WATER QUALITY STATUS REPORT NO. 102

Pend Oreille Lake
Fishery Assessment
Bonner and Kootenai Counties, Idaho
1951 - 1989

Idaho Department
of Health and Welfare

Division of
Environmental Quality

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

1993

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Pend Oreille Lake Fishery Assessment

Bonner and Kootenai Counties, Idaho 1951 - 1989

Prepared by
Brian Hoelscher

North Idaho Regional Office
2110 Ironwood Parkway
Coeur d'Alene, Idaho 83814

Idaho Department of Health and Welfare
Division of Environmental Quality
1410 North Hilton Street
Boise, Idaho 83720-9000

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

Idaho Department of Health and Welfare-Division of Environmental Quality compiled a summary of the fishes, fishery, and zooplankton existing in Pend Oreille Lake, Bonner and Kootenai counties, Idaho, between 1951 and 1989. The purpose of the summary was to provide a synopsis of fishery information and determine if water quality goals would have a significant adverse effect on the lake's aquatic resource.

The native sport fishes in Pend Oreille Lake are westslope cutthroat trout Oncorhynchus clarki lewisi, bull trout Salvelinus confluentus, and mountain whitefish Prosopium williamsoni. Due to reduced numbers, westslope cutthroat trout and bull trout are listed as federal sensitive species and state species of special concern. Other sport fishes have been stocked or found their way into the lake over the years: kokanee Oncorhynchus nerka, rainbow trout Oncorhynchus mykiss, Gerrard (Kamloops) rainbow trout, lake whitefish Coregonus culpeaformis, brook trout Salvelinus fontinalis, brown trout Salmo trutta, lake trout Salvelinus namaycush, yellow perch Perca flavescens, black crappie Pomoxis nigromaculatus, largemouth bass Micropterus salmoides, brown bullhead Ictalurus nebulosus, pumpkinseed Lepomis gibbosus, and northern pike Esox lucius.

Pend Oreille Lake is an important fishery resource in Idaho. From 1951 to 1965, the Pend Oreille Lake kokanee fishery was the most popular kokanee fishery. The sport and commercial fishery yielded an average annual harvest of about one million fish. The Gerrard rainbow trout of Pend Oreille Lake is truly a unique stock. Native to Kootenay Lake, British Columbia, this fish matures later than other strains of rainbow trout and grows to an unusually large size on a diet of kokanee. A world record rainbow trout, weighing 16.8 kg (37 lb), was caught in 1947. The current world record bull trout was caught in Pend Oreille Lake in 1949, weighing 14.5 kg (32 lb). In 1952, seven of the ten largest trout caught in the continent came from Pend Oreille Lake.

Fishing success for most salmonids saw dramatic declines between the 1950s and the 1980s. Kokanee harvest began to decline during the 1960s. It reached a low in 1986 and has increased in recent years. Bull trout harvest initially declined and has stabilized at a depressed level. The westslope cutthroat trout fishery has declined more dramatically than any other Pend Oreille Lake fishery. It is now very reduced and is being supported by fingerling stocking.

Several activities caused the marked declines. Hydropower development on the inlet and outlet of the lake was likely the single most important contributor to the decline in sport fish numbers. Albeni Falls Dam, completed in 1952, fluctuated lake levels between summer and winter. Winter drawdown dewatered shoreline spawning areas and killed kokanee eggs in the gravel. Cabinet Gorge Dam on Clark Fork River has been a complete migration block to all fishes since 1951, eliminating hundreds of miles of tributary spawning and rearing areas available to Pend Oreille Lake fishes. Fluctuations of the river below the dam also killed kokanee eggs.

Rainbow trout, bull trout, and westslope cutthroat trout must spawn and rear for several years in tributary streams before migrating to the lake. Improper land use practices and natural catastrophes have resulted in degraded habitat in the remaining accessible tributaries. These changes have resulted in fewer fish in the lake.

Opossum shrimp Mysis relicta were introduced into Pend Oreille Lake in 1966. They became abundant by 1976. This small shrimp competed with newly emerged kokanee fry for food sources, reducing the kokanee's survival during the first few weeks of life.

Diligent efforts have been made by public and private agencies to enhance the lake's fishery. During 1960 and 1961, Washington Water Power constructed bull trout spawning channels along Clark Fork River. In 1964, all major bull trout spawning streams were closed to bull trout harvest. In 1967, the United States Army Corps of Engineers changed the operation policy of Albeni Falls Dam to stabilize lake levels during the kokanee spawning and incubation period. Idaho Department of Fish and Game reduced the kokanee sport fishing limit and terminated the commercial fishery in 1973. They started stocking kokanee fry in 1974 and in 1985 began a cooperative effort with Washington Water Power and Bonneville Power Administration to further increase kokanee stocking from Cabinet Gorge Hatchery. Lastly, Idaho Department of Fish and Game initiated very restrictive size and bag limits on both the tributary and lake fishery to enhance the trophy rainbow trout fishery and began stocking pure strain Gerrard rainbow trout from Kootenay Lake once again.

Enhancement efforts are difficult, expensive, and may take years to see their full effects. However, they are working. Bull trout populations have stabilized and Pend Oreille Lake remains the State's best bull trout fishery. The kokanee population has increased 80% since 1986 and should increase even more as output from Cabinet Gorge Hatchery increases. Rainbow trout abundance in the lake is increasing. Catch rates have improved from 44 hours per fish in 1985 to 18 hours per fish in 1990. Even more improvements are expected as the abundance of their primary food source (kokanee) increases.

Enhancement efforts are far from over. Improvements are still necessary to return the fishery to its past level of production. The fishery has been estimated to be worth about $2 million annually and returns about $1 million to local communities (1990 dollars). As fish abundance increases, so will its value to the people of Idaho.

Large amounts of mining, milling, and smelting wastes containing heavy metals have entered upper Clark Fork River. At times, these metals were found in the river and lake at levels chronically and acutely toxic to aquatic life. Even though heavy metals concentrations in fish tissue did not exceed the recommended action limits, lead may limit the consumption of sport fishes from Pend Oreille Lake. These data were from a cursory investigation and do not represent statistically valid results. However, it does indicate further investigation into the human health risks is warranted.

Water quality management goals in a high quality water body like Pend Oreille Lake can sometimes be in conflict with fishery management goals. A more productive fishery requires a more productive system. Pend Oreille Lake has relatively low productivity in general. Also, the lake's water quality has remained stable since the 1950s. The fishery management goal for Pend Oreille Lake, restoration to historic production, is compatible with the water quality goal of maintaining high water quality.

CHAPTER 1

INTRODUCTION

Background

Pend Oreille Lake is an important fishery resource in Idaho. The lake provides food and sport for thousands due to its proximity to large population centers in northern Idaho and eastern Washington as well as being a vacation destination for many people throughout the west and inland British Columbia and Alberta, Canada.

In 1987, Congress authorized funding through an amendment, Section 525, to the Clean Water Act of 1987 for a three year comprehensive assessment of water quality "...in Lake Pend Oreille, Idaho, and the Clark Fork River and its tributaries [in] Idaho, Montana, and Washington..." (United States Environmental Protection Agency 1989). The purpose was to identify sources of nutrient pollution and make recommendations to control those sources.

When attempting to manage nutrient concentrations, decision-makers can be faced with concerns regarding too little as well as too much. Unlike most other pollutants like heavy metals, pesticides, or organic compounds, where reductions in concentrations result in better living conditions for aquatic life, it is essential certain levels of nutrients remain to support the basic food chain requirements of aquatic ecosystems.

Purpose

The goal of this summary was to provide a synopsis of Pend Oreille Lake fishery information and determine if water quality goals--maintaining the pelagic zone water quality while improving the water quality in the littoral zone--would have a significant adverse effect on the lake's aquatic resource. Emphasis was placed on whether reductions in nutrient concentrations would affect fishery yields.

Objectives

1. To provide a summary of the past and present Pend Oreille Lake fish communities. Existing data were used to summarize species composition and dominant sport fish distribution, abundance, density, biomass, survival, age, and growth.

2. To provide a summary of the past and present Pend Oreille Lake fishery. Existing data were used to summarize dominant sport fish harvest, effort, harvest rate, and size.

3. To estimate the economic value of the Pend Oreille Lake fishery.

4. To provide a summary of the past and present Pend Oreille Lake zooplankton communities and their relation to the fishery. Existing data were used to summarize species composition and trends and dominant zooplankton and mysid temporal and spatial distribution, abundance, density, biomass, and size.

5. To report on a cursory investigation of heavy metal and organic compound accumulation in fish tissue and determine if fish consumption poses human health risks.

6. To determine if proposed water quality goals have a significant adverse effect on the Pend Oreille Lake fishery.

7. To provide a bibliography of Pend Oreille Lake fisheries research from 1951 to 1989.

CHAPTER 2

STUDY AREA DESCRIPTION

Location

Pend Oreille Lake is located in the panhandle region of northern Idaho (Figure 2-1). Most of the lake lies in Bonner County. A small part of the southern end extends into Kootenai County.

Lake Morphometry

Pend Oreille Lake is the largest, natural lake in Idaho with a surface area of 383 km^2, mean depth of 164 m, and maximum depth of 351 m (Rieman and Falter 1976). Mean surface elevation of Pend Oreille Lake is 629 m (Jeppson and Vaughan 1952). Most of the lake's volume (southern basin) is contained in a glacially overdeepened portion of the Purcell Trench (Savage 1965) with a mean depth of 218 m (Rieman and Falter 1976). The north arm of the lake is shallower with a mean depth of 30 m.

Hydrology

Clark Fork River is Pend Oreille Lake's principal inlet. It is estimated to contribute as much as 90% of the annual inflow (Beckwith 1989a). The only surface outlet is Pend Oreille River located on the northwest part of the lake.

The construction of Cabinet Gorge Dam in 1951 on Clark Fork River eliminated 90% of the available spawning and rearing habitat for adfluvial fishes (Irving 1986). Adfluvial fishes spawn and live in tributaries to Pend Oreille Lake for up to three years before moving into the lake where they spend another two to four years before becoming mature. Presently, 16 km of Clark Fork River and 165 km of smaller tributaries to Pend Oreille Lake and the river are available to adfluvial fishes (Hoelscher and Bjornn 1989).

Fishes Present

A wide diversity of fish species are present in Pend Oreille Lake and its tributaries (Jeppson and Vaughan 1952; Klavano 1960; Simpson and Wallace 1982; Pratt 1985; Hoelscher and Bjornn 1989). Game fishes include: indigenous westslope cutthroat trout Oncorhynchus clarki lewisi, bull trout Salvelinus confluentus, and mountain whitefish Prosopium williamsoni and introduced kokanee Oncorhynchus nerka, rainbow trout Oncorhynchus mykiss, Gerrard (Kamloops) rainbow trout, lake whitefish Coregonus clupeaformis, brook trout Salvelinus fontinalis, brown trout

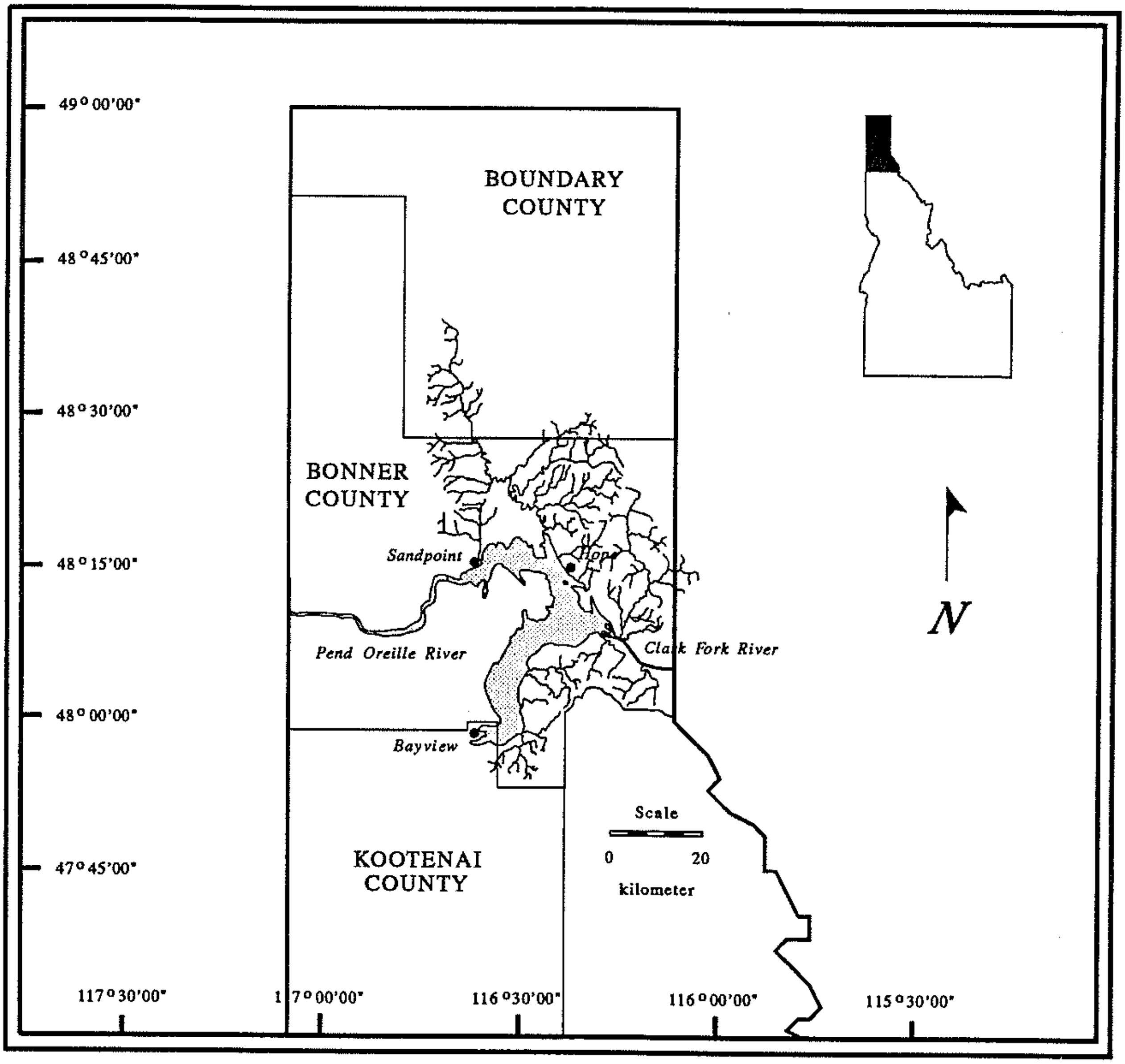

Figure 2-1. Map of Pend Oreille Lake, Idaho.

Salmo trutta, lake trout Salvelinus namaycush, yellow perch Perca flavescens, black crappie Pomoxis nigromaculatus, largemouth bass Micropterus salmoides, brown bullhead Ictalurus nebulosus, pumpkinseed Lepomis gibbosus, and northern pike Esox lucius. Other fishes include: northern squawfish Ptychocheilus oregonensis, largescale sucker Catostomus macrocheilus, longnose sucker Catostomus catostomus, peamouth Mylocheilus caurinus, redside shiner Richardsonius balteatus, slimy sculpin Cottus cognatus, torrent sculpin Cottus rhotheus, longnose dace Rhinichthys cataractae, pygmy whitefish Prosopium coulteri, and tench Tinca tinca. Several pacific lamprey Entosphenus tridentatus were collected from Pend Oreille Lake in 1967 (Simpson and Wallace 1982). They had not been observed previously and have been only once since. Artic grayling Thymallus arcticus have also been reported to have been released into the lake (Klavano 1960). Five walleye Stizostedion vitreum were recorded by creel census personnel in 1951 (Simpson and Wallace 1982). None have since been seen.

CHAPTER 3

FISH COMMUNITY

Westslope cutthroat trout, bull trout, and mountain whitefish are the indigenous salmonids in Pend Oreille Lake. In 1889, the United States Fish Commission introduced 1,300,000 lake whitefish fry (Simpson and Wallace 1982). Kokanee appeared naturally in Pend Oreille Lake about 1933 (Klavano 1960). The original stock likely migrated into the lake via the Flathead and Clark Fork rivers from Flathead Lake in Montana. During 1937, a tremendous die-off of lake whitefish occurred. The cause of this kill was never known. Many people speculated either effluent discharged into Pend Oreille Lake from mining activities or an epizootic disease was responsible. During this period of low lake whitefish numbers, kokanee became very abundant. In 1941, abundant kokanee prompted the introduction of Gerrard rainbow trout from Kootenay Lake, British Columbia. Other salmonids have been introduced into the Pend Oreille Lake drainage. These were brook trout, brown trout, lake trout, and arctic grayling. The introduction of arctic grayling apparently failed because there have been no catch records of this species. Lake trout and brown trout have established populations in the lake and provide some harvest. Brook trout occur primarily in the tributaries.

It is not known when yellow perch, black crappie, and largemouth bass were introduced into Pend Oreille Lake. These species compose an important part of the fish community in the shallow bays of the northern and western part of the lake.

Kokanee

Distribution - Kokanee were found throughout the pelagic zone of Pend Oreille Lake. Individual age classes displayed specific horizontal distributions. Wild kokanee fry were mostly collected from the south end of Pend Oreille Lake (Bowler 1978, 1979; Bowles et al. 1986, 1987, 1988, 1989; Hoelscher et al. 1990). This distribution suggested wild kokanee were mostly recruited on the south end of the lake, likely resulting from shoreline spawning (Bowler 1979). Throughout their first summer (age 0), kokanee fry moved northward (Bowler 1978, 1979). Most of these data indicated kokanee spent their second summer (age 1) rearing in the north end of the lake (Bowler 1975, 1976, 1977, 1978; Bowles et al. 1987, 1989; Hoelscher et al. 1990). The exceptions were during 1985 and 1987 when more age 1 kokanee were collected mid-lake (Bowles et al. 1986, 1988). Age 2 and older kokanee dispersed throughout Pend Oreille Lake, however, remained more abundant in the south end (Bowler 1978; Bowles et al. 1986, 1987, 1988, 1989; Hoelscher et al. 1990). Older age kokanee tended to concentrate in the south end of the lake during winter months (Bowler 1977) then displayed a general northward movement in early spring (Bowler 1978).

Nightly vertical distributions of kokanee in Pend Oreille Lake changed from month to month. Echosounding recorded most fish at 23 m during January and February (Bowler 1975, 1976, 1977). As the lake overturned in early spring, the fish began to ascend the water column until the thermocline formed, and the fish descended. With fall overturn, the fish began to ascend the water column again.

Kokanee in Pend Oreille Lake were both lakeshore and tributary spawners (Table 3-1; Figure 3-1). Jeppson (1960a) reported kokanee spawned in 27 different areas throughout the drainage during the 1950s. Gibson (1973) noted kokanee spawning trends in 1972 were consistently less than those found in the 1950s. Although there has been some variability in escapement estimates since 1972 (Appendix A), the general trend appeared less than those observed in the 1950s.

Lakeshore spawning typically occurred in gravelly and sandy sites at a depth less than two meters (Jeppson 1954). Gibson (1973) and Bowler (1974) reported kokanee actively spawning at depths greater than six meters. Preferred sites included shoals affected by wave action, near the mouths of minor tributaries, or where subterranean inflow from small mountainous watersheds entered the lake (Jeppson 1954, 1960a). Jeppson (1954) estimated kokanee spawned along one kilometer of lake shoreline during 1952.

Tributary spawning was not as widespread as lakeshore spawning in Pend Oreille Lake. Typically, spawning occurred in streams supplied largely by subterranean water during the winter months (Jeppson 1960a). Jeppson (1954) noted Clark Fork River appeared to be the principal spawning area for Pend Oreille Lake kokanee during the early 1950s. About 100,000 spawners were estimated in Clark Fork River annually between 1952 and 1954 (Jeppson 1960a). In subsequent years, only a fraction of this number was estimated. It is believed blocking kokanee spawning migrations and fluctuating river flows during the incubation of embryos had a detrimental effect on the production of kokanee in Clark Fork River (Jeppson 1954). More recently Granite Creek, and more specifically Sullivan Springs, appeared to be the principal tributary spawning area for Pend Oreille Lake kokanee. This spawning run has been enhanced through many years of hatchery supplementation (Bowles et al. 1988).

Abundance and Density - Kokanee population status has been monitored in Pend Oreille Lake from 1974 to 1989 using hydroacoustic (1974-1980) and midwater trawl (1977-1989) techniques. Bowler (1981) reported total kokanee abundance declined from 12.1 million (534 kokanee/ha) in 1974 to 3.6 million (159 kokanee/ha) using hydroacoustic estimates and 4.7 million (207 kokanee/ha) using trawl estimates in 1980 (Figure 3-2). It then varied over the next several years before reaching the population's low of 4.3 million (189 kokanee/ha) in 1986 (Bowles et al. 1987). Over the next three years, the kokanee population in Pend Oreille Lake increased 80% (Appendix B).

Several factors have contributed to the decline of kokanee in Pend Oreille Lake. Initial declines in population numbers have been attributed to hydropower development. The loss of spawning habitat in Clark Fork River following the construction of Cabinet Gorge Dam in 1951 and river flow fluctuations below the dam during incubation of embryos severely affected kokanee

Table 3-1. Game fishes observed (+) and suspected (?) in tributaries to Pend Oreille Lake, Idaho. Data were summarized by Pratt (1985); Hoelscher and Bjornn (1989); and Hoelscher et al. (1990).

