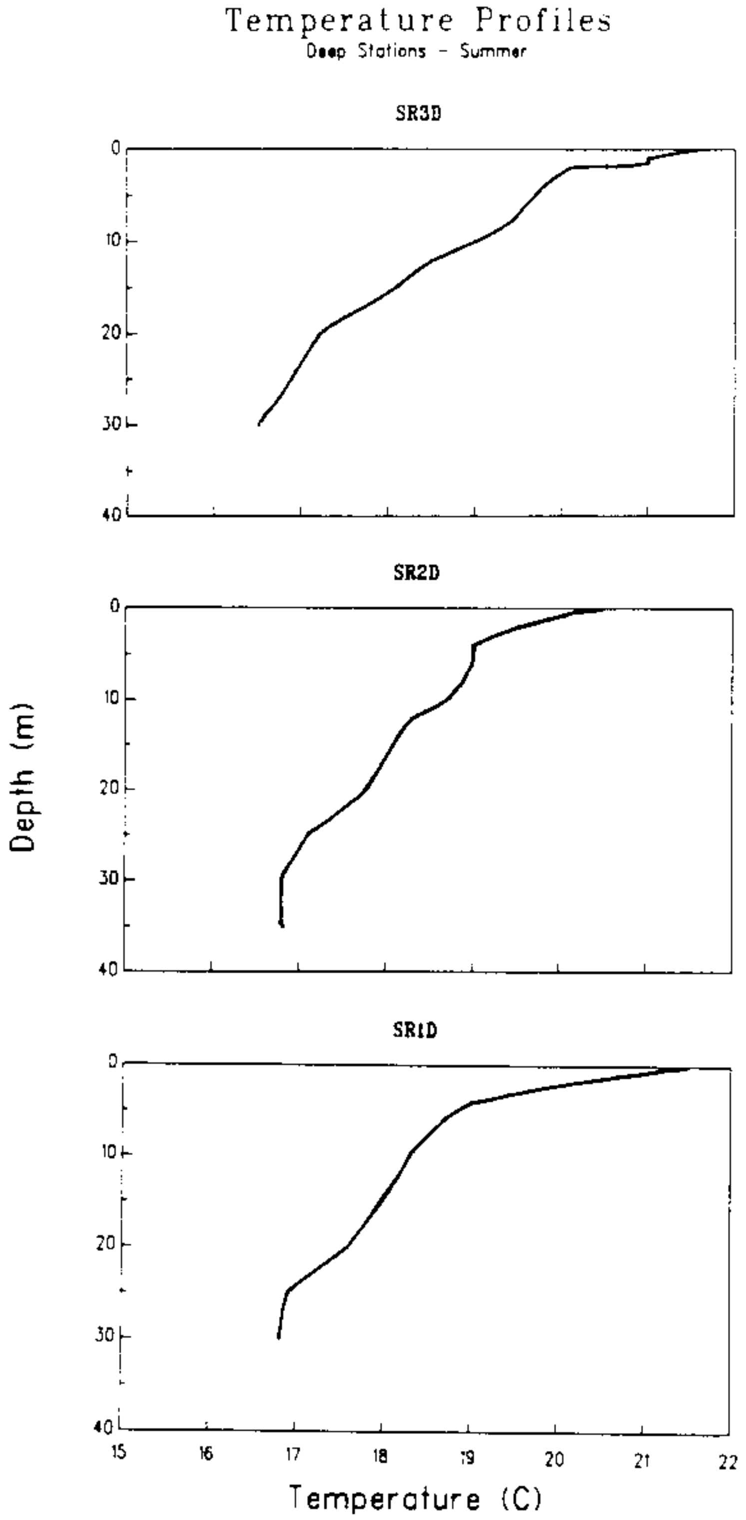


Figure 9. Summer temperature profiles at the deep stations on Lower Granite Reservoir, Washington, depicting thermal layering. Profiles were measured on 27 August, 1985.

Dissolved Oxygen

Dissolved oxygen profiles generally showed similar oxygen regimens within shallow and deep sites but variations between them. Dissolved oxygen profiles were similar among shallow stations and ranged from 8 to 14 mg/l. Although O_2 levels were lower near the bottom than at the surface of each shallow water station, dissolved oxygen levels never were considered limiting. In contrast, dissolved oxygen at deep stations, ranged from 2 to 13 mg/l. Dissolved oxygen levels below 25-30 m during the summer period indicated significant oxygen depletion (Fig. 10).

Water Velocity

Water velocities at all stations were highest in the winter (Figs. 11 and 12) and lowest in the summer. Water velocities ranged from 0 to 0.83 m/sec in shallow and 0 to 0.35 m/sec at deep stations. On the average, water velocities at shallow stations were highest at CR1S. Velocities were variable from surface to bottom, indicating non-linear flows within the shallow stations. Velocities for the deep stations were less variable than those at shallow stations. Some peaks in velocity were noted in the 10 to 20 m depth range which may have been an extension of water flow entering the gatewells at Lower Granite Dam.

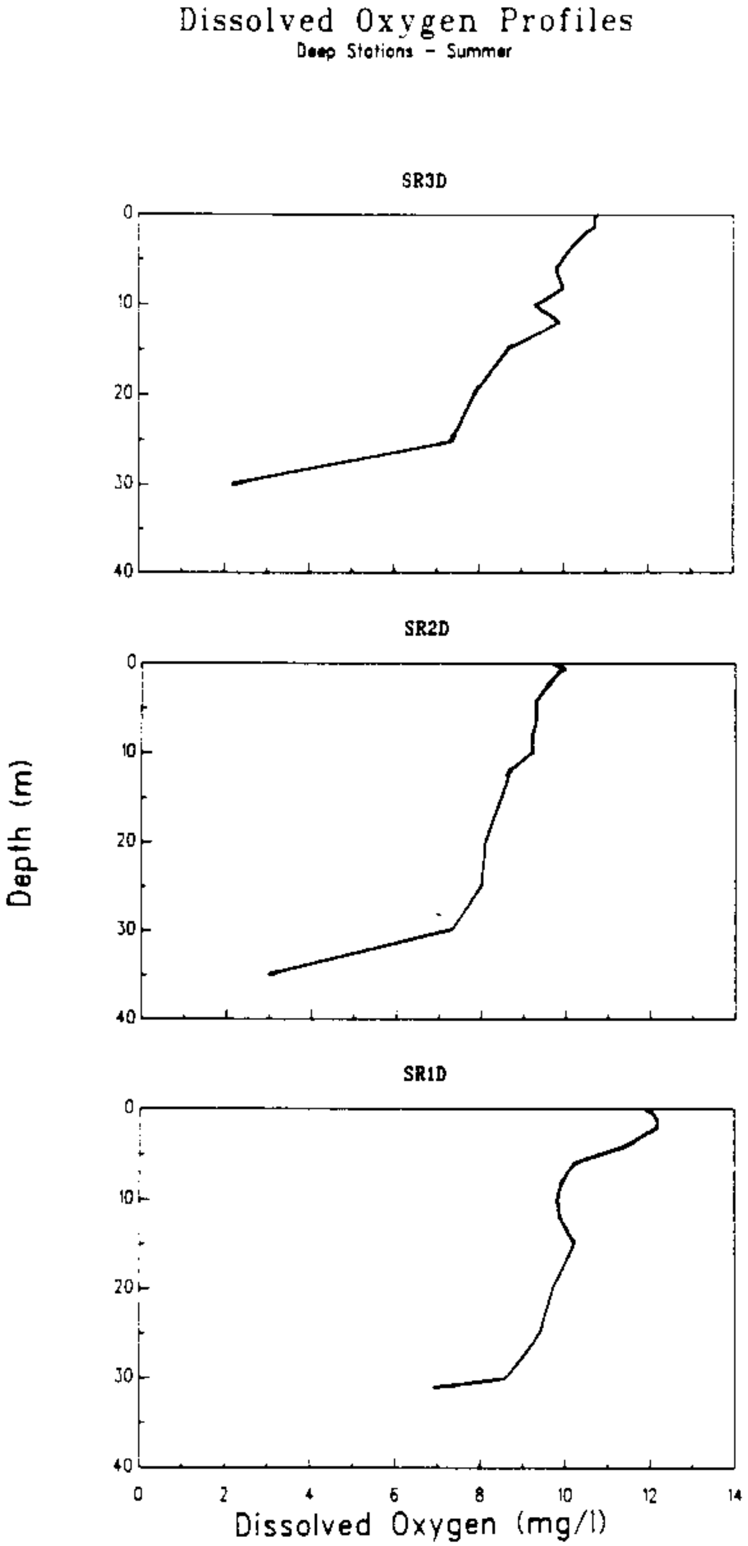


Figure 10. Summer dissolved oxygen profiles at the deep stations on Lower Granite Reservoir, Washington. Profiles were measured on 27, August, 1985.

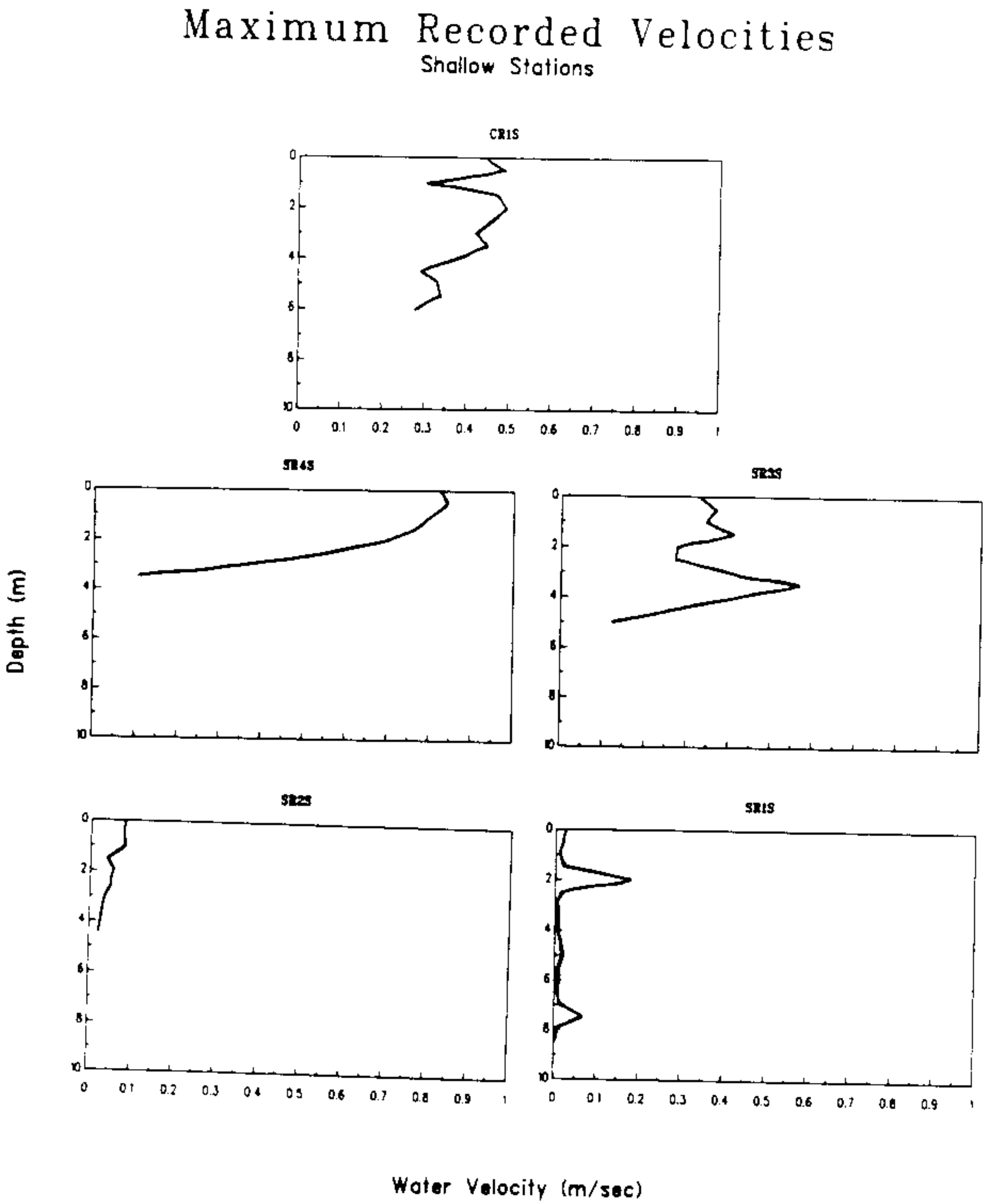


Figure 11. Maximum water velocities recorded at shallow stations on Lower Granite Reservoir, Idaho-Washington, during February 1986.

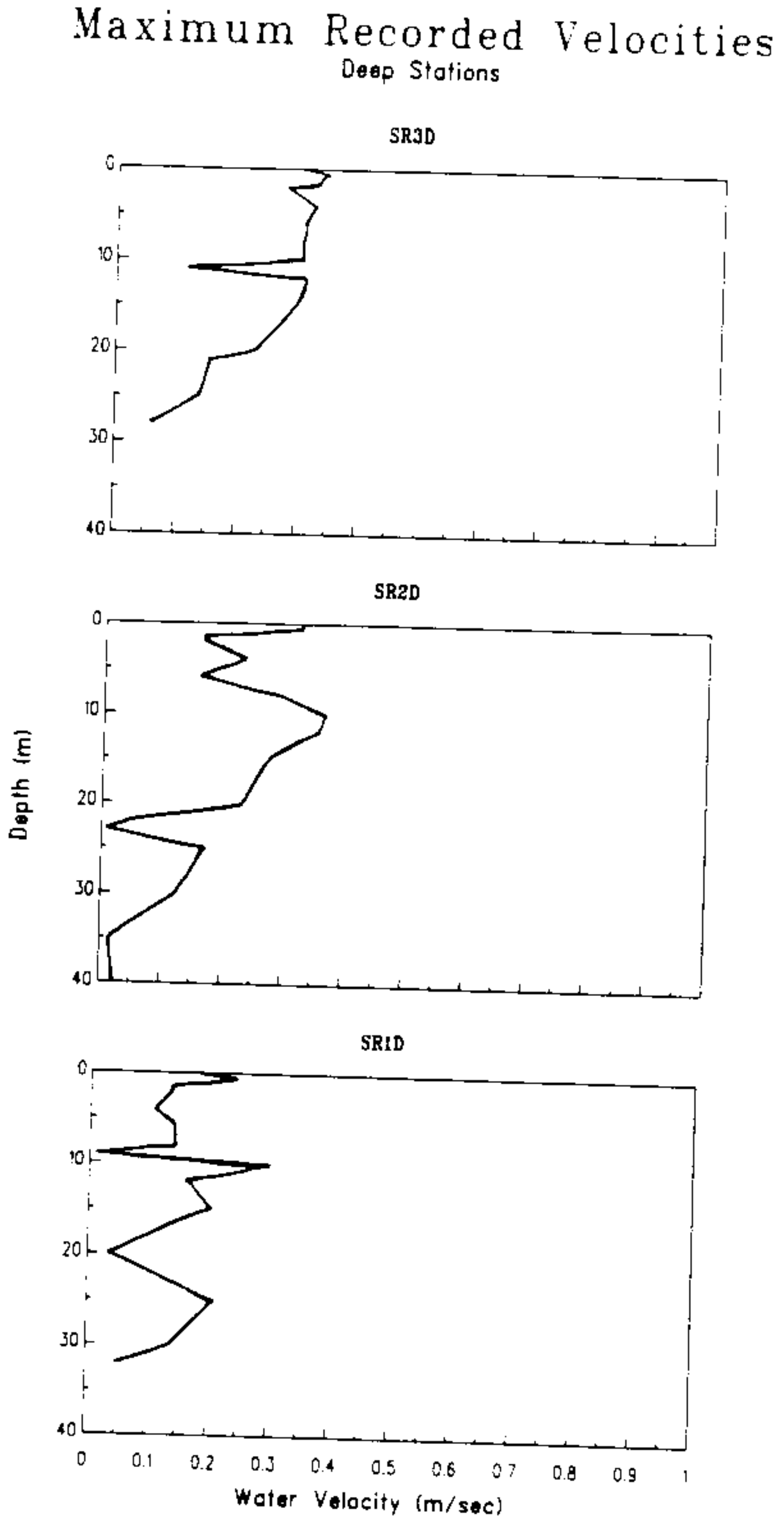


Figure 12. Maximum water velocities recorded at deep stations on Lower Granite Reservoir, Washington, during February 1986.

Substrate

Particle size distributions of substrate varied among stations. Substrate sizes among shallow stations and among deep stations were significantly different (shallow $X^2 = 36.99$, $P < 0.005$; deep $X^2 = 13.93$, $P < 0.01$). Silt was the predominant substrate at each of the six stations (Fig. 13). The proportion of sand varied from an average of 7.5% (SR1D) to 39.2% (SR3S). Silts were highest at SR2S (71.5%) and lowest at SR1S (41.4%). Clays were highest at SR1D (27.6%) and lowest at SR3S (14.0%). In general, clay content of substrate was higher with distance downstream in Lower Granite Reservoir (Fig. 13). We did not analyze additional substrate samples on SR4S because dredging activities preceeded our sampling. Initial substrate analyses suggested a higher proportion of sands and larger particles at SR1S and SR4S (Appendix A-3 and A-4).

Water Transparency and Turbidity

Weekly mean water transparencies (Appendix A-5) and turbidities (Appendix A-6) from shallow and deep stations demonstrate that turbidity was highest in the spring and decreased gradually following spring run-off, while transparency increased. Few differences were found among shallow and deep stations suggesting active mixing patterns at all stations. Low run-off during spring 1985 accounted for lower turbidities in 1985 than in 1986.

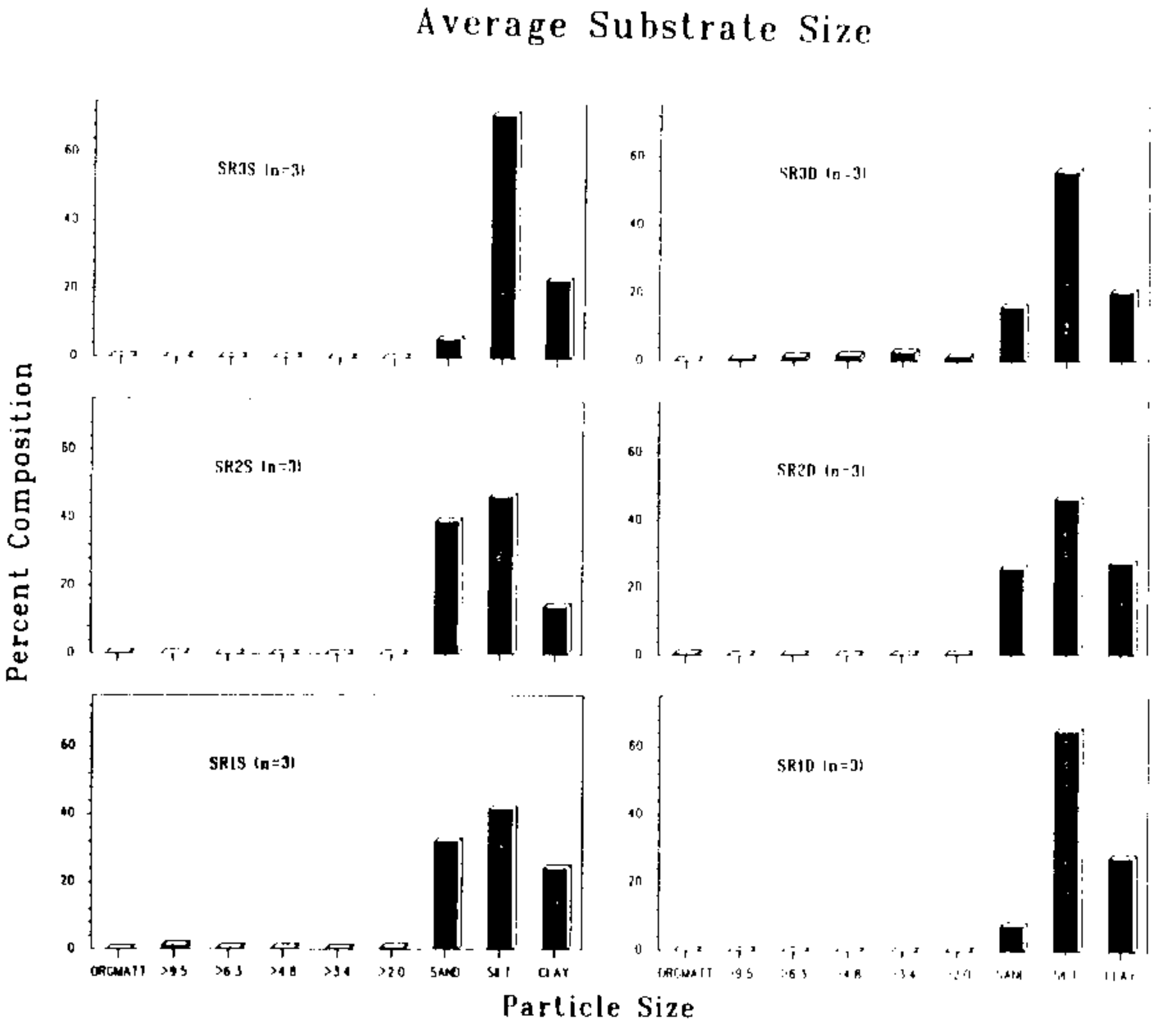


Figure 13. Average particle sizes found at selected shallow and deep stations in Lower Granite Reservoir, Washington, during September 1986.

Objective 6
"To determine species composition and relative abundance
of adult, juvenile, and larval fishes at selected sites
proposed for shallow and deep water disposal."

Fish sampling occurred during the same seasonal periods as limnological collections.

METHODS

To minimize sampling bias and make collections representative of the fish community, several gear types were used in Lower Granite Reservoir to collect fish. Electrofishing by night and day was used at both shallow and deep water stations. An output of approximately 300 volts and 4-5 amps was found to adequately stun fish while causing virtually no mortalities or visual evidence of injury. Electrofishing was conducted by paralleling the shoreline for two 15 minute passes. During the 30 minutes of sampling shallow stations generally were sampled the length of the station along the shoreline , whereas deep stations were sampled along both shorelines.

Three types of gill nets were used for sampling purposes:

1. Horizontal monofilament - 61 m long x 1.8 m deep, 8 panels each 7.6 m long, at 1.25 cm, 2.54 cm, 3.81 cm, 5.08 cm, 6.35 cm, 7.62 cm, 8.89 cm, and 10.16 cm bar measurement.

2. Horizontal multifilament - same as horizontal monofilament (61 x 1.8 m).

3. Vertical monofilament - 3.6 m wide with two 1.8 m panels at 2.54 cm and 5.08 cm bar measurement. Net depth was 45.7 m.

At shallow stations, four horizontal gill nets (2 each multi- and monofilament) were set perpendicular to the shoreline and at approximately equal intervals within the station area. Two of the nets were floating sets and two were contour. Floating sets were checked every hour over approximately a 7-8 hour period, while contour sets were checked every 2 hours. Short term effort was used to prevent net mortality of anadromous fishes. At deep water stations, three horizontal gill nets and two vertical gill nets were used. Vertical nets were set perpendicular to the shoreline in the deepest portion of the station and were checked every 2 hours. Horizontal nets were placed in three configurations as contour, mid-water, and floating sets. The mid-water set was a floating net anchored via 15 m (50 ft) ropes to the bottom with float leads attached that extended to the surface thereby creating a net "suspended" within the water column. Because of the difficulty in setting deep contour and mid-water nets, these nets were checked every 2 hours.

In addition to gill netting, four set lines were used at deep water stations. Each set line consisted of 12 m lines with six

(4/0 size) hooks on each. Hooks were baited with cut bait and were fished for approximately 7-8 hours.

Trap nets and standard beach seine hauls also were used at shallow water stations. Beach seining was conducted using a 30.5 x 2.4 m seine constructed of 6.35 mm knotless nylon mesh with a 2.4 x 2.4 x 2.4 m bag. A standard haul was made by setting the seine parallel to the shoreline using 15 m extension ropes. Three to five hauls were made at each station. Two trap nets also were employed at shallow stations. Traps were 0.9 m in diameter with 2.54 cm mesh with two 9 m wings 0.9 m deep. Traps were set with one wing perpendicular to shore and fished for approximately 7-8 hours. No trap netting was conducted during spring 1985 because of theft of our trap net.

Fish collected with all gear types were identified to species and total lengths (mm) were taken (except anadromous adults). All adult anadromous salmonids were released immediately and never removed from the water. Total weights (g) were taken on a portion of the fish captured. All anadromous salmonid smolts, smallmouth bass (> 200 mm), largemouth bass, crappies and yellow perch were drugged using tricaine methylsulfonate (MS-222) and their stomach contents sampled (Objective 7). The diversity of fishes was determined at each station using Brillouin's diversity index (Brillouin 1962).

Larval fishes were sampled during each seasonal period. Two conical plankton nets (2.134 m in length, 0.5 m diameter opening, 1 mm stretched mesh) extending about 1 m on opposite sides of the boat, were towed at approximately 1.3 m/sec. Boat speed was measured using a standard sailboating pitot tube. A calibrated flow meter, positioned in the mouth of one net, was used to determine volume of water filtered through each net. Stepwise oblique tows were replicated three times at each station per season resulting in six samples per station per season. Nets were towed 3 minutes at each depth from the surface to 3 m at 1 m increments although high plankton densities in the summer season necessitated reducing tow duration to 1 minute per depth.

All larval samples were immediately filtered through plankton netting (80 micron mesh) and preserved in FAA (50% ETOH, 40% H_2O, 10% Formalin, 2% Glacial acetic acid) (Pennak 1978) . Larval fish were identified to the lowest possible taxon using a dichotomous key developed for larval fishes in Little Goose Reservoir (Bratovich 1985). Larval fish abundance was expressed as the number of larvae per 1000 m^3 filtered water.

RESULTS

Fish Abundance

A total of 31,923 juvenile and adult fishes were collected at the eight stations by various sampling techniques (Tables 3-6). Young-of-year fishes collected in the summer contributed to the highest capture totals. Over 96% of these were collected at shallow stations, whereas the remaining 4% were captured at the deep stations. Of the individuals collected, the number of species captured per season varied from 23 species in the spring, to 21 species in the summer, 19 in the fall, and 15 in the winter.

Table 3. Abundance of various juvenile and adult fishes collected from Lower Granite Reservoir, Idaho-Washington, April-June, 1985.

	STATION								
SPECIES	CR1S	SR4S	SR3S	SR2S	SR1S	SR3D	SR2D	SR1D	TOTALS
white sturgeon	--	1	--	--	--	2	4	--	7
sockeye salmon	3	1	--	--	--	--	--	--	4
chinook salmon	28	43	70	86	402	3	--	3	635
mountain whitefish	1	2	27	--	--	--	--	--	30
rainbow trout	13	4	8	12	34	1	3	--	75
chiselmouth	55	12	7	46	131	11	1	7	270
carp	--	32	3	16	30	11	15	14	121
peamouth	2	10	--	59	124	1	--	--	196
northern squawfish	13	59	285	268	240	4	3	2	874
redside shiner	693	176	57	146	269	2	--	--	1343
bridgelip sucker	1	4	2	4	23	6	7	7	54
largescale sucker	2	70	73	88	164	15	24	28	464
yellow bullhead	--	--	--	1	3	--	--	2	6
brown bullhead	--	--	--	--	1	--	2	1	4
channel catfish	--	--	--	--	1	1	1	--	3
pumpkinseed	--	--	--	1	3	--	--	1	5
warmouth	--	--	--	1	--	--	--	--	1
bluegill	--	--	--	--	11	--	--	--	11
smallmouth bass	3	4	1	5	36	27	--	40	116
white crappie	--	--	--	2	8	--	--	--	10
black crappie	--	--	--	1	2	--	--	--	3
yellow perch	--	--	2	5	2	--	--	--	9
sculpin	3	7	--	3	1	1	--	--	15
TOTALS No. Collected	817	425	535	744	1485	85	60	105	4256
No. of Species	12	14	11	17	19	13	9	10	

Table 4. Abundance of various juvenile and adult fishes collected from Lower Granite Reservoir, Idaho-Washington, July-August, 1985.