Stream	Kokanee	Rainbow trout	Bull trout	Cutthroat trout	Brook trout	Brown trout	Mountain whitefish
Pack River		+	+	+	?		+
McCormick Creek				+			
Youngs Creek				+			
Jeru Creek				+	+		
Hellroaring Creek		+					
Caribou Creek		+		+			
Berry Creek		+		+	+		
Colburn Creek		+		+	+		
Sand Creek		+		+	+		
Grouse Creek		+	+	+	+		+
N.F. Grouse Cr.		+	?	+	+		?
S.F. Grouse Cr.		+	+	+	+		
Gold Creek		+					
Rapid Lightning Cr.		+	?	+	+		+
Trout Creek				+			
Sand (Sandpoint) Cr.		+		+	+		+
Schweitzer Creek		+		+	+		
Little Sand Creek		+		+			
Trestle Creek	+	+	+	+			?
Riser Creek				+			
Strong Creek				+			
Lightning Creek	+	+	+	+	+		+
Spring Creek	+	+		+	+	+	
Cascade Creek	+	+		+	+		
Morris Creek		+		+			
E.F. Lightning Cr.		+	+	+	+		
Savage Creek		+	+	+			
Char Creek		+	+	+			
Porcupine Creek		?	+	+	?		
Wellington Creek		+	+	+	?		+
Rattle Creek		?	+	+			
Johnson Creek	+	?	+	+			
Mosquito Creek	?	+		+	+		
Twin Creek	+	+	+	+	+	+	+
Granite Creek	+	+	+	+	?		
Falls Creek					+		
Cedar Creek	?				+		
North Gold Creek	+	+	+	+			
Gold Creek	+	+	+	+			+
West Gold Creek				+			

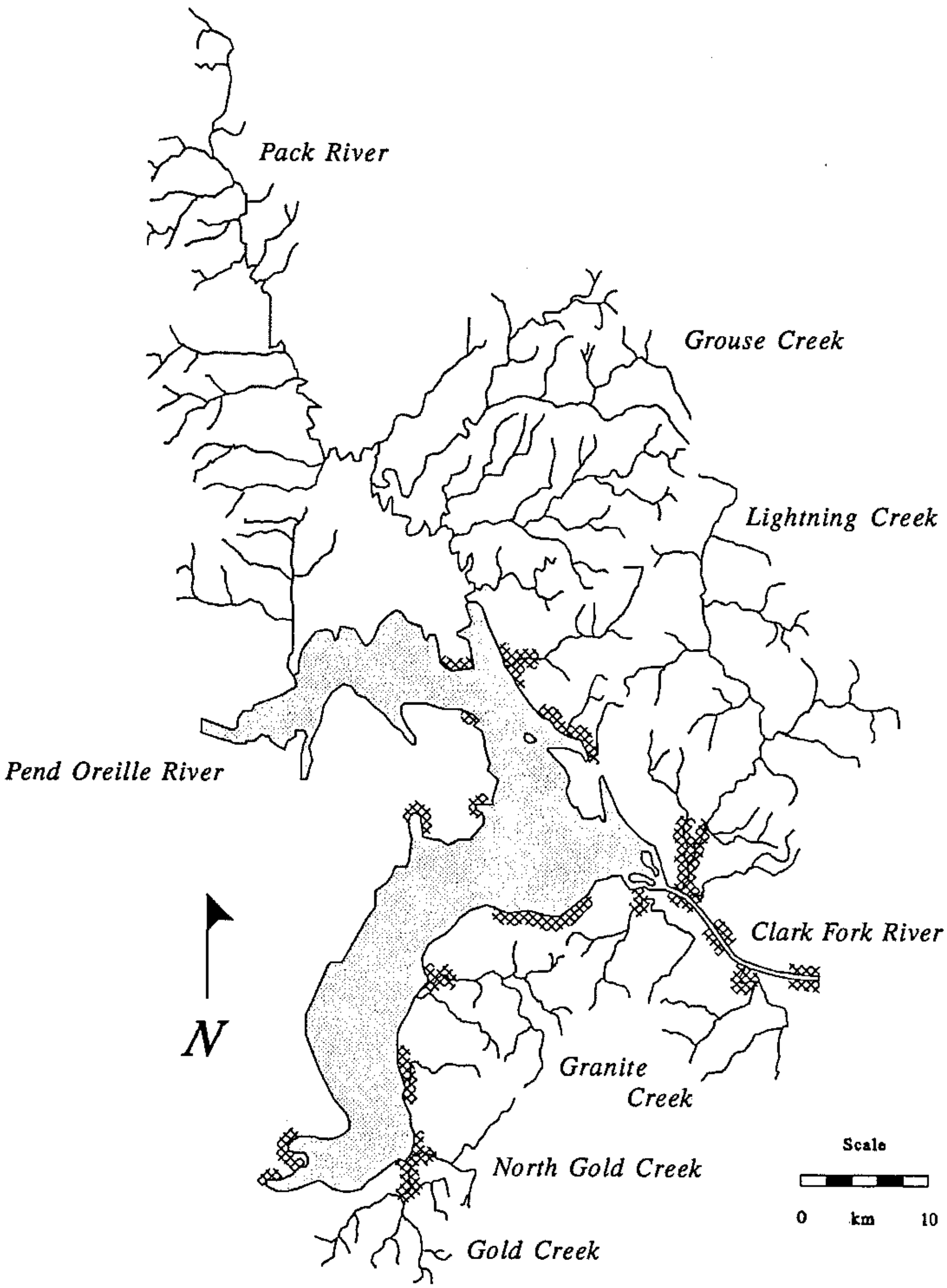

Figure 3-1. Distribution of kokanee spawning in Pend Oreille Lake, Idaho. Marked areas show general locations not actual linear kilometers of shoreline used by spawning kokanee. Data were summarized by Jeppson (1960a) and Hoelscher et al. (1990).

production in Clark Fork River (Jeppson 1954). Lake level fluctuations, caused by the operation of Albeni Falls Dam, dewatered kokanee eggs in shoreline gravel increasing embryo mortality of lakeshore-spawning kokanee (Bowler et al. 1979).

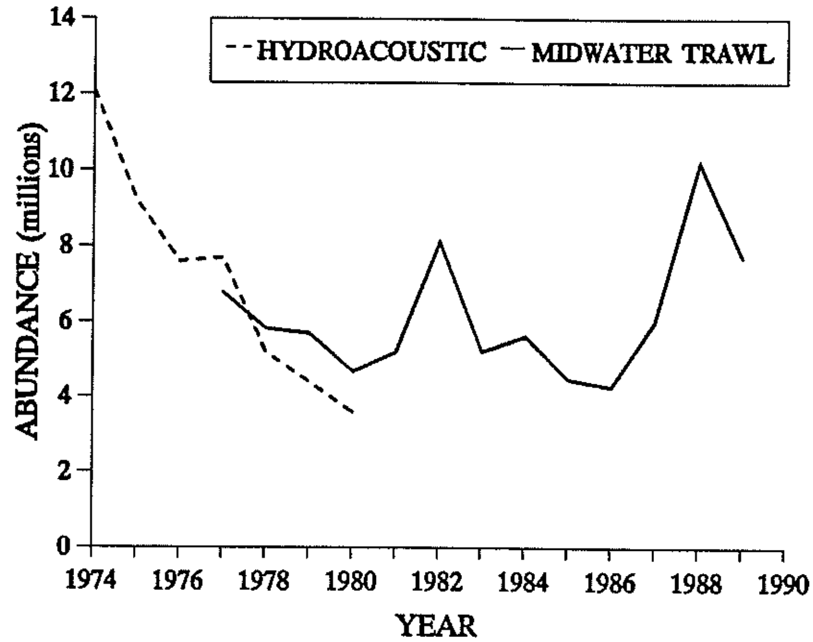

Figure 3-2. Total kokanee abundance estimated by hydroacoustic (1974-1980, excluding 1979) and midwater trawl (1977-1989) in Pend Oreille Lake, Idaho, from 1974 to 1989. Data were summarized by Bowler (1981); Bowles et al. (1988); and Hoelscher et al. (1990).

More recently, declines in the kokanee population have been associated with the introduction and establishment of opossum shrimp Mysis relicta in Pend Oreille Lake. Opossum shrimp became well established in the lake by 1975 (Rieman and Falter 1976). The establishment of mysids resulted in the temporal displacement of two cladocerans, Bosmina and Daphnia, and a net loss in food available for juvenile kokanee during a critical period of emergence and first feeding (Rieman and Bowler 1980). Poor survival of fry during this period was associated with the change in availability of zooplankton prey items and was believed to have contributed to the decline in kokanee abundance (Rieman 1979).

The recent increase in kokanee abundance was partially attributed to high fry recruitment from Cabinet Gorge Hatchery (Hoelscher et al. 1990). During eight years of hatchery supplementation prior to completion of Cabinet Gorge Hatchery in 1985, relative contribution of hatchery fish to total kokanee abundance averaged 17% (Figure 3-3). After four years of operation, contribution from Cabinet Gorge Hatchery increased to 41%. This relative contribution of hatchery fish was not an artifact of declining wild kokanee production, which also increased an average of 36% since completion of the hatchery.

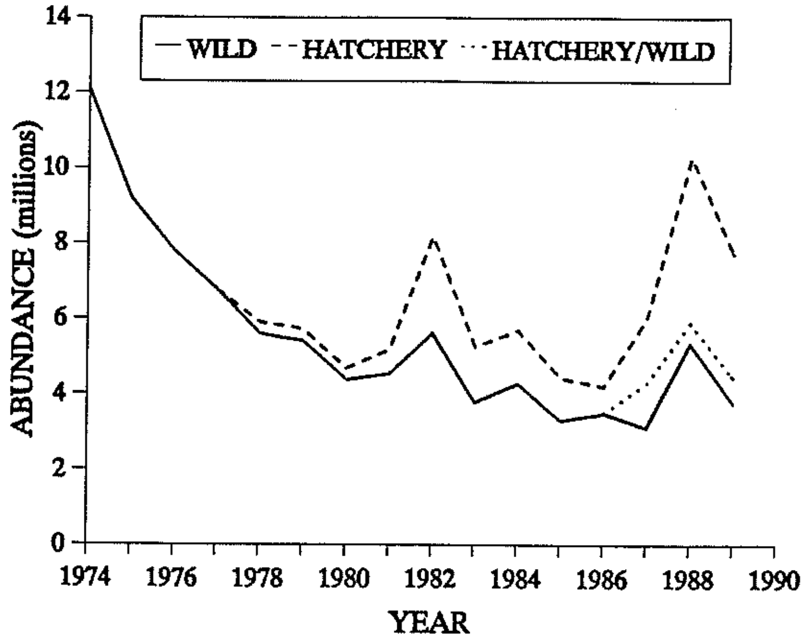

Figure 3-3. Relative hatchery contribution to total estimated kokanee abundance in Pend Oreille Lake, Idaho, from 1974 to 1989. The hatchery-wild component represented contribution from naturally spawning kokanee of hatchery origin. Data were summarized by Hoelscher et al. (1990).

Biomass - Estimated age 1 and older kokanee biomass in Pend Oreille Lake declined 45% from 312,300 kg (13.85 kg/ha) in 1977 to 171,500 kg (7.57 kg/ha) in 1988 (Figure 3-4). Kokanee biomass increased 26% in 1989. Kokanee fry contributed a very small part of the total kokanee biomass in Pend Oreille Lake. During 1988, kokanee fry biomass was 10,200 kg (0.45 kg/ha), composing only six percent of the total kokanee biomass and represented the strongest year class (1987) since monitoring began in the mid-1970s (Bowles et al. 1989). Biomass of hatchery-reared fry was 7,500 kg (0.33 kg/ha); 73% of total fry biomass. During 1989, biomass of hatchery-reared kokanee fry was 3,100 kg (0.14 kg/ha); 80% of total fry biomass in the lake and only one percent of total kokanee biomass (Hoelscher et al. 1990).

Even though kokanee abundance increased dramatically since 1986, biomass continued to decline through 1988 then began to increase in 1989. High fry recruitment from Cabinet Gorge Hatchery increased population numbers but did little to increase total kokanee biomass in the lake. Increased biomass was only recently becoming apparent as these younger age classes work through the population.

Survival - Prior to impoundment by Albeni Falls Dam, kokanee spawning in Pend Oreille Lake occurred when the lake was near its annual minimum level; about 624 m (Jeppson 1960a). Drying and freezing of kokanee eggs rarely occurred as a result of declining water levels. After impoundment, annual winter drawdown, which averaged 1.3 m from 1951 to 1968, increased embryo mortality by exposing redds of lakeshore-spawning kokanee (Bowler et al. 1979).

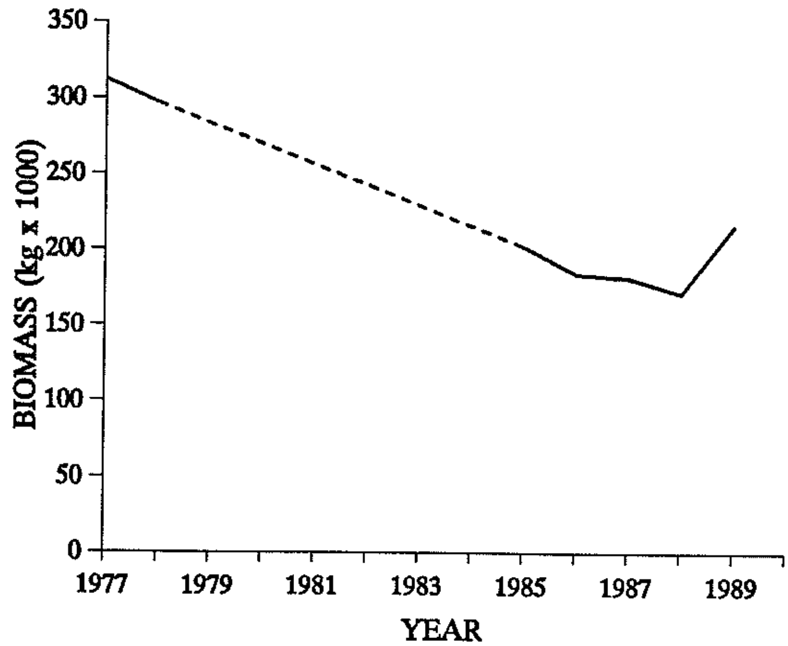

Figure 3-4. Estimated age 1 and older kokanee biomass in Pend Oreille Lake, Idaho, from 1977 to 1978 and 1985 to 1989. Age 1 fish were in their second summer of life. The 1978 estimate included age 0 kokanee.

Gibson (1973) found two-thirds of the lakeshore gravel samples collected in 1972 contained greater then 40% fines less than 6.35 mm. McCuddin (1977) reported survival decreased for both chinook salmon Oncorhynchus tshawytscha and steelhead trout Oncorhynchus mykiss as sediment less than 6.4 mm approached 25%. Less than 50% survival was observed when the percentage of sediments less than 6.4 mm reached 40%. Kokanee would likely select smaller gravel than either chinook salmon or steelhead trout so the net effect to kokanee embryos may be much greater.

Peaking Clark Fork River flows adversely affected kokanee production. Kokanee redds located in shallow, marginal areas of the lower river were repeatedly exposed to drying and freezing by daily river fluctuations as great as two meters (Jeppson 1954). Redds in well-drained spawning areas above minimum river flow level showed higher mortality of embryos than redds underlain by impermeable clay; which tended to puddle water in the redds during periods of exposure, thus limiting desiccation. Relatively high loss of kokanee embryos occurred in the river. Estimated mortality averaged 60% and was as high as 75%.

The establishment of opossum shrimp in Pend Oreille Lake had an effect on kokanee survival and year class abundance. Kokanee begin to emerge from spawning gravel in early April and continue until August (Jeppson 1960b; Bowler 1979). Historically, two Cladocerans, Daphnia and Bosmina, which are essential juvenile kokanee forage (Rieman and Bowler 1980), were available during this critical period of emergence and first feeding (Stross 1954). Mysids caused a temporal displacement of these important forage items and thus increased kokanee mortality (Rieman and Bowler 1980). Mortality of juvenile kokanee due directly to starvation seemed to be low and was likely more a function of predation (Rieman 1981). Rieman (1977) suggested increases in zooplankton in the lake (mainly Cladocerans) may be more critical to age 0 kokanee survival than total abundance of preferred items or intraspecific competition. Delayed planting of hatchery fry until midsummer to avoid early season forage deficiencies increased hatchery fry survival 13 times wild fry (Bowler 1981).

In 1988 and 1989, various release strategies were evaluated to optimize post-release fry survival in Pend Oreille Lake. After one year of replication, survival of hatchery fry from release to fall sampling ranged between 20 and 30% (Bowles et al. 1989; Hoelscher et al. 1990). Survival of individual releases ranged between 5 and 36%. Size of fry at release, abundant forage late in the summer, and an absence of predators may have all contributed to improved survival.

Bowler (1978, 1979) estimated an exploitation rate for age 3 and age 4 kokanee of 15% in 1977 and 10 % in 1978. Bowles et al. (1987) estimated a similar exploitation rate (15%) in 1985.

Age and Growth - Early records concerning the growth and development of kokanee populations in Pend Oreille Lake were lacking, however, several generalizations were possible. During the early and middle 1930s when the kokanee population was becoming established, reports of large kokanee (0.9 kg) in the catch were common (Whitt 1958a). In the late 1930s and early 1940s, kokanee size decreased. The fish remained small until the late 1940s when they began to increase in size. By 1952, kokanee averaged 300 mm at maturity (Figure 3-5). Kokanee size again decreased to about 250 mm by the mid-1970s. Since that time, kokanee size has been increasing. This increase in size was likely due to increased age at maturity (Hoelscher et al. 1990).

First-year kokanee growth varied from 1954 to 1976 year classes, and the 1974 year class showed a marked decline from the previous years (Figure 3-6). Growth to the first annulus from 1954 to 1973 year classes likely reflected a density dependent relation with growth being slower before the mid-1960s because of higher kokanee abundance than was found in the lake after the mid-1960s (Bowler 1977). The reduction in first-year growth rate of the 1974 year class was likely in response to the change in food supply that occurred in Pend Oreille Lake during the summer of 1975 when opossum shrimp abundance greatly increased. Similar growth rates were observed for the 1975 and 1976 year classes. These data suggested first-year growth had been reduced after mysids became established in Pend Oreille Lake. Growth rates of age 2 and older kokanee appeared to be more constant from 1953 to 1975 year classes. Adverse effects of the reduced food supply may still be evident in second-year growth, but the trend was not as obvious and may represent annual variability.

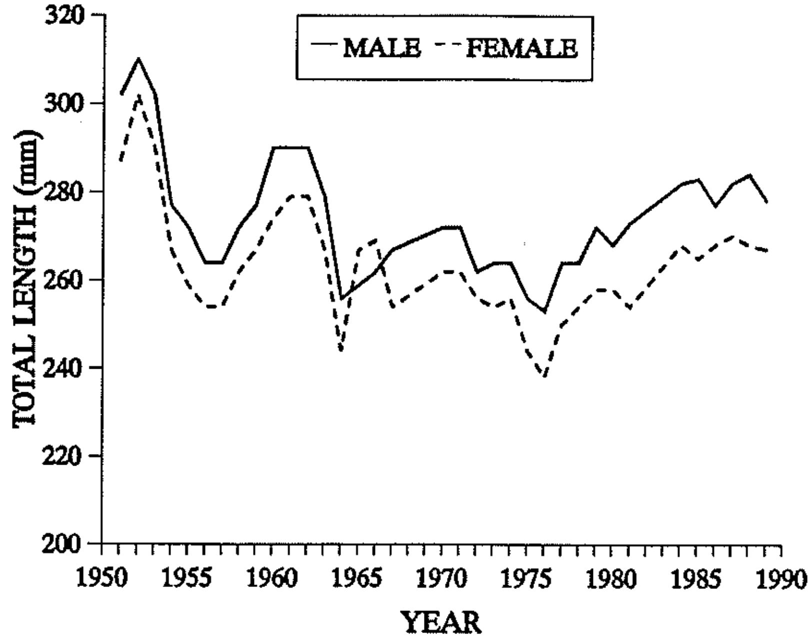

Figure 3-5. Estimated mean total length (mm) of male and female kokanee spawners from Pend Oreille Lake, Idaho, from 1951 to 1989. Data were summarized by Hoelscher et al. (1990).

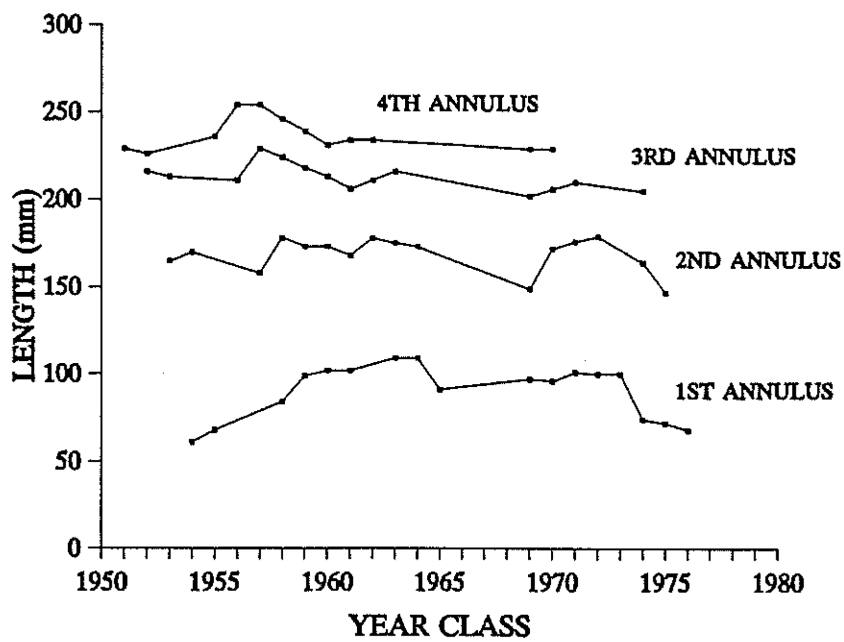

Figure 3-6. Estimated mean total length (mm) at annulus formation of kokanee from Pend Oreille Lake, Idaho, 1951 to 1976 year classes. Data were summarized by Allison (1958); Whitt (1958a); Mallet (1968a); and Bowler (1976, 1979).

The spawning population consisted mostly of fish in their fourth (age 3) and fifth (age 4) years of life with the percentages of each varying from year to year. About 75% of the mature kokanee were five years old (Bowles et al. 1988, 1989; Hoelscher et al. 1990). The remaining fish were four (age 3) and six (age 5) years old. Some evidence suggested before 1956 kokanee exhibited a four year life cycle (Whitt 1958a). This phenomenon may be a density dependent relation similar to that that governed kokanee growth during periods of high kokanee abundance.