	STATION								
SPECIES	CR1S	SR4S	SR3S	SR2S	SR1S	SR3D	SR2D	SR1D	TOTALS
white sturgeon	3	36	--	--	--	--	--	1	40
chinook salmon	--	1	--	--	--	--	--	--	1
rainbow trout	1	--	--	--	--	1	--	--	2
chiselmouth	17	132	10	1	1	19	3	5	188
carp	22	14	88	16	19	--	2	12	173
peamouth	179	970	4238	9	1	--	--	--	5397
northern squawfish	128	516	875	82	30	13	9	10	1663
redside shiner	18	110	13	12	12	11	4	--	180
bridgelip sucker	1	115	20	--	3	6	7	2	154
largescale sucker	238	5318	8895	6	33	49	38	10	14587
yellow bullhead	--	--	--	--	--	--	1	1	2
channel catfish	--	--	3	7	--	--	1	--	11
pumpkinseed	--	--	--	--	3	--	--	2	5
warmouth	--	--	--	--	--	--	--	2	2
bluegill	--	--	--	--	3	--	--	1	4
smallmouth bass	3	23	2335	56	84	18	65	96	2680
largemouth bass	--	--	--	--	1	--	--	--	1
white crappie	--	32		8	4	--	--	1	45
black crappie	--	--	--	--	8	--	--	--	8
yellow perch	--	--	--	--	1	--	--	--	1
sculpin	--	1	1	--	--	--	--	--	2
TOTALS No. Collected	610	7268	16478	197	203	117	130	143	25146
No. of Species	10	12	10	9	14	7	9	12	

Table 5. Abundance of various juvenile and adult fishes collected from Lower Granite Reservoir, Idaho-Washington, October-December, 1985.

	STATION								
SPECIES	CR1S	SR4S	SR3S	SR2S	SR1S	SR3D	SR2D	SR1D	TOTALS
white sturgeon	2	3	--	--	--	--	1	1	7
chinook salmon	1	--	4	4	2	1	--	4	16
mountain whitefish	1	--	2	17	--	1	--	--	21
rainbow trout	4	1	11	12	15	4	8	17	72
chiselmouth	15	12	1	8	11	7	7	22	83
carp	3	9	--	1	1	--	--	1	15
peamouth	64	47	24	1	2	--	1	2	141
northern squawfish	140	42	51	21	3	5	3	13	278
longnose dace	1	--	--	--	--	--	--	--	1
speckled dace	--	--	--	--	--	1	--	--	1
redside shiner	17	41	17	20	13	30	3	11	152
bridgelip sucker	7	4	2	14	2	26	6	14	75
largescale sucker	48	90	58	75	52	97	25	68	513
yellow bullhead	--	--	--	3	--	--	--	--	3
pumpkinseed	--	--	--	--	1	1	--	--	2
bluegill	--	3	--	16	10	2	--	1	32
smallmouth bass	103	27	38	58	29	43	3	33	334
largemouth bass	4	--	--	--	7	--	1	3	15
white crappie	--	3	1	1	1	3	--	--	9
black crappie	--	--	--	1	--	1	--	1	3
sculpin	10	5	--	--	--	1	--	--	16
TOTALS No. Collected	420	287	209	252	149	223	58	191	1789
TOTALS No. of Species	15	13	11	15	14	15	10	14	

Table 6. Abundance of various juvenile and adult fishes collected from Lower Granite Reservoir, Idaho-Washington, January-March, 1986.

		STATION								
SPECIES		CR1S	SR4S	SR3S	SR2S	SR1S	SR3D	SR2D	SR1D	TOTALS
sockeye salmon		--	1	--	--	--	--	--	1	2
chinook salmon		2	15	20	14	2	3	1	--	57
mountain whitefish		3	--	1	2	--	--	--	1	7
rainbow trout		12	2	3	5	12	15	5	15	69
chiselmouth		30	52	1	11	20	9	6	9	138
carp		--	5	--	--	1	1	2	--	9
peamouth		21	--	--	--	--	--	--	--	21
northern squawfish		28	10	5	6	--	3	5	1	58
redside shiner		88	28	12	13	45	3	17	9	215
bridgelip sucker		8	8	--	6	3	--	--	3	28
largescale sucker		13	32	11	5	24	9	12	10	116
channel catfish		--	--	--	--	--	--	1	--	1
smallmouth bass		7	--	--	--	--	--	--	--	7
white crappie		--	--	--	--	1	--	--	--	1
sculpin		2	1	--	--	--	--	--	--	3
TOTALS	No. Collected	214	154	53	62	108	43	49	49	732
	No. of Species	11	10	7	8	8	7	8	8	

Differences in the number of species represented were a result, in part, of the presence or absence of migrating salmonids and the absence of warmwater fishes in the winter sample.

Juvenile chinook salmon were captured during the winter sampling period at virtually every shallow water and most deep stations in the reservoir (Table 6). Six juvenile chinook salmon, known to be coded wire tagged, were kept to identify their origins. All six fish were part of a pre-smolt release program from Looking Glass hatchery in Oregon. During November 1985 and January 1986, over one million pre-smolts were released into the Grand Ronde River. Capture of these fish suggest that at least some were over-wintering in Lower Granite Reservoir.

Of all the stations, SR1S (spring sample) had the most diverse community (19 species), whereas the fewest number of species was collected at SR3D (7 species). Northern squawfish, redside shiners, suckers and smallmouth bass were collected at all stations. Species diversity indices corroborate that the highest fish diversity occurred at SR1S (Fig. 14). Evenness was generally similar among stations (Fig. 15). Fish species diversity at SR1S demonstrated a marked difference over other stations (except fall), while CR1S and SR3S generally were low in fish diversity. During the winter, diversity was similar among stations.

Our data indicate high abundance of cyprinid and catostomid fishes at shallow and deep water stations. Largescale sucker, redside shiner, northern squawfish, chiselmouth and peamouth accounted for mean ranks in overall abundance of 2.2, 3.0, 3.5, 4.5 and 5.2, respectively. The relative abundance of various species

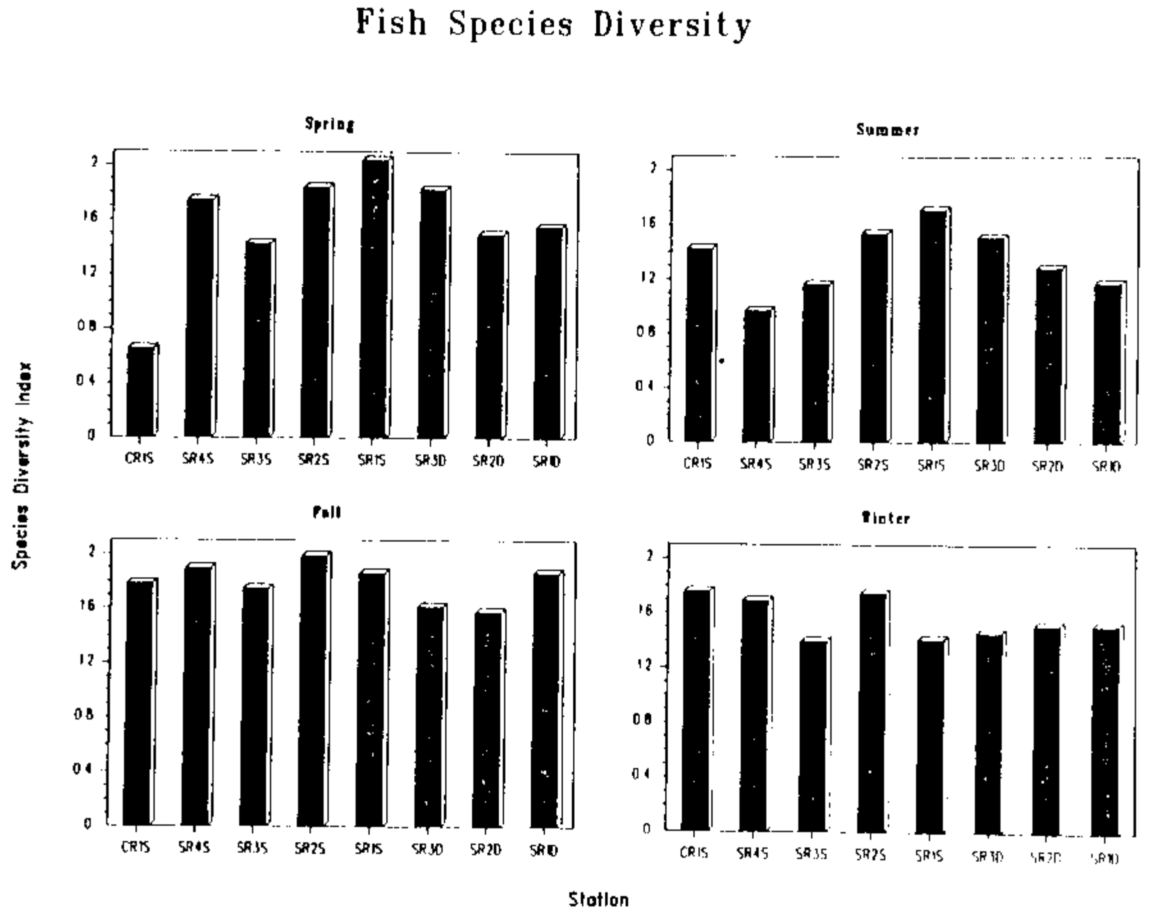


Figure 14. Species diversity indexes (Brillouin 1962) for fishes captured at each of the study stations on Lower Grantie Reservoir during spring, summer, and fall 1985 and winter 1986.

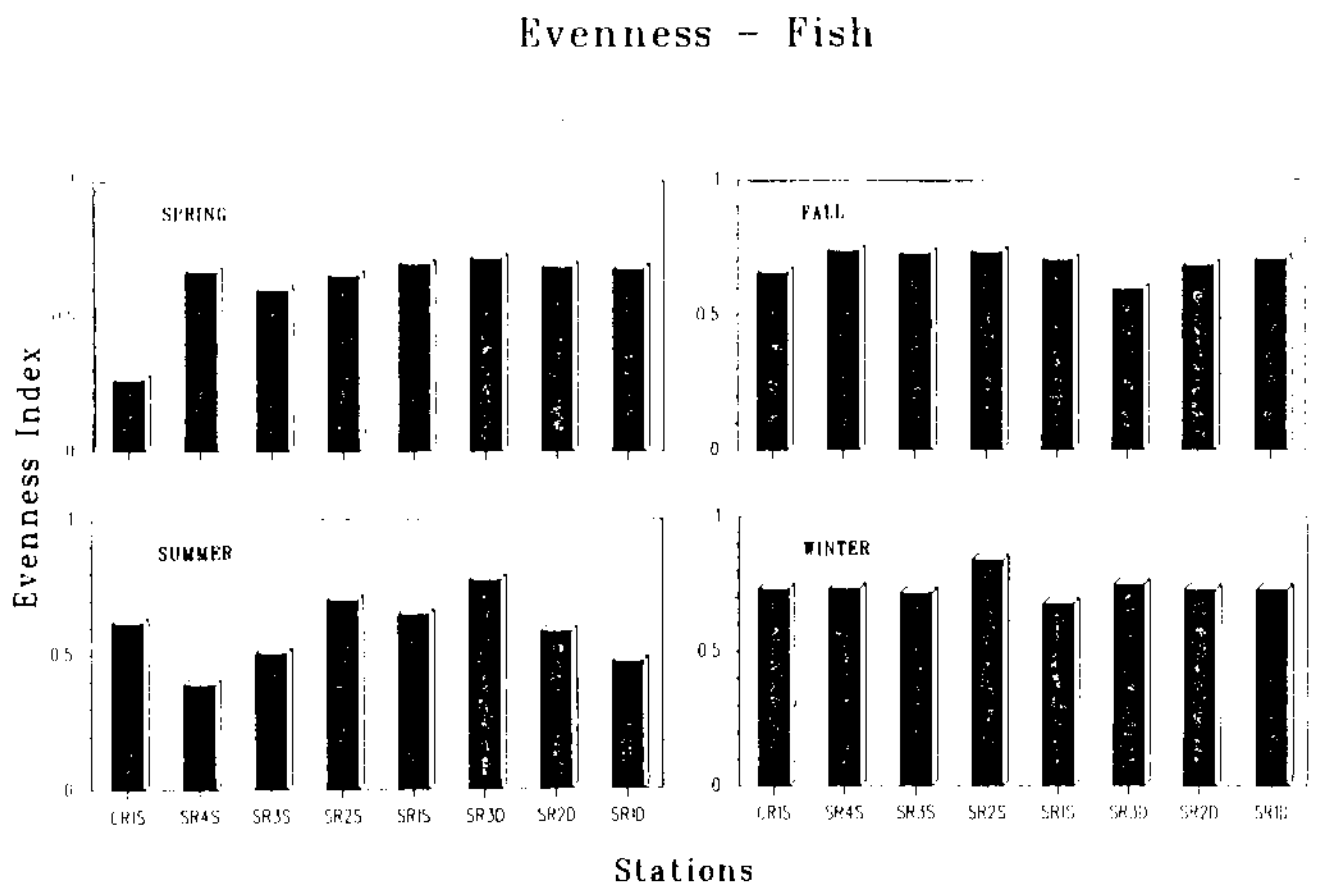


Figure 15. Evenness indexes for fishes captured in Lower Grantie Reservoir, Idaho-Washington, during spring, summer and fall 1985 and winter 1986. Evenness indexes were calculated using Brillouin's species diversity index.

shows moderate uniformity in abundance within shallow and deep water stations (Figs. 16-23) and between seasons. The high abundance of salmonid fishes in the spring and winter are exceptions especially at shallow water stations. Smallmouth bass were consistently the most abundant game species at shallow and deep water stations during the spring, summer and fall. However, salmonids dominated the winter catch. As expected, catch per effort (CPE) was higher for juvenile salmonid fishes during spring and winter and lowest during summer and fall. Seasonal CPEs were consistently higher at lower sampling stations (deep and shallow) indicating higher catch rates for all gear types (Appendix A-7 - A-10). Much variation existed in the effectiveness of each gear type for the various species at each station (Appendix A-11 - A-18). Overall, electrofishing and beach seining were the more effective techniques at capturing a variety of fishes.

Comparison of the abundance of game and nongame fishes sampled suggests the predominance of nongame fishes at CR1S and the up-reservoir Snake River stations (Fig. 24). The proportion of nongame species was higher in the summer at the shallow water stations and higher in the fall at the deep water stations. Although variable among stations, the proportion of game vs. nongame fishes was relatively consistent. Overall, seasonal means show a progressive downstream increase in abundance of game species (CR1S=12%; SR4S=10%; SR3S=26%; SR2S=34%; SR1S=38%; SR3D=31%; SR2D=26%; SR1D=46%). This trend generally existed for shallow and deep water stations except in the winter when smallmouth bass were not present in the catch.

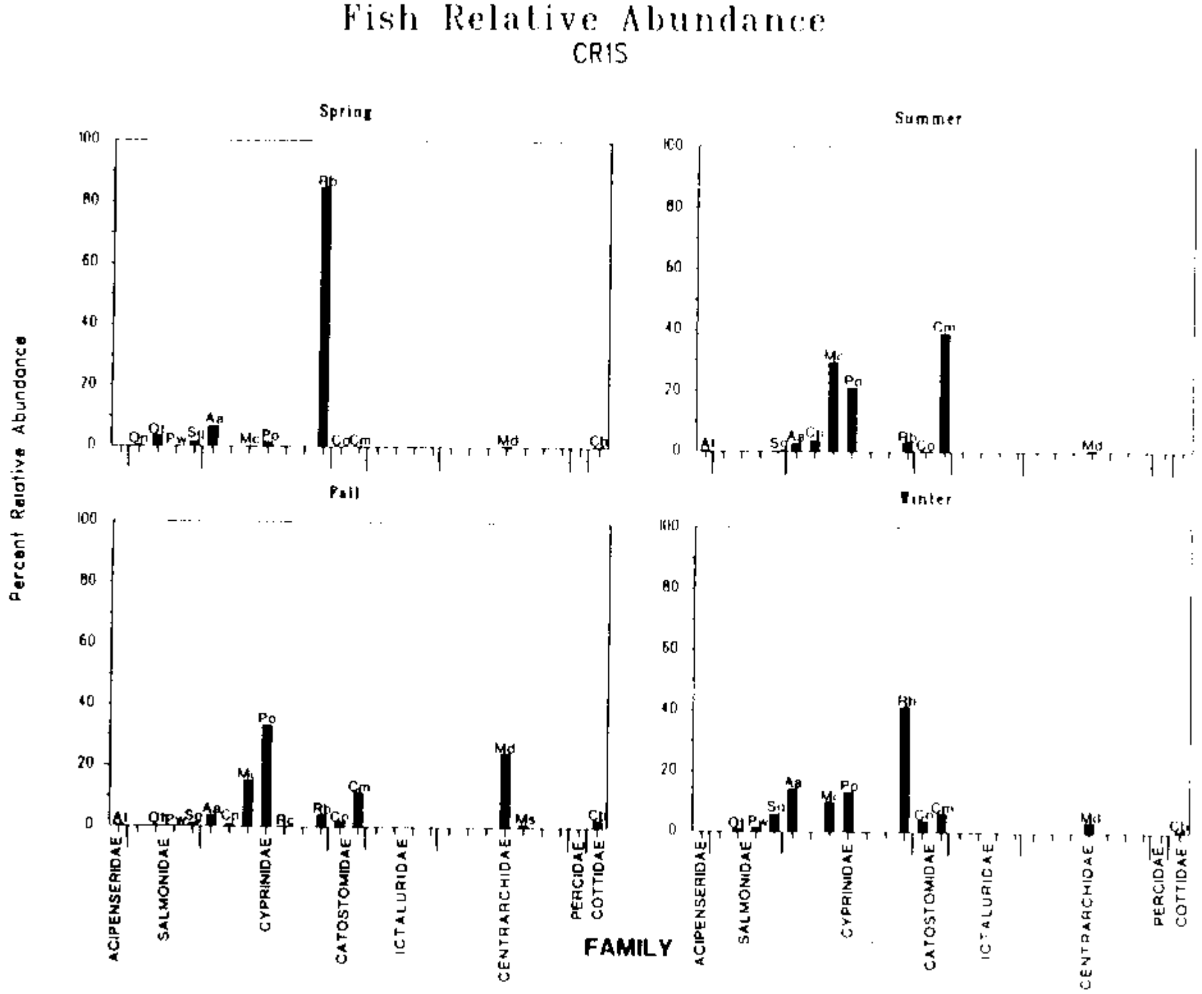


Figure 16. Percent relative abundance of fishes captured at CRIS in Lower Granite Reservoir, Idaho, during spring - fall 1985 and winter 1986. Species abbreviations are: At - white sturgeon; On - sockeye salmon; Ot - chinook salmon; Pw - mountain whitefish; Sg - rainbow trout; Aa - chiselmouth; Cp - carp; Mc - peamouth; Po - northern squawfish; Rc - longnose dace; Ro - speckled dace; Rb - redside shiner; Co - bridgelip sucker; Cm - largescale sucker; Ia - yellow bullhead; In - brown bullhead; Ip - channel catfish; Lg - pumpkinseed; Lu - warmouth; Lm bluegill; Md - smallmouth bass; Ms - largemouth bass; Pa - white crappie; Pn - black crappie; Pf - yellow perch; Cb - sculpin.

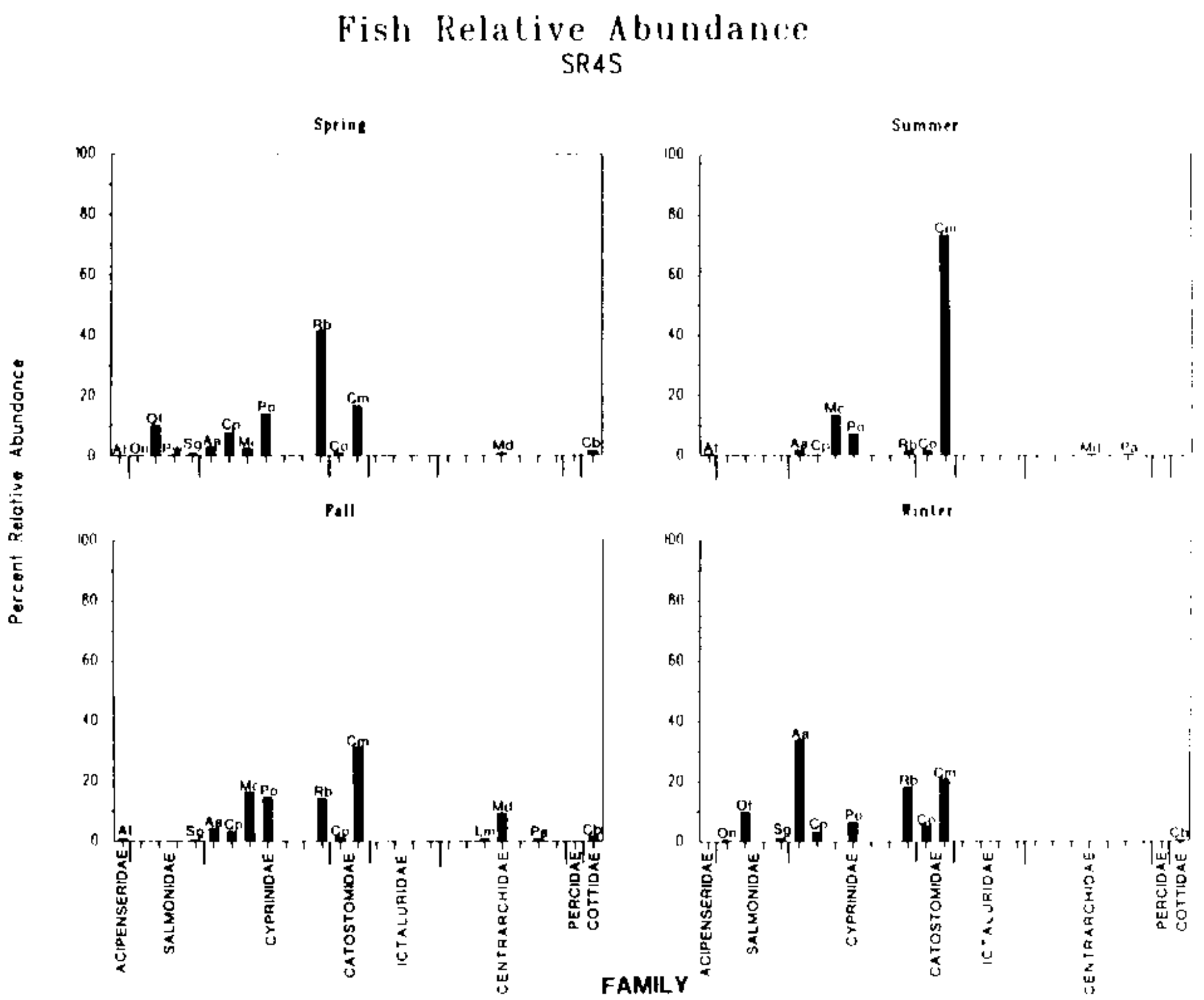


Figure 17. Percent relative abundance of fishes captured at SR4S in Lower Granite Reservoir, Idaho, during spring - fall 1985 and winter 1986. Species abbreviations are: At - white sturgeon; On - sockeye salmon; Ot - chinook salmon; Pw - mountain whitefish; Sg - rainbow trout; Aa - chiselmouth; Cp - carp; Mc - peamouth; Po - northern squawfish; Rc - longnose dace; Ro - speckled dace; Rb - redside shiner; Co - bridgelip sucker; Cm - largescale sucker; Ia - yellow bullhead; In - brown bullhead; Ip - channel catfish; Lg - pumpkinseed; Lu - warmouth; Lm - bluegill; Md - smallmouth bass; Ms - largemouth bass; Pa - white

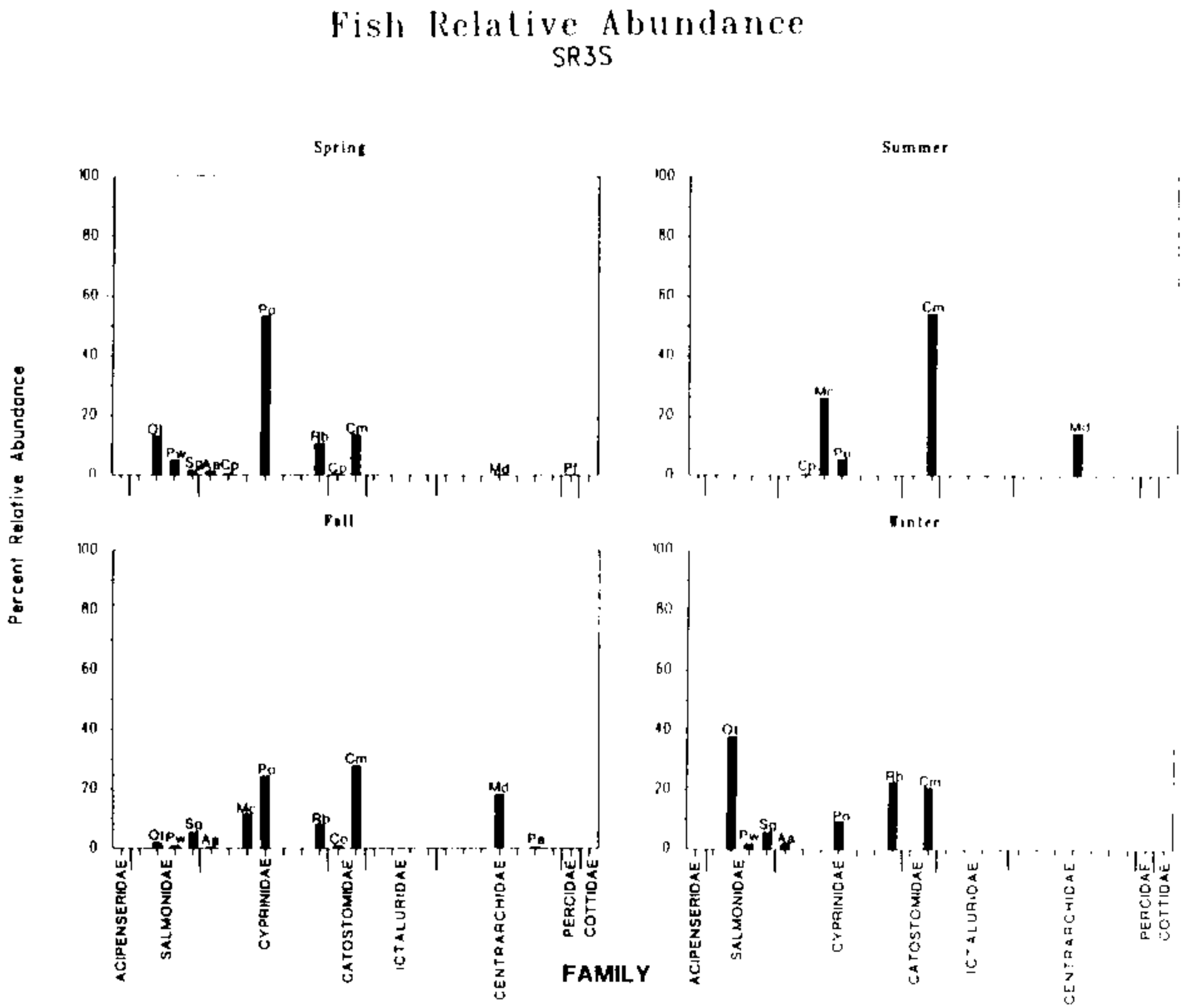


Figure 18. Percent relative abundance of fishes captured at SR3S in Lower Granite Reservoir, Idaho, during spring - fall 1985 and winter 1986. Species abbreviations are: At - white sturgeon; On - sockeye salmon; Ot - chinook salmon; Pw - mountain whitefish; Sg - rainbow trout; Aa - chiselmouth; Cp - carp; Mc - peamouth; Po - northern squawfish; Rc - longnose dace; Ro - speckled dace; Rb - redside shiner; Co - bridgelip sucker; Cm - largescale sucker; Ia - yellow bullhead; In - brown bullhead; Ip - channel catfish; Lg - pumpkinseed; Lu - warmouth; Lm - bluegill; Md - smallmouth bass; Ms - largemouth bass; Pa - white crappie; Pn - black crappie; Pf - yellow perch; Cb - sculpin.