Rainbow Trout

Distribution - Juvenile rainbow trout were moderately distributed throughout Pend Oreille Lake tributaries and were observed in 70% of the streams surveyed (Table 3-1; Figure 3-7). Pratt (1985) observed relatively high numbers of rainbow trout fry in Granite Creek in 1984. Even though eyed Gerrard rainbow trout eggs were placed in Granite Creek and Sullivan Springs between 1958 and 1960 and numerous fry observed in the stream during late summer (Jeppson 1960b), other researchers have been unable to document rainbow trout use of Granite Creek either through underwater observation (Hoelscher and Bjornn 1989) or attempting to trap downstream migrants (Goodnight and Reininger 1978). The fry may have been westslope cutthroat trout as they were observed in Granite Creek (Pratt 1985; Hoelscher and Bjornn 1989). Others have found it difficult to distinguish between rainbow (or steelhead) trout and westslope cutthroat trout fry when viewed underwater (Graham 1977; Shepard 1983; Hoelscher and Bjornn 1989).

Juvenile rainbow trout were most often found in the middle and lower reaches of streams (Pratt 1984a; Hoelscher and Bjornn 1989). Use of the middle and lower reaches of Pend Oreille Lake tributaries was similar to distributions of Gerrard rainbow trout in the upper reaches of the Lardeau River, British Columbia (Irvine 1978). Gerrard rainbow trout from the Lardeau River were the parental stock of Pend Oreille Lake rainbow trout. Considering the size of the Lardeau River, the area could be compared to the larger, lower stream reaches used by juvenile rainbow trout in the Pend Oreille Lake basin. Steelhead trout used lower stream reaches in the Salmon and Clearwater river drainages (Hanson 1977; Thurow 1983).

Rainbow trout spawning areas have been poorly defined in the Pend Oreille Lake basin. Fry distribution and observations of rainbow trout spawners provided a generalized distribution of spawning sites (Figure 3-8). As early as 1953, spawning runs of large rainbow trout had been observed in Spring Creek (Jeppson 1960a). Beginning in 1958, small runs were reported in Clark Fork River, Grouse Creek, and Rapid Lightning Creek. During the same year, two large rainbow trout were observed in Granite Creek and one in North Gold Creek (Whitt 1958b). Goodnight and Reininger (1978) observed rainbow trout spawners in Pack River, Grouse Creek, North Fork Grouse Creek, Rapid Lightning Creek, and Lightning Creek in 1976 and 1977. No spawners were observed in Granite Creek during 1976. It appeared the naturally produced rainbow trout population in Pend Oreille Lake was largely dependant on north shore tributary spawning sites. In 1977, total spawning escapement was estimated between 200 and 300 adult

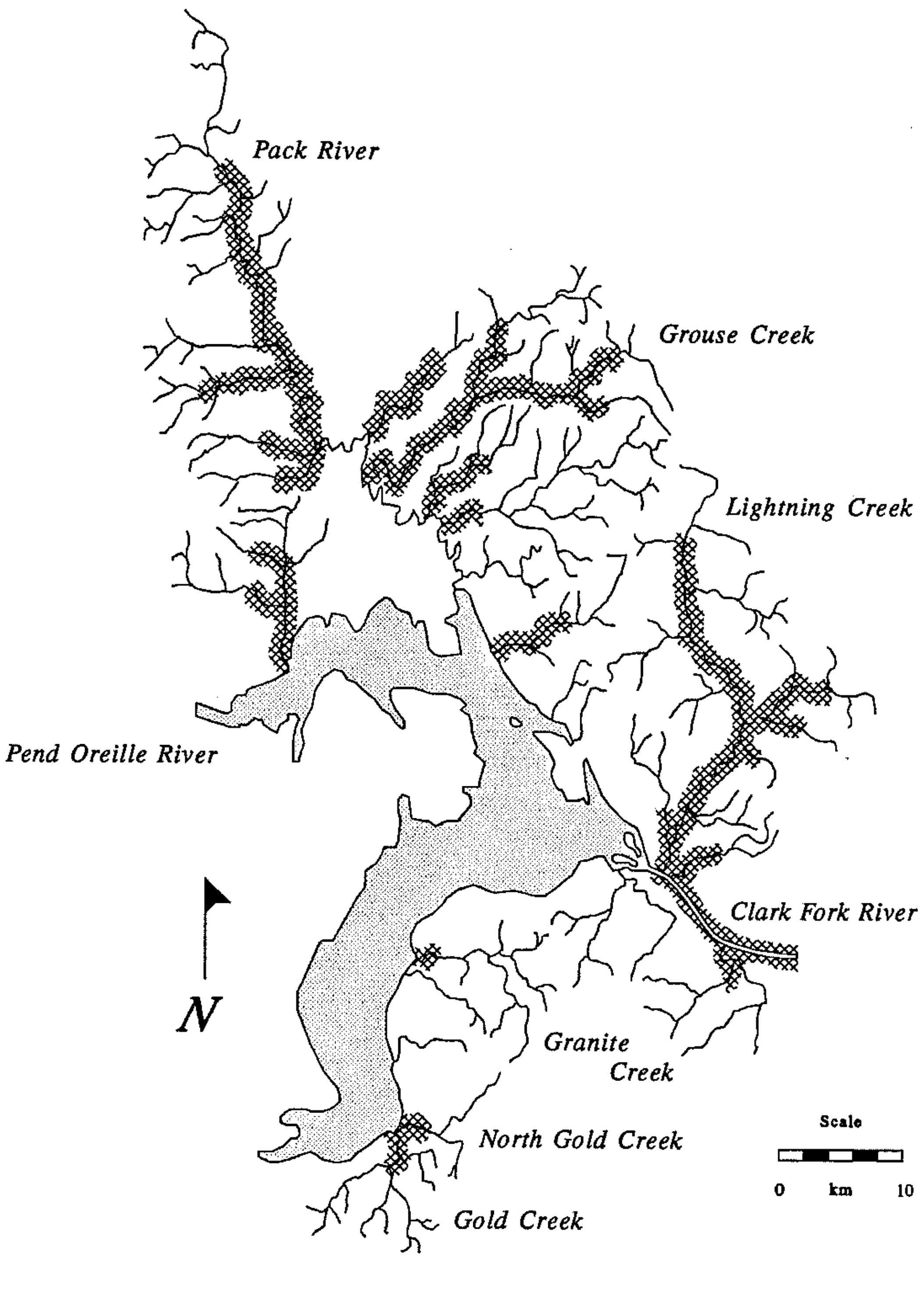

Figure 3-7. Distribution of juvenile rainbow trout in tributaries to Pend Oreille Lake, Idaho. Data were summarized by Goodnight and Reininger (1978); Pratt (1985); and Hoelscher and Bjornn (1989).

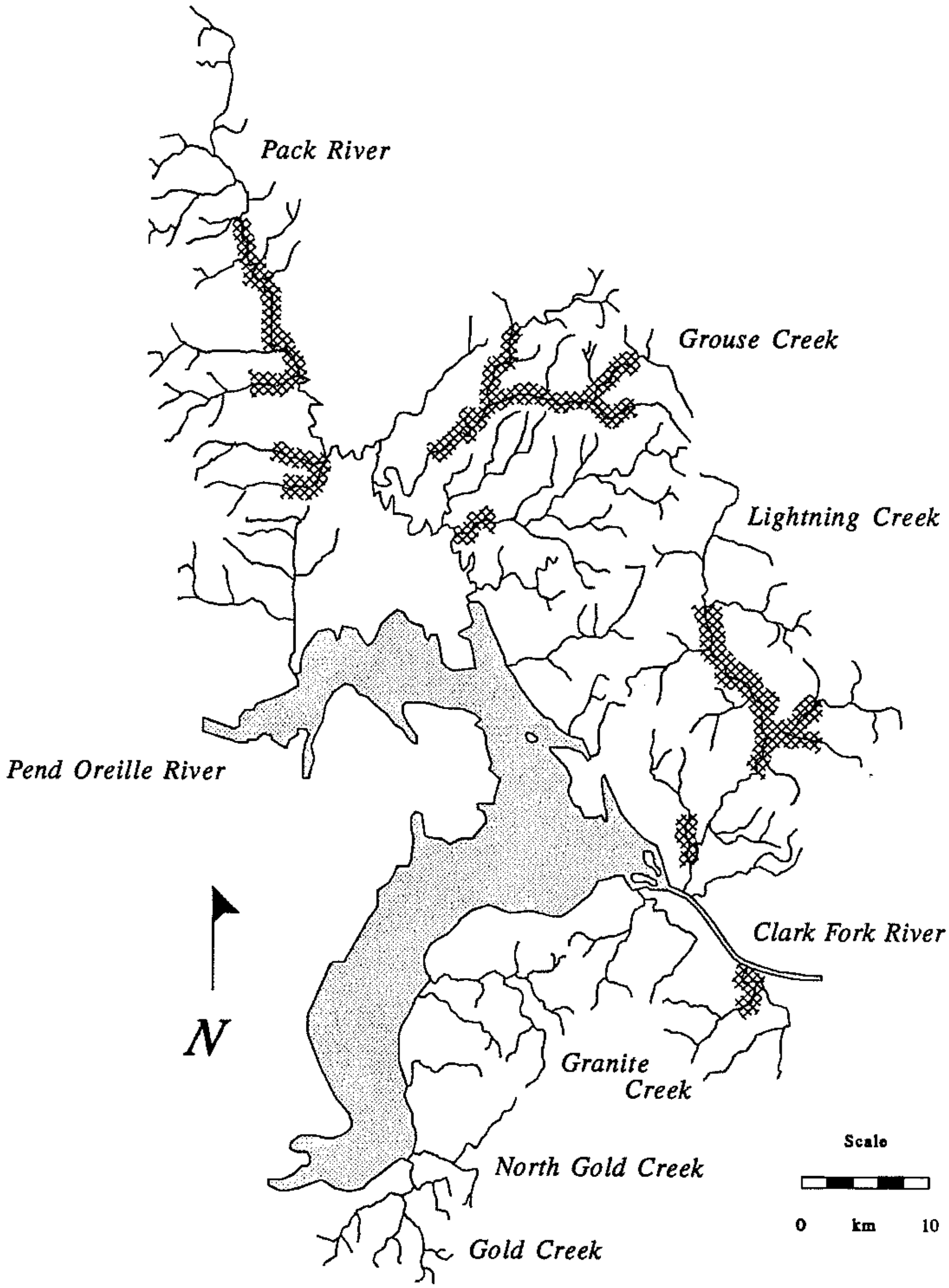

Figure 3-8. Estimated distribution of rainbow trout spawning in tributaries to Pend Oreille Lake, Idaho, based on fry distribution and observations of rainbow trout spawners. Data were summarized by Goodnight and Reininger (1978); Pratt (1985); and Hoelscher and Bjornn (1989).

rainbow trout with at least one-third to one-half of the fish spawning in Lightning Creek (Goodnight and Reininger 1978).

Rainbow trout may spawn on lake shoals in Pend Oreille Lake. In 1953, large rainbow trout were observed in mid-May along the shoreline east of Deadman's Point in 3.5 to 4.5 m of water and were believed to have been spawning (Jeppson 1954). Old redds were observed in this area in October when the lake level receded. In mid-May, 1958, researchers found what appeared to be a recently excavated rainbow trout redd near Kilroy Bay in about 1.5 m of water (Whitt 1958b). Cartwright (1961) reported although no spawning fish nor identifiable redds had been observed in Kootenay Lake, British Columbia, it was possible rainbow trout could spawn along the lakeshore in areas of subsurface springs.

Abundance and Density - Relatively large numbers of rainbow trout fry were observed in several Pend Oreille Lake tributaries. Irving (1986) calculated average densities of 82.7 fry/100 m^2 in Lightning Creek and 92.7 fry/100 m^2 in Grouse Creek in 1985. Hoelscher and Bjornn (1989) estimated an average density of 31.3 fry/100 m^2 in Pend Oreille Lake tributaries available to adfluvial fishes during 1986 and 1987. Mean densities as high as 95.7 fry/100 m^2 were observed (Appendix C). At stocking rates of 830 and 990 steelhead trout fry/100 m^2 in Lochsa River tributaries, densities stabilized at about 100 fry/100 m^2 by the end of the summer (Graham 1977). High rainbow trout fry densities observed within some Pend Oreille Lake tributaries indicated rainbow trout recruitment was maximized within those areas.

Even though rainbow trout fry were abundant in some areas, densities of age 1 and older rainbow trout in Pend Oreille Lake tributaries were low. Irving (1986) calculated mean densities for age 1 and older rainbow trout of 10.2 fish/100 m^2 in Grouse Creek and 40.6 fish/100 m^2 in Lightning Creek in 1985. (The author feels a value of 8.5 fish/100 m^2 better represented the population for Lightning Creek if a transect exhibiting unusually high densities was deleted. This transect was located in a reach that regularly goes subsurface and may represent fish that were stranded.) Estimated densities corroborated with those calculated by Pratt (1985) in 1983 and 1984 (Appendix D). Hoelscher and Bjornn (1989) reported a mean density of 3.6 age 1 and older rainbow trout/100 m^2 in surveyed tributaries available to adfluvial fishes during 1986 and 1987. Estimated densities were 40% lower for Grouse Creek and 50% lower for Lightning Creek (Appendix C) than those reported by Irving (1986). The 1986 and 1987 values represented estimates weighted by habitat type and took into account large amounts of sub-optimum (riffle) habitat. If only pools were considered, mean densities would be similar to those of Pratt (1985) and Irving (1986).

Densities were within the range reported for rainbow (or steelhead) trout in similar infertile drainages of the northwest. Observed densities were low compared to those currently reported for steelhead trout in Lochsa River tributaries (Idaho Cooperative Fish and Wildlife Research Unit, unpublished data), however, comparable to densities during low escapement years (Graham 1977; Mabbott 1982). Densities were higher than those for steelhead trout in Middle Fork Salmon River tributaries (Thurow 1982, 1983, 1985), while only slightly higher than Gerrard rainbow trout densities in Lardeau River, British Columbia (Irvine 1978).

Mean densities of rainbow trout in Pend Oreille Lake tributaries were highest in pools, less in runs and pocketwaters, and lowest in riffles (Hoelscher and Bjornn 1989). A similar distribution was observed for steelhead trout in tributaries of South Fork Clearwater River and were found not to be significantly different (Shepard 1983).

Low rainbow trout abundance in Pend Oreille Lake tributaries has resulted from low spawner escapement and limited amounts of preferred habitat (Hoelscher and Bjornn 1989). While both factors affect potential abundance, the size of the spawning run may be limiting at the present time. Even though large numbers of rainbow trout fry have been observed in some tributaries, many accessible streams still had low if any rainbow trout production (Pratt 1985; Hoelscher and Bjornn 1989). Some researchers had found with small spawning escapements, the seeding rate was the most important variable in determining year class abundance of juvenile steelhead trout (Graham 1977) and juvenile chinook salmon (Sekulich 1980) in some Idaho streams. Anderson (1978) reported 29% of the rainbow trout over 43 cm collected from Pend Oreille Lake between 1972 and 1976 had spawned at least once, and as many as 15% had spawned more than once. Several of the rainbow trout had spawned three and four times. Pratt (1985) found during 1983 and 1984 less than 14% of the fish over 43 cm had spawned and only 2% had spawned twice. Although the comparative data should be interpreted with caution, it implied a declining potential for a self-sustaining population in Pend Oreille Lake. Current rainbow trout regulations, however, were aimed at protecting rainbow trout in the fishery until they can spawn at least once. With increased numbers of spawners, the available habitat would be more fully used either through pioneering new areas or by distribution of juvenile fish to rearing areas adjacent to spawning grounds. Hoelscher and Bjornn (1989) estimated potential abundance of age 1 and older rainbow trout could be three times higher than at present with full seeding of the presently available habitat. This assumed no other bottlenecks existed to limit abundance (*e.g.* sub-optimum summer or winter rearing habitat).

Limited amounts of optimum fish habitat existed in several Pend Oreille Lake tributaries. Several streams had large expanses of rapid, shallow water (*i.e.* riffles) with infrequent stretches of more preferred habitat types (*i.e.* pools) (Anderson 1971; Hoelscher and Bjornn 1989). Suitable habitat for young-of-the-year and age 1 and older fish in summer and winter must be present, however, the optimum features for both seasons are not completely understood. High rainbow trout fry densities and low densities of age 1 and older fish may be evidence overwinter habitat was limiting the number of rainbow trout in several tributaries, especially those with high proportions of rapid, shallow water (Hoelscher and Bjornn 1989). Pratt (1985) observed large numbers of rainbow trout fry in the intermittent section of Lightning Creek, a stream with large expanses of rapid, shallow water and few pools, when water was present during the fall. Other researchers have noticed downstream migrations of sub-yearling steelhead trout during fall and early winter triggered by winter "hiding" behavior and a lack of adequate cover (Bjornn 1966, 1971). Pools and a streambed consisting of unsedimented cobble and boulder material have been shown to provide overwinter habitat (Everest 1969).

Cabinet Gorge Dam likely had little direct effect on the rainbow trout population in Pend Oreille Lake (Klavano 1960). Spawning runs were first observed in Spring Creek in 1953 and in Clark

Fork River in 1958 (Jeppson 1960a). Blockage of Clark Fork River and its tributaries in 1951 limited the abundance of rainbow trout in the lake to a smaller population size than if these streams were available for spawning.

Survival - Pratt (1985) estimated rainbow trout egg-to-emergent fry survival rates from streambed composition sampled in Pend Oreille Lake tributaries during 1984. In Grouse and Twin creeks, two streams known to have been used by rainbow trout, fines less than 6.35 mm composed 30% of the substrate. Estimated survival averaged 56% (range 37-75%) in Grouse Creek; survival was higher (58-75%) for the upstream site than for the area below North Fork Grouse Creek (37-52%). Survival in Twin Creek was estimated at 39% (range 11-57%). The percent fines less than 6.35 mm were lower in Spring Creek and estimated survival was 68% (range 41-83%). McCuddin (1977) found particles less than 6.4 mm in diameter seemed to be mostly responsible for steelhead trout fry mortality in experimental troughs. Egg-to-emergent fry survival was less than 30% when particles less than 6.4 mm approached 30% of substrate composition.

Total annual mortality of juvenile rainbow trout in Pend Oreille Lake tributaries was quite high. Rates ranging from 84 to 85% in Lightning Creek and 64 to 95% in Grouse Creek were estimated for one to three year old fish in 1985 using electrofishing data (Irving 1986). It is important to note these estimates not only took into account natural and fishing mortality; they also included losses due to emigration. Therefore, these rates simply indicated annual changes in population abundance and age structure. Harvest of juvenile rainbow trout in streams appeared to be relatively low (Irving 1986) compared to past census data (Anderson 1971). Exploitation of rainbow trout fully recruited to the fishery (ages 1 to 3) ranged from nearly zero to about three percent in Lightning Creek and 0 to 13% in Grouse Creek in 1985 (Irving 1986).

Total annual mortality for rainbow trout collected in Pend Oreille Lake from 1971 to 1980 averaged 58% (Ellis and Bowler 1981). Pratt (1985) estimated a total annual mortality of 38% in 1983 and 69% in 1984. Since the sub-trophy (< 432 mm) component of the rainbow trout sport fishery was not completely represented in the sample during those years, it was believed the mortality estimates were conservative. Horner et al. (1988) estimated a total annual mortality of 61% in 1985. Estimates of total mortality were for fish recruited to the fishery and represented fish four to seven years old.

Age and Growth - Since an adfluvial stock of rainbow trout was introduced into Pend Oreille Lake, it was assumed rainbow trout in the drainage were adfluvial. Rainbow trout in Pend Oreille Lake reached an age of nine years (Anderson 1978). As many as three years of life was spent in the stream environment. Estimated mean total length at annulus formation of rainbow trout varied depending upon the age at migration to the lake (Table 3-2). The differences between length at annulus formation were quite pronounced for rainbow trout. Rainbow trout grew at accelerated rates upon entering the lake environment and averaged about 19 cm their first year (Pratt 1985). The differences in length at annulus formation between migration classes became less apparent with age. Growth rates were similar for fish collected during different studies on Pend Oreille Lake and the parental stock from Kootenay Lake, British Columbia (Table 3-3).

Table 3-2. Estimated mean total length at annulus formation of rainbow trout migrating as age 0, age 1, age 2, and age 3 fish, Pend Oreille Lake, Idaho, from 1983 to 1984. Age 0 fish were in their first summer of life. Data were summarized by Pratt (1985).

	Age at annulus formation					
Migration year	1	2	3	4	5	6
Total						
cm	7.8	17.0	33.4	46.0	58.1	67.2
in	3.1	6.7	13.2	18.1	22.9	26.5
(N)	(490)	(472)	(400)	(285)	(177)	(70)
Migration year 0						
cm	9.8	19.4	33.1	44.6	55.4	75.2
in	3.9	7.6	13.0	17.6	21.8	29.6
(N)	(14)	(14)	(12)	(9)	(7)	(2)
Migration year 1						
cm	8.3	28.3	40.2	51.9	65.0	70.0
in	3.3	11.1	15.8	20.4	25.6	27.6
(N)	(135)	(117)	(90)	(61)	(34)	(7)
Migration year 2						
cm	7.5	13.2	33.0	45.3	57.7	67.6
in	3.0	5.2	13.0	17.8	22.7	26.6
(N)	(308)	(308)	(265)	(193)	(122)	(55)
Migration year 3						
cm	7.4	12.3	18.6	37.0	45.9	57.5
in	2.9	4.8	7.3	14.6	18.1	22.6
(N)	(33)	(33)	(33)	(22)	(14)	(6)

Age at maturity appeared to be related to age at migration in Pend Oreille Lake (Pratt 1985). Most (62%) of the rainbow trout aged from 1983 to 1984 had migrated into the lake after spending two full summers rearing in the streams (age 2; entering their third year of growth). Twenty-eight percent of the fish examined had migrated after spending one or three growth seasons in the streams. These data should be interpreted with caution because it likely does not represent the true proportion of each migration class. Juveniles migrating during their first year of life (age 0) undoubtedly have much higher mortality associated with their smaller size. Similarly, fish leaving the streams in search of winter habitat may have been exposed to higher mortality rates than those directly seeking the lake. Therefore, the age-at-migration classes may

Table 3-3. Estimated mean total length at annulus formation of rainbow trout in Pend Oreille Lake, Idaho, and its tributaries during 1970, 1972-1976, 1983-1984, and 1985 and in Kootenay Lake, British Columbia, from 1942 to 1957. Kootenay Lake data were converted from fork lengths to total lengths using Carlander (1969).

Location	Age at annulus formation					
	1	2	3	4	5	6
Pend Oreille Lake (Anderson 1978)						
cm	8.0	14.3	28.9	43.4	62.5	77.9
in	3.2	5.6	11.4	17.1	24.6	30.7
Pend Oreille Lake (Pratt 1985)						
cm	7.8	17.0	33.4	46.0	58.1	67.2
in	3.1	6.7	13.1	18.1	22.9	26.4
Pend Oreille Lake tributaries (Anderson 1971)						
cm	5.2	10.7	16.7	-	-	-
in	2.0	4.2	6.6	-	-	-
Pend Oreille Lake tributaries (Anderson 1978)						
cm	7.8	12.2	-	-	-	-
in	3.1	4.8	-	-	-	-
Pend Oreille Lake tributaries (Pratt 1985)						
cm	7.7	13.1	18.6	-	-	-
in	3.0	5.2	7.3	-	-	-
Pend Oreille Lake tributaries (Irving 1986)						
cm	8.1	12.6	16.1	-	-	-
in	3.2	5.0	6.3	-	-	-
Kootenay Lake (Cartwright 1961)						
cm	7.3	16.5	32.7	51.3	69.4	83.1
in	2.9	6.5	12.9	20.2	27.3	32.7

be misrepresented when examining fish collected in the lake. Accurate estimates could only be obtained by trapping downstream migrants. Anderson (1978) speculated it may be possible to determine the age of stream out-migration using known growth increments of juvenile rainbow trout in tributary streams. Using this theory, several conjectures could be drawn. First-year growth was similar between fish collected from the tributaries and those collected from the lake (Table 3-3). Two possible explanations were fish collected from the lake had spent their first year in the stream environment or growth in the streams was as good as growth in the lake. Observance of high fry densities in the streams supported the previous contention; most rainbow trout spent their first year rearing in the tributaries. The larger incremental growth between the first and second annuli of fish collected in the lake suggested fish had begun to leave the tributaries by their second year of growth (age 1). This corroborates with the observance of low age 1 and older rainbow trout densities in the tributaries. These fish may have left the streams in the fall due to a lack of winter habitat or in the spring as a general out-migration to the lake. Another observation became apparent from these data. Incremental growth between annuli one and two of fish collected in the lake has increased between 1972 to 1976 and 1983 to 1984. This increase suggested either growth during the interim has increased due to an increase in food supply or of fish collected in the lake more had left the streams at an earlier age than did during 1972 to 1976. Woods (1991a) reported measures of productivity (*e.g.* nutrient and chlorophyll-*a* concentrations) in the lake have not changed statistically since the early 1950s. Therefore, rainbow trout must be leaving the streams at an earlier age than previously. This phenomenon may have been caused due to habitat changes, inter- and intraspecific competition, or angler harvest of older age rainbow trout in the tributaries. Removal of the older age fish from the migrating population would increase the occurrence of younger migrating fish in the lake sample and elevate the length at annulus formation. Even though this discussion is purely speculative, it seems to support what is being observed in the fishery.

Delayed age at maturation is a characteristic unique to Gerrard rainbow trout (Cartwright 1961; Anderson 1978; Pratt 1985). Anderson (1978) found maturity generally occurred at age 6 (61%) with conditions suitable for multiple spawning (Table 3-4). One fish was documented to have been nine years old and had spawned three times. Similar age at maturation was reported for Kootenay Lake stocks (Cartwright 1961). Pratt (1985) found during 1983 and 1984 age at maturation had decreased. Twenty-four percent spawned for the first time at ages 3 and 4 while only 37% matured at age 6. It appeared there was a shift in the population toward earlier maturity. This became more important in light of the fact fish growth slows in the years following maturation and the larger fish in the fishery were those that had not reached maturity until age 7. Delayed maturation allows additional years of sustained feeding on kokanee. Researchers speculated juvenile harvest in the tributaries, where anglers target the older age classes, may have contributed to the reduced age at maturity (Pratt 1985; Irving 1986). This was based on the contention age at maturation was positively correlated to age at out-migration (Pratt 1985).

Bull Trout

Distribution - Bull trout were sparsely distributed in Pend Oreille Lake tributaries (Figure 3-9). Juvenile bull trout were observed in less than half (38%) of the tributaries surveyed (Table 3-1). Distribution could be described as headwater to mid-drainage (Pratt 1985; Hoelscher and Bjornn

Table 3-4. Percent age at first spawning of rainbow trout collected from 1972 to 1976 and 1983 to 1984 from Pend Oreille Lake, Idaho, and from 1942 to 1957 from Kootenay Lake, British Columbia. Numbers per age are shown in parentheses.

Location Time period	Age at first spawning 3	 4	 5	 6	 7
Pend Oreille Lake					
1972-1976	-	1	18	61	20
(Anderson 1978)	-	(2)	(24)	(80)	(26)
			--------	99%	--------
				81%	--------
1983-1984					
(Pratt 1985)	5	19	22	37	17
	(3)	(11)	(13)	(22)	(10)
			--------	76%	--------
				54%	--------
Kootenay Lake					
1942-1957	-	4	92%	--------	4
(Cartwright 1961)			--------	96%	--------

1989). Streams frequented by bull trout were often characterized by large substrate, closed or partial canopy, and high gradients (Pratt 1985).

Bull trout spawning areas have been well identified in the Pend Oreille Lake basin (Figure 3-10). Bull trout spawn in a small part of the accessible tributaries to the lake. Distribution between spawning areas varied from year to year (Table 3-5). Bull trout spawning occurred from mid-August through October and was readily observed throughout the drainage by mid-September (Heimer 1965; Pratt 1984a). Many spawning bull trout entered tributaries early in the year when flows were still high (Pratt 1985). This enabled fish to reach spawning areas above seasonally dry stretches of tributaries. Spawning in the Lightning Creek drainage occurred upstream from the seasonally dry area between Spring and Cascade creeks and occasionally above seasonally dry areas in tributaries. In the Flathead River drainage, seasonally dry areas created migration barriers to bull trout spawners (Graham et al. 1980). The occurrence of different migration habits may indicate different stocks.

Abundance and Density - Bull trout were less abundant than either rainbow trout or westslope cutthroat trout in the Pend Oreille Lake drainage (Pratt 1985; Hoelscher and Bjornn 1989). In transects where juvenile bull trout were observed, Pratt (1985) estimated a mean density of 4.3 fish/100 m^2 (Appendix D). Hoelscher and Bjornn (1989) calculated a mean density of 0.4 juvenile bull trout/100 m^2 in accessible Pend Oreille Lake tributaries. Mean densities greater than 1.0 fish/100 m^2 were reported for several tributaries (Appendix C). Densities were generally higher than those reported by other researchers in tributaries to the Priest lakes system

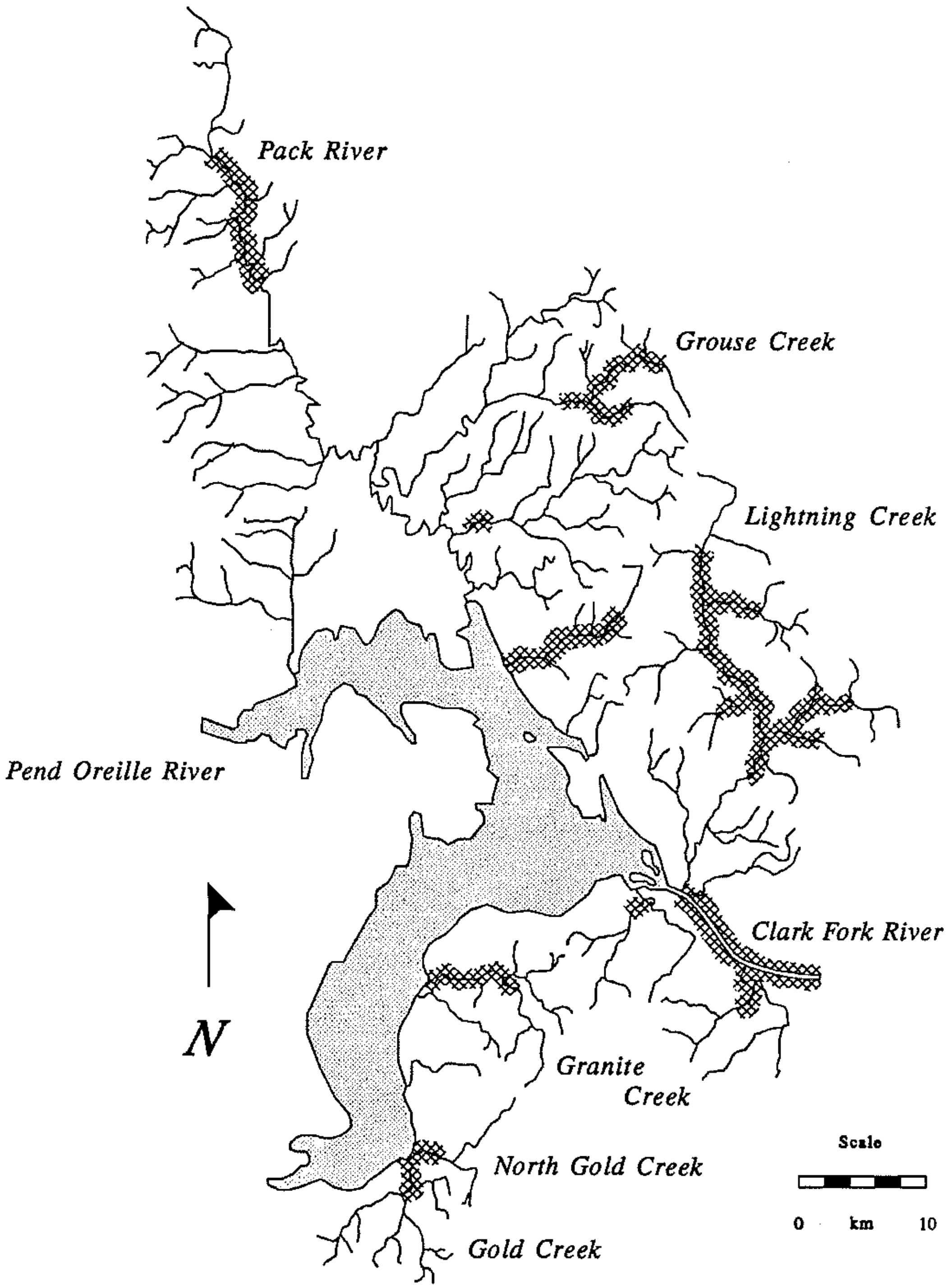

Figure 3-9. Distribution of juvenile bull trout in tributaries to Pend Oreille Lake, Idaho. Data were summarized by Pratt (1985) and Hoelscher and Bjornn (1989).

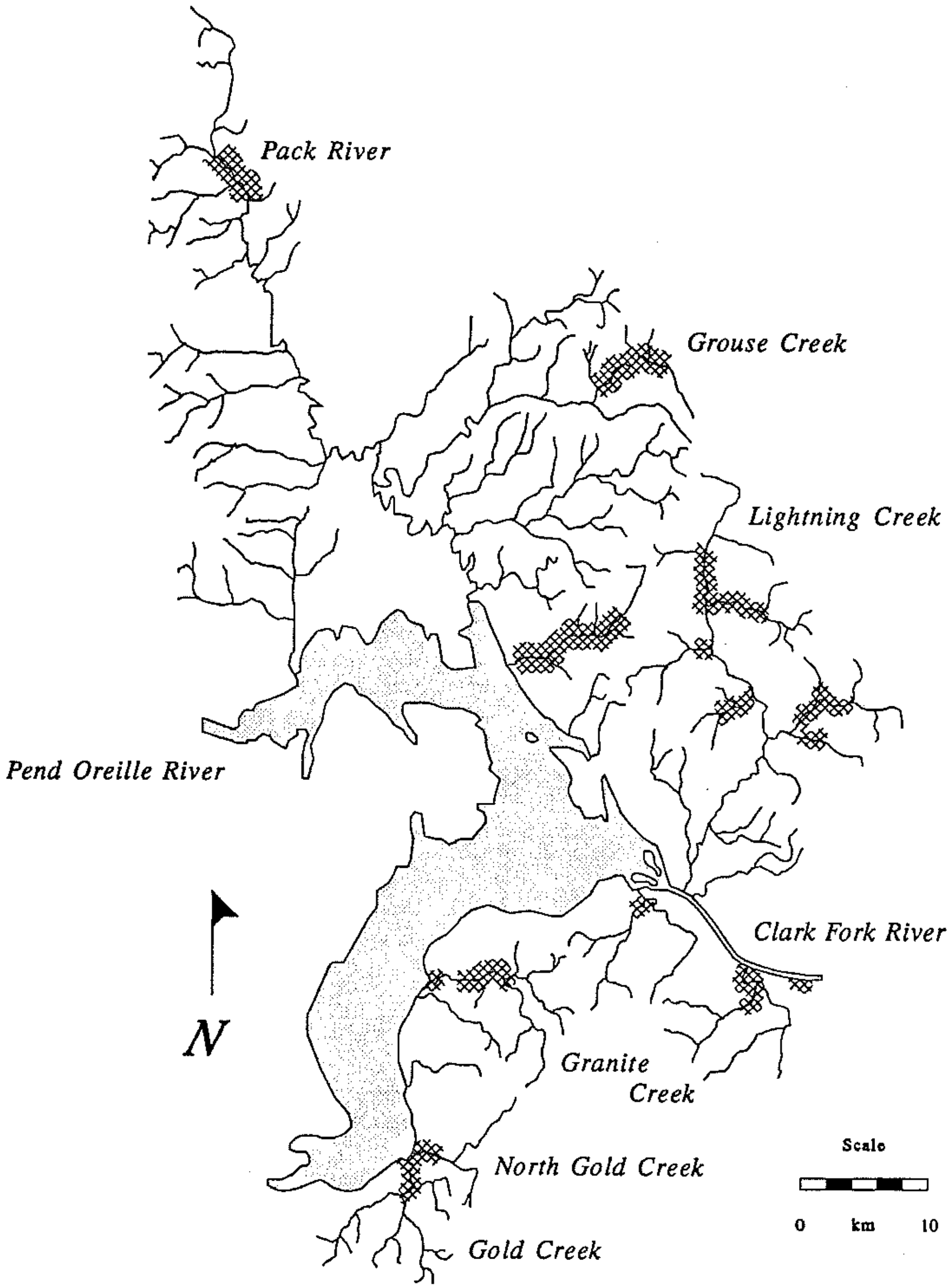

Figure 3-10. Distribution of bull trout spawning in tributaries to Pend Oreille Lake, Idaho. Data were summarized by Pratt (1985); Irving (1986); and Hoelscher and Bjornn (1989).

Table 3-5. Number of bull trout redds observed in tributaries to Pend Oreille Lake, Idaho, drainage from 1983 to 1989.

LAKE AREA Stream	Total number of redds						
	1983[a]	1984[a]	1985[b]	1986[c]	1987[c]	1988[d]	1989[e]
CLARK FORK RIVER							
Lightning Creek	28	9	46	14	4	-	-
Spring Creek	0	-	0	-	-	-	-
E.F. Lightning Creek	110	24	132	8	59	79	100
Savage Creek	36	12	29	-	0	-	-
Char Creek	18	9	11	0	2	-	-
Porcupine Creek	37	52	32	1	9	-	-
Wellington Creek	21	18	15	7	2	-	-
Rattle Creek	51	32	21	10	35	-	-
Johnson Creek	13	33	23	36	10	4	17
Twin Creek	7	25	5	28	0	-	-
NORTHERN SHORE							
Trestle Creek	298	272	298	147	230	244	217
Pack River	34	37	49	25	14	-	-
Rapid Lightning Creek	0	-	0	-	-	-	-
Grouse Creek	2	108	55	13	56	24	50
Hellroaring Creek	0	-	4	-	-	-	-
Jeru Creek	0	-	0	-	-	-	-
EASTERN SHORE							
Granite Creek	3	81	37	37	30	-	-
Sullivan Springs	9	8	14	-	6	-	-
North Gold Creek	16	37	52	8	36	24	37
Gold Creek	131	124	111	78	62	111	122
Totals	814	881	937	412	555	486	543

a data were summarized from Pratt (1985)
b data were summarized from Irving (1986)
c data were summarized from Hoelscher and Bjornn (1989)
d data were summarized from Horner et al. (1989)
e data were summarized from Horner et al. (1990)

(Irving 1987), Lochsa River (Graham 1977; Mabbott 1982), South Fork Clearwater River (Shepard 1983), and Middle Fork Salmon River (Thurow 1982, 1983, 1985). Juvenile bull trout densities in Pend Oreille Lake tributaries were within the range of densities reported in tributaries to the Flathead River system (Graham et al. 1980; Fraley et al. 1981; Shepard et al. 1982).

Juvenile bull trout densities in the Pend Oreille Lake drainage were highest in pocketwater and pool habitat, decreasing in riffles, and were lowest in runs (Hoelscher and Bjornn 1989). Similar distributions among habitat types were reported for juvenile bull trout in Priest lakes tributaries (Irving 1987). Other researchers have reported juvenile bull trout densities to be similar among habitat features with age 2 and age 3 fish showing a slight preference for pools (Graham et al. 1980; Fraley et al. 1981; Shepard et al. 1982; Pratt 1984b). Pratt (1984b) found juvenile bull trout used small pockets of slow water (0.1 mps) associated with submerged cover along the stream bottom and, therefore, bull trout densities were related to the wetted area of the stream bottom more than to habitat feature. Unembedded substrate and woody debris provided the bulk of this habitat. Future bull trout habitat enhancement programs should focus on creating small pockets of slow water along the stream bottom which offer visual isolation (*i.e.* rock piles, boulder clusters, organic debris) instead of large homogeneous habitat units (*i.e.* pools). Efforts to deter sedimentation in drainages known to contain bull trout rearing habitat would help prevent the loss of these important microhabitats.

Bull trout redd surveys have been conducted on Pend Oreille Lake tributaries each fall since 1983 and served as an index of adult abundance (Pratt 1984a, 1985; Hoelscher and Bjornn 1989). Similar monitoring programs have been used in the Flathead River system (Graham et al. 1980; Fraley et al. 1981; Shepard et al. 1982). Since 1987, six monitoring areas have been surveyed. Fraley (1985) stated counts in monitoring areas of the Flathead River drainage accurately reflected drainage-wide trends. The number of bull trout redds observed declined dramatically in 1986 (Table 3-5; Figure 3-11). Horner et al. (1988) speculated the inexperience of the survey crew resulted in low counting efficiency. Counts in 1987 increased 35% and likely still represent a minimum as numerous bull trout were observed on the spawning areas during the survey (Hoelscher and Bjornn 1989). Fraley et al. (1981) stated timing of these surveys was critical. Observations made during the spawning season may result in lower counts and delaying observations until long after spawning resulted in siltation of redds, making them difficult to distinguish. Redd counts continued to increase through 1989 and indicated the bull trout population in Pend Oreille Lake was stable (Horner et al. 1990). The number of spawning bull trout per unit area for Pend Oreille Lake was comparable to Flathead Lake and an order of magnitude less than Swan Lake (Table 3-6). Bull trout spawning escapement was derived from estimates of 3.9 fish per redd as calculated for the Flathead River basin (Fraley et al. 1981).

The blockage of Clark Fork River by Cabinet Gorge Dam in 1951 and the resultant loss of many miles of spawning and rearing habitat was believed to be responsible for the decline in bull trout abundance in Pend Oreille Lake (Klavano 1960; Mallet 1966). Present abundance was reflective of the current production of the remaining available spawning and rearing habitat.

Survival - Pratt (1985) estimated bull trout egg-to-emergent fry survival rates from streambed composition sampled in Pend Oreille Lake tributaries in 1984. In the Pend Oreille Lake spawning sites sampled, the percent fines less than 6.35 mm averaged 34 to 37% and estimated egg-to-emergent fry survival was less than 50%. Other researchers found egg-to-fry survival declined rapidly as fines less than 6.35 mm exceeded 30% (Weaver and White 1983; as cited from Pratt 1985).

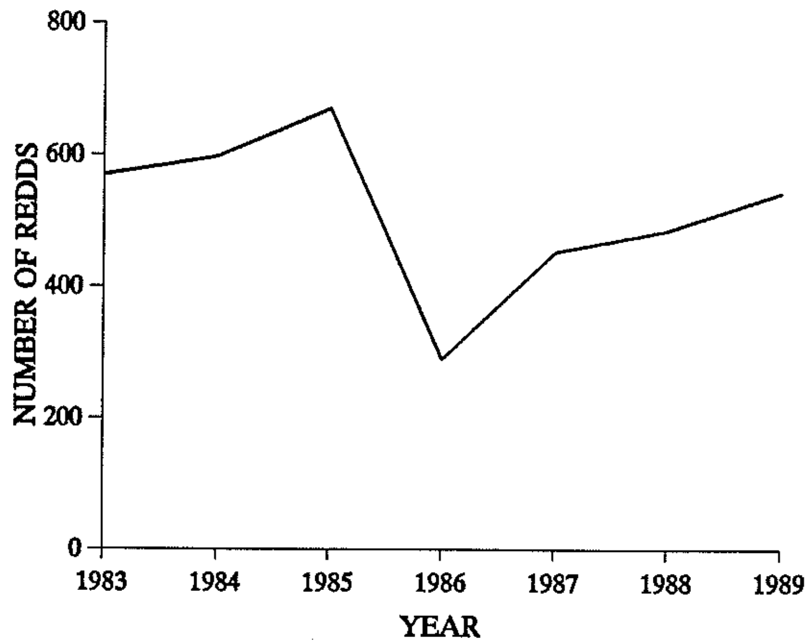

Figure 3-11. Total number of bull trout redds counted in East Fork Lightning Creek, Johnson Creek, Trestle Creek, Grouse Creek, North Gold Creek, and Gold Creek, tributaries of Pend Oreille Lake, Idaho, from 1983 to 1989. Data were summarized by Horner et al. (1990).