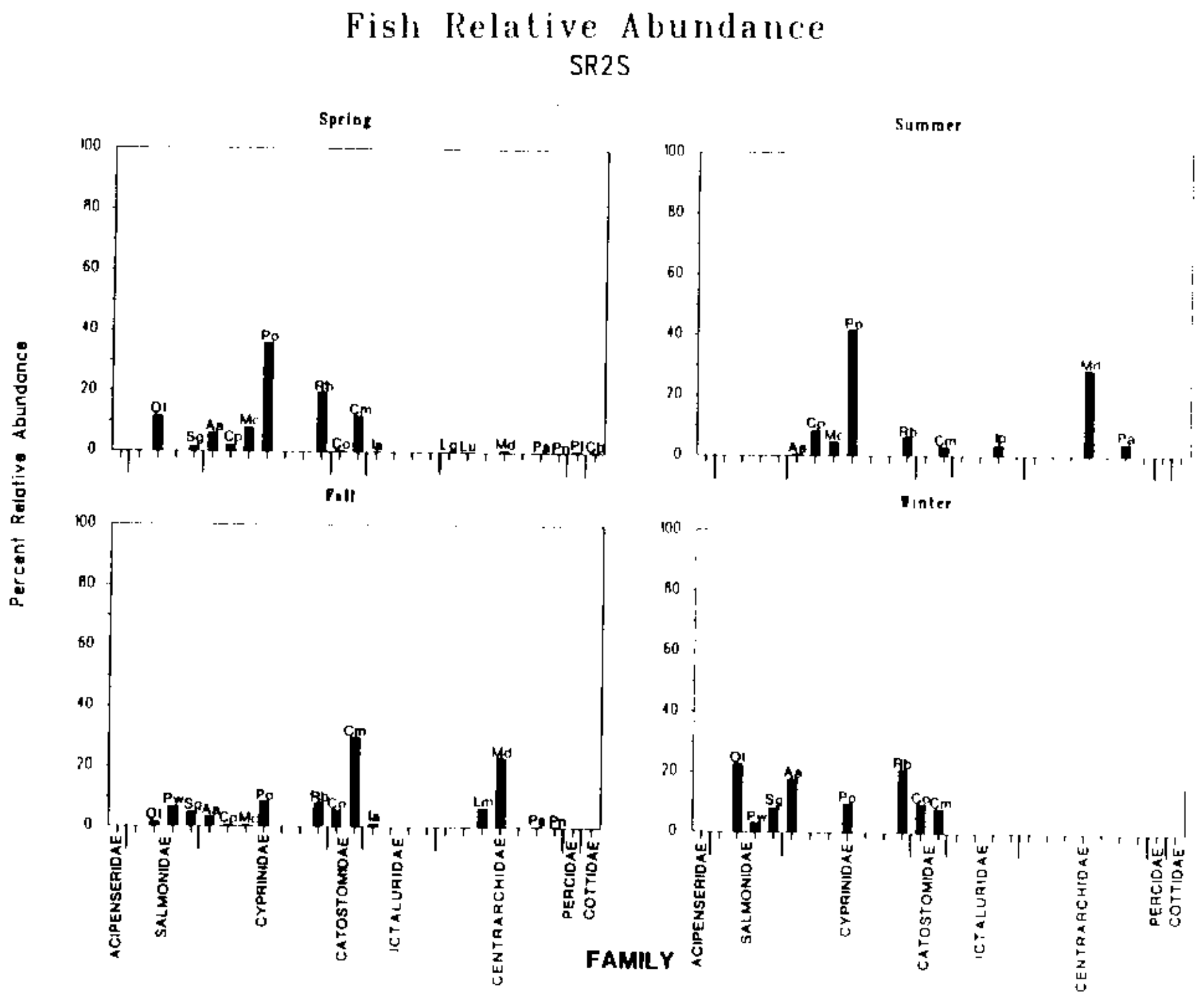


Figure 19. Percent relative abundance of fishes captured at SR2S in Lower Granite Reservoir, Idaho, during spring - fall 1985 and winter 1986. Species abbreviations are: At - white sturgeon; On - sockeye salmon; Ot - chinook salmon; Pw - mountain whitefish; Sg - rainbow trout; Aa - chiselmouth; Cp - carp; Mc - peamouth; Po - northern squawfish; Rc - longnose dace; Ro - speckled dace; Rb - redside shiner; Co - bridgelip sucker; Cm - largescale sucker; Ia - yellow bullhead; In - brown bullhead; Ip - channel catfish; Lg - pumpkinseed; Lu - warmouth; lm - bluegill; Md - smallmouth bass; Ms - largemouth bass; Pa - white crappie; Pn - black crappie; Pf - yellow perch; Cb - sculpin

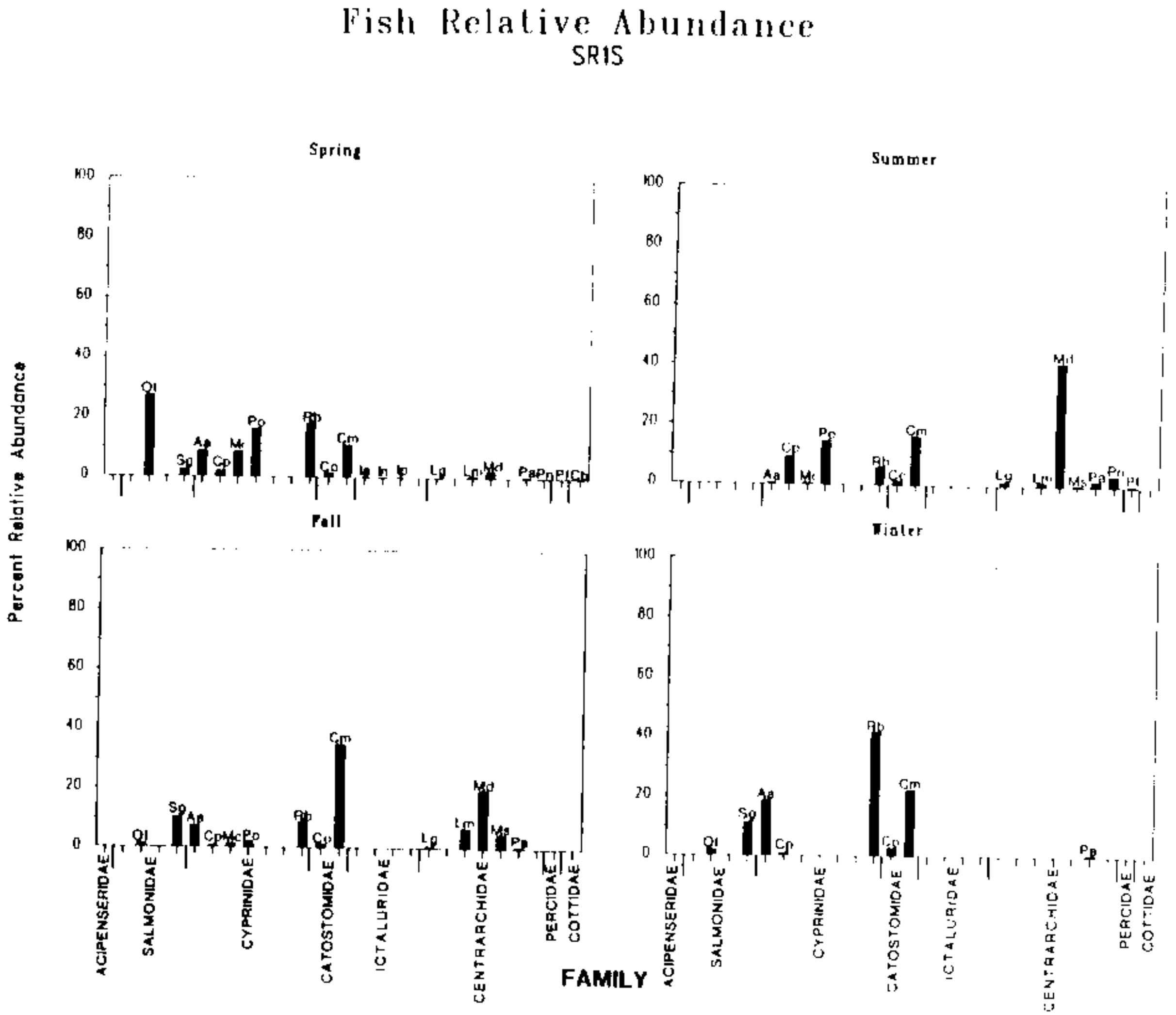


Figure 20. Percent relative abundance of fishes captured at SR1S in Lower Granite Reservoir, Idaho, during spring - fall 1985 and winter 1986. Species abbreviations are: At - white sturgeon; On - sockeye salmon; Ot - chinook salmon; Pw - mountain whitefish; Sg - rainbow trout; Aa - chiselmouth; Cp - carp; Mc - peamouth; Po - northern squawfish; Rc longnose dace; Ro - speckled dace; Rb - redside shiner; Co - bridgelip sucker; Cm - largescale sucker; Ia - yellow bullhead; In - brown bullhead; Ip - channel catfish; Lg - pumpkinseed; Lu - warmouth; Lm - bluegill; Md - smallmouth bass; Ms - largemouth bass; Pa - white crappie; Pn - black crappie; Pf - yellow perch; Cb - sculpin.

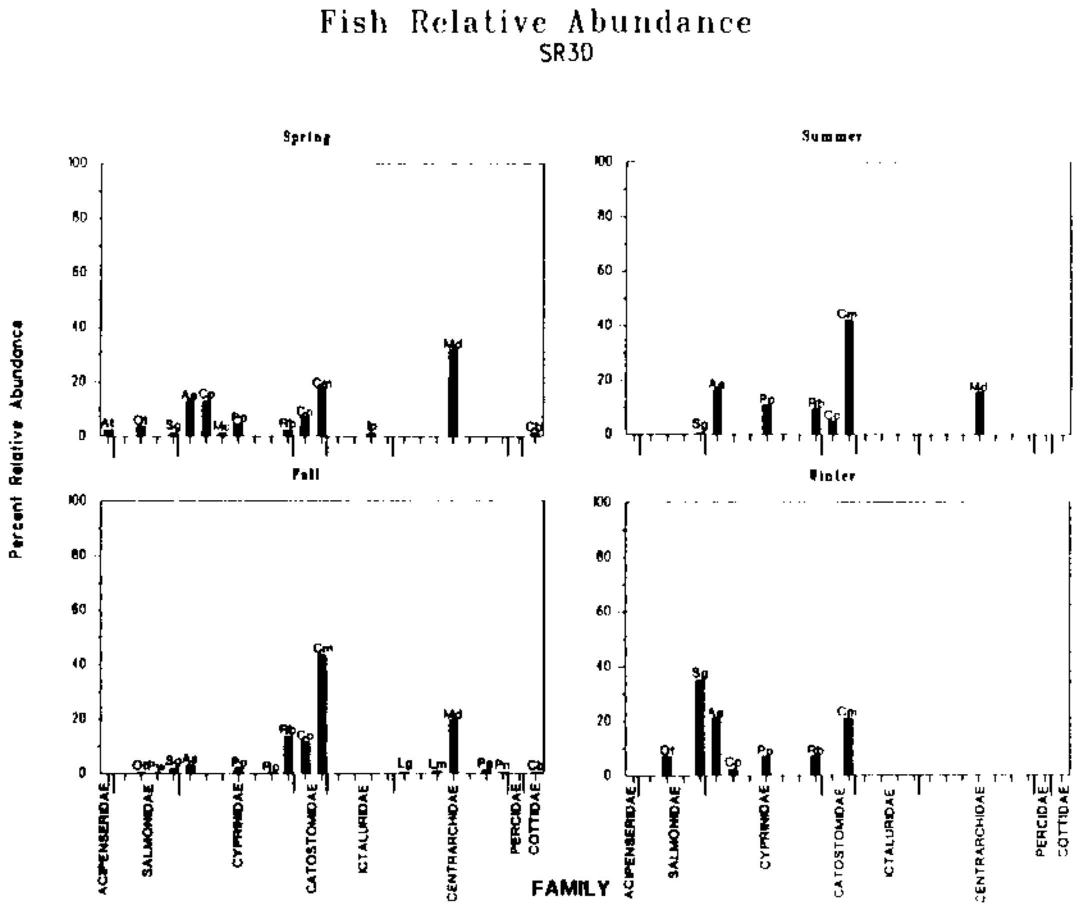


Figure 21. Percent relative abundance of fishes captured at SR3D in Lower Granite Reservoir, Idaho, during spring - fall 1985 and winter 1986. Species abbreviations are: At - white sturgeon; On - sockeye salmon; Ot - chinook salmon; Pw - mountain whitefish; Sg - rainbow trout; Aa - chiselmouth; Cp - carp; Mc - peamouth; Po - northern squawfish; Rc - longnose dace; Ro - speckled dace; Rb - redside shiner; Co - bridgelip sucker; Cm - largescale sucker; Ia - yellow bullhead; In - brown bullhead; Ip - channel catfish; Lg - pumpkinseed; Lu - warmouth; Lm - bluegill; Md - smallmouth bass; Ms - largemouth bass; Pa - white crappie; Pn - black crappie; Pf - yellow perch; Cb - sculpin.

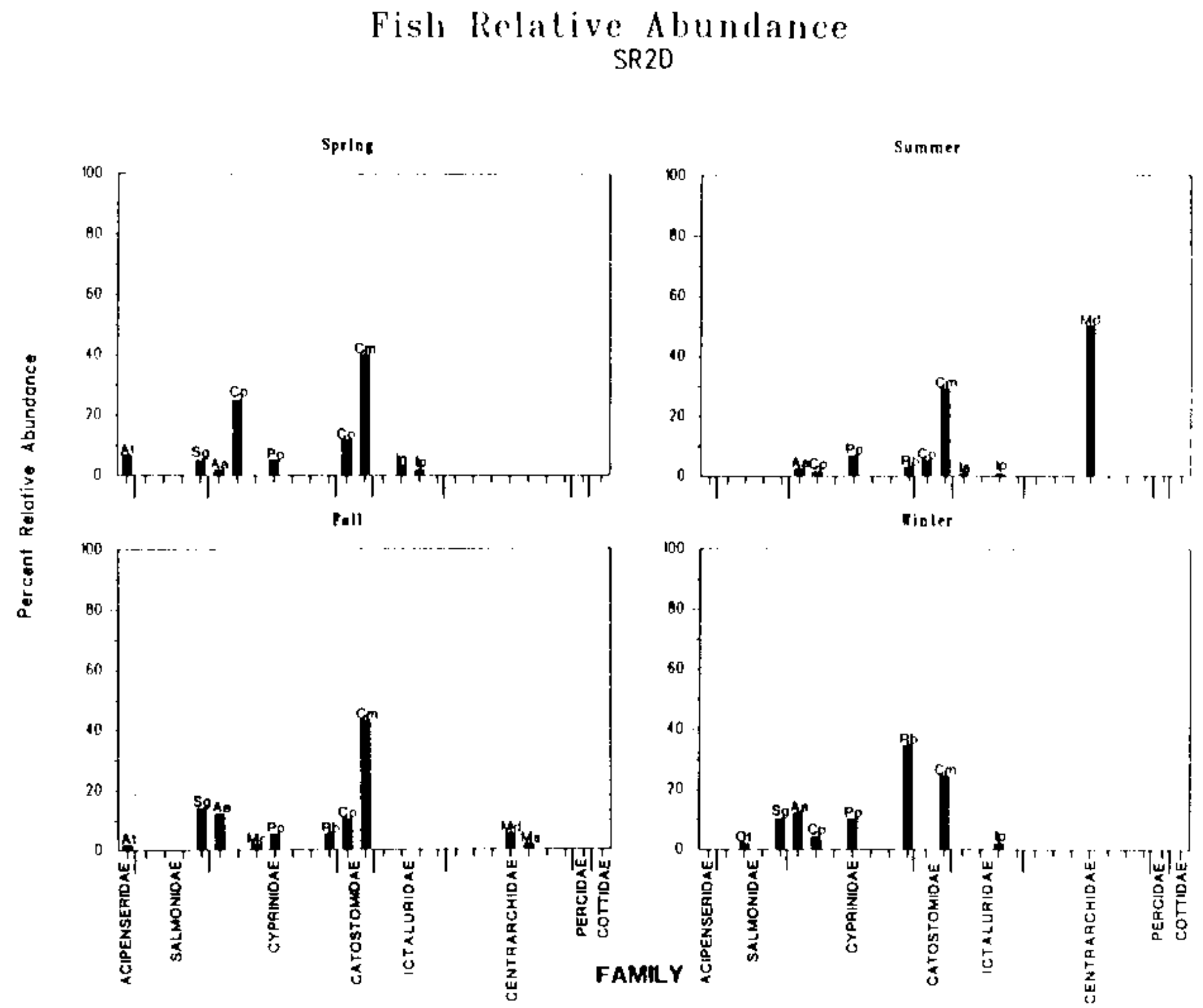


Figure 22. Percent relative abundance of fishes captured at SR2D in Lower Granite Reservoir, Idaho, during spring - fall 1985 and winter 1986. Species abbreviations are: At - white sturgeon; On - sockeye salmon; Ot - chinook salmon; Pw - mountain whitefish; Sg - rainbow trout; Aa - chiselmouth; Cp - carp; Mc - peamouth; Po - northern squawfish; Rc - longnose dace; Ro - speckled dace; Rb - redside shiner; Co - bridgelip sucker; Cm - largescale sucker; Ia - yellow bullhead; In - brown bullhead; Ip - channel catfish; Lg - pumpkinseed; Lu - warmouth; Im - bluegill; Md - smallmouth bass; Ms - largemouth bass; Pa - white crappie; Pn - black crappie; Pf - yellow perch; Cb - sculpin.

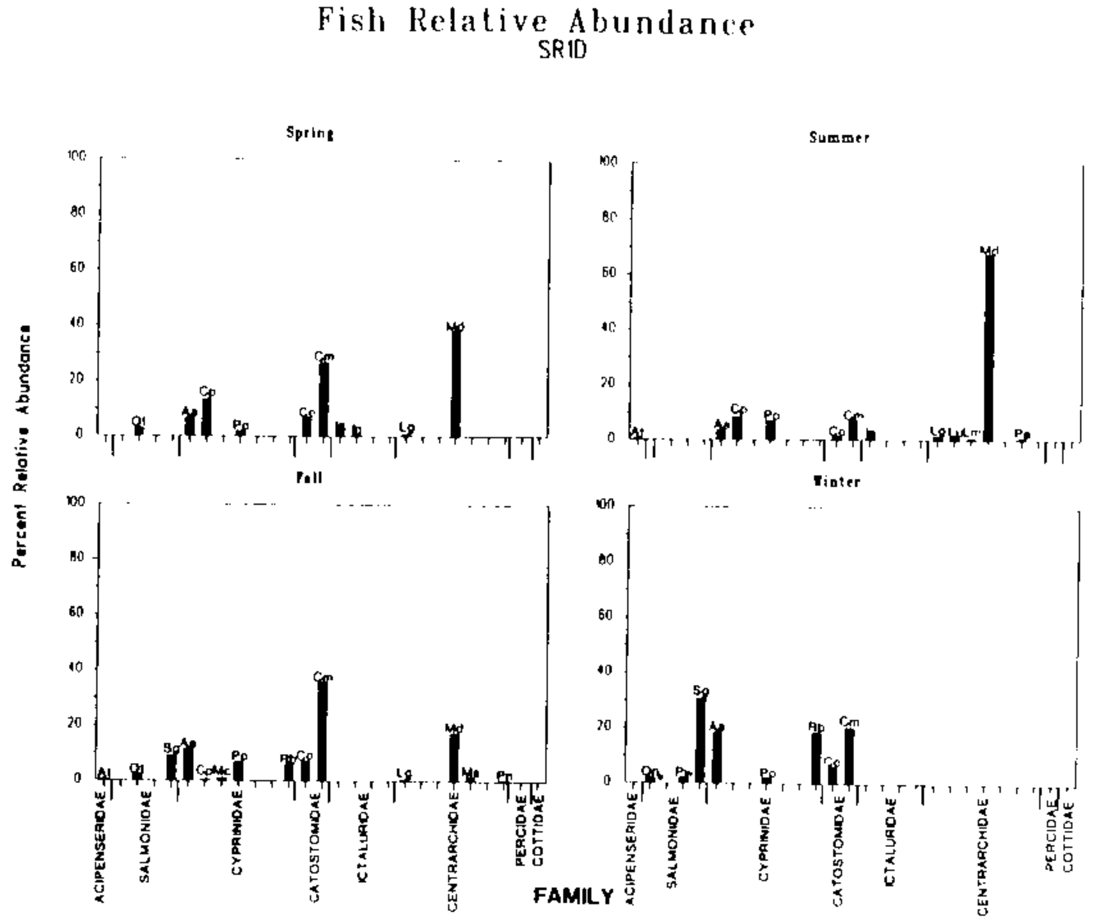


Figure 23. Percent relative abundance of fishes captured at SR1D in Lower Granite Reservoir, Idaho, during spring - fall 1985 and winter 1986. Species abbreviations are: At - white sturgeon; On - sockeye salmon; Ot - chinook salmon; Pw - mountain whitefish; Sg - rainbow trout; Aa - chiselmouth; Cp - carp; Mc - peamouth; Po - northern squawfish; Rc - longnose dace; Ro - speckled dace; Rb - redside shiner; Co - bridgelip sucker; Cm - largescale sucker; Ia - yellow bullhead; In - brown bullhead; Ip - channel catfish; Lg - pumpkinseed; Lu - warmouth; Lm - bluegill; Md - smallmouth bass; Ms - largemouth bass; Pa - white crappie; Pn - black crappie; Pf - yellow perch; Cb - sculpin.

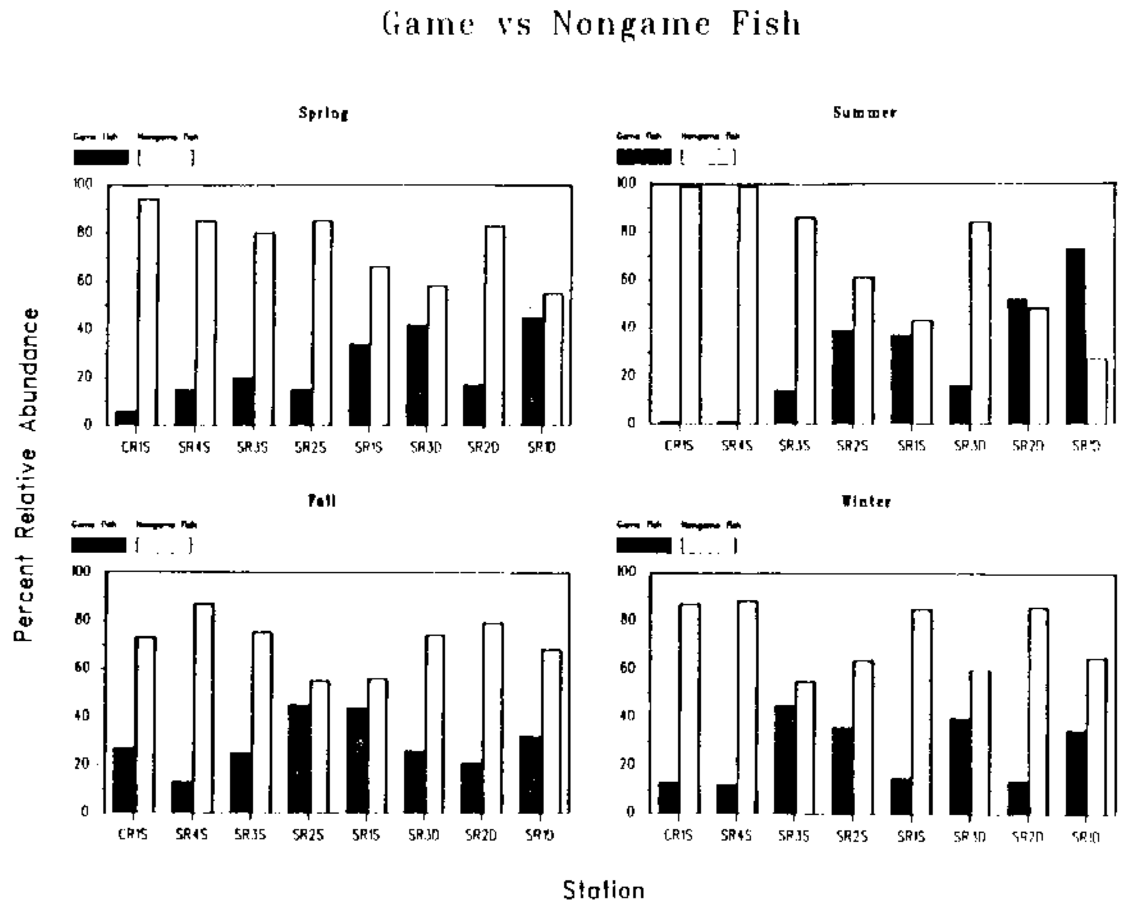


Figure 24. Game versus nongame fish abundance from each of the Lower Granite Reservoir stations, Idaho-Washington, during spring, summer, and fall 1985 and winter 1986.

Another measure of fish abundance and size at the various stations is the biomass of fish flesh sampled. Total biomass sampled at each station varied considerably with season (Fig. 25). Biomass at SR4S, SR2S and SR1S generally was higher than at other shallow water stations. Biomass of fish flesh sampled in the spring was high at shallow stations of the Snake River associated with large numbers of migrating salmonid smolts and spawning adults of other species present in the shallow areas. In the summer, although total numbers of fish captured increased dramatically (Table 4), biomass sampled showed a marked decrease over spring (Table 3) as a result of the presence of many young-of-the-year fish (Fig. 25). Relative to the spring, summer and winter biomass of fish captured remained low except at SR4S where numerous adult carp and suckers were present. Biomass sampled at deep water stations was more consistent among stations and highest during the fall.