Estimated total annual mortality of bull trout in Pend Oreille Lake was high; ranging between 47 and 82% (Pratt 1985). This value was for fish recruited to the fishery; ages four and five.

Mortality associated with spawning may be quite high due to the length of time bull trout are easily accessible in natal streams. Illegal harvest of spawners in the streams was difficult to estimate and may contribute to the high total annual mortality.

Age and Growth - Bull trout are adfluvial in the Pend Oreille Lake system, emigrating from tributaries by their third year of life (Jeppson 1959, 1960a; Anderson 1971; Goodnight and Reininger 1978, Pratt 1985) then spending another one to three years in the lake as sub-adults or adults before re-entering the tributaries to spawn. Bull trout in the Pend Oreille Lake basin spawned between four and six years of age, although an eight year old spawner was observed, with the majority being five and six years old (Pratt 1985). In the Flathead River basin, ages of spawners were between five and seven years, with most being six and seven years old (Fraley 1985).

Estimated growth rates of bull trout in the Pend Oreille Lake drainage were higher than those reported for other drainages (Table 3-7). Bull trout grew nine cm in their first year and seven cm their second (Pratt 1985). During their third and fourth years, bull trout grew rapidly. As the fish matured, growth rates slowed to about eight cm per year. Bull trout collected in Lightning Creek (Anderson 1971) were smaller at all ages than fish collected in the lake (Pratt 1985) and likely represented the difference in growth between a productive lake and a more infertile tributary environment. Growth rates in Lightning Creek (Anderson 1971) were comparable to those in tributaries of the Flathead River basin (Graham et al. 1980, Fraley et al. 1981).

Table 3-6. Comparison of bull trout population densities in Pend Oreille Lake, Idaho, and Flathead Lake and Swan Lake, Montana. Data were summarized by Shepard et al. (1982); Pratt (1985); Irving (1986); Hoelscher and Bjornn (1989); Horner et al. (1989); and Horner et al. (1990).

Drainage	Lake surface area (km^2)	Year	Number of redds	Fish per redd[a]	Estimated escapement	Density ($fish/km^2$)
Pend Oreille Lake	383	1983	814	3.9	3,175	8.3
		1984	881	3.9	3,436	9.0
		1985	937	3.9	3,654	9.5
		1986	412	3.9	1,607	4.2
		1987	555	3.9	2,164	5.6
		1988	678[b]	3.9	2,644	6.9
		1989	758[b]	3.9	2,956	7.7
Flathead Lake	477	1981[c]	902[b]	3.9	3,517	7.4
		1982	1,300[b]	3.9	5,070	10.6
Swan Lake	477	1982	220	3.9	858	84.9
		1983	260	3.9	1,014	100.4

a estimate derived from Flathead River, Montana (Fraley et al. 1981)
b number of redds expanded from counts of monitoring areas
c includes North Fork and Middle Fork Flathead River drainages

Westslope Cutthroat Trout

Distribution - Westslope cutthroat trout were widely distributed in the Pend Oreille Lake drainage and have been observed in 90% of the tributaries surveyed (Table 3-1; Figure 3-12). Resident and adfluvial westslope cutthroat trout were present in the system (Pratt 1984a). Pratt (1984a) and Hoelscher and Bjornn (1989) found streams with westslope cutthroat trout were characteristically headwater areas. Apperson et al. (1988) speculated adfluvial westslope cutthroat trout were dominant in tributaries to lower reaches of a drainage and in small streams

Table 3-7. Estimated mean total length (cm) at annulus formation of bull trout from various waters in Idaho and Montana. Data were summarized by Anderson (1971) and Pratt (1985).

Location	Number of fish	Age at annulus formation								
		1	2	3	4	5	6	7	8	9
Priest Lake (Bjornn 1961)	61	7.1	11.4	18.3	31.0	42.4	51.6	60.5	-	-
Upper Priest Lake (Bjornn 1961)	41	6.6	10.2	15.5	23.9	35.8	46.2	54.6	61.2	-
Lightning Creek (Anderson 1971)	11	6.3	11.8	17.1	21.5	-	-	-	-	-
Pend Oreille Lake (Pratt 1985)	169	9.1	16.4	27.2	40.3	49.7	57.8	-	-	-
Flathead Lake										
(Block 1955)	80	7.6	15.0	23.4	33.5	45.7	56.6	69.1	78.0	-
(Rohrer 1963)	289	7.1	14.0	20.8	32.3	45.2	59.4	72.4	87.6	-
(Leathe and Graham 1982)	929	6.8	13.0	20.4	29.2	38.4	47.2	56.7	65.8	73.1
Hungry Horse Reservoir (Huston 1974)	212	7.2	14.4	22.5	32.4	42.9	51.3	59.4	67.1	-
Lake Koocanusa (May et al. 1979)	162	6.7	12.3	21.2	30.9	39.0	48.2	51.8	-	-
Middle Fork Flathead River (Fraley et al. 1981)	122	4.8	9.7	17.4	28.6	38.9	48.4	57.5	63.6	-
North and Middle Fork Flathead River tributaries (Fraley et al. 1981)	196	7.2	10.8	14.0	-	-	-	-	-	-

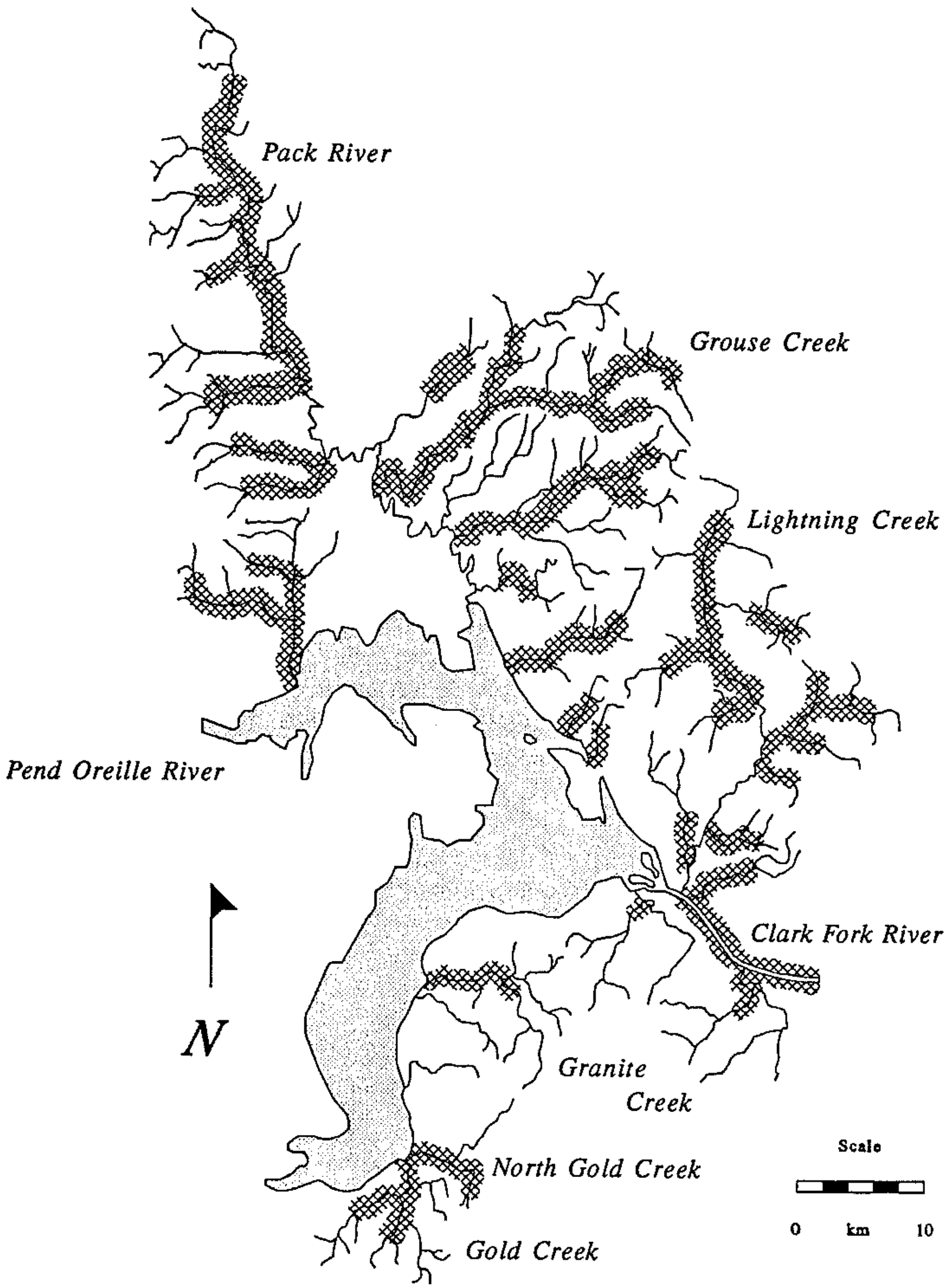

Figure 3-12. Distribution of juvenile westslope cutthroat trout in tributaries to Pend Oreille Lake, Idaho. Data were summarized by Pratt (1985) and Hoelscher and Bjornn (1989).

directly flowing into a lake. If similar distributions occurred in the Pend Oreille Lake system, many of the westslope cutthroat trout observed high in the drainages may represent resident populations. Resident populations were frequently observed above stream barriers (Pratt 1985).

Distribution of westslope cutthroat trout spawning has been poorly defined in the Pend Oreille Lake basin. In the past, spawning areas were more widespread than those of other salmonids with spawning runs known to have occurred in almost every tributary with access from the lake and suitable spawning gravel (Jeppson 1955). More recently, westslope cutthroat trout spawning was estimated in only a fraction of the Pend Oreille Lake drainage (Pratt 1985). This distribution would not be adequate to seed those drainages where westslope cutthroat trout were observed. Therefore, spawning distribution, as delineated by Pratt (1985), must represent a minimum.

Abundance and Density - Even though westslope cutthroat trout were widespread in the Pend Oreille Lake basin, densities were low in areas accessible to adfluvial fishes (Pratt 1985; Hoelscher and Bjornn 1989) in comparison to other adfluvial westslope cutthroat trout populations (Lukens 1978; Graham et al. 1980; Fraley et al. 1981; Shepard et al. 1982). Pratt (1985) reported densities less than five fish/100 m^2 in areas accessible to adfluvial fishes (Appendix D). Hoelscher and Bjornn (1989) reported a mean density of 0.8 juvenile westslope cutthroat trout/100 m^2 in Pend Oreille Lake tributaries available to adfluvial fishes. Mean densities of tributaries ranged from 0.0 to 4.5 fish/100 m^2 (Appendix C). Densities as high as 55 fish/100 m^2 were observed in resident populations above stream barriers (Pratt 1985). Westslope cutthroat trout were most abundant in upper stream reaches (Pratt 1985; Hoelscher and Bjornn 1989).

Westslope cutthroat trout were observed in all habitat types (Hoelscher and Bjornn 1989). Other researchers found pools to be a particularly important habitat for rearing westslope cutthroat trout (Graham et al. 1980; Fraley et al. 1981; Shepard et al. 1982; Pratt 1984b; Irving 1987).

The present low densities of juvenile westslope cutthroat trout in accessible Pend Oreille Lake tributaries and the decline in harvest since monitoring began in 1951 indicated a depressed adfluvial population. Westslope cutthroat trout populations have declined in other areas due to habitat loss, over-exploitation, competition with introduced species, and hybridization (Rieman and Apperson 1989). Habitat loss and over-exploitation were speculated to be mostly responsible for the decline in westslope cutthroat trout abundance in Pend Oreille Lake (Bowles et al. 1987). The construction of Cabinet Gorge Dam on Clark Fork River eliminated access to spawning and rearing habitat once available to adfluvial fishes (Jeppson and Vaughan 1952). Researchers believed the migration block was partially responsible for the decline in abundance in the lake (Klavano 1960). If the decline in the population had been entirely due to the loss of Clark Fork River, the decline would have been more precipitous than was observed. Competition with introduced rainbow trout likely contributed to the decline of the westslope cutthroat trout population. Small runs of spawning rainbow trout were first observed in Spring Creek as early as 1953 and in other tributaries throughout the drainage in 1958 (Whitt 1958b; Jeppson 1960a), well after the initial decline of westslope cutthroat trout harvest in the lake.

Rainbow trout likely filled habitat vacated by reduced westslope cutthroat trout populations. Pratt (1985) and Hoelscher and Bjornn (1989) found westslope cutthroat trout and introduced rainbow trout segregated, although overlap in macrohabitat use was common. Presently, competition with introduced species may limit the recovery of adfluvial westslope cutthroat trout populations. Hybridization between the species exists in the Pend Oreille Lake basin. Westslope cutthroat trout and rainbow trout introgression was confirmed during electrophoretic analysis of Pend Oreille Lake rainbow trout (Leary et al. 1984).

Survival - Very little work has been done on the survival of westslope cutthroat trout in Pend Oreille Lake, mainly because very few fish were harvested annually from the lake. Pratt (1985) calculated egg-to-emergent fry survival rates from streambed composition sampled in Pend Oreille Lake tributaries in 1984. Estimated egg-to-emergent fry survival was low, ranging from 4 to 65%. Positive correlations were observed between egg-to-emergent fry survival rates and juvenile westslope cutthroat trout densities. In streams where few fish were seen, survival rates were below 35%. In tributaries having higher densities, survival rates from 34 to 65% were estimated. Pratt (1985) believed the poor quality of spawning habitat may be affecting the distribution and relative abundance of westslope cutthroat trout in the Pend Oreille Lake system.

Mauser et al. (1988) estimated a total annual mortality of 57% for adfluvial westslope cutthroat trout populations in Priest Lake. Estimates of total annual mortality were for fish vulnerable to fishing and represented fish four to seven years old.

Age and Growth - Westslope cutthroat trout emigrated from Pend Oreille Lake tributaries as age 0, age 1, age 2, or age 3 fish (Pratt 1985). Other researchers have documented similar ages at migration (Rankel 1971; Lukens 1978; Shepard et al. 1982; Apperson et al. 1988). Growth rates of adfluvial westslope cutthroat trout varied depending upon age at migration (Table 3-8). The differences between length at annulus formation of fish migrating at different ages were evident but not as pronounced as the trend for rainbow trout. Westslope cutthroat trout, migrating as age 1, age 2, or age 3 fish, grew at accelerated rates upon entering the lake environment. Pratt (1985) reported growth rates in Pend Oreille Lake were higher than other drainages (Table 3-9). This was especially evident for the two- and three-year migrants upon entering the lake environment. Rieman and Apperson (1989) stated growth was likely related to the productivity of individual waters, although no one has shown such a relationship. Growth rates in the stream environment were within the range of other drainages. Westslope cutthroat trout collected in 1970 from Lightning Creek, a tributary to Pend Oreille Lake, were 3.5 cm smaller at first annulus formation (Anderson 1971) than those from fish collected in Pend Oreille Lake (Pratt 1985), even though fish in the lake had reared in the stream environment. Pratt (1985) calculated growth rates with the assumption all fish formed annuli their first year. Anderson (1971) reported a high incidence of retarded formation of the first annulus in fish collected from Lightning Creek. Rankel (1971) found only 40% of the westslope cutthroat trout aged from the St. Joe River formed an annulus after the first growing season. By assuming all fish formed annuli their first year, Pratt (1985) may have underestimated the age of the fish and overestimated length-at-age. Rieman and Apperson (1989) thought growth estimates tend to be higher among adfluvial than fluvial populations, but such differences were not consistent. The

Table 3-8. Estimated mean total length at annulus formation of westslope cutthroat trout migrating as age 0, age 1, age 2, and age 3 fish, Pend Oreille Lake, Idaho, from 1983 to 1984. Age 0 fish were in their first summer of life. Data were summarized by Pratt (1985).

Migration year	Age at annulus formation 1	2	3	4
Total				
cm	8.0	14.8	26.1	35.8
in	3.1	5.8	10.3	14.1
(N)	(84)	(79)	(42)	(9)
Migration year 0				
cm	7.8	13.0	17.5	-
in	3.1	5.1	6.9	-
(N)	(15)	(9)	(2)	
Migration year 1				
cm	8.1	19.1	29.3	33.9
in	3.2	7.5	11.5	13.3
(N)	(18)	(18)	(7)	(1)
Migration year 2				
cm	8.3	14.0	31.2	34.7
in	3.3	5.5	12.3	13.7
(N)	(37)	(37)	(19)	(3)
Migration year 3				
cm	7.3	12.5	18.8	36.9
in	2.9	4.9	7.4	14.5
(N)	(14)	(14)	(14)	(5)

difference between growth rates of fish collected in Lightning Creek and those collected in the lake may represent the difference between resident and adfluvial westslope cutthroat trout stocks.

Other Trout and Char

Brook trout were widely distributed in the Pend Oreille Lake basin and were well established in several tributaries (Pratt 1984a, 1985; Hoelscher and Bjornn 1989). They were observed in nearly half (45%) of the streams surveyed (Table 3-1). Brook trout were more frequently encountered in lower stream reaches and likely represented resident populations (Pratt 1984a). A few have been caught by anglers in the lake (Klavano 1960).

Table 3-9. Estimated mean total length (cm) at annulus formation of westslope cutthroat trout migrating as age 1, age 2, and age 3 fish from waters in Idaho and Montana. Age 1 fish were in their second summer of life. Data were summarized by Lukens (1978) and Pratt (1985).

AGE AT MIGRATION	Age at annulus formation						
Location	1	2	3	4	5	6	7
ONE-YEAR MIGRANTS							
Pend Oreille Lake	8.1	19.1	29.3	33.9	-	-	-
Wolf Lodge Creek	8.6	17.7	25.2	29.5	35.8	-	-
Upper Priest Lake	10.7	22.4	31.0	-	-	-	-
St. Joe River	7.5	17.4	25.8	31.4	-	-	-
Hungry Horse Creek	8.5	21.8	30.6	36.0	38.6	-	-
TWO-YEAR MIGRANTS							
Pend Oreille Lake	8.3	14.0	31.2	34.7	-	-	-
Wolf Lodge Creek	7.4	12:5	21.4	28.7	32.8	36.5	-
Upper Priest Lake	9.9	14.7	27.4	32.5	-	-	-
Priest Lake	8.9	14.7	27.2	32.5	36.6	-	-
St. Joe River	7.2	14.3	26.6	33.8	38.6	-	-
Hungry Horse Creek	6.7	12.4	26.4	33.0	37.0	39.7	43.2
THREE-YEAR MIGRANTS							
Pend Oreille Lake	7.3	12.5	18.8	36.9	-	-	-
Wolf Lodge Creek	6.9	10.7	14.9	23.6	29.9	34.3	-
Upper Priest Lake	8.9	13.0	17.3	27.9	33.8	39.1	-
Priest Lake	7.9	12.7	17.5	28.2	34.0	37.1	-
St. Joe River	7.0	14.8	21.6	27.5	32.1	-	-
Hungry Horse Creek	5.7	10.3	16.2	28.9	35.0	38.0	40.7

Brown trout were the least widely distributed salmonid in the Pend Oreille Lake drainage. Juvenile brown trout were observed in only two (5%) tributaries (Table 3-1). Brown trout observed in Spring Creek could have been from the Clark Fork State Fish Hatchery and may not represent natural populations. Brown trout in the Pend Oreille Lake basin were likely from fluvial and adfluvial stocks (Pratt 1984a). This species was only observed in the Clark Fork River area.

Lake trout were not well established in Pend Oreille Lake (Klavano 1960). Each year a few lake trout were taken incidentally by anglers fishing for rainbow trout and bull trout (Simpson and Wallace 1982; Pratt 1984a).

Spiny-Rayed Fishes

Yellow perch, black crappie, largemouth bass, brown bullhead, and pumpkinseed were found mainly in the shallow bays of the northern and western part of Pend Oreille Lake (Jeppson 1954, 1960c).

CHAPTER 4

LAKE FISHERY

Historically, native westslope cutthroat trout, bull trout, and mountain whitefish provided food and sport to anglers. From 1900 to 1937, Pend Oreille Lake supported a commercial lake and mountain whitefish fishery (Klavano 1960). In the early 1940s, a kokanee sport fishery developed and commercial harvest began in 1945. Since the 1940s, the lake has been well known for both its kokanee and trophy trout fishery. Although kokanee provided more than 90% of the yearly harvest, nearly half (46%) of the anglers surveyed in recent years sought trout (Ellis and Bowler 1981). In 1947, a record-size rainbow trout of 16.8 kg was harvested from Pend Oreille Lake while the world record bull trout of 14.5 kg was caught in 1949. In 1952, seven of the ten largest trout caught in the continent came from Pend Oreille Lake (Irving 1986).

Kokanee

Harvest - Until the early 1970s, Pend Oreille Lake supported the most popular kokanee fishery in Idaho. Ellis and Bowler (1981) reported the sport and commercial fishery yielded an average annual harvest of about 1,000,000 kokanee from 1951 to 1965 (Figure 4-1; Appendix E). Kokanee harvest declined from 1965 to 1985, resulting in an annual harvest of less than 100,000 fish (Bowles et al. 1987). Because of the declining catch and low level of spawning escapement in 1972, the commercial fishery was closed and sport limit reduced in 1973 (Irizarry 1974a). Based on an assumed exploitation rate of 25%, the fishery in the late 1980s supported a harvest of about 200,000 kokanee (Bowles et al. 1989; Hoelscher et al. 1990). Overall, harvest statistics indicated present levels of kokanee abundance in the lake were less than they were in the mid-1960s.

The age of kokanee creeled in Pend Oreille Lake ranged from age 3 to age 6 with the predominant ages being age 4 and age 5. Percent age composition of the catch has varied from year to year and has averaged 4% age 3, 20% age 4, and 76% age 5 from 1960 to 1975 (Ellis and Bowler 1979). The percentage of age 3 fish taken seemed dependent on the strength of the year classes and their growth during early summer.

Effort and Harvest Rate - Effort of sport and commercial anglers averaged 360,000 hours annually from 1951 to 1965 (Ellis and Bowler 1981). Effort of sport anglers seeking kokanee has steadily declined from 1960 to 1985 (Figure 4-2). Effort decreased 74% from 250,000 hours in 1960 to 65,000 in 1985 (Bowles et al. 1987). Harvest rates have also declined from a high of about 3.5 kokanee/h during the mid-1960s (Ellis and Bowler 1981) to about 1.0 kokanee/h in 1985 (Bowles et al. 1987).

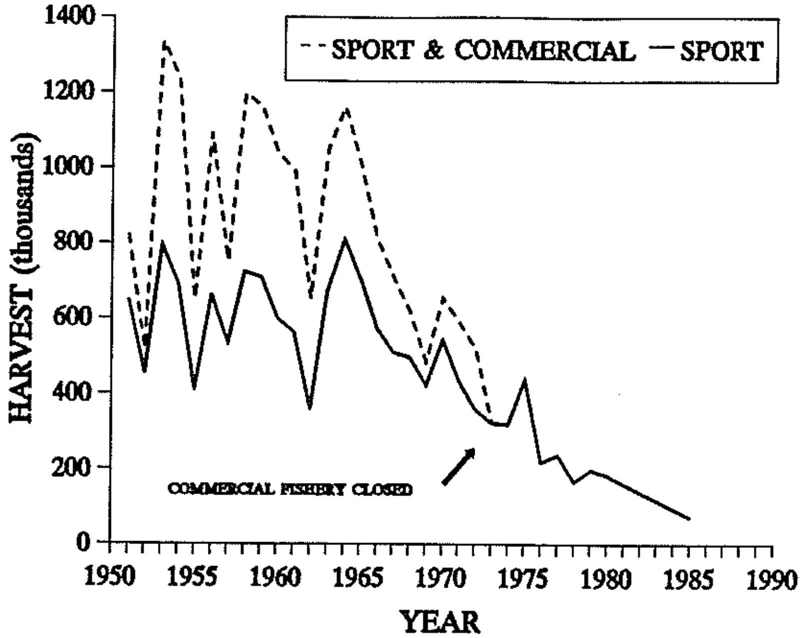

Figure 4-1. Estimated minimum total and sport (resident and non-resident) kokanee harvest from Pend Oreille Lake, Idaho, from 1951 to 1980 and a 1985 point estimate. Data were summarized by Ellis and Bowler (1981) and Bowles et al. (1987).

Size - The size of kokanee entering angler creels varied throughout the year and represented kokanee growth (Figure 4-3). As the fishery commenced in early spring, kokanee in the creel averaged 220 mm (Ellis and Bowler 1981; Bowles et al. 1987). Toward the end of the season, kokanee had gained 20 mm in total length. Average size of kokanee harvested from July to November from 1960 to 1985 averaged 240 mm.

Rainbow Trout

Harvest - Rainbow trout harvest in Pend Oreille Lake has increased ten-fold from the early 1950s (Ellis and Bowler 1981) to the most recent creel survey in 1985 (Bowles et al. 1987). More rainbow trout have been harvested annually since 1959 than any other trout or char (Appendix E). Most (78%) of the harvest from 1960 to 1985 were sub-trophy (<432 mm) fish (Pratt 1985; Bowles et al. 1987). Many of these smaller fish were taken incidentally by anglers seeking other species or trophy (>432 mm) rainbow trout. Trophy rainbow trout harvest doubled from an average annual take of about 1,000 fish from 1960 to 1975 to the average yield of about 2,000 since 1980 (Figure 4-4). Trends of the trophy fishery became apparent when harvest was separated into various weight categories. Percent harvest of fish from 0.5 to 4.5 kg has increased between 1960 and 1985, especially since 1975, while those over 4.5 kg have declined (Irving 1986). The increase in harvest of the 0.5 to 4.5 kg fish was likely in response

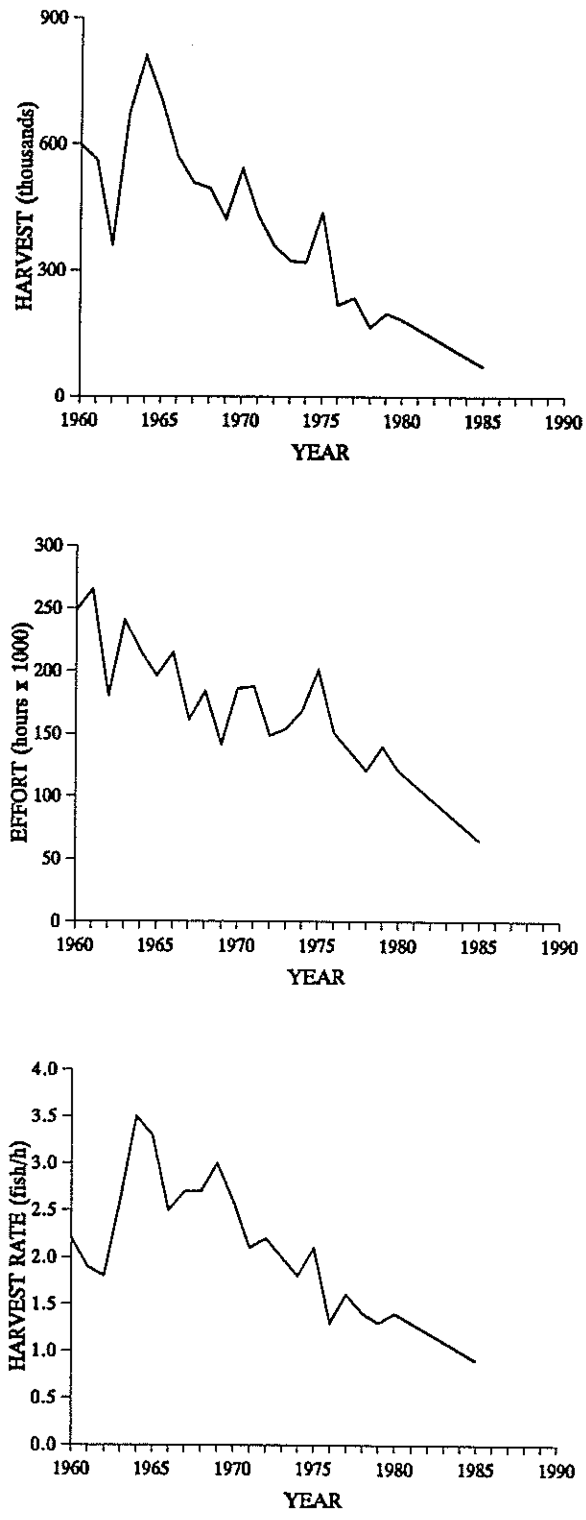

Figure 4-2. Estimated minimum harvest, effort, and harvest rate for sport anglers seeking kokanee in Pend Oreille Lake, Idaho, from 1960 to 1980 and a 1985 point estimate. Data were summarized by Ellis and Bowler (1981) and Bowles et al. (1987).

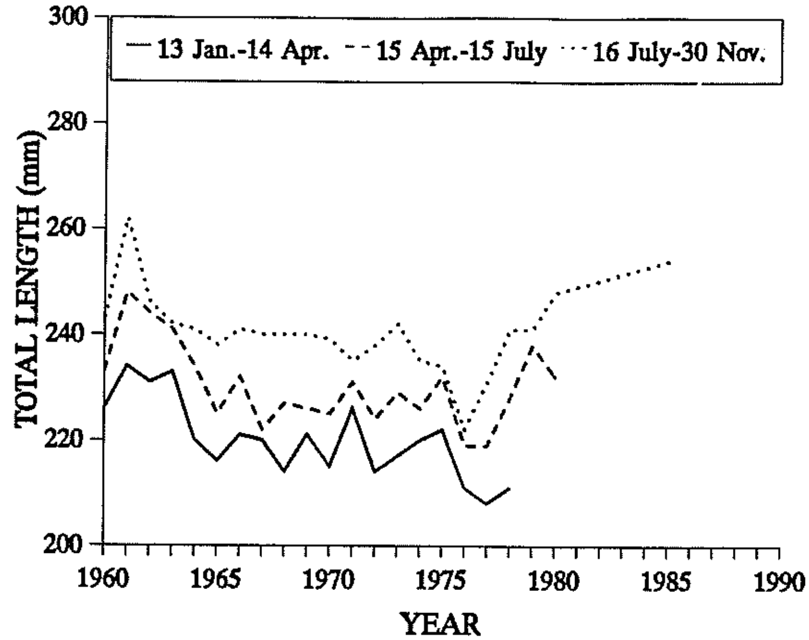

Figure 4-3. Estimated mean total length (mm) of kokanee entering angler creels by census period on Pend Oreille Lake, Idaho, from 1960 to 1980 and a 1985 point estimate. Data were summarized by Ellis and Bowler (1981) and Bowles et al. (1987).

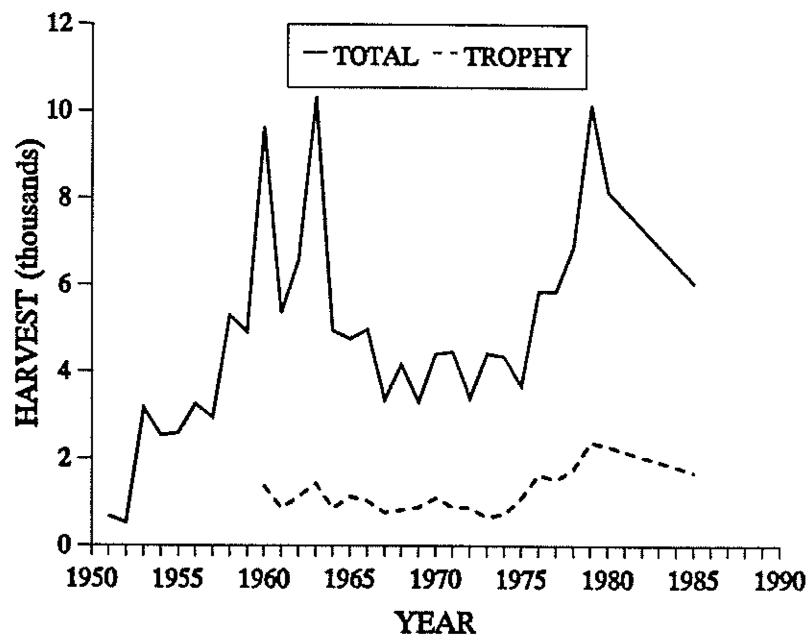

Figure 4-4. Estimated minimum harvest of rainbow trout and trophy (>432 mm) rainbow trout from Pend Oreille Lake, Idaho, from 1951 to 1980 and a 1985 point estimate. Data were summarized by Ellis and Bowler (1981) and Bowles et al. (1987).

to an increase in effort (Figure 4-5). Age composition of the harvest from 1983 to 1985 indicated about 75% (range 66-82%) were age 4 and younger and about 90% (range 84-95%) were age 5 and younger (Pratt 1985; Horner et al. 1988). These statistics have greater meaning in light of the fact mean age at maturity is 5.5 years (Horner et al. 1988).

Hatchery released rainbow trout have contributed very little to angler creels. During 1967, a program was initiated to mark rainbow trout released into Pend Oreille Lake in an effort to evaluate the relative contribution of hatchery fish to the lake fishery (Mallet 1968b). By 1978, less than 0.10% of the 500,000 marked hatchery rainbow trout had returned to angler creels (Ellis and Bowler 1979). Poor survival had been attributed to a hatchery broodstock that had been removed from the wild for many generations. Other researchers believed the catchable stocking program could have been responsible for maintaining the rainbow trout fishery during the 1950s and early 1960s (Klavano 1960; Mallet 1968b). A sharp increase in rainbow trout harvest in 1953 (Figure 4-4) coincided with an increase in the catchable rainbow trout stocking program (Ellis and Bowler 1981). Jeppson (1954) estimated about one-third of the rainbow trout harvested in 1953 were stocked during 1953.

Management goals of the trophy rainbow trout rehabilitation program included an average size of 3.2 kg/fish, with trout over 9 kg making up 5% of the harvest (Ned Horner, Idaho Department of Fish and Game, Region I, personal communication). Current regulations were designed to reduce the harvest of juvenile rainbow trout rearing in the tributaries and younger age rainbow trout in the lake. By reducing the harvest of younger age fish in the lake, more fish could spawn at least once. Increasing spawning escapement would more fully use the available habitat and theoretically increase potential production of the system. According to trend count data on North Fork Grouse Creek, it appeared the number of spawners had increased since initiation of the new regulations, however, it is unlikely the increase was statistically significant due to the poor precision of such counts (Dave Thorson, United States Forest Service, Sandpoint District, personal communication). Acquisition of pure Gerrard rainbow trout eggs in 1988 and 1989 were expected to increase hatchery contribution to the creel and provide a continual egg source of Gerrard rainbow trout to Cabinet Gorge Hatchery.

Effort and Harvest Rate - Effort of anglers seeking trophy rainbow trout has increased (Figure 4-5). Estimated effort has more than doubled from 43,000 hours in 1960 (Ellis and Bowler 1981) to 100,000 hours in 1985 (Bowles et al. 1987). Harvest rates of rainbow trout over 432 mm have been highly variable, averaging over 60 hours per fish and have generally worsened since 1960.

Effort for rainbow trout should increase in the future as rainbow trout abundance increases under the new regulations. Horner et al. (1988) projected rainbow trout effort in 1995 to be 150,000 hours based on current trends.

Size - Mean total length of rainbow trout and trophy rainbow trout entering angler creels have shown some change over the years (Figure 4-6). Mean total length of rainbow trout has slightly increased since 1960 with an average length of 382 mm (Ellis and Bowler 1981; Bowles et al

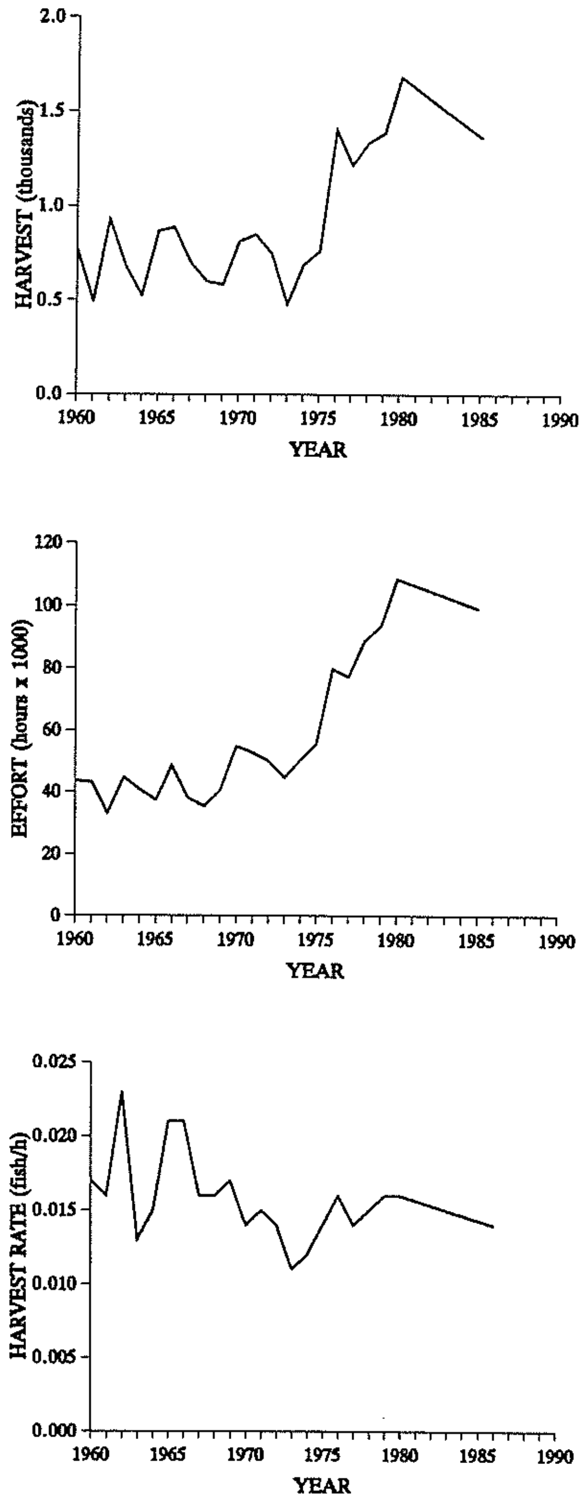

Figure 4-5. Estimated minimum harvest, effort, and harvest rate for sport anglers seeking trophy (>432 mm) rainbow trout in Pend Oreille Lake, Idaho, from 1960 to 1980 and a 1985 point estimate. Data were summarized by Ellis and Bowler (1981) and Bowles et al. (1987).

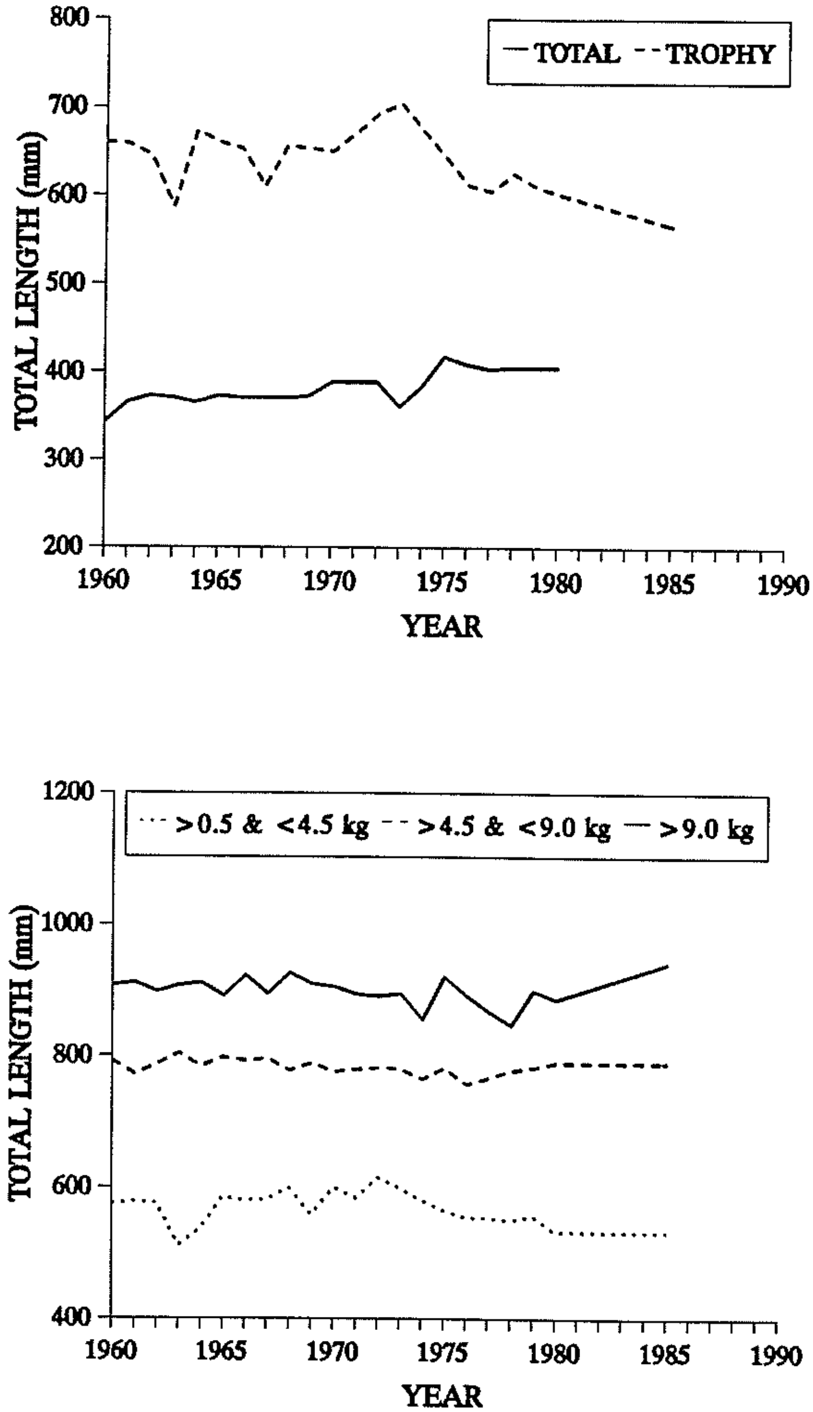

Figure 4-6. Estimated mean total length (mm) of rainbow trout and trophy (>432 mm) rainbow trout and trophy rainbow trout by weight category entering angler creels on Pend Oreille Lake, Idaho, from 1960 to 1980 and a 1985 point estimate. Data were summarized by Ellis and Bowler (1981) and Bowles et al. (1987).

1987). Mean total length of trophy rainbow trout in the creel remained relatively constant from 1960 to the early 1970s then decreased from 704 mm in 1973 to 566 mm in 1985. Once again, trends of the trophy fishery became apparent when harvest was separated into weight categories. Mean total length of trophy rainbow trout in from 0.5 to 4.5 kg has decreased since the early 1970s while the mean length of fish over 4.5 kg remained relatively constant (Figure 4-6).