Size Comparisons

Comparison of length frequency distributions indicates seasonal use patterns by various sizes of fish using shallow and deep water stations (Figs. 26-33). Although affected by sampling efficiencies, our data show that shallow water stations are inhabited predominantly by smaller fishes ($\leq$ 100 mm). This was especially true for stations CR1S, SR4S, SR3S and SR2S during the summer. Deep water stations typically support larger fish and wider variations in size. The wide range of lengths in fall

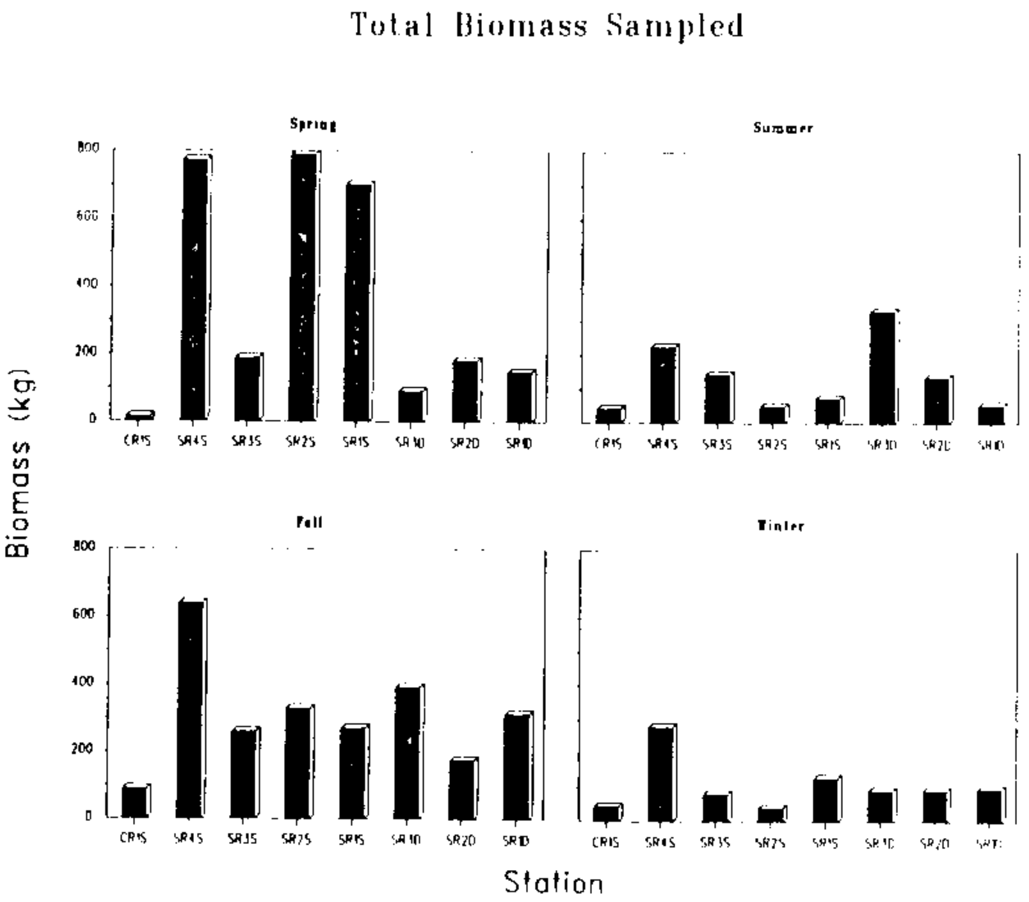


Figure 25. Comparison of total biomass of fishes sampled at each study station in Lower Granite Reservoir, Idaho-Washington, during spring, summer, and fall 1985 and winter 1986.

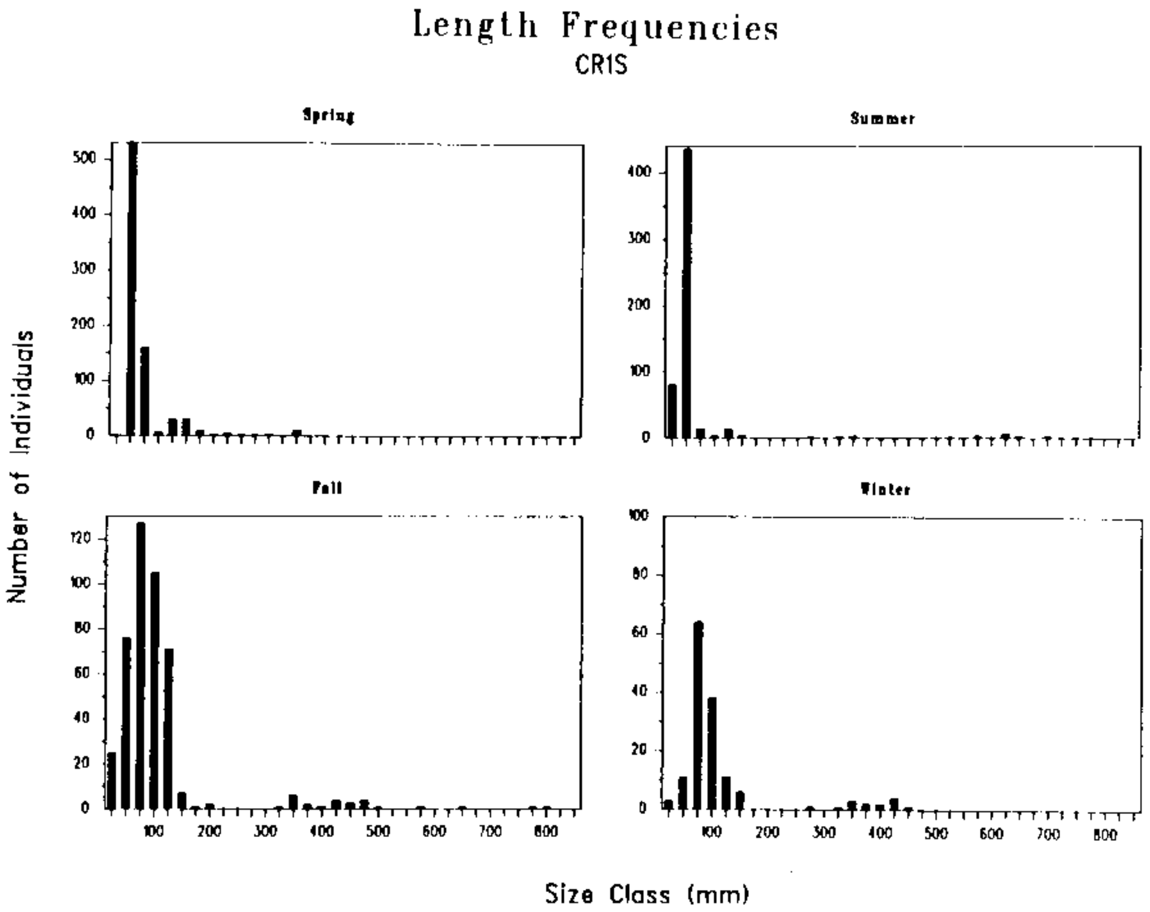


Figure 26. Seasonal length frequencies of fishes captured at CRIS on Lower Granite Reservoir, Idaho in 1985-86.

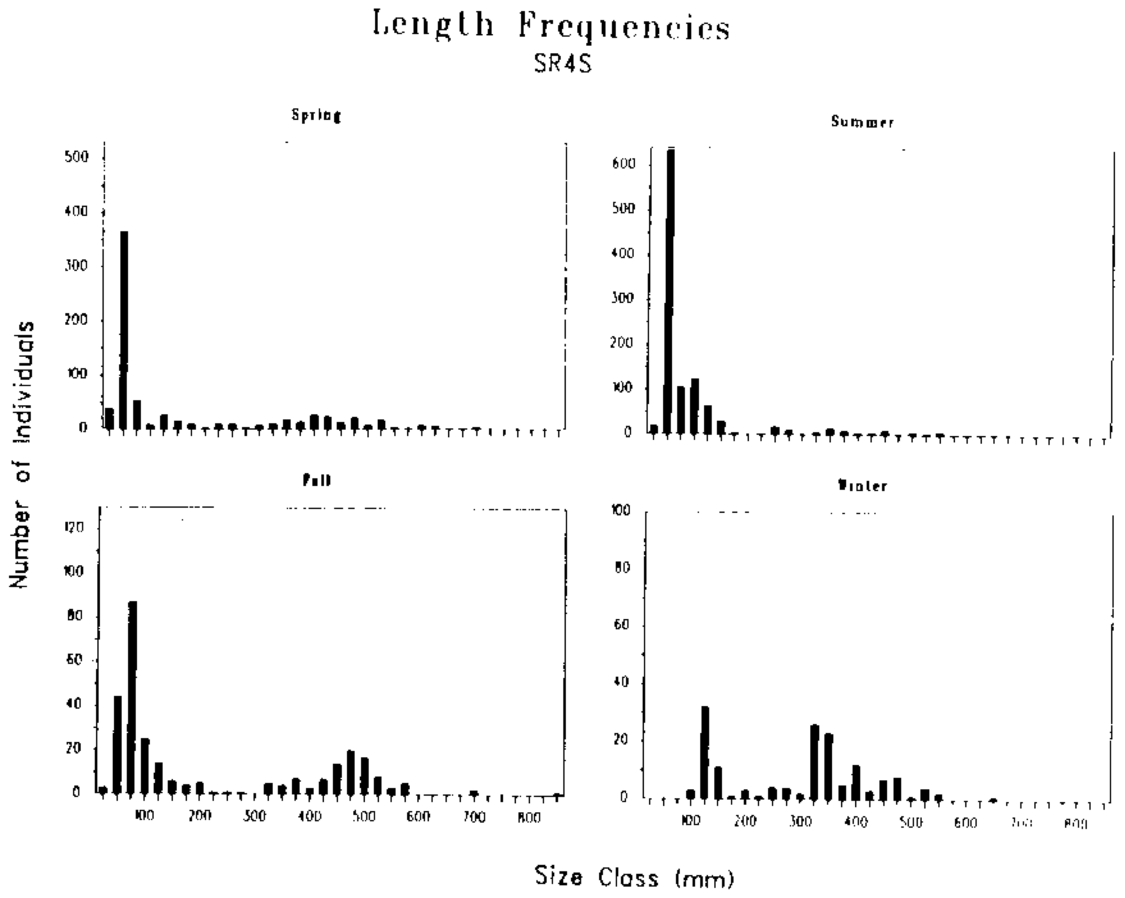


Figure 27. Seasonal length frequencies of fishes captured at SR4S on Lower Granite Reservoir, Washington in 1985-86.

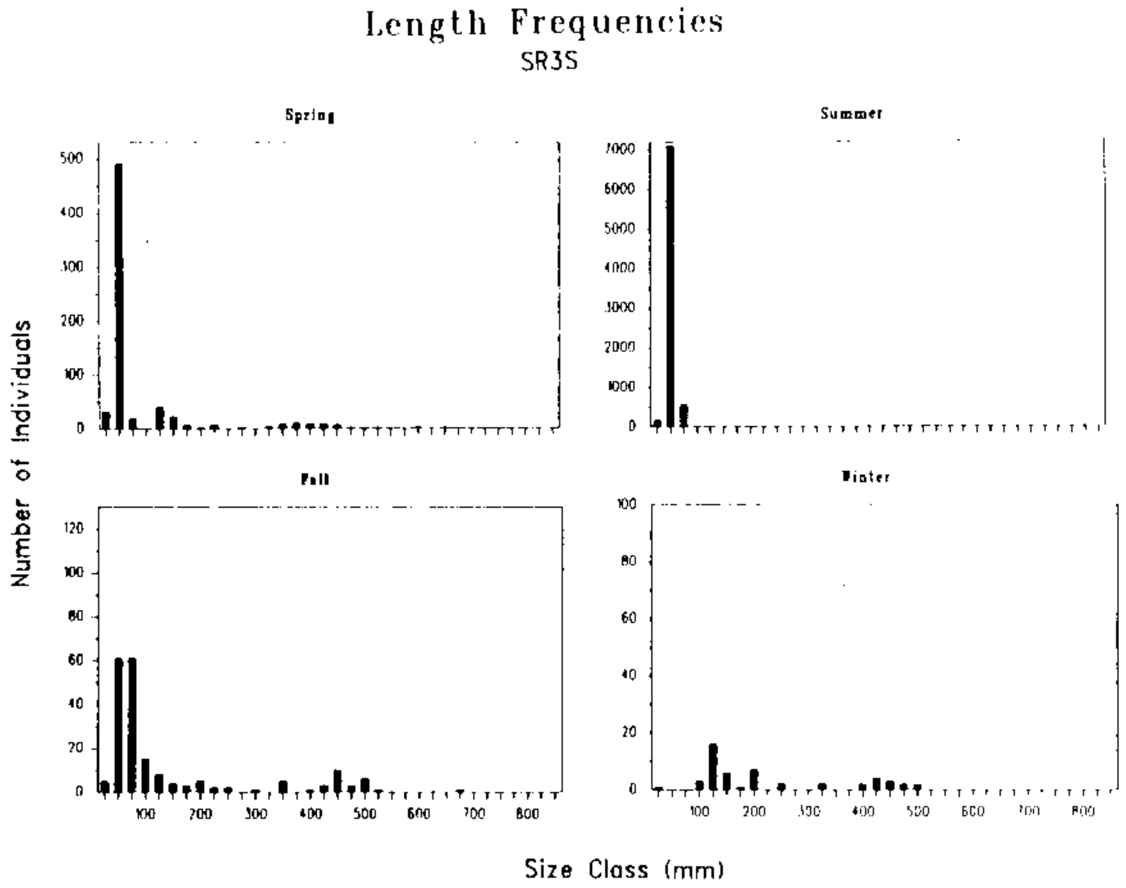


Figure 28. Seasonal length frequencies of fishes captured at SR3S on Lower Granite Reservoir, Washington in 1985-86.

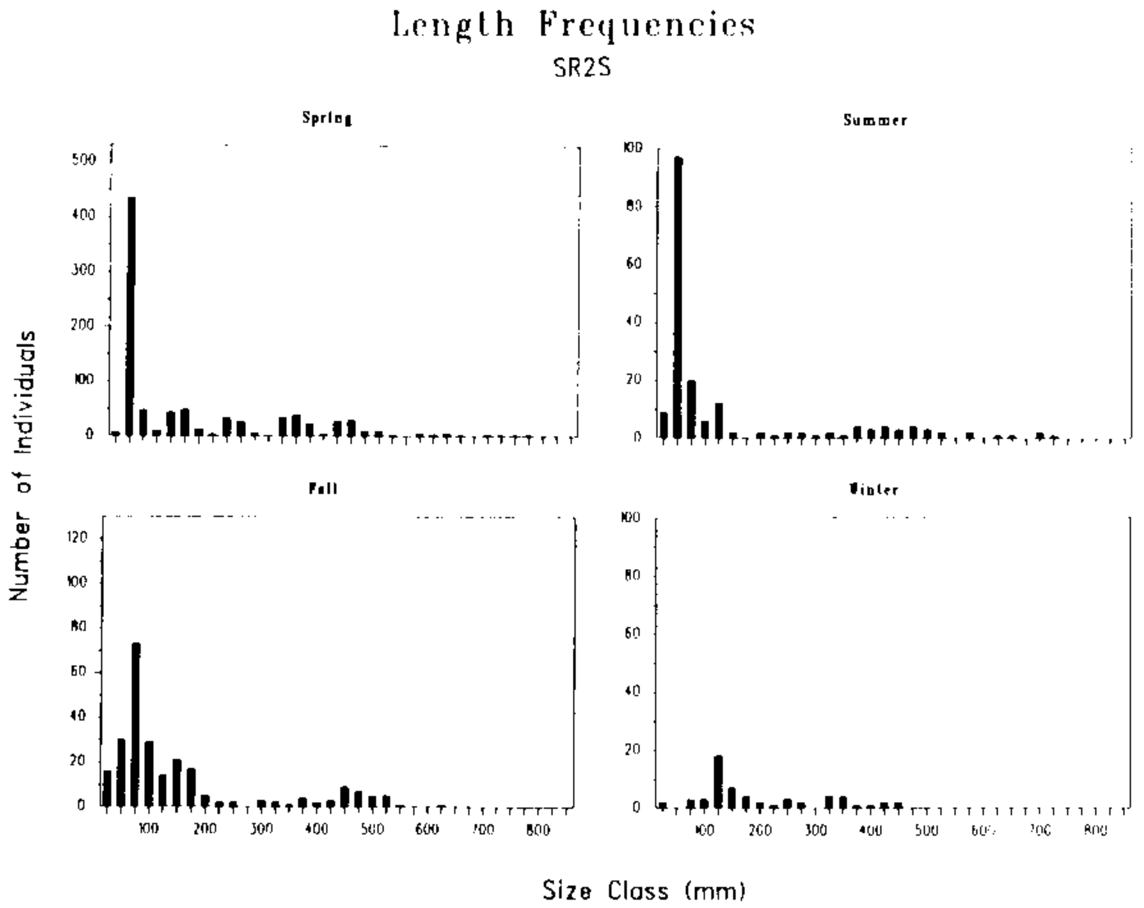


Figure 29. Seasonal length frequencies of fishes captured at SR2S on Lower Granite Reservoir, Washington in 1985-86.

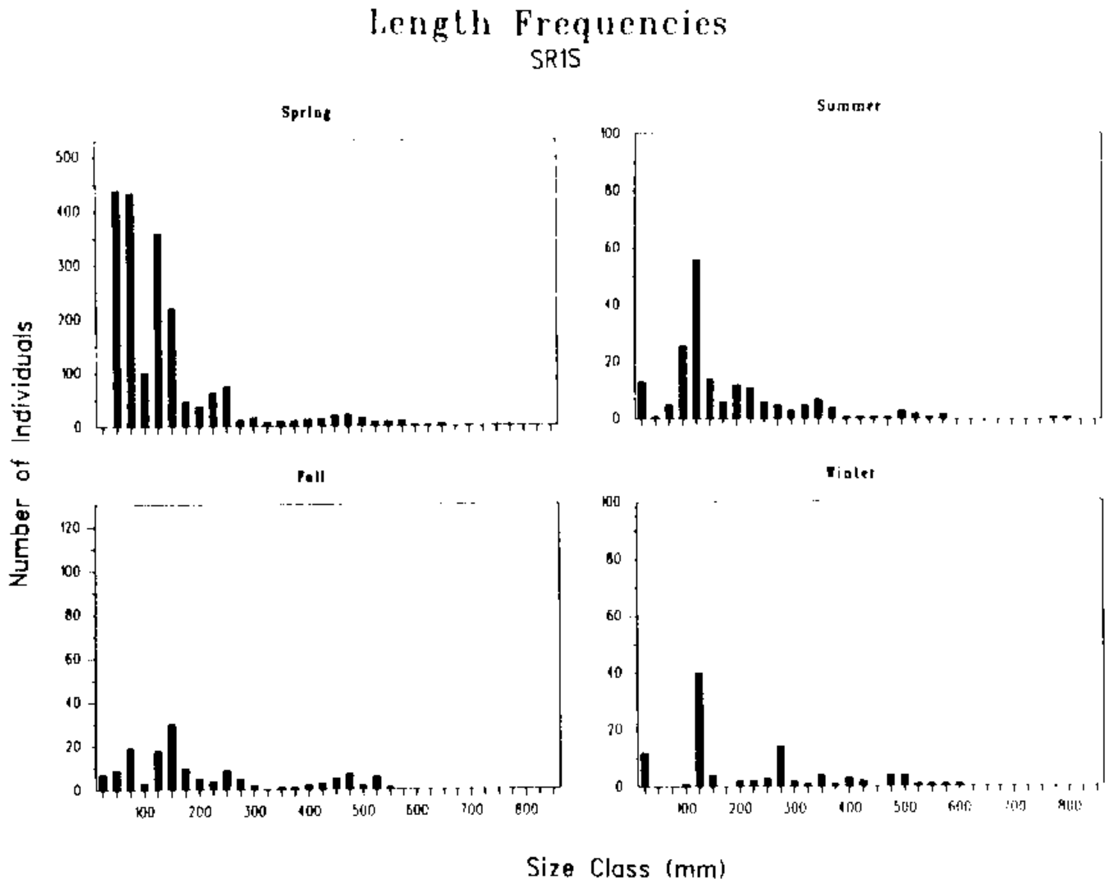


Figure 30. Seasonal length frequencies of fishes captured at SR1S on Lower Granite Reservoir, Washington in 1985-86.

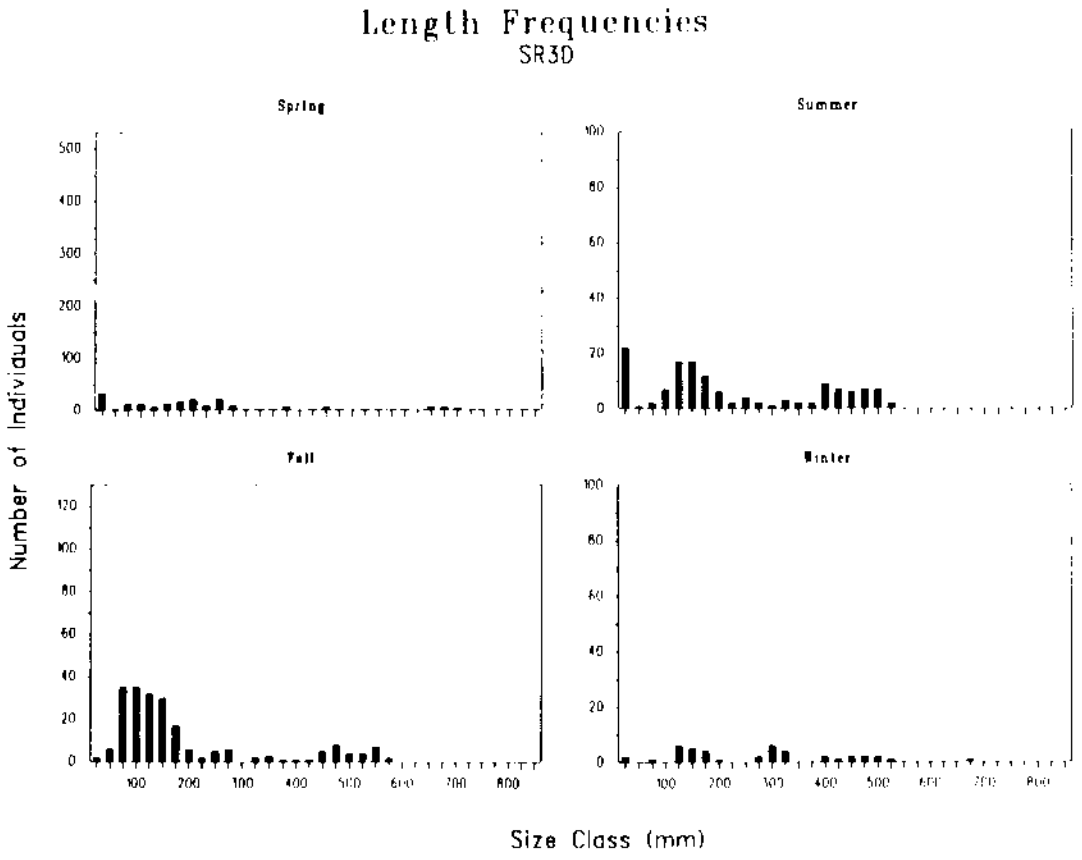


Figure 31. Seasonal length frequencies of fishes captured at SR3D on Lower Granite Reservoir, Washington in 1985-86.

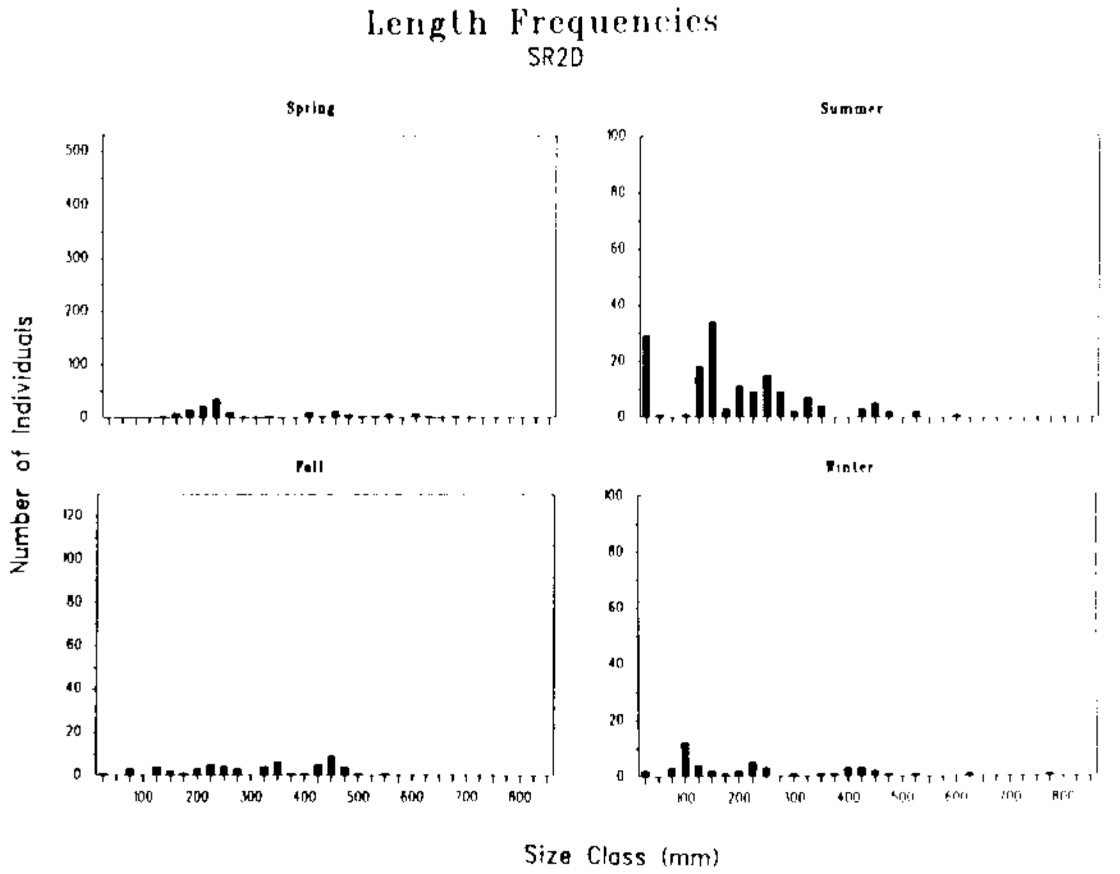


Figure 32. Seasonal length frequencies of fishes captured at SR2D on Lower Granite Reservoir, Washington in 1985-86.

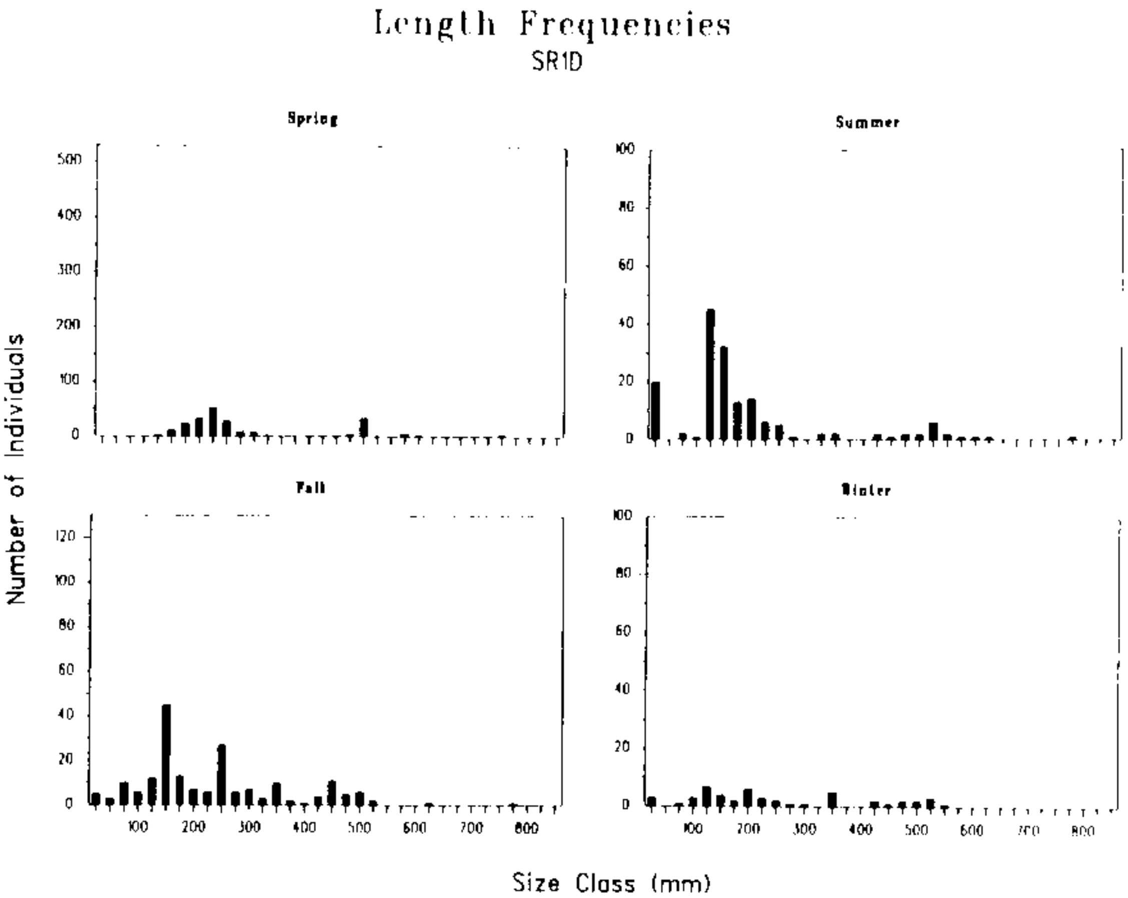


Figure 33. Seasonal length frequencies of fishes captured at SR1D on Lower Granite Reservoir, Washington in 1985-86.

samples and occurrence of smaller fish suggest recruitment of younger fish to open waters. The skewed distribution toward smaller size classes during all seasons at shallow stations suggest the importance of the shallow stations for rearing and holding areas. A majority of the fishes captured at shallow stations were less than 200 mm.