Bull Trout

Harvest - Pend Oreille Lake is one of the few places in Idaho with a viable bull trout fishery. Like many of the lake's other fisheries, bull trout harvest has declined. Ellis and Bowler (1981) and Bowles et al. (1987) reported harvests of about 1,000 fish annually since 1960 (Figure 4-7). A slight increase in bull trout harvest in recent years was likely the result of increased effort (Figure 4-8). More native bull trout than westslope cutthroat trout have appeared in angler creels since the mid-1970s (Appendix E). The fishery was mostly incidental, with about 56% of the harvest in 1985 taken by anglers seeking other species (Bowles et al. 1987). Trophy (>432 mm) bull trout made up a higher percentage (60%) of the total harvest than observed for rainbow trout (Ellis and Bowler 1981). Under current regulations, anglers historically targeting small rainbow trout may shift to bull trout as a consumptive fishery.

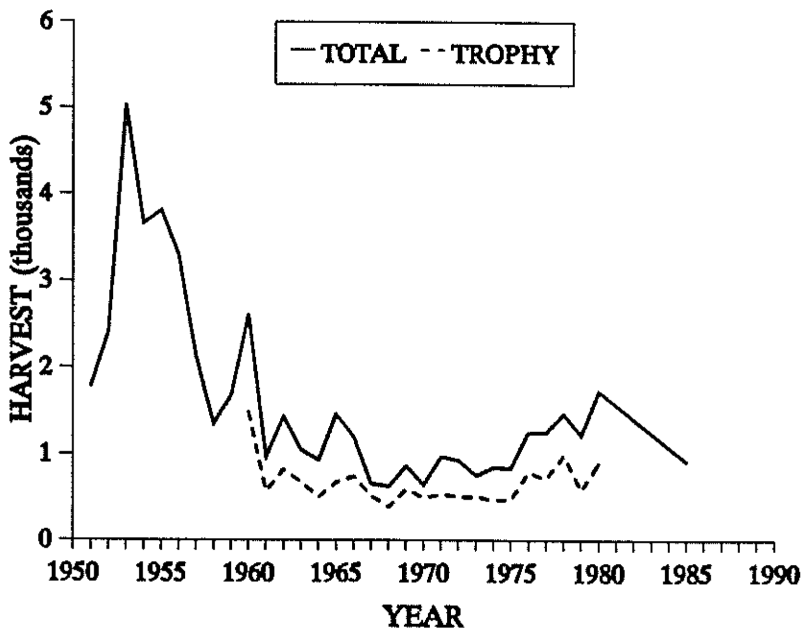

Figure 4-7. Estimated minimum harvest of bull trout and trophy (>432 mm) bull trout from Pend Oreille Lake, Idaho, from 1951 to 1980 and a 1985 point estimate. Data were summarized by Ellis and Bowler (1981) and Bowles et al. (1987).

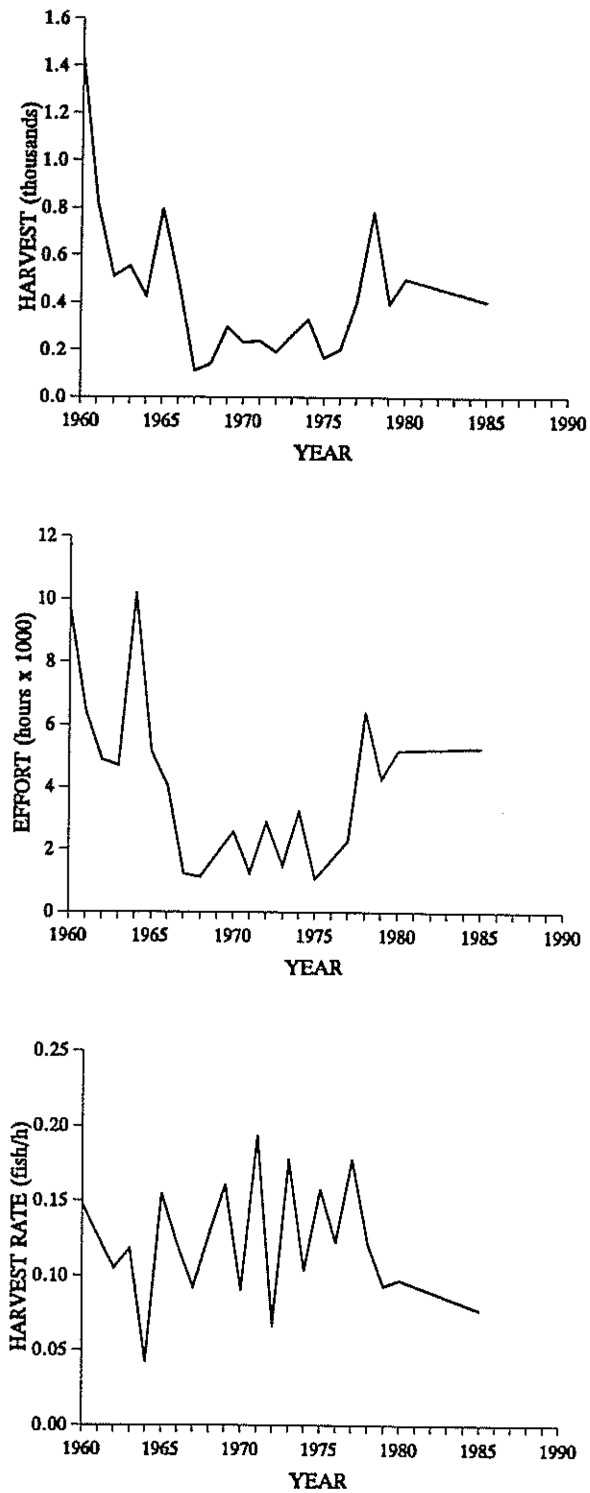

Figure 4-8. Estimated minimum harvest, effort, and harvest rate for sport anglers seeking bull trout on Pend Oreille Lake, Idaho, from 1960 to 1980 and a 1985 point estimate. Data were summarized by Ellis and Bowler (1981) and Bowles et al. (1987).

Effort and Harvest Rate - Effort of sport anglers seeking bull trout on Pend Oreille Lake declined 90% from 1960 to the mid-1970s and has since increased 400% to about 5,000 hours annually (Ellis and Bowler 1981; Bowles et al. 1987). Relatively constant harvest rates of about 9 hours per fish between 1960 and 1985 indicated a stable population (Figure 4-8).

Size - Total length of bull trout and trophy bull trout entering angler creels remained relatively constant from 1960 to 1985 (Ellis and Bowler 1981; Bowles et al. 1987) and was another indicator of a stable population. Mean length of bull trout and trophy bull trout was 487 mm and 549 mm (Figure 4-9).

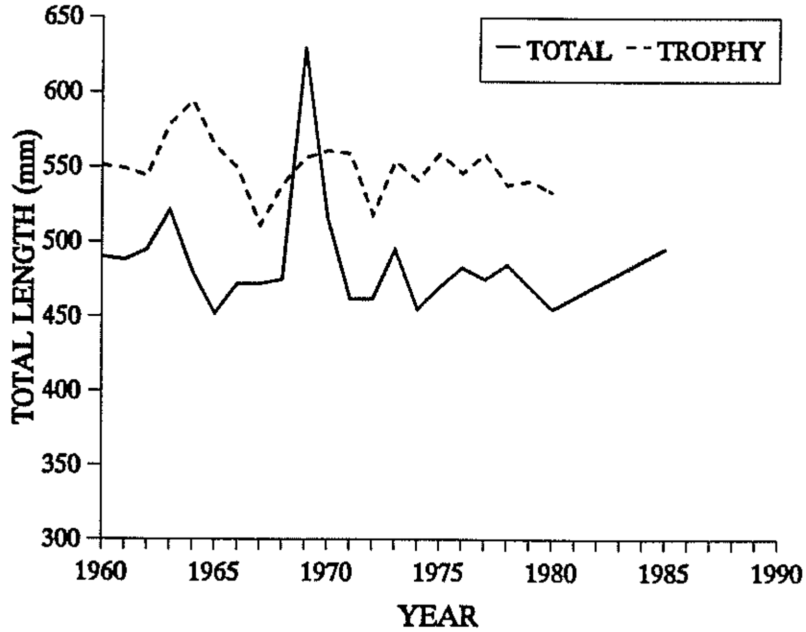

Figure 4-9. Estimated mean total length (mm) of bull trout and trophy (>432 mm) bull trout entering angler creels on Pend Oreille Lake, Idaho from 1960 to 1980 and a 1985 point estimate. Data were summarized by Ellis and Bowler (1981) and Bowles et al. (1987).

Westslope Cutthroat Trout

Harvest - The westslope cutthroat trout fishery has declined more dramatically than any other Pend Oreille Lake fishery (Figure 4-10). Harvest has decreased over 90% from 8,200 fish in 1953 (Ellis and Bowler 1981) to the most recent census of 660 in 1985 (Bowles et al. 1987). Westslope cutthroat trout were historically the most abundant native salmonid in the Pend Oreille Lake drainage (Klavano 1960). More westslope cutthroat trout were harvested annually than any other trout species until 1959 (Appendix E). Now, they were less abundant in the sport harvest than either rainbow trout or bull trout. Although a remnant population remains in the system, about 94% of the current harvest is incidental, indicating the fishery is functionally extinct (Bowles et al. 1987). Mallet (1966) speculated the decline in harvest may have been intensified by a shift in some of the angling pressure from the westslope cutthroat trout fishery to the more popular and higher yield kokanee fishery as westslope cutthroat trout abundance declined. Today, the fishery is being supported by fingerling stockings.

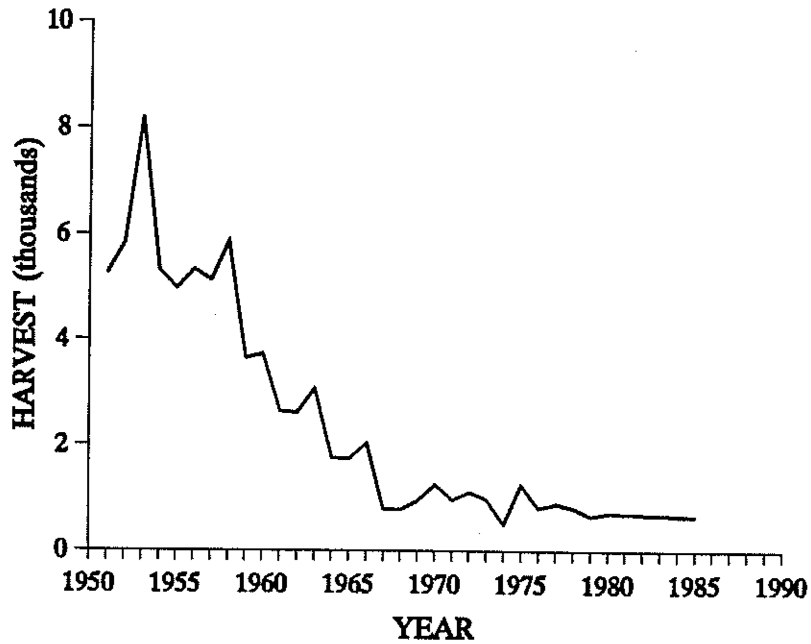

Figure 4-10. Estimated minimum harvest of westslope cutthroat trout from Pend Oreille Lake, Idaho, from 1951 to 1980 and a 1985 point estimate. Data were summarized by Ellis and Bowler (1981) and Bowles et al. (1987).

Effort and Harvest Rate - Effort of sport anglers seeking westslope cutthroat trout decreased 90% from 14,000 hours in 1960 (Ellis and Bowler 1981) to 1,400 hours in 1985 (Bowles et al. 1987) with a period of increased effort during the 1970s (Figure 4-11). Beginning in the early 1970s, effort increased and by 1978 exceeded 10,000 hours annually. This increase in effort could have been in response to the declining kokanee fishery during this period and represented a shift back to the traditional westslope cutthroat trout fishery. By 1980, effort had again declined to about 1,300 hours and remains low today. With decreasing effort and harvest, harvest rates remained relatively constant at about 6.5 hours per fish from 1960 to the early 1970s. Harvest rates had worsened by the late 1970s to 30 hours per fish, an indication of a declining population.

Size - Mean total length of westslope cutthroat trout entering angler creels on Pend Oreille Lake increased 15% from 1960 to 1985 (Figure 4-12). In 1960, mean total length was estimated at 300 mm (Ellis and Bowler 1981) and by 1985 had increased to 345 mm (Bowles et al. 1987).

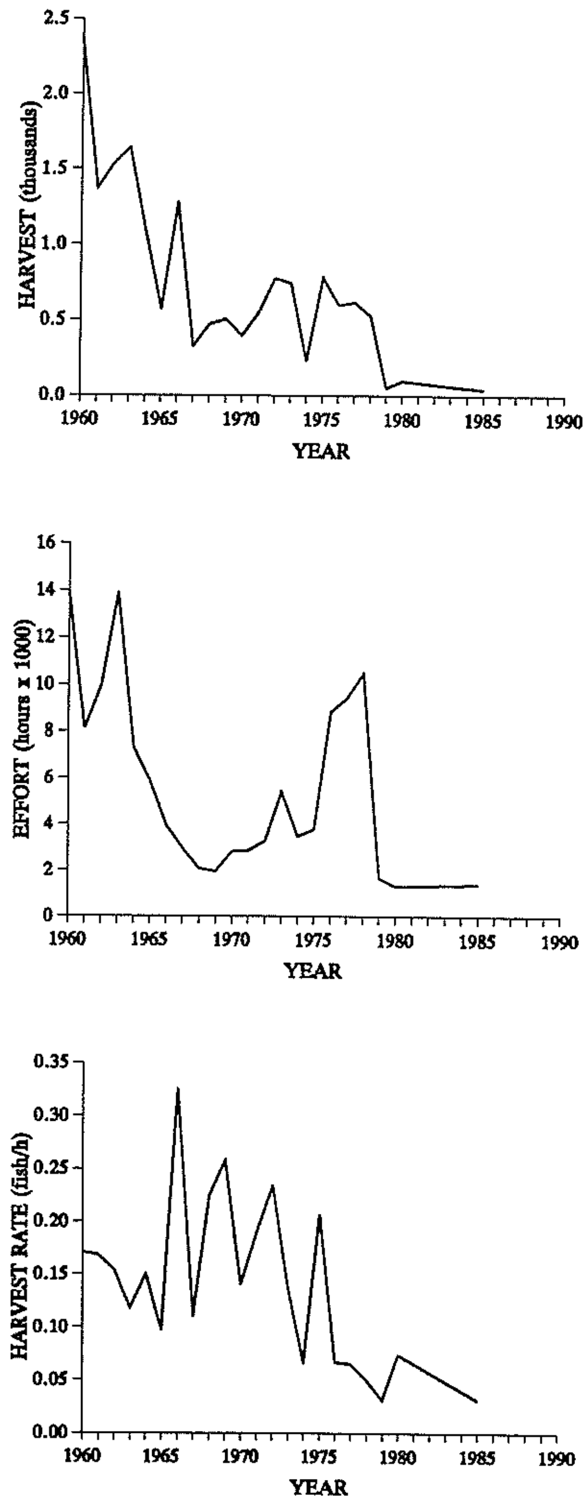

Figure 4-11. Estimated minimum harvest, effort, and harvest rate for sport anglers seeking westslope cutthroat trout in Pend Oreille Lake, Idaho, from 1960 to 1980 and a 1985 point estimate. Data were summarized by Ellis and Bowler (1981) and Bowles et al. (1987).

Increasing length may be the result of reduced competition for forage due to low population densities.

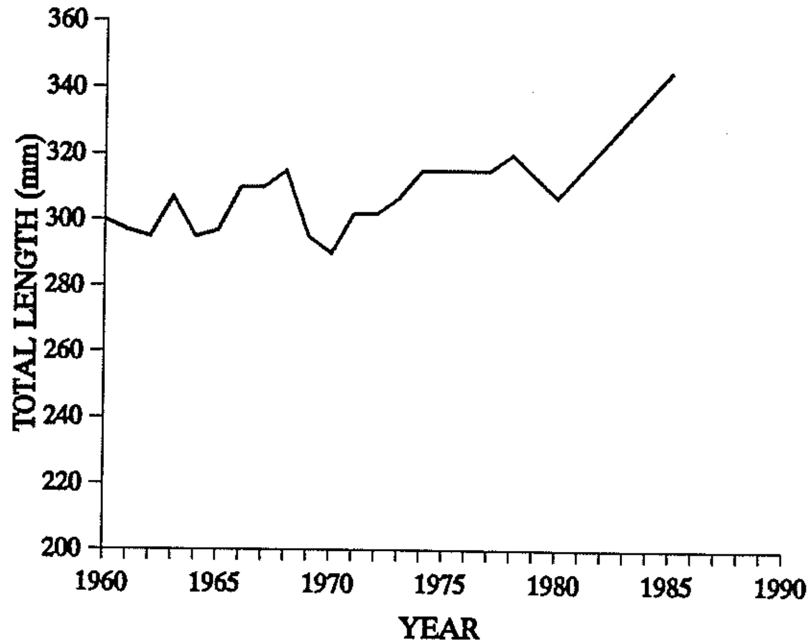

Figure 4-12. Estimated mean total length (mm) of westslope cutthroat trout entering angler creels on Pend Oreille Lake, Idaho from 1960 to 1980 and a 1985 point estimate. Data were summarized by Ellis and Bowler (1981) and Bowles et al. (1987).

Additional Harvest

Lake and mountain whitefish harvest declined during the census period 1951 to 1985 (Figure 4-13) and contributed no more than one percent to the total annual harvest (Appendix E). Lake whitefish never constituted a significant part of the whitefish harvest (Klavano 1960).

Estimated harvest of yellow perch, black crappie, and largemouth bass decreased between 1951 and 1985 (Figure 4-14). Contribution of spiny-rayed fishes to total annual harvest averaged 1.4% (Appendix E). The largest contribution was in 1957 (7.4%) while the largest harvest of 9,100 fish occurred in 1958.

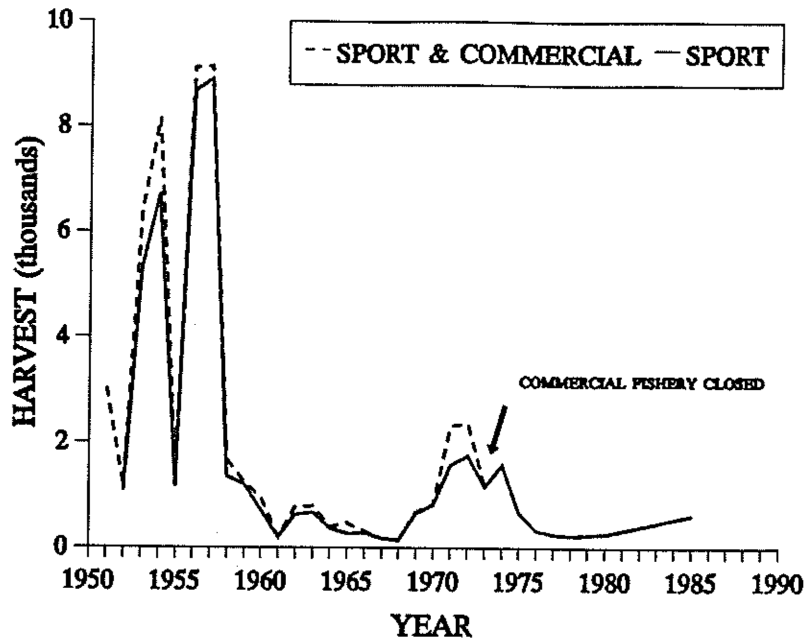

Figure 4-13. Estimated minimum total and sport (resident and non-resident) lake and mountain whitefish harvest from Pend Oreille Lake, Idaho, from 1951 to 1980 and a 1985 point estimate.

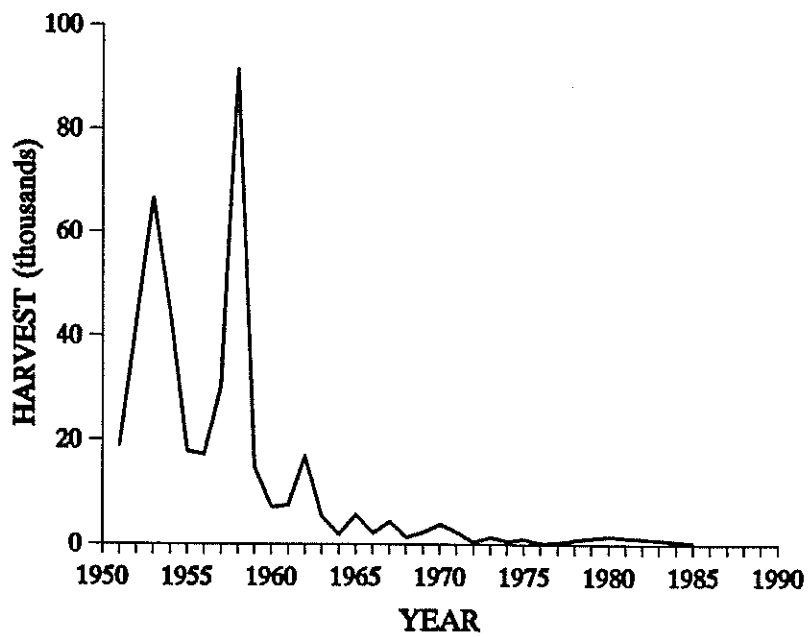

Figure 4-14. Estimated minimum spiny-rayed fishes harvest from Pend Oreille Lake, Idaho, from 1951 to 1980 and a 1985 point estimate (1953-1970 values based only on harvest of yellow perch, black crappie, and largemouth bass).

CHAPTER 5

ECONOMIC VALUE OF LAKE FISHERY

Recreational use, defined as the number of angler hours, of Pend Oreille Lake by sport anglers has decreased 62% from 477,000 hours in 1953 (Ellis and Bowler 1981) to the current low of 179,000 hours expended in 1985 (Bowles et al. 1987). Since the early 1970s, use has been relatively constant, averaging about 234,000 hours (Figure 5-1). Present angler effort was estimated by multiplying the 1985 hours expended by the projected population increase (4.6%) in Idaho and Washington from 1985 to 1990 (United States Bureau of the Census 1989).