Adult Salmonids

Fifty-three adult steelhead trout and three chinook salmon were captured during the study. A majority were captured during the fall and winter (Fig. 34). During the fall, steelhead trout were most abundant at SR3S while none were captured at SR4S. Fewer steelhead were captured during the winter sample and none were captured at SR4S and SR3S. Reduced captures during the winter suggest reduced levels of activity. Most of the steelhead trout captured at deep stations were collected at SR3D.

Larval Fish Abundance

Larval fish densities varied by station and season (Fig. 35). As expected, summer sampling produced the highest number of larval fishes and, in particular, larval fish abundance was highest at SR3S. Abundance of larval fishes at deep water stations was consistently low. During any season, representative larval fishes were limited to four families: cyprinidae; catostomidae; ictaluridae; and centrarchidae (Table 7). Species of larval fish

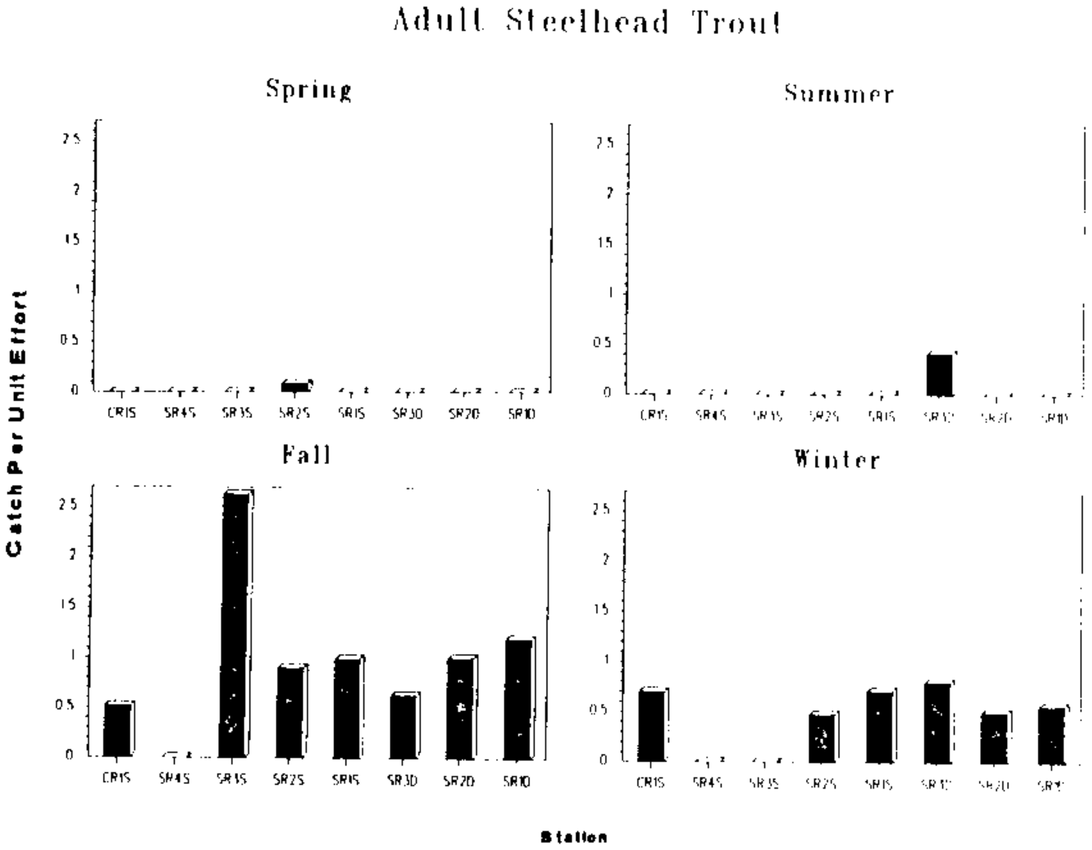


Figure 34. Seasonal comparison of catch per effort (nos./hour) of adult steelhead trout in Lower Granite Reservoir, Idaho-Washington, during spring - fall 1985 and winter 1986.

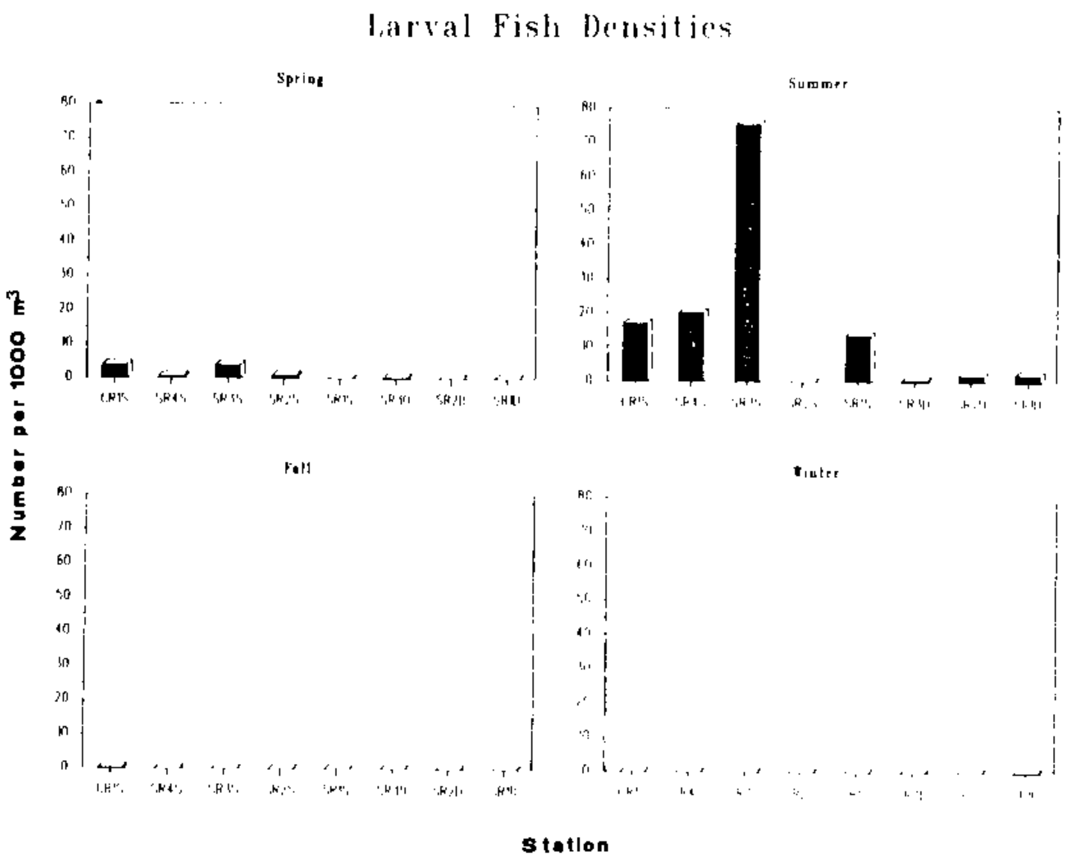


Figure 35. Comparison of larval fish densities (no./1000m^3) at each of the study stations on Lower Granite Reservoir, Idaho-Washington, during spring - fall 1985 and winter 1986.

Table 7. Seasonal comparison of larval fish percent relative abundance in Lower Granite Reservoir 1985-86. Number of fish captured is shown (n).

Species	Season			
	Spring	Summer	Fall	Winter
peamouth		36.9(92)		
northern squawfish		48.2(120)		
redside shiner		7.6(19)	100(1)	
unidentified cyprinid		0.8(2)		
largescale sucker		1.6(4)		
unidentified catostomid	100(56)			100(1)
yellow bullhead		0.4(1)		
tadpole madtom		0.8(2)		
unidentified ictalurid		2.4(6)		
smallmouth bass		1.2(3)		

present were virtually identical between shallow and deep water stations during any given season.

Objective 7
"To determine the importance of the proposed in-water disposal sites to resident and anadromous fishes."

Use of study stations for feeding, spawning, and/or fish food production was assessed through analysis of stomach contents, snorkel transects at shallow stations and benthic sampling.

METHODS

Three benthic samples for statistical replication were collected seasonally at each station using a Ponar dredge (239.25 cm^2). According to Brinkhurst (1974), the Ponar dredge provides a good quantitative estimate of benthic abundance. The particular location of sampling was identical to that for temperature, velocity and oxygen profiles (Objective 5). Samples were strained through a U.S. Standard No. 30 sieve (0.595 mm openings), preserved in FAA and later identified to the lowest possible taxon. The Brillouin's (1962) species diversity index was used to compare diversity among stations.

All five shallow stations were surveyed for spawning activity using shoreline snorkel transects. Biologist divers swam in pairs (one shallow and one deep (2 m)) parallel to the shoreline at each station for 1093-1700 m long transects. Two pairs of swimmers started at opposite ends of the transect and converged while enumerating spawning nests.

To evaluate food habits of potential juvenile salmonid predators and juvenile salmonids and assess the importance of shallow and deep water habitat for feeding, we examined stomach contents. We used a lavage technique similar to that used by Light et al. (1983) except for the pump apparatus. We adapted a boat bilge pump (750 gph) to a pistol type garden hose shut-off and attached a modified flexible copper tube (1/4") that was inserted into the stomach of the fish through the esophagus. Stomach contents were flushed into a bucket, strained through plankton mesh (80 micron), and preserved in FAA. All fish sampled by lavage were anesthetized in MS-222. Stomachs of northern squawfish and channel catfish were surgically removed as a result of the inadequacies of the lavage technique to sample food habits from these particular species.

Stomach contents of fish were identified with dissecting and compound microscopes. Aquatic organisms were identified to the lowest possible taxon; terrestrial organisms were identified to order. Keys used in identification were Pennak (1978), Mason (1968), Merritt and Cummins (1978), Wiggins (1977), and Borror et al. (1976). Weights and numbers of unidentifiable insect parts were categorized under miscellaneous insects and assigned a numeric value of one. Digestion of various body parts often precluded species identification. As a result, these items were placed in miscellaneous categories.

Wet weights of food items were measured by blotting each organism on a paper towel before weighing. Weights for unidentifiable insect parts (miscellaneous insects category) were determined by averaging all insect weights per organism and dividing by eight (average number of insect body parts). Small organisms were counted and weighed as a taxonomic group. An average weight for an individual organism in each taxon was then calculated. Mean weights were used to compute total weights of smaller organisms.

RESULTS

Benthos Abundance, Diversity and Evenness

Mean densities of benthos generally were highest in the summer and lowest in the spring (Tables 8 - 11) although few trends were found. Little consistent difference was found in numbers of benthos between shallow and deep stations. Two shallow stations, CR1S and SR1S, consistently produced the lowest numbers of benthos, while stations SR4S and SR3S yielded the highest number of benthos. Two types of organisms, annelids and dipterans, accounted for 98.0% (winter) - 100.0% (summer) of the total benthic abundance. Plecopterans, coleopterans, amphipods, and tricopterans contributed to the diversity but were numerically low in abundance.

Diversity and evenness of benthos were highest in the winter and lowest in the summer (Fig. 36 and 37). Although benthic densities at shallow stations SR1S and CR1S (Tables 8 - 11) were low, benthic diversity and evenness generally were high at these stations. Conversely, density was high at SR4S and SR3S and diversity and evenness were low. Indices of benthic diversity and evenness generally were lower at deep stations than at shallow stations, especially at SR2D that exhibited low diversity and evenness.

Table 8. Mean density of benthic organisms (nos./m^2) collected from Lower Granite Reservoir, Idaho-Washington, April-June (spring), 1985.

	STATION								
TAXA	CR1S	SR4S	SR3S	SR2S	SR1S	SR3D	SR2D	SR1D	TOTALS
NEMATODA	--	28	--	--	--	--	--	--	28
ANNELIDA									
Oligochaeta	724	906	2466	1003	14	1505	683	753	8054
Hirudinea	--	--	--	--	--	14	--	--	14
COPEPODA									
Temoridae									
Epischura nevadensis	--	--	--	--	28	--	--	--	28
AMPHIPODA									
Gammaridae									
Gammarus lacustris	--	--	--	--	14	--	--	--	14
TRICHOPTERA									
Polycentropodidae									
Polycentropus sp.	--	--	14	--	--	--	--	--	14
DIPTERA									
Chironomidae									
Tanypodinae									
Procladius sp.	14	--	98	181	14	112	153	153	725
Pupae	--	--	--	14	--	--	--	56	70
Chironominae									
Chironomini									
Chironomus chironomus	14	14	98	348	28	14	28	28	572
Cryptochironomus sp.	70	--	--	14	--	28	--	--	112
Endochironomus sp.	111	--	--	--	--	--	--	--	111
Polypedilum sp.	14	56	56	84	--	--	--	--	210
Tribelos sp.	--	--	14	--	--	--	--	--	14
TOTALS	947	1004	2746	1644	98	1673	864	990	9966

Table 9. Mean density of benthic organisms (nos./m^2) collected from Lower Granite Reservoir, Idaho-Washington, July-September (summer), 1985.

	STATION								
TAXA	CR1S	SR4S	SR3S	SR2S	SR1S	SR3D	SR2D	SR1D	TOTALS
ANNELIDA									
Oligochaeta	1198	5789	1952	1435	1658	1755	2285	3971	20043
DIPTERA									
Chironomidae									
Tanypodinae									
Procladius sp.	14	84	209	42	77	376	125	139	1066
Chironominae									
Chironomini									
Chironomus chironomus	669	989	362	571	84	139	42	223	3079
Cryptochironomus sp.	--	--	--	--	14	--	--	--	14
Endochironomus sp.	56	--	--	--	--	--	--	--	56
Polypedilum sp.	--	28	111	14	21	--	--	14	188
Pupae	28	14	--	--	--	--	--	28	70
Tanytarsini									
Tanytarsus sp.	--	28	--	--	--	--	--	--	28
TOTALS	1965	6932	2634	2062	1854	2270	2452	4375	24544

Table 10. Mean density of benthic organisms (nos./m^2) collected from Lower Granite Reservoir, Idaho-Washington, October-December (fall), 1985.

	STATION								
TAXA	CR1S	SR4S	SR3S	SR2S	SR1S	SR3D	SR2D	SR1D	TOTALS
ANNELIDA									
Oligochaeta	543	2800	2621	1087	70	1768	1910	573	11372
Hirudinea	--	--	--	12	--	--	12	--	24
AMPHIPODA									
Corophium sp.	--	--	--	--	12	--	--	--	12
DIPTERA									
Chironomidae									
Tanypodinae									
Procladius sp.	--	--	155	96	14	322	125	29	741
Dicrotendipes sp.	29	12	--	--	--	--	--	--	41
Chironominae									
Chironomini									
Chironomus chironomus	238	138	155	1032	--	138	42	222	1965
Cryptochironomus sp.	--	--	29	12	--	--	--	--	41
PELECYPODA									
Corbidulidae									
Corbicula manilensis	--	--	--	--	70	--	12	--	82
TOTALS	810	2950	2960	2239	166	2228	2101	824	14278

Table 11. Mean density of benthic organisms (nos./m^2) collected from Lower Granite Reservoir, Idaho-Washington, January-March (winter), 1986.

TAXA	STATION								
	CR1S	SR4S	SR3S	SR2S	SR1S	SR3D	SR2D	SR1D	TOTALS
NEMATODA	--	42	14	--	--	--	--	--	56
ANNELIDA									
Oligochaeta	28	2522	2480	975	223	738	1839	1379	10184
PLECOPTERA									
Chloroperlidae	14	--	--	--	--	--	--	--	14
AMPHIPODA									
Corophium	--	28	14	--	--	--	84	--	126
TRICHOPTERA									
Psychomyiidae									
Psychomyia sp.	--	--	14	--	--	--	--	--	14
DIPTERA									
Chironomidae									
Tanypodinae									
Procladius sp.	--	--	--	279	28	112	--	139	558
Chironominae									
Chironomini									
Chironomus chironomus	70	14	334	655	28	153	21	209	1484
Cryptochironomus sp.	--	--	--	139	--	--	--	--	139
Dicrotendipes sp.	--	--	28	--	--	--	--	--	28
Phaenopsectra sp.	--	56	28	--	--	--	--	--	84
Micropsectra sp.	14	--	--	--	--	--	--	--	14
Orthocladiinae									
Orthocladius sp.	28	--	--	--	--	14	--	--	42
PELECYPODA									
Corbidulidae									
Corbicula manilensis	--	--	--	--	--	--	--	14	14
COLEOPTERA									
Elmidae									
Microcylloepus sp.	14	--	--	--	--	--	--	--	14
Carabidae	14	--	--	--	--	--	--	--	14
TOTALS	182	2662	2912	2048	279	1017	1944	1741	12785

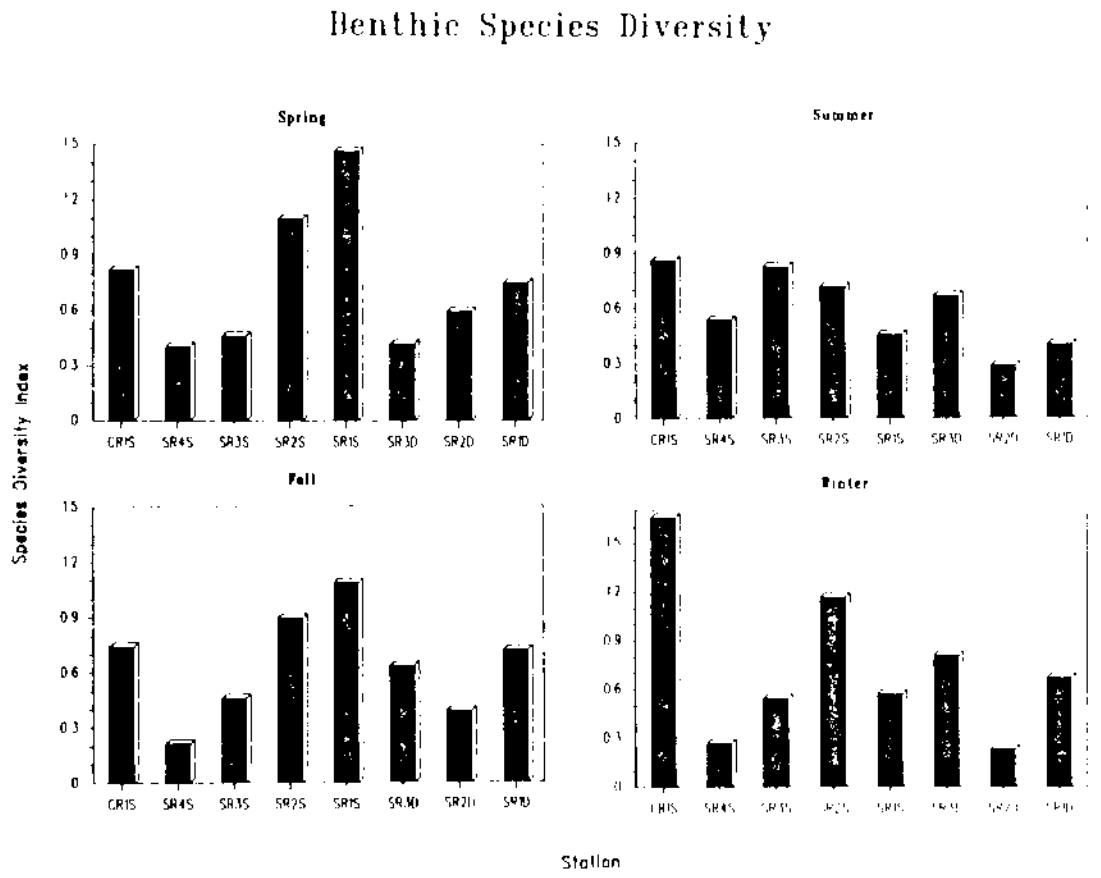


Figure 36. Species diversity indexes (Brillouin 1962) for benthos at each of the study stations on Lower Granite Reservoir, Idaho-Washington, during spring - fall 1985 and winter 1986.

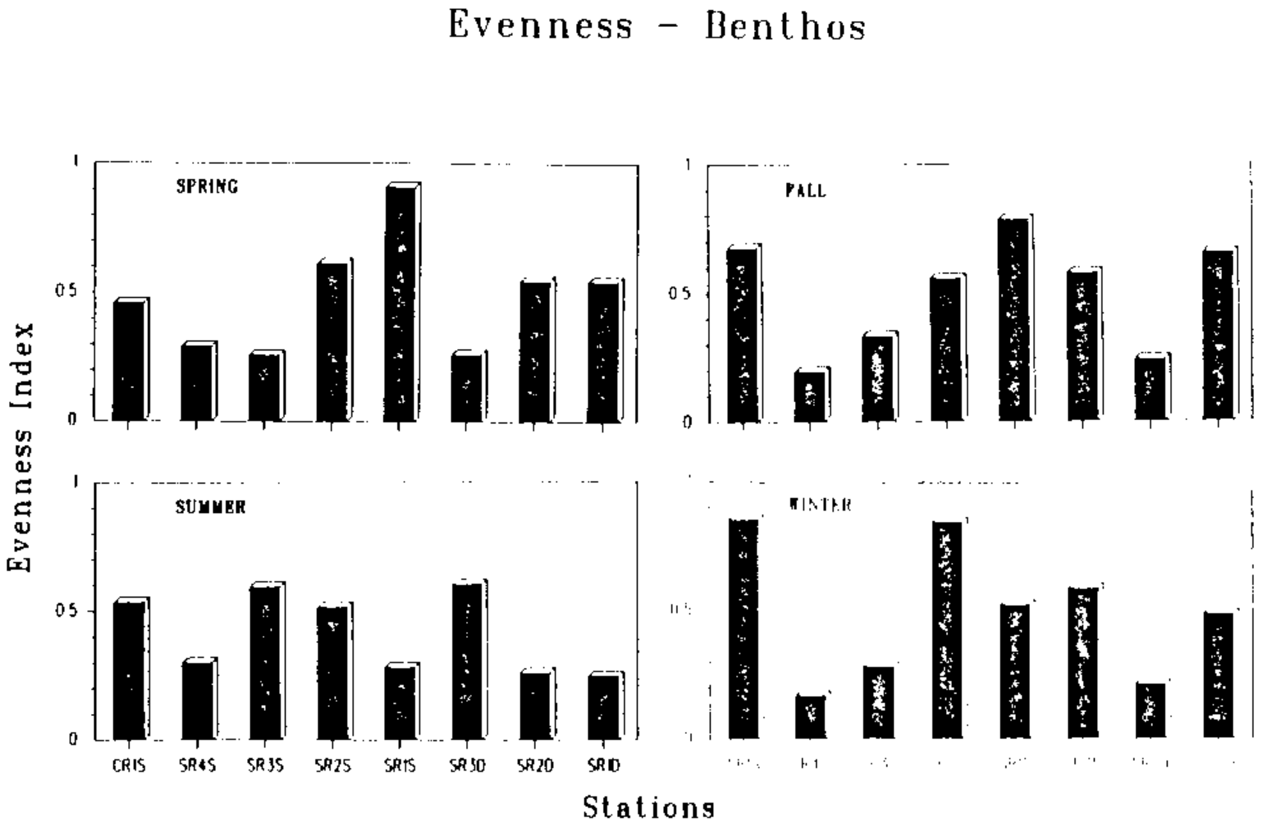


Figure 37. Evenness indexes for benthos collected in Lower Granite Reservoir, Idaho-Washington, during spring, summer and fall 1985 and winter 1986. Evenness indexes were calculated suing Brillouin's species diversity index.

Spawning Activity

Evidence of spawning, based on the presence of nests, was observed at each of the Snake River shallow water stations (Table 12). The appearance of nests enabled their enumeration and provided an index of use by centrarchid/ictalurid fishes for spawning. Although most of the nests were inactive, one nest (SR1S) contained bass fry. Stations SR1S, SR2S and SR4S had the highest number of nests, whereas at CR1S, no nests were observed. Comparisons of the density of nests suggests relatively low utilization of the shallow stations for spawning, except possibly SR1S.

Food Habits

Salmonid fishes

Juvenile salmonid fishes fed on a variety of aquatic invertebrates and fish (Figs. 38 - 41). Diptera, at various stages of development (adults, pupae, etc.), comprised the bulk of the diet. Few differences were found between dietary items of steelhead trout and chinook salmon, although juvenile salmon stomachs contained higher amounts of fish flesh. The few salmonids collected in the summer contained dipterans, miscellaneous insects and fish. In the fall, terrestrial insects and fish made up the bulk of the diet of both juvenile steelhead and chinook salmon. In

Table 12. Number of spawning sites (nests) counted on 1 August, 1985 at shallow water sampling stations on Lower Granite Reservoir.

Station	Effort(hours)	Transect Length	No. of Sites	No./m
CR1S	3	1350	0	0.0
SR4S	3	1350	21	.016
SR3S	4	1700	6	.004
SR2S	3	1350	23	.017
SR1S	4	1093m	28	.026

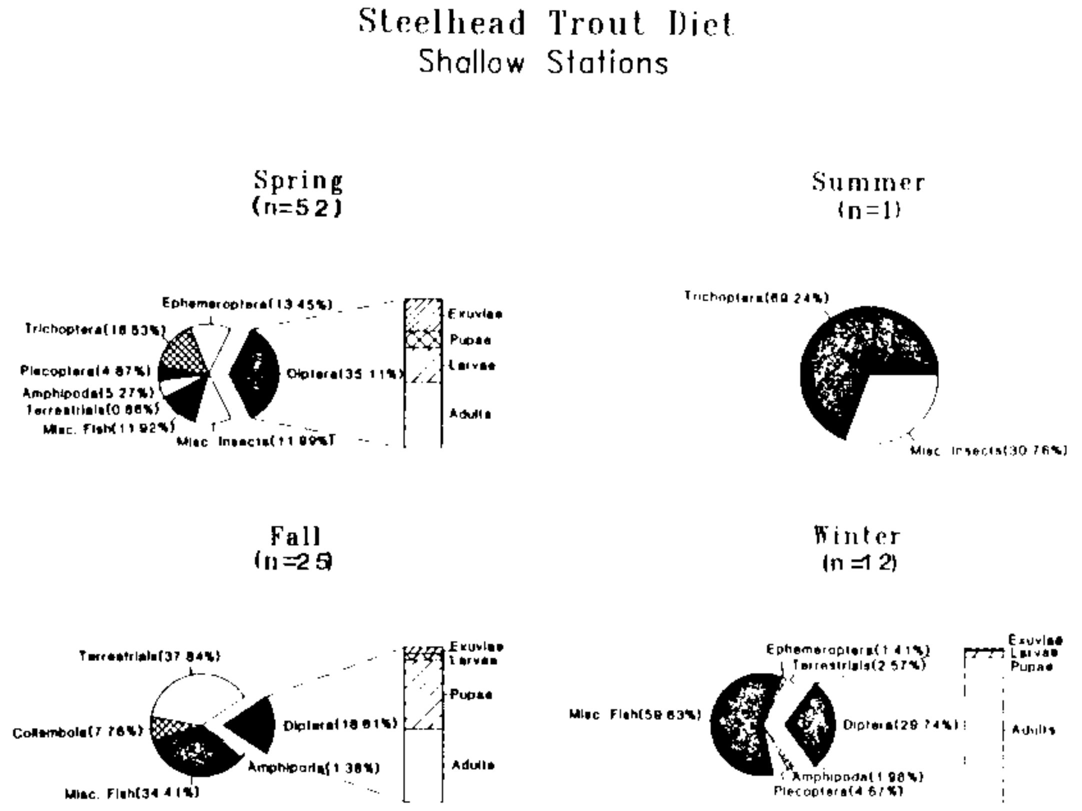


Figure 38. Seasonal food habits (percent wet weight) of juvenile steelhead trout captured at shallow stations on Lower Granite Reservoir, Idaho-Washington, during spring - fall 1985 and winter 1986.

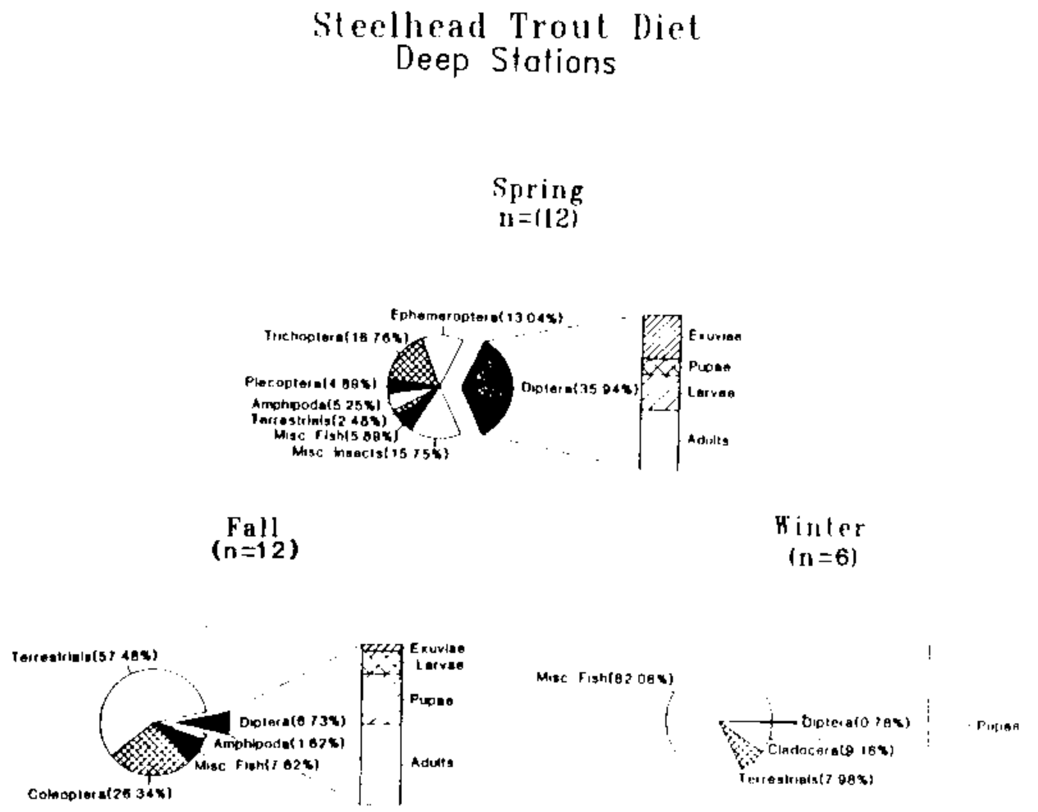


Figure 39. Seasonal food habits (percent wet weight) of juvenile steelhead trout captured at deep stations on Lower Granite Reservoir, Washington, during spring and fall 1985 and winter 1986.

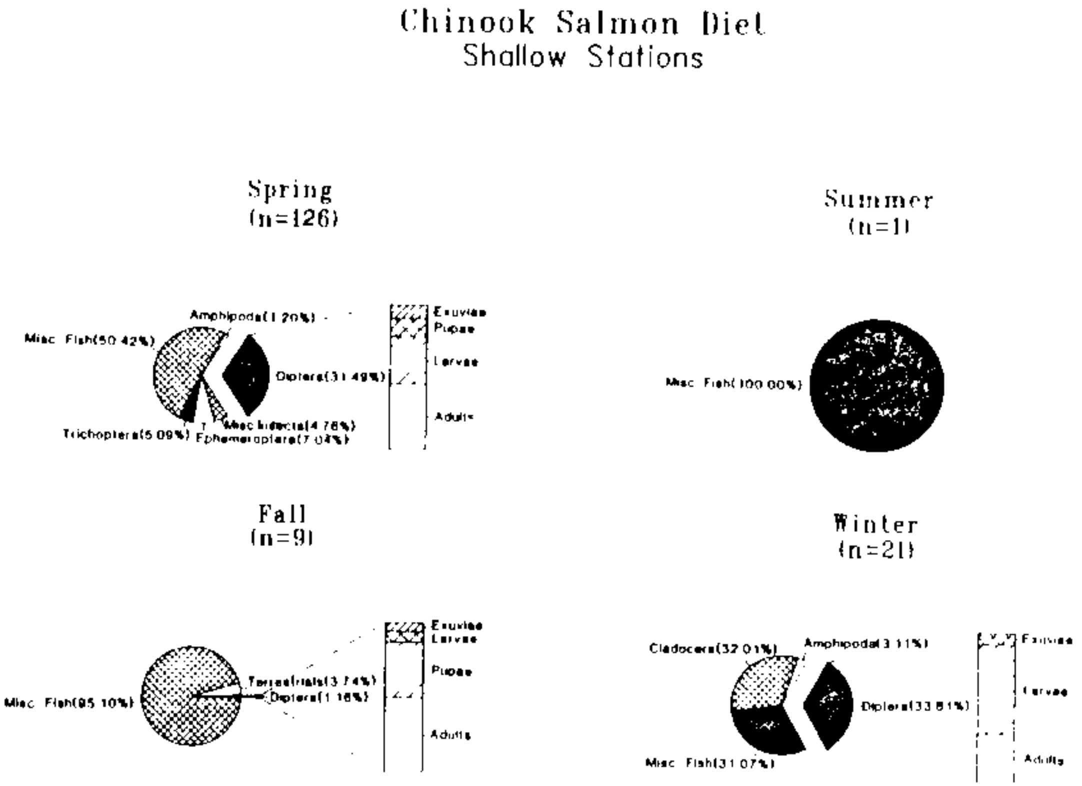


Figure 40. Seasonal food habits (percent wet weight) of juvenile chinook salmon captured at shallow stations on Lower Granite Reservoir, Idaho-Washington, during spring - fall 1985 and winter 1986.

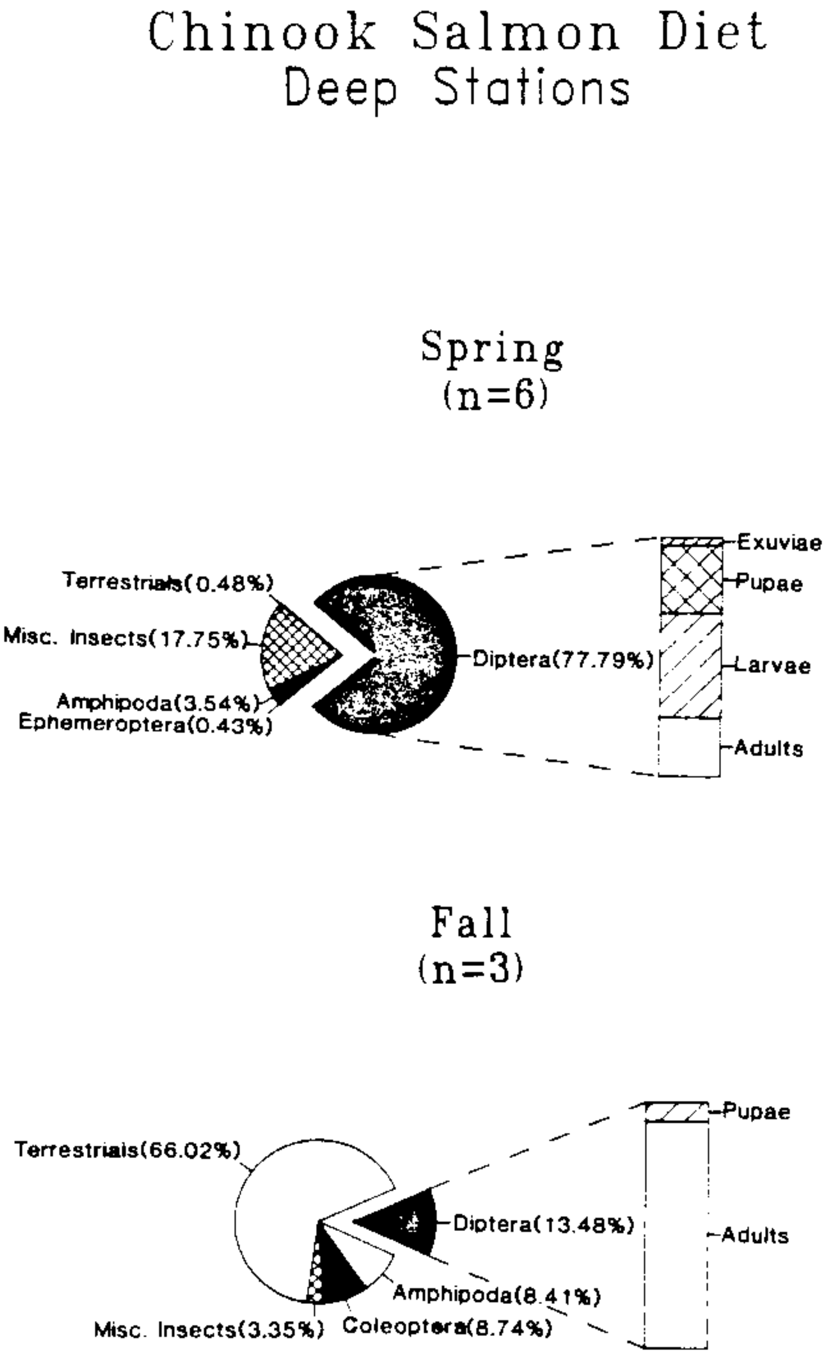


Figure 41. Seasonal food habits (percent wet weight) of juvenile chinook salmon captured at deep stations on Lower Granite Reservoir, Washington, during spring and fall 1985.

general, steelhead trout stomachs contained a higher diversity of organisms than those of chinook salmon.

Comparison of the diet between salmonids collected from deep and shallow stations is difficult. Smaller sample sizes from deep stations and possibly timing differences within a seasonal period permit only generalities. Diversity of dietary items in juvenile chinook salmon and steelhead trout collected from shallow and deep stations was similar. In general, items abundant in stomachs of salmonids from shallow stations also were abundant in fish from deep stations. The higher incidence of terrestrial insects in the diet of salmonids in the deep water was surprising and may suggest near-surface feeding. Also, the low percentage of fish in the diet of chinook salmon and steelhead trout in all seasons but winter suggests low availability of forage in deep waters.

Smallmouth Bass

Smallmouth bass fed on a variety of organisms although crayfish (Decapoda) was consistently the dominant food item (Figs. 42 and 43). Salmonid (26%) and miscellaneous (22.4%) fishes comprised more than 48% of the diet of smallmouth bass in the spring at shallow stations but considerably less (15%) at deep stations. In the summer, crayfish was the dominant food item in bass from shallow and deep stations. Diversity of dietary items generally was higher in fish from shallow stations.

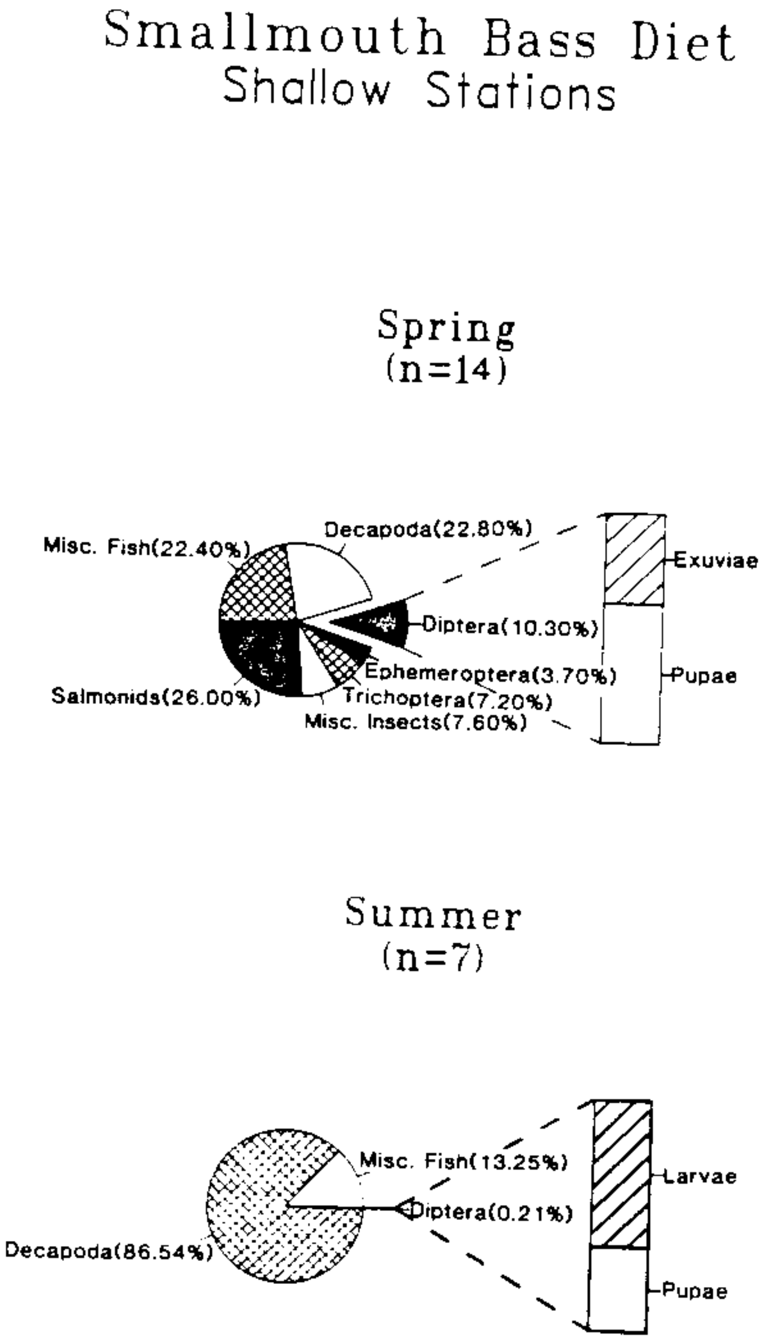


Figure 42. Seasonal food habits (percent wet weight) of adult smallmouth bass captured at shallow stations on Lower Granite Reservoir, Idaho-Washington, during spring and summer 1985.

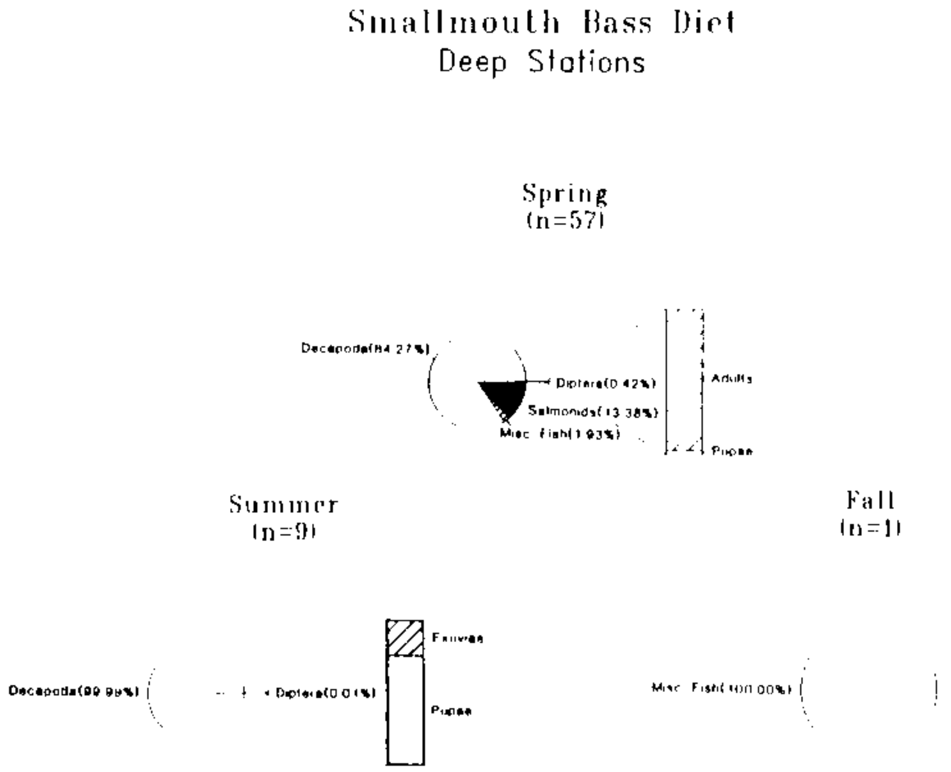


Figure 43. Seasonal food habits (percent wet weight) of adult smallmouth bass captured at deep stations on Lower Granite Reservoir, Washington, during spring - fall 1985.

Northern Squawfish

Dietary items of northern squawfish were most diverse in the spring and decreased in diversity through the summer and fall (Figs. 44 and 45). Food habits of northern squawfish in the winter exhibited high diversity similar to the spring. Stomach contents were more diverse in fish from shallow stations than those from deep stations especially during the spring and winter periods. In the fall, crayfish comprised more than 70% of the diet of northern squawfish from shallow stations and nearly 100% of the diet at deep stations. Fish, including salmonids, was of varying importance comprising from 5-86% of the wet weight of dietary items. Fish was an important dietary component in the spring, summer and fall. Aquatic and terrestrial insects comprised more than 25% of the food items.

Miscellaneous Fishes

Yellow perch, sockeye salmon, white crappie, and channel catfish were collected in low abundance in Lower Granite Reservoir (Fig. 46). Yellow perch (n=5) consumed dipterans and various terrestrial and aquatic insects, while 47% of the diet consisted of miscellaneous fish. Sockeye salmon stomachs (n=2) contained ephemeropterans and terrestrial insects but exhibited lower diversity than food items in chinook salmon. White crappie (n=5) contained mainly miscellaneous fish. Samples of channel catfish (n=5) indicate heavy feeding on crayfish in the summer. Insects were not abundantly represented in channel catfish stomachs. Fish comprised only 3.2% of the weight of food items for channel

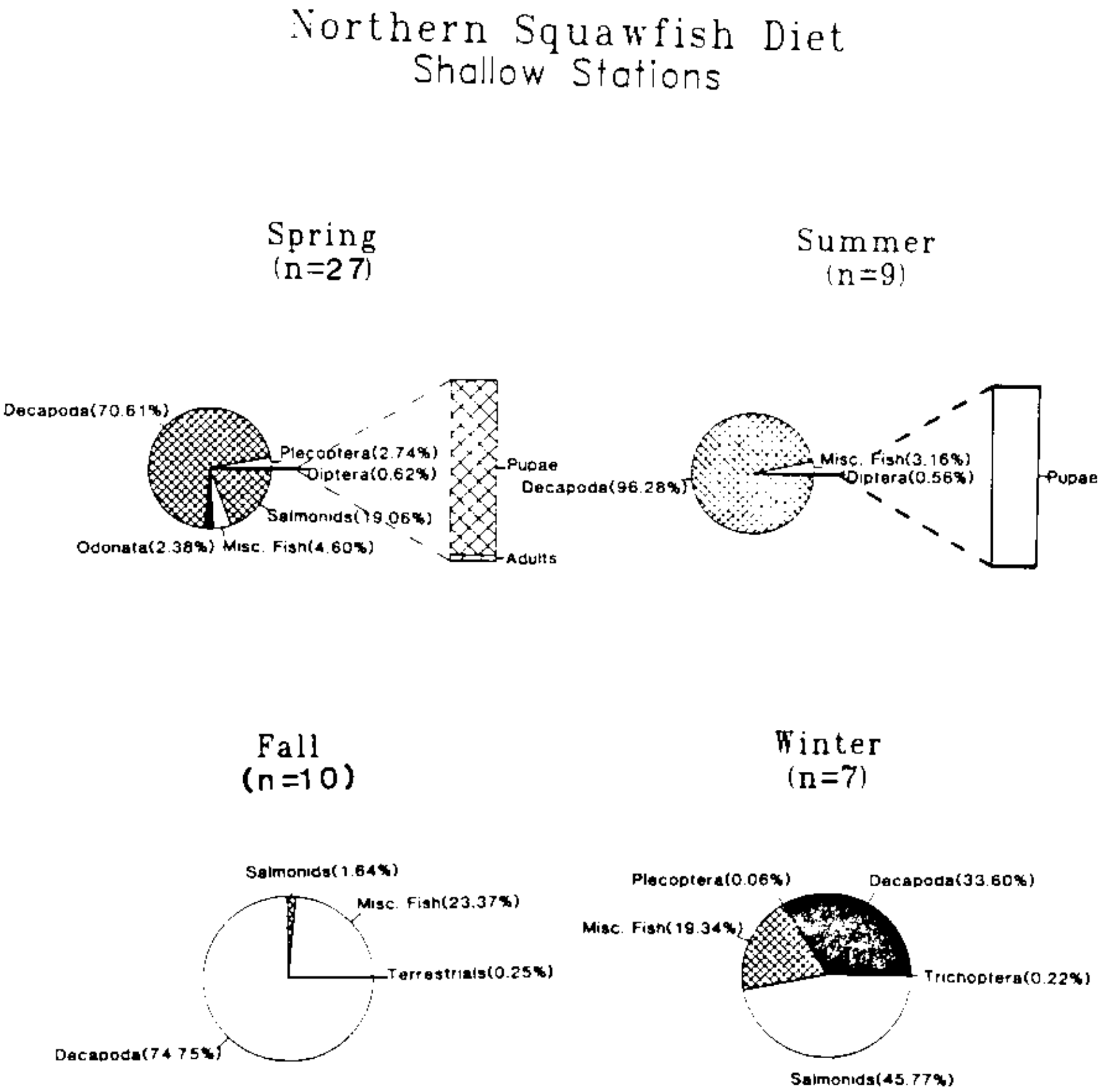


Figure 44. Seasonal food habits (percent wet weight) of adult northern squawfish captured at shallow stations on Lower Granite Reservoir, Idaho-Washington, during spring - fall 1985 and winter 1986.

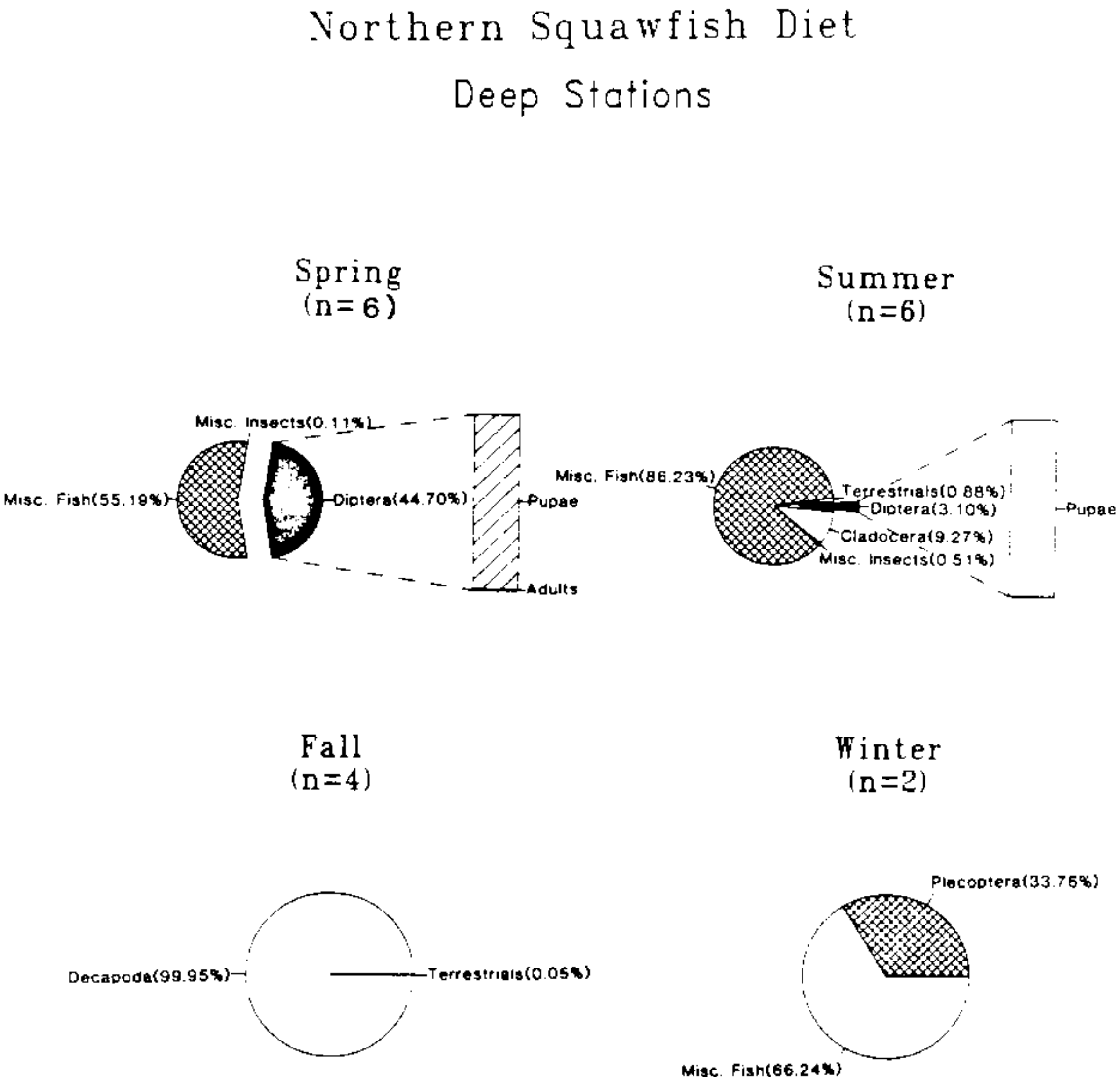


Figure 45. Seasonal food habits (percent wet weight) of adult northern squawfish captured at deep stations on Lower Granite Reservoir, Washington, during spring - fall 1985 and winter 1986.

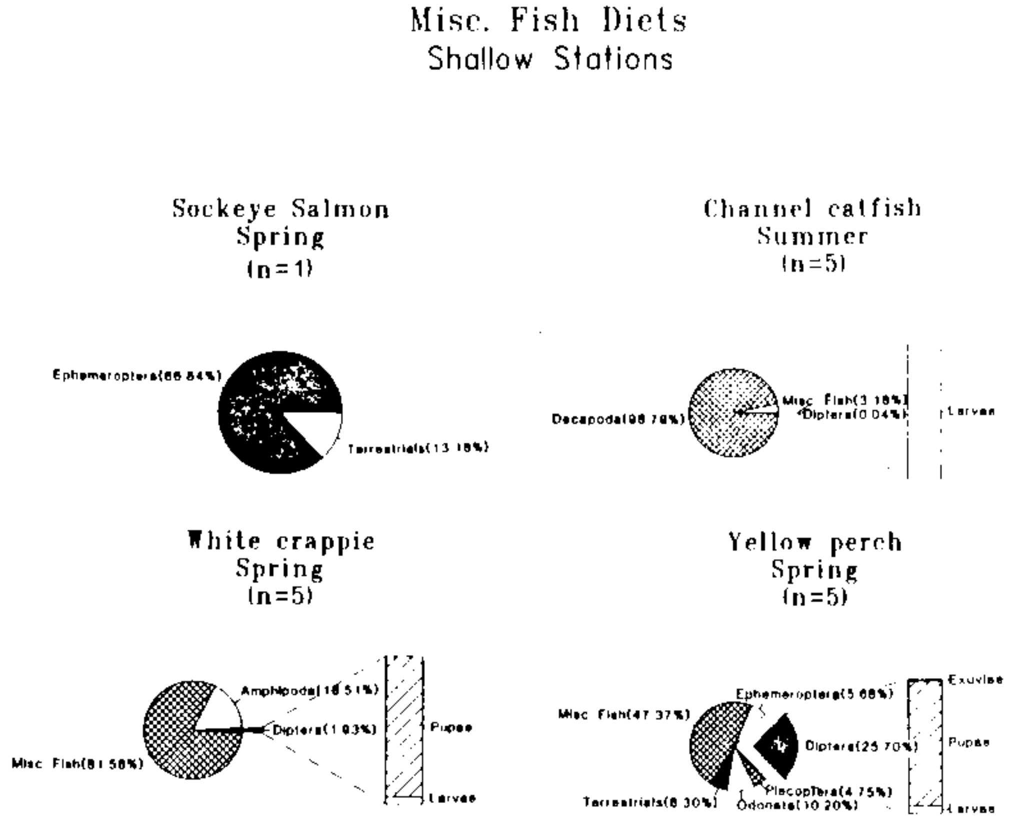


Figure 46. Food habits (percent wet weight) of miscellaneous fishes captured at shallow stations on Lower Granite Reservoir, Idaho-Washington, during spring and summer 1985.

catfish. Although all of these species contained fish, we cannot say with confidence that any of these were or were not salmonid juveniles because of the high degree of digestion.

DISCUSSION

Physical-Chemical Characteristics

Our results have shown that each sampling station provided a slightly different habitat from the others. For example, our initial substrate analysis suggested that particle size distributions generally were similar among stations, with the exception of SR1S which provided a wider breadth of substrate sizes (Appendix A-3 and A-4). However, when we analyzed for particles smaller than 0.25 mm we found significant differences ($P<0.01$) among deep and shallow stations (Fig. 13). That analysis showed that clay content of the substrate generally increased with distance downstream in Lower Granite Reservoir. Percent clay particles ranged from 14 (SR3S) - 28% (SR1D). Both values are higher than those (~10%) reported by Dorband (1980) for Lower Granite Reservoir in the late 1970's. Dorband reported a homogeneous distribution of silt particles from the upstream end of Lower Granite (RM 140) downstream to near the dam (RM 107) which was not found in our study. Differences in particle sizes may be related to the increased build-up of smaller particles or sampling design as we generally sampled shallow water substrates in the upper reservoir and deep water substrates in the lower reservoir, whereas Dorband (1980) examined cross sectional profiles at about five sites throughout Lower Granite.

Water temperatures and dissolved oxygen levels were similar among shallow and deep stations on the Snake River. Other than minor depth differences that could account for differences in temperature and dissolved oxygen, the stations were similar (Figs. 9 and 10).

As in Little Goose Reservoir (Bennett et al. 1983), no thermal stratification was present at either the shallow or deep stations. Velocity was another habitat variable that did vary among stations (Figs. 11 and 12). As expected, upstream stations had higher velocities and more homogeneous velocities within a station. However, the range of velocities measured in Lower Granite Reservoir was not considered limiting to any of the fishes collected.

One shallow station, SR1S, provided considerably more diverse habitat from other stations. The key question was what characteristics contributed to higher habitat diversity at SR1S than at other stations. Water temperatures and dissolved oxygen levels were similar, while substrate (Fig. 13), depth, and velocity (Fig. 11) were different. Slope of the shoreline was gradual and a wide diversity of substrates were available. The station location of SR1S was situated on the downstream side of a rip-rapped spit. The rip-rap was boulder to cobble-sized material (128 - >256 mm) which provided good cover for smaller fish and substrate for attached benthic organisms. Dorband (1980) reported that tricopterans, ephemeropterans, and dipterans dominated hard substrates in Lower Granite Reservoir. Organisms in these orders were commonly found in chinook salmon and steelhead trout stomachs (Figs. 38-41). The position of the spit running perpendicular to the river channel created a wide range of velocities from a high of those presented (Fig. 11) to no perceptible water movement. Also, aquatic macrophytes were present to further contribute to habitat diversity and productivity at SR1S (Table 1).

Biotic Communities

Benthos

We found that benthic organisms generally were abundant at all stations (Tables 8 - 11). Densities were highest in the summer and lowest in the spring. Stations SR4S and SR3S consistently had the highest number of organisms, while SR1S and CR1S had the lowest number of organisms. Density of benthos and diversity and evenness were inversely related. For example, densities at SR1S and CR1S were low (Tables 8 - 11) but evenness (Fig. 37) and diversity (Fig. 36) were high. We attribute the high diversity and evenness at CR1S and SR1S to substrate diversity. Dorband (1980) did not find any correlations between substrate size and benthic abundance but he did report that tricopterans, ephemeropterans and dipterans dominated the hard substrates in Lower Granite Reservoir. As indicated earlier, these organisms are important fish food items.

Our benthic sampling with a Ponar dredge emphasized a larger sample area but sacrificed sampling effectiveness in depth. Brinkhurst (1974) indicated that the Ponar dredge provides a good quantitative estimate of benthos abundance but the limited depth of sampling (< 15 cm) probably precluded sampling various instars as compared to a multiple corer. Word (1976) in his evaluation of benthic invertebrate sampling devices rated the Ponar dredge from good to poor, which was the third best grab sampler of six tested.

His research indicated that about 90% of organisms are sampled in the upper 10 cm although the Ponar dredge may not penetrate to that depth in some substrates. We believe that the softer substrate in Lower Granite Reservoir permitted depth penetration to at least 10 cm and therefore enabled us to adequately sample the benthos. Word (1976) reported that corers typically sampled small in surface area and as a result tended to miss some of the more mobile and sparsely distributed invertebrates. According to Brinkhurst (1974), the Ponar dredge is about 50% efficient for Oligochaetes and dipterans. Also, we used a Standard No. 30 sieve (0.595 mm) to screen benthic samples which may have allowed smaller instars to escape. We do not believe these smaller instars are that important in the diet of fishes, however, because our sampling of food habits with plankton mesh (80 microns) failed to show their abundance.

General Fish Abundance

We found some significant differences among stations in the fish community. Our data (Figs. 16 - 23; Tables 3 - 6) and observations suggest a higher abundance of resident game fish in the lower reservoir. This generality also was true for the abundance of salmonid smolts. Conversely, some stations were more commonly inhabited by nongame fish. SR3S is the station where the highest number of fish were collected. However, a majority of these fish were young-of-the-year northern squawfish. Their abundance apparently attracted juvenile smallmouth bass for feeding, which is probably the reason for high bass abundance at that site in the summer (Table 4). Collectively, fish sampled at SR3S accounted for low biomass (Fig. 25).

We have established the ecological importance of shallow water habitat in Lower Granite Reservoir. These areas are ecologically important for food production and feeding, probably resting habitat, rearing by salmonid fishes and spawning and rearing of resident game and nongame fishes. All shallow stations are receiving varying amounts of natural sedimentation based on our substrate analysis. The finer clays were most abundant at SR1S (23.9%) of all shallow stations, while sands were most abundant at SR3S (Fig. 13). Comparison of the ecological importance of shallow stations provides some insight into possible effects of disposal. First, utilization for spawning was highest at SR1S and lowest at SR3S (Table 12). No sign of spawning activity was observed at CR1S because the water is too cool in the summer to provide suitable spawning habitat for centrarchid fishes (Appendix A-2). Benthic production, although lower at SR1S than SR3S and SR4S, was generally higher in diversity (Fig. 36) and evenness (Fig. 37). Higher community diversity is believed to support a more stable community and one more resistant to wide fluctuations in biotic abundance (Odum 1971). Community evenness reflects the numerical distribution of species within a community (Pielou 1966). Thus, more species dominate the benthic community at SR1S than at most of the other stations. Fish diversity was higher and resident game fishes were more abundant at SR1S (Figs. 14 and 24). Also, catches of adult steelhead trout were on the average highest at SR1S (Fig. 34). Conversely, nongame fishes were more abundant at SR3S (Tables

3 - 6) and, in general, more abundant at "upriver" stations than "downriver" stations (Fig. 24). These comparisons suggest the importance of maintaining and/or enhancing the integrity, quality, and diversity of shallow habitat in the lower reservoir. Data collected by the Army Corps of Engineers (Witt Anderson, U. S. Army Corps of Engineers, Walla Walla, WA, personal communication) show a continuous influx of sediments into the upper portion of the reservoir. This trend will not change substantially in the near future and substrates in these areas will continue to be modified by sediment deposition. However, we believe that higher habitat diversity in the lower reservoir is the reason for the higher organismal diversity and evenness and thus, provides more attractive habitat for game fishes. If the habitat diversity were changed as a result of sediment disposal in the lower reservoir, the biological community also would change.

Numerous larval cyprinid fishes were collected in Little Goose Reservoir (Tables 7 and 13). Northern squawfish and peamouth were the two more abundant larval fishes. These fish were approximately 100 times more abundant in our tow samples than ictalurid and smallmouth bass larvae. Although these densities of larval cyprinids appear high, comparison with those found in Little Goose Reservoir (Bennett et al. 1983) indicated lower abundance in Lower Granite Reservoir (Table 13). Higher densities of larval game fish in Little Goose Reservoir may reflect higher abundance or be related to the intensity of sampling (biweekly vs. seasonal). More frequent sampling would yield a higher probability of capturing game fishes during their short larval stages.

Table 13. Comparison of larval fish densities from Little Goose Reservoir (Bennett et al. 1983) and Lower Granite Reservoir in 1985-86.

Family	Species	Mean Densities (No./1000m^3) Lower Granite	Little Goose
Cyprinidae	peamouth	4.0	0.3
	northern squawfish	6.0	1.1
	redside shiner	1.0	1.8
	unidentified cyprinids	0.05	56.3
Catostomidae	suckers (*Catostomus* sp.)	1.0	3.4
Ictaluridae	yellow bullhead	0.05	0.3
	tadpole madtom	0.05	---
	unidentified ictalurids	0.01	0.1
Centrarchidae	smallmouth bass	0.1	0.2

Our samples provide a seasonal index of relative abundance of various species inhabiting Lower Granite Reservoir. We standardized our effort among shallow and deep stations and believe that differences in abundance reflect actual changes in abundance as effort was similar and catchabilities probably did not change significantly. For example, increased abundance of smaller fishes at deep stations in the fall probably reflects a "real" movement of fishes from littoral areas to deep water. Low numbers of game fishes captured in the winter at the shallow stations probably represents a time when these fish are inhabiting deeper water. Catch rates of most fishes are typically low in the winter, however, as a result of low water temperatures. Lower catch rates at shallow stations and wider length frequency distributions (Figs. 31 - 33) at deep stations support our interpretations of fish movement from shallow to deep areas of Lower Granite Reservoir.

Salmonid Fish Abundance

Our catches of adult steelhead trout probably reflect changes in their abundance and use of various areas. Catches of adult steelhead were low in the spring and summer but increased substantially during the fall and winter (Fig. 34). Adult steelhead were caught at all stations in the fall except SR4S. Highest steelhead trout abundance in the fall was found at SR3S. High catch per effort at SR3S may reflect high abundance and/or high availability to the gear. In contrast, during the winter, no adult steelhead trout were collected at SR3S and SR4S, while their presence was ascertained at other stations. Our fall sampling preceded the dredging at SR4S which began on 16 January 1986, whereas winter sampling coincided with the dredging activities at both stations. These data suggest possible avoidance of these areas by steelhead trout. We cannot make further interpretations as to these changes in abundance (changes in turbidity and/or changes in activity) but the extreme differences in catch rates are noteworthy.

The number of smolts collected at all shallow stations suggest high abundance and wide distribution throughout the Lower Granite Reservoir. Samples collected at shallow stations SR4S, SR3S, SR2S, and SR1S indicated higher abundance of salmonid juveniles (Tables 3, 5 and 6) than at other stations. Assuming we sampled a limited area (3 hauls at approximately 0.04 ha/haul = 0.12 ha seining effort/season), the number of smolts at those sites must be extremely high to account for the high numbers collected.

One of our more significant findings was the high importance of shallow sites for feeding and/or resting by downstream migrating juvenile salmonids. We found that some juvenile salmonids move into the reservoir in the fall and remain there until the following spring, when they continue their downstream migration. For example, we were able to identify that six juvenile chinook were part of a pre-smolt release from Looking Glass Hatchery in Oregon. The influx of juvenile salmonid fishes into Lower Granite Reservoir in the fall is similar to that observed in Little Goose Reservoir (Bennett et al. 1983). During our fall and winter sampling we collected numerous chinook salmon and rainbow trout juveniles (Tables 5 and 6). Many of these fish contained food organisms that ostensibly originated from those shoreline areas. When sampling stomach contents, numerous organisms were still alive and moving, indicating very recent consumption. Organisms found in the stomachs also were collected in benthic samples (Tables 8-11). As indicated earlier, dipterans were a major food item for steelhead trout at shallow stations in the spring and chinook salmon at shallow and deep stations in fall, winter and spring.

We believe that the relatively high use of SR3S by juvenile chinook salmon and rainbow trout is a result of high food abundance. SR3S was one of the more productive stations for dipterans (Tables 8 - 11) which were important in the diets of juvenile salmonids (Figs. 38 and 40). The presence of numerous, small (Table 4; Fig. 28) fish at SR3S also may be an attraction especially for chinook salmon as fish was their major dietary item in the spring and fall (Fig. 40). In addition to the high abundance of food at SR3S, the "openness" or lack of cover for potential predators may enhance the suitability of the area for juvenile salmonids. We did not make a station-by-station comparison of predation, but believe that potential predators will be less successful at capturing salmonid juveniles at SR3S than at sites with more cover and more habitat diversity. Although our sampling data suggest that northern squawfish also are abundant at SR3S in the spring and summer (Tables 3 - 6), comparison of biomass sampled (Fig. 25) and length frequency distributions (Fig. 28) suggests that most of these fish were small.

Predation

Predation on salmonid juveniles in Lower Granite Reservoir could be significant, based on our sampling. Salmonids were found in stomachs of northern squawfish and smallmouth bass and possibly in channel catfish, yellow perch and white crappies (Figs. 43-46). For example, salmonids comprised over 26% of the wet weight of dietary items in the spring from smallmouth bass from shallow stations and 13% from deep stations (Figs. 42 and 43). In addition, over 19% of the wet weight of food items from northern squawfish were salmonid fishes (Figs. 44 and 45). This high incidence of smolt consumption represents an absolute minimum since many of the unidentifiable fish as a result of digestion could have been salmonids.

Probable Effects of In-Water Disposal

Our sampling has shown that fish were abundant at all sites sampled in Lower Granite Reservoir. Some stations, however, provided more favorable habitat for game vs. nongame fish (Fig. 24), longer vs. shorter fish (Figs. 26-33), increased fish diversity (Fig. 14) and evenness (Fig. 15) and salmonid fishes vs. nonsalmonid fishes (Tables 3-6). If disposal were planned for shallow sites, our data could provide direction to decision makers as to the resultant fish communities. In the fall, winter and spring, we have found that juvenile salmonid fishes utilize shallow waters (Tables 3-6) in Lower Granite Reservoir. Shorelines with silty, sandy substrates and having perceptible velocities offer suitable habitat for salmonids based on our collections at SR4S and SR3S. If shallow sites were created by sediment disposal having similar homogeneous habitat characteristics as SR4S and SR3S, we would expect these areas to provide suitable habitat for juvenile salmonids. We found shallow, relatively low gradient shorelines with sandy substrate to be attractive to small chinook salmon in Little Goose Reservoir (Bennett et al. 1983). Also, because of the lack of cover, we have not found many potential predators. However, when salmonids leave these areas in the summer, they provide limited habitat for resident game fishes. Peamouths, suckers and northern squawfish comprised a significant proportion of the catch at SR4S (95%) and SR3S (85%). In contrast, these fishes comprised a smaller proportion of the catch at SR1S (33%) and SR2S (49%). A key element in creating habitat for game fishes is heterogenity of habitat. Diversity in substrate, depth and velocity and aquatic vegetation seems to be related to game fish abundance in Lower Granite Reservoir.

We believe our sampling at deep stations provided representative samples of the benthic and fish community. White sturgeon were collected at all deep stations plus miscellaneous game and nongame fishes (Tables 3-6; Figs. 21-23). A number of "littoral" species were collected along the shorelines. The presence and abundance of these fishes are related to the existing substrate (rip rap) and cover. Unless disposal were conducted along the shoreline, the abundance of these littoral species at deep sites would not change. Because some habitat conditions at deep stations (temperature, dissolved oxygen) would change little as a result of sediment disposal, our data indicate little change would probably occur in the benthic and fish communities using deep areas. With disposal of dredge material, depth will decrease resulting in increased velocities. However, velocities would not increase sufficiently to limit the biotic community at deep stations. Our findings suggest that the deep stations were similar in fish species composition (Tables 3-6), fish species diversity (Fig. 14), evenness (Fig. 15), biomass sampled (Fig. 25) and game and nongame fish abundance (Fig. 24). Differences among stations were probably associated with sampling rather than major biotic differences. Also, few differences would occur in benthic communities as a result of disposal of dredge material. Because a majority of the proposed dredge material is sand, we would expect the benthic communities at deep disposal sites to be similar in composition and abundance to those at SR3S and SR4S. Benthic communities at SR3S and SR4S were abundant (Tables 8-11), although low in diversity (Fig. 36) and evenness (Fig. 37).

Our findings have described selected aspects of the physical and chemical habitat, assessed species composition and relative abundance of fishes and determined the ecological "importance" of possible disposal sites. We collected numerous substrate, water samples and over 30,000 fish by seasonal sampling and strongly believe our data to be representative of the physical, chemical and biotic environment. Disposal of dredged material in Lower Granite Reservoir could be conducted with no significant impacts to biotic communities in areas with low habitat diversity, whereas sediment disposal at sites with higher habitat diversity could alter the structure and dynamics of the biological communities. However, habitat conditions could be enhanced in selected areas and dredged material could contribute to increased habitat diversity. If in-water disposal is implemented in Lower Granite Reservoir, we encourage COE personnel and aquatic resource managers to innovatively examine possibilities to enhance habitat conditions with dredged materials as recommended by Gordon (1986).

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APPENDIX

Appendix A-1. List of scientific and common names of fishes collected in Lower Granite Reservoir
Idaho and Washington.

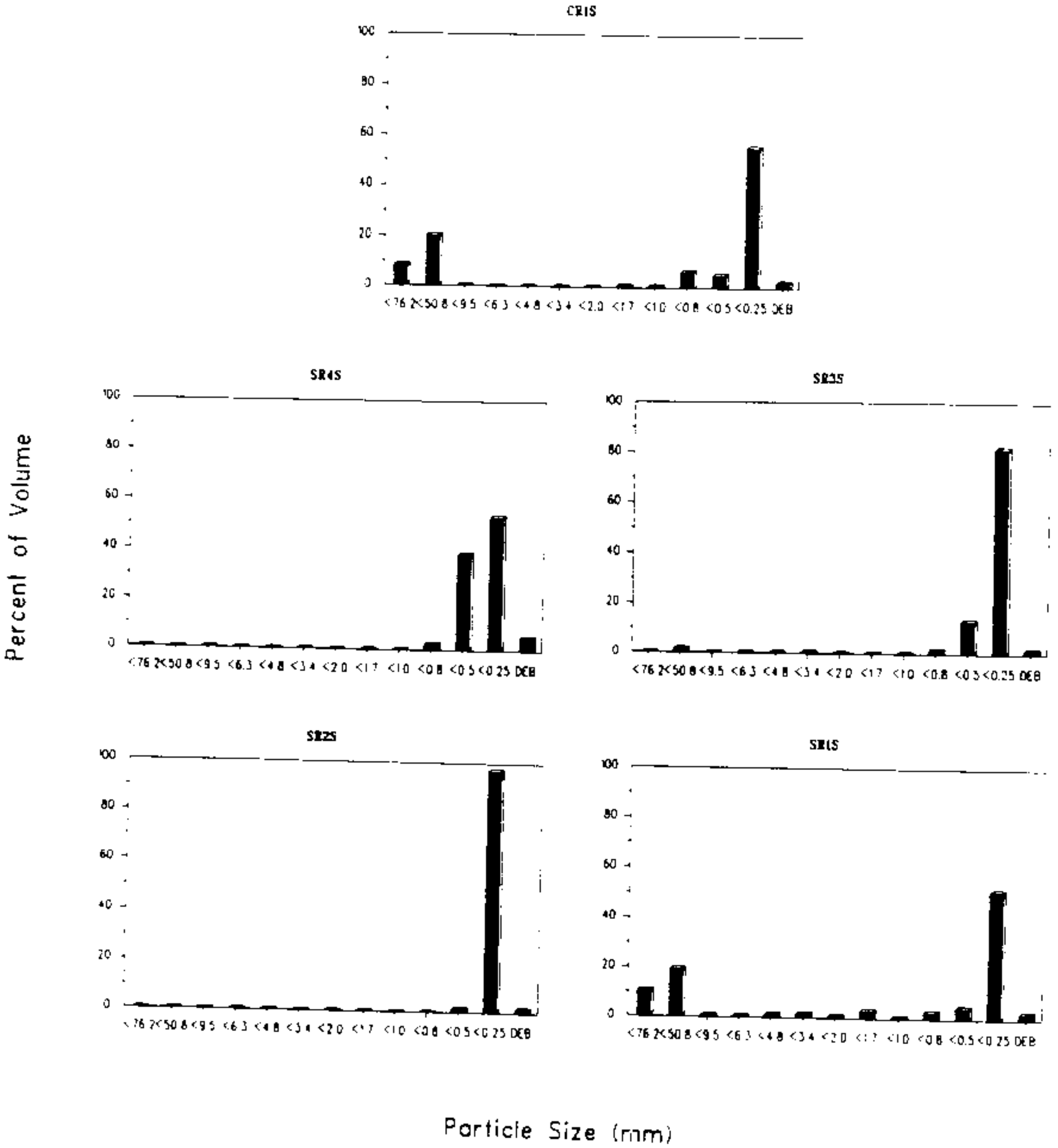
Family	Scientific Name	Common Name
Acipenseridae	*Acipenser transmontanus*	white sturgeon
Salmonidae	*Oncorhynchus nerka*	sockeye salmon
	O. tshawytscha	chinook salmon
	O. gorbuscha	pink salmon
	O. keta	chum salmon
	Prosopium williamsoni	mountain whitefish
	Salmo gairdneri	rainbow trout/steelhead trou
	S. clarki	cutthroat trout
Cyprinidae	*Acrocheilus alutaceus*	chiselmouth
	Cyprinus carpio	carp
	Mylocheilus caurinus	peamouth
	Notemigonus crysoleucas	golden shiner
	Ptychocheilius oregonensis	northern squawfish
	Rhinichthys osculus	longnose dace
	R. cataractae	speckled dace
	Richardsonius balteatus	redside shiner
Catostomidae	*Catostomus columbianus*	bridgelip sucker
	C. macrocheilus	largescale sucker
Ictaluridae	*Ictalurus natalis*	yellow bullhead
	I. nebulosus	brown bullhead
	I. punctatus	channel catfish
Centrarchidae	*Lepomis gibbosus*	pumkinseed
	L. gulosus	warmouth
	L. macrochirus	bluegill
	Micropterus dolomieui	smallmouth bass
	M. salmoides	largemouth bass
	Pomoxis annularis	white crappie
	P. nigromaculatus	black crappie
Percidae	*Perca flavescens*	yellow perch
Cottidae	*Cottus* sp.	sculpin

Appendix A-2. Weekly mean water surface temperatures (C) in Lower Granite Reservoir, Washington-Idaho during 1985-86.

	STATION							
Week	CR1S	SR4S	SR3S	SR2S	SR1S	SR3D	SR2D	SR1D
1985 -								
4/21 - 4/27	7.0	--	11.0	10.0	10.0	--	--	--
4/28 - 5/4	10.0	--	--	--	12.0	--	--	--
5/5 - 5/11	7.0	--	--	13.0	15.0	--	--	--
5/12 - 5/18	10.0	14.0	11.0	15.0	15.0	--	--	--
5/19 - 5/25	--	--	14.0	--	12.0	--	13.0	12.0
5/26 - 6/1	--	13.0	--	12.0	12.5	12.0	--	--
6/2 - 6/8	--	15.0	14.0	13.0	--	--	--	--
6/9 - 6/15	--	--	--	--	15.0	--	--	15.0
6/16 - 6/22	16.0	19.0	--	--	18.0	--	18.0	17.5
6/23 - 6/29	14.0	--	--	--	--	19.3	20.0	19.0
6/30 - 7/2	--	--	--	--	--	--	21.0	--
8/4 - 8/10	18.0	--	24.0	24.0	26.0	--	--	23.0
8/11 - 8/17	--	--	--	22.0	24.0	--	24.0	--
8/18 - 8/24	--	--	--	--	--	20.5	22.5	24.5
8/25 - 8/31	15.0	--	--	21.0	21.50	22.0	22.0	23.0
10/20-10/26	9.5	12.5	12.0	12.0	13.0	13.0	13.0	12.5
10/27- 11/2	12.0	12.0	12.0	12.0	--	--	--	--
11/3 - 11/9	7.5	10.5	8.0	--	--	--	--	--
11/10-11/16	--	--	7.0	7.0	--	--	--	7.0
11/17-11/23	--	--	--	--	7.0	6.0	--	7.0
12/1 - 12/7	--	--	--	--	4.0	3.5	3.0	--
12/8 -12/14	--	--	--	--	--	4.0	4.0	--
1986 -								
1/26 - 2/1	1.0	1.5	2.0	2.0	2.0	2.0	2.0	2.0
2/2 - 2/8	3.0	--	3.0	3.0	--	--	--	--
2/9 - 2/15	--	--	--	--	3.0	4.0	--	--
2/16 - 2/22	2.0	--	--	3.0	--	5.0	--	4.0
2/23 - 3/1	--	--	--	--	--	5.0	6.0	5.5
3/23 - 3/29	--	11.0	--	--	--	--	--	--
3/30 - 4/5	10.0	--	--	--	--	--	--	--

Average Substrate Sizes

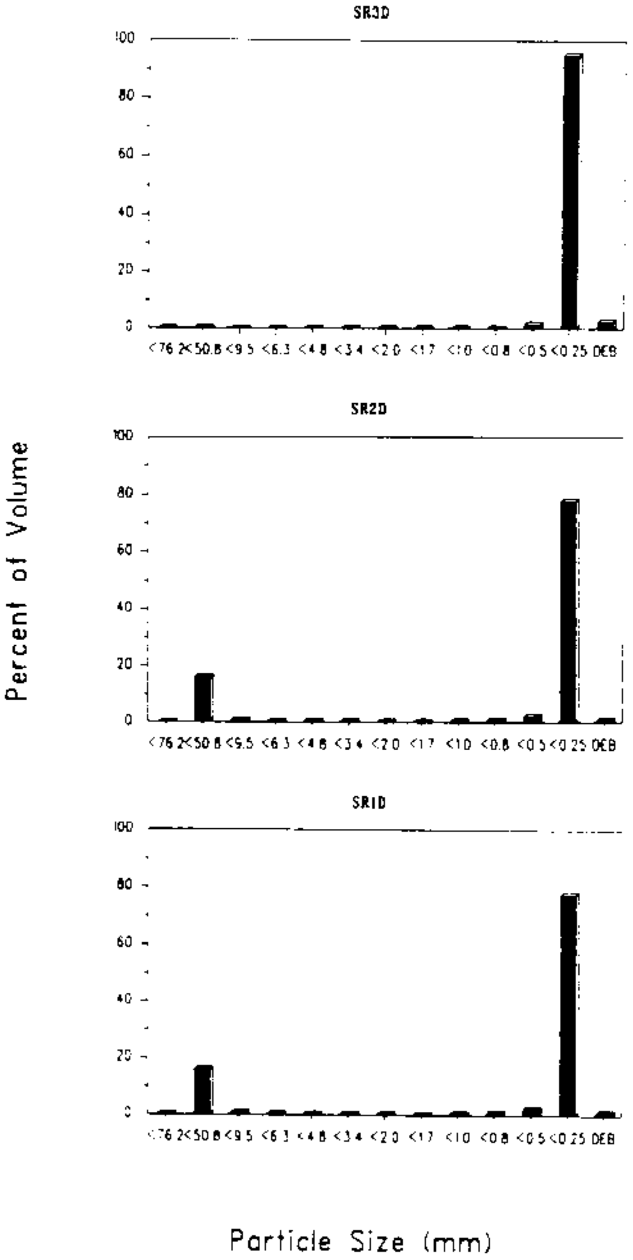
Shallow Stations (n=12)



Appendix A-3. Average particle sizes found in shallow station substrate samples in Lower Granite Reservoir during spring, summer and fall of 1985 and winter 1986. DEB represents organic debris (sticks, leaves, etc.).

Average Substrate Sizes

Deep Stations (n=12)



Appendix A-4. Average particle sizes found in deep water station substrate samples in Lower Granite Reservoir during spring, summer and fall 1985 and winter 1986. DEB represents organic debris (sticks, leaves, etc.).

Appendix A-5. Weekly mean water transparencies (secchi depth -m) in Lower Granite Reservoir, Washington-Idaho during 1985-86.

	STATION							
Week	CR1S	SR4S	SR3S	SR2S	SR1S	SR3D	SR2D	SR1D
1985 -								
4/21 - 4/27	--	1.0	--	--	--	--	--	--
4/28 - 5/4	1.0	--	--	--	1.0	--	--	--
5/5 - 5/11	2.0	--	--	--	--	--	--	--
5/12 - 5/18	2.0	1.0	1.0	1.0	1.0	--	--	--
5/19 - 5/25	--	--	1.0	--	--	--	--	--
5/26 - 6/1	--	--	--	1.0	--	--	--	--
6/2 - 6/8	--	--	--	--	--	--	--	1.0
6/9 - 6/15	--	1.5	--	--	--	--	1.5	--
6/16 - 6/22	3.0	--	--	--	--	1.0	2.0	1.0
6/23 - 6/29	3.0	--	--	--	--	--	--	--
6/30 - 7/2	--	--	--	--	--	--	--	2.0
8/4 - 8/10	2.5	--	1.0	2.0	3.0	--	--	--
8/11 - 8/17	--	--	--	1.0	2.0	--	2.0	1.5
8/18 - 8/24	--	--	--	--	--	--	--	--
8/25 - 8/31	--	--	--	--	--	--	--	--
10/20-10/26	1.0	1.0	2.0	--	--	--	--	--
10/27- 11/2	--	--	--	--	--	--	--	--
11/3 - 11/9	--	--	--	--	--	--	--	--
11/10-11/16	--	--	--	--	--	--	--	--
11/17-11/23	--	--	--	--	--	--	--	--
12/1 - 12/7	--	--	--	--	--	--	--	--
12/8 -12/14	--	--	--	--	--	--	--	--
1986 -								
1/26 - 2/1	1.0	2.0	2.0	1.0	1.0	--	--	--
2/2 - 2/8	--	--	--	--	--	--	--	--
2/9 - 2/15	--	--	--	--	--	--	--	--
2/16 - 2/22	--	--	--	--	--	--	--	--
2/23 - 3/1	--	--	--	--	--	--	--	--
3/23 - 3/29	--	--	--	--	--	--	--	--
3/30 - 4/5	--	--	--	--	--	--	--	--

Appendix A-6. Weekly mean turbidity (NTU) readings from Lower Granite Reservoir, Washington-Idaho during 1985-86.

	STATION							
Week	CR1S	SR4S	SR3S	SR2S	SR1S	SR3D	SR2D	SR1D
1985 -								
4/21 - 4/27	6.25	--	9.1	8.25	9.75	--	--	--
4/28 - 5/4	5.50	8.5	--	--	8.5	--	--	--
5/5 - 5/11	1.80	--	--	5.25	3.25	--	--	--
5/12 - 5/18	1.60	2.5	2.6	--	3.4	--	--	--
5/19 - 5/25	--	--	6.2	--	--	--	3.25	3.7
5/26 - 6/1	--	7.3	--	6.0	4.2	3.75	--	--
6/2 - 6/8	--	3.95	3.79	4.70	--	--	--	--
6/9 - 6/15	--	--	--	--	3.5	--	2.20	2.25
6/16 - 6/22	1.25	1.65	--	--	--	--	1.50	2.5
6/23 - 6/29	1.50	--	--	--	--	1.52	1.25	--
6/30 - 7/2	--	--	--	--	--	--	--	1.25
8/4 - 8/10	1.375	--	1.75	2.6	1.25	--	--	--
8/11 - 8/17	--	--	--	2.1	1.50	--	2.1	--
8/18 - 8/24	--	--	--	--	--	1.60	1.65	1.85
8/25 - 8/31	1.0	--	--	2.1	1.55	1.2	1.40	--
10/20-10/26	2.25	2.62	1.97	2.52	2.2	1.8	1.45	1.25
10/27- 11/2	1.75	1.60	1.50	1.75	--	--	--	2.05
11/3 - 11/9	2.6	1.65	1.50	--	--	--	--	--
11/10-11/16	--	--	2.0	--	--	--	--	2.30
11/17-11/23	--	--	--	2.87	1.6	1.75	--	1.60
12/1 - 12/7	--	--	--	--	1.9	1.35	1.65	--
12/8 -12/14	--	--	--	--	--	2.0	1.70	--
1986 -								
1/26 - 2/1	9.9	2.5	3.2	4.25	4.9	3.4	4.5	4.0
2/2 - 2/8	3.75	--	2.0	9.5	--	--	--	--
2/9 - 2/15	--	--	--	--	8.0	4.5	--	--
2/16 - 2/22	1.0	--	--	6.0	--	1.0	--	6.0
2/23 - 3/1	--	--	--	--	--	3.0	7.0	3.0
3/23 - 3/29	--	5.0	--	--	--	--	--	--
3/30 - 4/5	--	2.0	--	--	--	--	--	--

Appendix A-7. Mean catch per effort for all stations on Lower Granite Reservoir in Spring 1985. Effort for gill nets, traps, setlines and electrofishing was one hour, while seine effort was one standardized haul.

		GEAR TYPE						
Station	Electrofishing	Horizontal Contour Gill Net	Horizontal Floating Gill Net	Horizontal Mid-water Gill Net	Vertical Gill Net	Trap	Setline	Seine
CR1S	22.40	0.52	0.29	----	----	----	----	29.85
SR4S	68.00	0.66	0.29	----	----	----	----	12.00
SR3S	0.00	0.49	0.12	----	----	0.00	----	24.12
SR2S	18.29	1.23	0.19	----	----	----	----	15.86
SR1S	80.00	0.99	1.28	----	----	----	----	30.77
SR3D	72.00	0.27	0.51	0.17	----	----	0.00	----
SR2D	78.40	0.37	0.73	0.00	----	----	0.02	----
SR1D	105.33	0.36	0.25	0.12	----	----	0.03	----

Appendix A-8. Mean catch per effort for all stations on Lower Granite Reservoir in Summer 1985. Effort for gill nets, traps, setlines and electrofishing was one hour, while seine effort was one standardized haul.

		GEAR TYPE						
Station	Electrofishing	Horizontal Contour Gill Net	Horizontal Floating Gill Net	Horizontal Mid-water Gill Net	Vertical Gill Net	Trap	Setline	Seine
CR1S	37.00	0.75	0.45	----	----	0.00	----	28.11
SR4S	16.80	1.30	0.82	----	----	0.11	----	31.00
SR3S	20.00	0.43	0.39	----	----	0.00	----	289.52
SR2S	4.00	0.37	0.38	----	----	0.06	----	7.50
SR1S	307.69	0.41	0.43	----	----	0.22	----	3.67
SR3D	76.00	0.00	0.16	0.00	0.14	----	0.00	----
SR2D	69.71	0.09	0.20	0.00	0.43	----	0.00	----
SR1D	48.80	0.23	0.00	0.06	0.00	----	0.00	----

Appendix A-9. Mean catch per effort for all stations on Lower Granite Reservoir in Fall 1985. Effort for gill nets, traps, setlines and electrofishing was one hour, while seine effort was one standardized haul.

		GEAR TYPE						
Station	Electrofishing	Horizontal Contour Gill Net	Horizontal Floating Gill Net	Horizontal Mid-water Gill Net	Vertical Gill Net	Trap	Setline	Seine
CR1S	156.00	0.14	0.13	----	----	0.00	----	0.33
SR4S	67.00	0.16	0.18	----	----	0.04	----	3.08
SR3S	49.82	0.24	0.13	----	----	0.00	----	1.19
SR2S	68.33	0.24	0.19	----	----	0.00	----	0.87
SR1S	26.77	0.22	0.11	----	----	0.00	----	2.00
SR3D	60.29	0.00	0.12	0.08	0.00	----	0.00	----
SR2D	24.00	0.08	1.00	0.00	0.04	----	0.00	----
SR1D	64.73	0.15	0.18	0.00	0.07	----	0.00	----

Appendix A-10. Mean catch per effort for all stations on Lower Granite Reservoir in Winter 1986. Effort for gill nets, traps, setlines and electrofishing was one hour, while seine effort was one standardized haul.

		GEAR TYPE						
Station	Electrofishing	Horizontal Contour Gill Net	Horizontal Floating Gill Net	Horizontal Mid-water Gill Net	Vertical Gill Net	Trap	Setline	Seine
CR1S	53.45	0.28	0.18	----	----	0.00	----	0.00
SR4S	28.00	0.55	0.33	----	----	0.10	----	0.33
SR3S	30.67	0.36	0.12	----	----	0.00	----	0.33
SR2S	18.86	0.27	0.12	----	----	0.11	----	0.00
SR1S	22.67	0.40	0.90	----	----	0.16	----	0.50
SR3D	20.80	0.33	0.09	0.00	0.06	----	0.02	----
SR2D	21.60	0.08	0.94	0.12	0.06	----	0.00	----
SR1D	46.00	0.01	0.22	0.00	0.03	----	0.00	----

Appendix A-11. Mean catch per effort for species captured at station CR1S in Lower Granite Reservoir, 1985-86. Effort for gill nets, traps and electrofishing was one hour, while seine effort was one standardized haul.

	Gear Type				
Species	Electrofishing	Horizontal Contour Gill Net	Horizontal Floating Gill Net	Trap	Seine
white sturgeon	0.00	0.07	0.00	0.00	0.00
sockeye salmon	0.00	0.00	0.02	0.00	0.17
chinook salmon	1.50	0.00	0.02	0.00	2.33
mountain whitefish	3.00	0.01	0.00	0.00	0.04
rainbow trout	15.50	0.07	0.01	0.00	0.83
chiselmouth	51.00	0.11	0.10	0.00	0.00
carp	0.00	0.73	0.00	0.00	0.00
peamouth	84.00	0.02	0.00	0.00	14.49
northern squawfish	188.50	0.33	0.08	0.00	8.25
speckled dace	0.00	0.00	0.00	0.00	0.00
longnose dace	0.00	0.00	0.00	0.00	0.00
redside shiner	59.50	0.37	0.25	0.00	56.08
bridgelip sucker	12.50	0.06	0.00	0.00	0.08
largescale sucker	53.00	0.19	0.00	0.00	19.75
yellow bullhead	0.00	0.00	0.00	0.00	0.00
brown bullhead	0.00	0.00	0.00	0.00	0.00
channel catfish	0.00	0.00	0.00	0.00	0.00
tadpole madtom	0.00	0.00	0.00	0.00	0.00
pumpkinseed	0.00	0.00	0.00	0.00	0.00
warmouth	0.00	0.00	0.00	0.00	0.00
bluegill	0.00	0.00	0.00	0.00	0.00
smallmouth bass	119.50	0.00	0.00	0.00	0.08
largemouth bass	4.00	0.00	0.00	0.00	0.00
white crappie	0.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	0.00	0.00	0.00
yellow perch	0.00	0.00	0.00	0.00	0.00
sculpin	17.50	0.00	0.00	0.00	0.00

Appendix A-12. Mean catch per effort for species captured at station SR4S in Lower Granite Reservoir, 1985-86. Effort for gill nets, traps and electrofishing was one hour, while seine effort was one standardized haul.

	Gear Type				
Species	Electrofishing	Horizontal Contour Gill Net	Horizontal Floating Gill Net	Trap	Seine
white sturgeon	0.00	0.83	0.00	0.02	0.00
sockeye salmon	0.00	0.00	0.01	0.00	0.17
chinook salmon	4.00	0.06	0.06	0.03	5.69
mountain whitefish	0.00	0.00	0.00	0.00	0.33
rainbow trout	5.00	0.01	0.01	0.00	0.25
chiselmouth	9.00	0.92	0.58	0.10	4.42
carp	1.00	0.49	0.24	0.00	1.00
peamouth	5.00	0.00	0.00	0.00	4.42
northern squawfish	30.00	0.48	0.27	0.03	25.92
speckled dace	0.00	0.00	0.00	0.00	0.00
longnose dace	0.00	0.00	0.00	0.00	0.00
redside shiner	31.00	0.35	0.39	0.08	27.92
bridgelip sucker	5.00	0.14	0.04	0.00	9.67
largescale sucker	158.00	0.78	0.18	0.02	21.33
yellow bullhead	0.00	0.00	0.00	0.00	0.00
brown bullhead	0.00	0.00	0.00	0.00	0.00
channel catfish	0.00	0.00	0.00	0.00	0.00
tadpole madtom	0.00	0.00	0.00	0.00	0.00
pumpkinseed	0.00	0.00	0.00	0.00	0.00
warmouth	0.00	0.00	0.00	0.00	0.00
bluegill	4.00	0.00	0.00	0.00	0.08
smallmouth bass	23.00	0.00	0.00	0.00	1.75
largemouth bass	0.00	0.00	0.00	0.00	0.00
white crappie	0.00	0.01	0.01	0.01	2.75
black crappie	0.00	0.00	0.00	0.00	0.00
yellow perch	0.00	0.00	0.00	0.00	0.00
sculpin	18.00	0.00	0.00	0.01	0.00

Appendix A-13. Mean catch per effort for species captured at station SR3S in Lower Granite Reservoir, 1985-86. Effort for gill nets, traps and electrofishing was one hour, while seine effort was one standardized haul.

Species	Gear Type				
	Electrofishing	Horizontal Contour Gill Net	Horizontal Floating Gill Net	Trap	Seine
white sturgeon	0.00	0.00	0.00	0.00	0.00
sockeye salmon	0.00	0.00	0.00	0.00	0.00
chinook salmon	22.00	0.00	0.01	0.00	5.92
mountain whitefish	2.00	0.00	0.00	0.00	2.33
rainbow trout	6.00	0.05	0.03	0.00	0.83
chiselmouth	2.00	0.12	0.09	0.00	0.50
carp	3.00	0.33	0.07	0.00	4.50
peamouth	15.00	0.00	0.00	0.00	179.83
northern squawfish	39.00	0.24	0.14	0.00	68.75
speckled dace	0.00	0.00	0.00	0.00	0.00
longnose dace	0.00	0.00	0.00	0.00	0.00
redside shiner	13.00	0.34	0.03	0.00	15.33
bridgelip sucker	0.00	0.01	0.01	0.00	1.58
largescale sucker	55.00	0.53	0.12	0.00	332.08
yellow bullhead	0.00	0.00	0.00	0.00	0.00
brown bullhead	0.00	0.00	0.00	0.00	0.00
channel catfish	0.00	0.03	0.05	0.00	0.00
tadpole madtom	0.00	0.00	0.00	0.00	0.00
pumpkinseed	0.00	0.00	0.00	0.00	0.00
warmouth	0.00	0.00	0.00	0.00	0.00
bluegill	0.00	0.00	0.00	0.00	0.00
smallmouth bass	26.00	0.02	0.00	0.00	91.42
largemouth bass	0.00	0.00	0.00	0.00	0.00
white crappie	1.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	0.00	0.00	0.00
yellow perch	0.00	0.02	0.00	0.00	0.08
sculpin	0.00	0.00	0.00	0.00	0.08

Appendix A-14. Mean catch per effort for species captured at station SR2S in Lower Granite Reservoir, 1985-86. Effort for gill nets, traps and electrofishing was one hour, while seine effort was one standardized haul.

	Gear Type				
Species	Electrofishing	Horizontal Contour Gill Net	Horizontal Floating Gill Net	Trap	Seine
white sturgeon	0.00	0.00	0.00	0.00	0.00
sockeye salmon	0.00	0.00	0.00	0.00	0.00
chinook salmon	17.00	0.00	0.02	0.00	0.08
mountain whitefish	11.00	0.00	0.00	0.00	7.83
rainbow trout	6.00	0.13	0.03	0.00	0.83
chiselmouth	3.00	0.81	0.16	0.00	0.33
carp	1.00	0.60	0.07	0.00	0.25
peamouth	0.00	0.00	0.00	0.00	5.75
northern squawfish	22.00	0.31	0.19	0.02	20.83
speckled dace	0.00	0.00	0.00	0.00	0.00
longnose dace	0.00	0.00	0.00	0.00	0.00
redside shiner	18.00	0.15	0.24	0.04	11.67
bridgelip sucker	20.00	0.09	0.00	0.00	0.08
largescale sucker	82.00	1.44	0.07	0.00	2.08
yellow bullhead	0.00	0.00	0.00	0.00	0.00
brown bullhead	0.00	0.05	0.00	0.00	0.00
channel catfish	0.00	0.00	0.04	0.00	0.00
tadpole madtom	0.00	0.00	0.00	0.00	0.00
pumpkinseed	0.00	0.02	0.00	0.00	0.00
warmouth	0.00	0.02	0.00	0.00	0.00
bluegill	16.00	0.00	0.00	0.00	0.00
smallmouth bass	64.00	0.10	0.00	0.00	4.58
largemouth bass	0.00	0.00	0.00	0.00	0.00
white crappie	1.00	0.00	0.00	0.00	0.75
black crappie	1.00	0.04	0.00	0.00	0.08
yellow perch	0.00	0.07	0.00	0.00	0.08
sculpin	6.00	0.00	0.00	0.00	0.08

Appendix A-15. Mean catch per effort for species captured at station SR1S in Lower Granite Reservoir, 1985-86. Effort for gill nets, traps and electrofishing was one hour, while seine effort was one standardized haul.

	Gear Type				
Species	Electrofishing	Horizontal Contour Gill Net	Horizontal Floating Gill Net	Trap	Seine
white sturgeon	0.00	0.00	0.00	0.00	0.00
sockeye salmon	0.00	0.00	0.00	0.00	0.00
chinook salmon	9.00	0.15	0.11	0.00	44.33
mountain whitefish	4.00	0.00	0.00	0.00	0.00
rainbow trout	12.00	0.15	0.35	0.00	3.33
chiselmouth	89.00	0.60	0.29	0.00	4.08
carp	2.00	0.66	0.30	0.00	0.00
peamouth	1.00	0.00	0.00	0.00	0.00
northern squawfish	25.00	0.13	0.14	0.00	22.67
speckled dace	0.00	0.00	0.00	0.00	0.00
longnose dace	0.00	0.00	0.00	0.00	0.25
redside shiner	31.00	0.21	0.54	0.04	28.08
bridgelip sucker	24.00	0.44	0.00	0.00	0.67
largescale sucker	153.00	0.69	0.06	0.00	8.91
yellow bullhead	4.00	0.00	0.00	0.00	0.00
brown bullhead	2.00	0.03	0.00	0.00	0.00
channel catfish	0.00	0.03	0.00	0.00	0.00
tadpole madtom	0.00	0.00	0.00	0.00	0.00
pumpkinseed	5.00	0.00	0.00	0.00	0.17
warmouth	0.00	0.00	0.00	0.00	0.00
bluegill	7.00	0.00	0.00	0.00	1.67
smallmouth bass	121.00	0.04	0.00	0.00	4.58
largemouth bass	2.00	0.00	0.00	0.00	0.50
white crappie	5.00	0.02	0.00	0.00	0.58
black crappie	4.00	0.06	0.02	0.00	0.17
yellow perch	1.00	0.00	0.00	0.00	0.25
sculpin	2.00	0.00	0.00	0.00	0.00

Appendix A-16. Mean catch per effort for species captured at station SR3D in Lower Granite Reservoir, 1985-86. Effort for gill nets, setlines and electrofishing was one hour.

Species	Gear Type					
	Electro- fishing	Horizontal Contour Gill Net	Horizontal Floating Gill Net	Horizontal Mid-water Gill Net	Vertical Gill Net	Setline
white sturgeon	0.00	0.06	0.00	0.00	0.00	0.00
sockeye salmon	0.00	0.00	0.00	0.00	0.00	0.00
chinook salmon	3.00	0.03	0.00	0.00	0.00	0.00
mountain whitefish	1.00	0.00	0.00	0.00	0.00	0.00
rainbow trout	15.00	0.00	0.10	0.02	0.05	0.00
chiselmouth	49.00	0.14	0.00	0.00	0.00	0.00
carp	0.00	0.21	0.27	0.00	0.00	0.00
peamouth	0.00	0.00	0.00	0.00	0.00	0.00
northern squawfish	21.00	0.08	0.00	0.00	0.00	0.01
speckled dace	0.00	0.00	0.00	0.00	0.00	0.00
longnose dace	0.00	0.00	0.00	0.00	0.00	0.00
redside shiner	44.00	0.00	0.06	0.00	0.00	0.00
bridgelip sucker	44.00	0.00	0.00	0.00	0.00	0.00
largescale sucker	174.00	0.00	0.04	0.00	0.05	0.00
yellow bullhead	0.00	0.00	0.00	0.00	0.00	0.00
brown bullhead	0.00	0.00	0.00	0.00	0.00	0.00
channel catfish	0.00	0.03	0.00	0.00	0.00	0.00
tadpole madtom	0.00	0.00	0.00	0.00	0.00	0.00
pumpkinseed	1.00	0.00	0.00	0.00	0.00	0.00
warmouth	0.00	0.00	0.00	0.00	0.00	0.00
bluegill	2.00	0.00	0.00	0.00	0.00	0.00
smallmouth bass	116.00	0.00	0.00	0.00	0.00	0.00
largemouth bass	0.00	0.00	0.00	0.00	0.00	0.00
white crappie	3.00	0.00	0.00	0.00	0.00	0.00
black crappie	1.00	0.00	0.00	0.00	0.00	0.00
yellow perch	0.00	0.00	0.00	0.00	0.00	0.00
sculpin	3.00	0.00	0.00	0.00	0.00	0.00

Appendix A-17. Mean catch per effort for species captured at station SR2D in Lower Granite Reservoir, 1985-86. Effort for gill nets, setlines and electrofishing was one hour.

	Gear Type					
Species	Electro-fishing	Horizontal Contour Gill Net	Horizontal Floating Gill Net	Horizontal Mid-water Gill Net	Vertical Gill Net	Setline
white sturgeon	0.00	0.14	0.00	0.00	0.00	0.00
sockeye salmon	0.00	0.00	0.00	0.00	0.00	0.00
chinook salmon	1.00	0.00	0.00	0.00	0.00	0.00
mountain whitefish	0.00	0.00	0.00	0.00	0.00	0.00
rainbow trout	10.00	0.00	0.32	0.00	0.02	0.00
chiselmouth	12.00	0.00	0.00	0.02	0.04	0.00
carp	2.00	0.09	0.32	0.02	0.11	0.00
peamouth	1.00	0.00	0.00	0.00	0.00	0.00
northern squawfish	11.00	0.00	0.02	0.04	0.03	0.01
speckled dace	0.00	0.00	0.00	0.00	0.00	0.00
longnose dace	0.00	0.00	0.00	0.00	0.00	0.00
redside shiner	17.00	0.00	0.31	0.00	0.01	0.00
bridgelip sucker	27.00	0.00	0.00	0.00	0.00	0.00
largescale sucker	110.00	0.15	0.00	0.04	0.01	0.00
yellow bullhead	0.00	0.03	0.00	0.00	0.00	0.00
brown bullhead	1.00	0.00	0.00	0.00	0.00	0.00
channel catfish	0.00	0.02	0.02	0.00	0.00	0.01
tadpole madtom	0.00	0.00	0.00	0.00	0.00	0.00
pumpkinseed	0.00	0.00	0.00	0.00	0.00	0.00
warmouth	0.00	0.00	0.00	0.00	0.00	0.00
bluegill	0.00	0.00	0.00	0.00	0.00	0.00
smallmouth bass	108.00	0.00	0.00	0.00	0.00	0.00
largemouth bass	1.00	0.00	0.00	0.00	0.00	0.00
white crappie	0.00	0.00	0.00	0.00	0.00	0.00
black crappie	0.00	0.00	0.00	0.00	0.00	0.00
yellow perch	0.00	0.00	0.00	0.00	0.00	0.00
sculpin	0.00	0.00	0.00	0.00	0.00	0.00

Appendix A-18. Mean catch per effort for species captured at station SR1D in Lower Granite Reservoir, 1985-86. Effort for gill nets, setlines and electrofishing was one hour.

	Gear Type					
Species	Electro-fishing	Horizontal Contour Gill Net	Horizontal Floating Gill Net	Horizontal Mid-water Gill Net	Vertical Gill Net	Setline
white sturgeon	0.00	0.04	0.00	0.01	0.00	0.00
sockeye salmon	1.00	0.00	0.00	0.00	0.00	0.00
chinook salmon	0.00	0.00	0.00	0.04	0.03	0.00
mountain whitefish	1.00	0.00	0.00	0.00	0.00	0.00
rainbow trout	25.00	0.01	0.16	0.00	0.01	0.00
chiselmouth	47.00	0.00	0.04	0.00	0.01	0.00
carp	0.00	0.25	0.13	0.03	0.00	0.00
peamouth	2.00	0.00	0.00	0.00	0.00	0.00
northern squawfish	23.00	0.03	0.01	0.01	0.01	0.00
speckled dace	0.00	0.00	0.00	0.00	0.00	0.00
longnose dace	0.00	0.00	0.00	0.00	0.00	0.00
redside shiner	18.00	0.00	0.04	0.00	0.00	0.00
bridgelip sucker	34.00	0.03	0.00	0.00	0.00	0.00
largescale sucker	130.00	0.15	0.00	0.02	0.00	0.00
yellow bullhead	1.00	0.00	0.00	0.00	0.00	0.00
brown bullhead	0.00	0.07	0.00	0.00	0.00	0.00
channel catfish	0.00	0.00	0.00	0.00	0.00	0.00
tadpole madtom	0.00	0.00	0.00	0.00	0.00	0.00
pumpkinseed	4.00	0.00	0.00	0.00	0.00	0.00
warmouth	2.00	0.00	0.00	0.00	0.00	0.00
bluegill	2.00	0.00	0.00	0.00	0.00	0.00
smallmouth bass	206.00	0.00	0.00	0.00	0.00	0.00
largemouth bass	3.00	0.00	0.00	0.00	0.00	0.00
white crappie	1.00	0.00	0.00	0.00	0.00	0.00
black crappie	1.00	0.00	0.00	0.00	0.00	0.00
yellow perch	0.00	0.00	0.00	0.00	0.00	0.00
sculpin	0.00	0.00	0.00	0.00	0.00	0.00