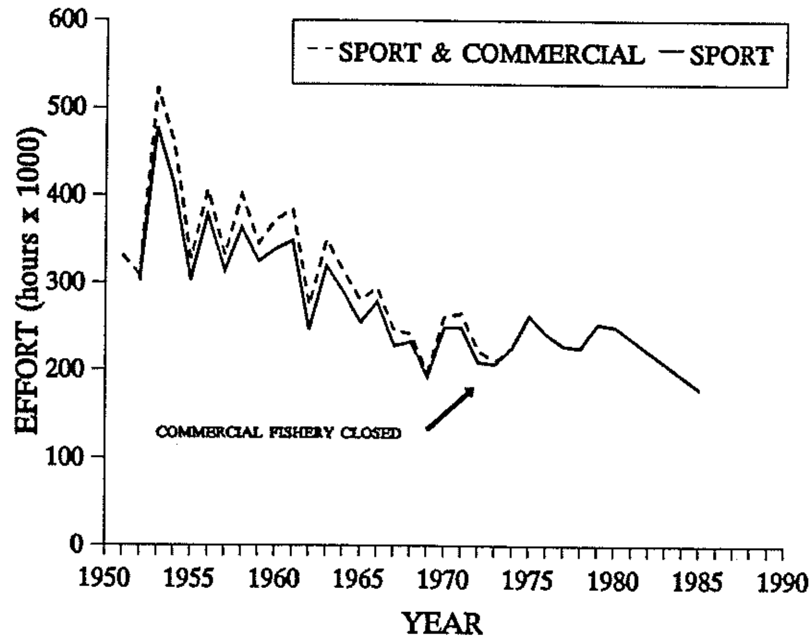

Figure 5-1. Estimated minimum total and sport (resident and non-resident) hours fished on Pend Oreille Lake, Idaho, from 1951 to 1980 and a 1985 point estimate. Data were summarized by Ellis and Bowler (1981) and Bowles et al. (1987).

The gross economic worth of the fishery was the summation of that that could be realized if a monopolistic owner charged each user of the resource the maximum price the angler was willing to pay (net "willingness to pay") and the net expenditures anglers assumed (gas, food, lodging, tackle). Net expenditures were a measure of net inflow of dollars to the local economy. Monetary values equaled angler hours multiplied by the cost/h (Sorg et al. 1985) multiplied by the consumer price index.

The gross economic worth of the Pend Oreille Lake fishery in 1990 was estimated at 1.96 million dollars. Net "willingness to pay" (net WTP) was 0.99 million dollars and net expenditures were 0.97 million dollars. The kokanee fishery had a gross economic worth of 0.71 million dollars with a net WTP of 0.36 million dollars and net expenditures of 0.35 million dollars. The rainbow trout fishery was worth 1.09 million dollars (gross economic worth) in 1990 with net expenditures of 0.54 million dollars and a net WTP of 0.55 million dollars.

Projected value (1990 dollars) of the Pend Oreille Lake fishery was based on management goals for the kokanee restoration program and estimated angling hours for the rainbow trout fishery. Kokanee restoration goals are an annual harvest of 750,000 kokanee with catch rates of 2.0 fish/h (Bowles et al. 1986). This equates to 375,000 hours of angling effort. Horner et al. (1988) estimated rainbow trout effort would reach 150,000 hours by 1995. This estimate seemed realistic as rainbow trout effort has been increasing and the new regulations should improve trophy rainbow trout abundance. Gross economic worth of the kokanee fishery was estimated at 3.92 million dollars. Net WTP was 1.97 million dollars and net expenditures were 1.95 million dollars. The cost of Cabinet Gorge Hatchery was 2.25 million dollars and annual operating cost are $200,000 (Scott Patterson, Idaho Department of Fish and Game, Region I, personal communication). Gross economic worth of the rainbow trout fishery was estimated at 1.57 million dollars with net expenditures of 0.79 million dollars and net WTP of 0.78 million dollars. The total fishery would be valued at 5.49 million dollars (gross economic worth).

CHAPTER 6

ZOOPLANKTON COMMUNITY

Species Composition

Eleven species of crustacean zooplankton have been identified from Pend Oreille Lake: Cyclops bicuspidatus thomasi, Diaptomus ashlandi and Epischura nevadensis of the Copepoda order; Daphnia thorata, Daphnia galeata mendotae, Bosmina longirostris, Diaphanasoma leuchtenbergianum, Chydorus sphaericus, Ceriodaphnia sp. and Leptodora kindtii of the Cladocera order and Mysis relicta of the Malacostraca order (Rieman and Bowler 1980). Of these, two copepods (Cyclops and Diaptomus) and two cladocerans (Daphnia and Bosmina) along with Mysis composed most of the zooplankton community.

Some changes have occurred in species composition of the Pend Oreille Lake zooplankton community. Bosmina were not collected in the lake during 1923 (Kemmerer *et al.* 1923; as cited from Rieman and Falter 1976). By 1953, Stross (1954) reported Bosmina were an important component of the zooplankton community. It was during the same time period kokanee became established in the lake. A reduction of Daphnia due to selective predation by kokanee could have provided a competitive advantage to Bosmina, allowing it to exist as a limnetic form (Rieman and Falter 1976). The dominance of cladoceran zooplankton by Bosmina in 1953 yielded to a 1974 dominance of Daphnia (Rieman and Falter 1975). At the same time, a decline in kokanee harvest had taken place. Increases or decreases in the kokanee population may result in the co-fluctuation of the two cladocerans.

Other changes in the zooplankton composition suggested Mysis introductions have had a major effect on the existing Pend Oreille Lake zooplankton community. Daphnia thorata was the dominant Daphnia species in the lake during 1974 (Rieman and Falter 1976). Evidence suggested it was also dominant in 1955. Beginning in 1975, D. thorata were replaced by Daphnia galeata mendotae (Rieman and Falter 1976; Rieman 1977, 1978, 1979). Rieman and Falter (1976) suggested D. g. mendotae interacted less with Mysis and gradually replaced D. thorata. Diaphanasoma, another cladoceran zooplankton, became established during the 1970s. Reduced competitive pressure on Diaphanasoma was likely the result of Mysis and allowed for its increase in abundance.

Distribution

Temporal distribution of cladoceran zooplankton has changed since the establishment of Mysis in Pend Oreille Lake in 1974. Stross (1954) found both copepod and cladoceran zooplankton in May 1952 and 1953. By July, numbers of each had peaked. Since 1975, cladocerans have exhibited a delayed appearance in the zooplankton samples (Rieman and Falter 1976; Rieman

1977, 1978, 1979; Bowler 1982; Bowles et al. 1986, 1987, 1989; Hoelscher et al. 1990). Daphnia were absent from samples until late July while Bosmina began appearing a few weeks earlier. Both genera peaked during August. Similar distributions to pre-Mysis years occurred in 1977 and 1987, two years of earlier initial warming of surface waters (Rieman 1978, Bowles et al. 1988). Rieman and Falter (1976) stated the importance of spring and early summer warming in the lake to seasonal timing and development of zooplankton biomass. Irizarry (1974b) concluded thermal stratification isolated mysids from surface waters in Pend Oreille Lake. This isolation reduced interaction with other zooplankton (Rieman and Falter 1975).

Displacement of cladoceran zooplankton was believed to have increased juvenile kokanee mortality (Rieman and Bowler 1980). Daphnia and Bosmina are important food items for kokanee (Bowler 1975, Rieman 1977). Delayed appearance of these zooplankton at the time of kokanee emergence and first feeding (April-August) was believed to have adversely affected kokanee year class abundance (Rieman and Bowler 1980).

Temporal distribution of copepod zooplankton has not been affected by the establishment of Mysis in Pend Oreille Lake. Both Cyclops and Diaptomus generally became abundant during July and peaked by August (Stross 1954; Rieman and Falter 1976; Rieman 1977, 1978, 1979, Bowles et al. 1986, 1987, 1988, 1989; Hoelscher et al. 1990).

A consistent distribution of summer mean zooplankton standing crop was observed in Pend Oreille Lake over the years. Highest biomass occurred in the southern end of the lake and the lowest in the northern (Rieman and Falter 1975, 1976; Rieman 1977, 1978, 1979). Bowles et al. (1988, 1989) and Hoelscher et al. (1990) reported similar distributions for total zooplankton densities in the lake. Rieman and Falter (1976) speculated the influence of Clark Fork River (*i.e.* increased turbidity and flushing rate) reduced production in the northern part of the lake. Warmer runoff waters of Clark Fork River may have stimulated earlier production of certain zooplankton (Cyclops) in the north.

Mysids displayed a similar distribution as was observed in other zooplankton. Mysid densities were highest in the southern half of the lake and substantially lower in the north (Bowles et al. 1987, 1989; Hoelscher et al. 1990). Only in 1987, was there equal distribution of mysids throughout the lake (Bowles et al. 1988).

Abundance and Density

Copepods were more abundant than cladocerans in Pend Oreille Lake. Cladoceran abundance was about 12% of copepod abundance from 1974 to 1981 (Bowler 1982) and 9% from 1985 to 1989 (Bowles et al. 1986, 1987, 1988, 1989; Hoelscher et al. 1990). Of the copepods, Cyclops were the most abundant followed by Diaptomus (Table 6-1). Epischura made up a small percentage of the copepod production. Cyclops and Diaptomus were also the most abundant zooplankton in the zooplankton community. Daphnia and Bosmina were equally abundant from 1974 to 1981 even though their contribution varied between years (Bowler 1982). From 1985

Table 6-1. Mean zooplankton density (organisms/L) by genera, total zooplankton density (organisms/L), and total zooplankton biomass (mg/m^3) in Pend Oreille Lake, Idaho, from May through September 1974 to 1981 and 1985 to 1989. Data were summarized by Bowler (1982); Bowles et al. (1986, 1987, 1988, 1989); and Hoelscher et al. (1990).

Year	Cyclops	Diaptomus	Epischura	Bosmina	Daphnia	Diaphanasoma	Total density	Total biomass
1974	6.98	3.42	0.09	1.39	1.39	0.08	13.3	33.8
1975	5.10	3.35	0.05	1.44	0.07	0.02	10.0	16.3
1976	8.62	4.73	0.06	1.20	0.22	0.20	15.0	34.8
1977	13.88	8.16	0.06	1.08	1.71	0.10	25.0	54.3
1978	8.63	5.28	0.05	0.95	0.54	0.21	15.7	31.1
1979	11.71	6.80	0.05	0.59	1.71	0.11	21.0	42.0
1980	9.32	5.84	0.05	0.17	0.49	0.01	15.9	31.4
1981	9.24	6.27	0.05	0.17	0.85	0.03	16.6	35.2
1985	9.30	6.46	0.05	0.41	0.37	0.04	19.8	
1986	6.44	5.70	0.01	0.03	1.51	0.01	13.7	
1987	8.90	4.84	0.02	0.64	1.25	0.02	16.6	
1988	13.70	8.44	0.01	0.18	0.83	0.17	23.3	
1989	11.15	8.56	0.01	1.12	0.81	0.38	22.0	
1974-1981	9.19	5.48	0.06	0.87	0.87	0.10	16.6	34.8
1985-1989	9.90	6.80	0.02	0.48	0.95	0.12	19.1	

to 1989, Bosmina abundance decreased to half Daphnia abundance (Bowles et al. 1986, 1987, 1988, 1989; Hoelscher et al. 1990). During this same period, kokanee abundance increased due to high fry recruitment from Cabinet Gorge Hatchery. Diaphanasoma were not a common zooplankton in Pend Oreille Lake.

Total zooplankton abundance increased 15% from the 1974 to 1981 period to the 1985 to 1989 period (Bowler 1982, Bowles et al. 1986, 1987, 1988, 1989; Hoelscher et al. 1990). The majority of this increase was due to an increase in copepod abundance, especially Diaptomus.

Mysis were introduced into Pend Oreille Lake in 1966 (Rieman and Falter 1976). A ten-fold increase in abundance occurred between 1974 and 1975 (Figure 6-1). Abundance continued to increase in 1976 with a more than doubling of mysid numbers. Since 1976, mysid abundance has remained at elevated levels with large fluctuations in abundance between years (Bowles et al. 1987, 1988, 1989; Hoelscher et al. 1990).

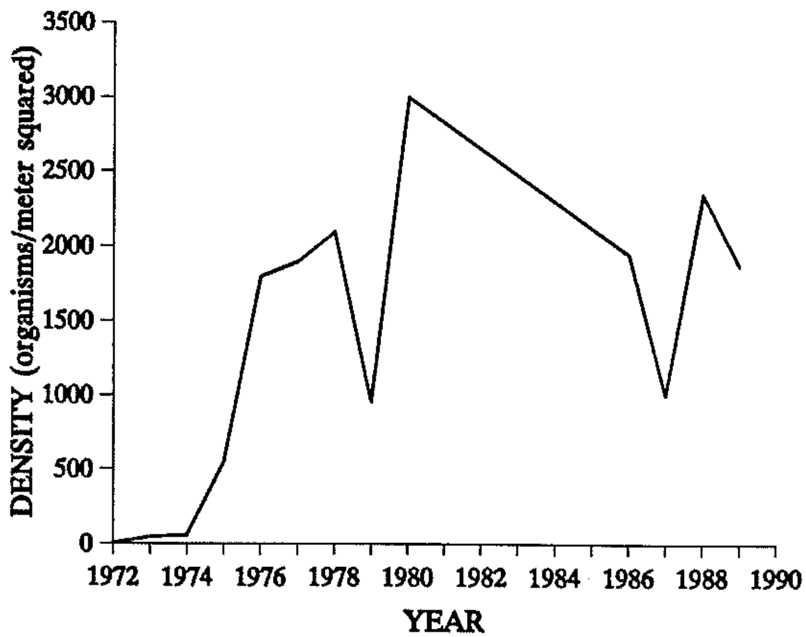

Figure 6-1. Estimated density (organisms/m²) of opossum shrimp in Pend Oreille Lake, Idaho, from 1972 to 1989, excluding from 1981 to 1985. Data were summarized by Rieman and Falter (1976); Bowles et al. (1987, 1988, 1989); and Hoelscher et al. (1990)

Biomass

Bowler (1982) estimated zooplankton biomass (excluding Mysis) averaged 34.8 mg/m^3 between 1974 and 1981 (Table 6-1). The large size of certain zooplankton species (*i.e.* Epischura, Daphnia, and Diaphanasoma) increased their contribution to total zooplankton biomass despite their low abundance.

Mysis were estimated to contribute about 14% of total zooplankton biomass during July, 1974 (Rieman and Falter 1976). Based strictly on the magnitude of population increase, Mysis could have composed as much as 90% of the zooplankton biomass in July, 1975. Some of this increase in production may have been historically copepod and cladoceran biomass, but most of it was likely new biomass due to the exploitation of a new niche in the deeper waters of Pend Oreille Lake.

Size

Mysis were the largest member of the zooplankton community in Pend Oreille Lake ranging between 3 and 20 mm in length (Hoelscher et al. 1990). Other zooplankton are listed in descending size: Epischura, Daphnia sp., Diaphanasoma, Diaptomus, Cyclops, and Bosmina.

CHAPTER 7

HUMAN HEALTH RISKS FROM FISH CONSUMPTION

A century of mining, milling, and smelting have supplied large amounts of tailings containing arsenic, cadmium, copper, lead, and zinc to upper Clark Fork River. Large quantities of the tailings have been transported downstream and deposited along the flood plain and in Milltown Reservoir (Lambing 1991). Dissolved and suspended metals and sediment still enter Pend Oreille Lake via Clark Fork River (Beckwith 1989a).

Metals concentrations exceeded United States Environmental Protection Agency recommended freshwater chronic and acute toxicity criteria in Clark Fork River and Pend Oreille Lake. Beckwith (1989a) noted total recoverable cadmium in Clark Fork River inflow between 1984 and 1988 was consistently above United States Environmental Protection Agency chronic and acute toxicity criteria. On occasion, copper and zinc exceeded United States Environmental Protection Agency criteria. In the fall of 1984, zinc inhibited algal growth in one bioassay sample from Pend Oreille Lake (Greene et al. 1984). While conducting similar bioassays in April 1986, Gangmark and Cummins (1987) found mercury concentrations at all stations exceeded the freshwater chronic criterion of 0.012 $\mu g/L$. They reported zinc values less than the detection limit.

Fish are good indicators of biologically available pollutants. They bioaccumulate these materials to much greater levels than would be found in the surrounding water. Pollutant concentrations in fishes were of concern because of the importance of sport fishing in Pend Oreille Lake.

Heavy metals and organic compounds in fish tissue have not been adequately evaluated in Pend Oreille Lake. This cursory investigation may be used as a gross indication of potential human health risks from fish consumption and to identify whether further testing may be needed. Suggested maximum dietary consumption was based upon the sample concentrations and available literature for adult daily dietary intake and rates of ingestion of metals that cause adverse health effects.

Collections and analysis

In the fall of 1989, Idaho Department of Fish and Game collected fish samples from Clark Fork River and Pend Oreille Lake (Table 7-1). The samples represented two trophic levels and fishes targeted by anglers for consumption. Detailed procedures for sample collection, sample handling, analysis, and quality assurance were described by Nautch (1989).

Samples were processed and analyzed by Idaho Bureau of Laboratories for six metals and 16 organic compounds (Table 7-2). Whole body composites were prepared from all samples.

Table 7-1. Length (mm) and weight (g) by species of fish collected from Pend Oreille Lake and Clark Fork River, Idaho, in 1989.

Species	Sample	Length	Weight	Location
kokanee	1	267	155	Pend Oreille Lake
	2	273	156	
	3	241	110	
	4	254	137	
	5	305	220	
	mean	268	156	
rainbow trout	1	432	680	Pend Oreille Lake
	2	546	1,417	
	3	425	624	
	4	508	1,020	
	5	368	454	
	mean	456	839	
northern squawfish	1	464	960	Clark Fork River
	2	578	2,500	
	3	425		
	mean	489		
mountain whitefish	1	350	310	Clark Fork River
	2	353	330	
	3	376	380	
	mean	360	340	
bridgelip sucker	1	540	1,700	Clark Fork River
	2	565	2,270	
	3	514	980	
	4	511	1,800	
	5	559	2,040	
	mean	538	1,758	

Mercury was determined by the atomic absorption spectrophotometric manual cold vapor technique. Copper was determined by flame atomic adsorption using deuterium background correction. Arsenic, cadmium, chromium, and lead were determined via method of additions using graphite furnace atomic adsorption with Zeeman background correction. For analysis of organics, an extraction procedure was followed by florisil fractionation for cleanup, and silicar was used for further separation. The sample was then analyzed by electron capture gas chromatography.

Suggested maximum fish consumption quantities were computed using the following equation (Bennett et al. 1990).

$$MAI = (MDI - MEDI)/MMC \qquad \text{(Equation 1)}$$

Where:

MAI = suggested maximum allowable intake (kg/d)
MDI = maximum dietary intake with no-observed-adverse-health-effect for a 70 kg (154 lb) adult (mg/d)
MEDI = mean dietary intake for a 70 kg (154 lb) adult (mg/d)
MMC = mean metal concentration (mg/kg wet weight)

Heavy metals

Federal and state guidelines for metals concentrations in fish tissue have not been officially established. However, the Food and Drug Administration has set an action limit for mercury in edible fish at 1.0 mg/kg wet weight (Food and Drug Administration 1987). In addition, the Food and Agriculture Organization of the United Nations has published a compilation of international legal limits for hazardous substances in fish (Nauen 1983). The median of these legal limits were used as guidelines for evaluation of these data.

Arsenic and chromium were not detected in any samples above the method detection limits. Those values that appear in the Table 7-3 met or exceeded the method detection limits and represent positive concentrations (α=0.005) detected in the tissue. Based upon the action limits given, none of the metals of interest were in exceedance.

Cadmium - Mean cadmium concentrations were 0.05 mg/kg wet weight in mountain whitefish and 0.12 mg/kg in bridgelip sucker Catostomus columbianus (Table 7-3). Cadmium was not detected above method detection limits in the remaining fishes. Concentrations tend to be higher in sediment than in filtered water, perhaps, explaining the higher concentration in the bridgelip sucker sample; a bottom feeder.

The major source of cadmium for the general population was from food. The National Academy of Sciences (1984) estimated the total daily intake of cadmium from all sources ranged from 0.04 mg/d for the rural non-smoker on a low cadmium diet to 0.19 mg/d for the urban smoker on a high cadmium diet. Friberg et al. (1974), as cited from the National Academy of Sciences (1984), estimated the average daily intake at 0.05 mg/d. Other researchers have reported chronic health effects to the kidney at ingestion rates of 0.60 mg/d (National Academy of Sciences 1984).

Based upon the samples and available information for cadmium, fish consumption should not pose either a chronic or acute toxicity human health risk (Table 7-3).

Table 7-2. Organic compounds and heavy metals analyzed and the corresponding method detection limits (ppm for organic compounds and mg/kg wet weight for heavy metals).

Organic compounds	Method detection limit	Heavy metal	Method detection limit
PCB-1254		arsenic	0.49
PCB-1260		cadmium	0.04
dieldrin	0.012	chromium	0.35
total DDT (calculated)		copper	0.25
pp' DDE	0.065		
pp' DDD	0.016	lead	0.08
pp' DDT	0.015		
op' DDT	0.032	mercury	0.06
endrin			
methoxychlor			
hexachlorobenzene	0.003		
chlordane			
trans isomer of nonachlor (or T-Nonachlor)			
hexachlorocyclobenzene			
alpha BHC isomer			
gamma isomer (lindane)			
dachthal (DCPA)			
toxaphene	0.757		

Copper - Mean copper concentrations were similar among all fishes, except kokanee (Table 7-3). Mean concentration in kokanee was two to three times higher than any other fish species. However, it was only 11% of the recommended action limit.

Copper is a gastrointestinal tract irritant and can be highly toxic (National Academy of Sciences 1984). Toxicity in humans is typically not a problem. Taste usually becomes unpleasant before concentrations reach a level capable of causing health risks. A few people

Table 7-3. Mean heavy metal concentrations (mg/kg wet weight) in fishes collected from Pend Oreille Lake and Clark Fork River, Idaho, action limits (mg/kg wet weight), and dietary intake information (mg/d) for consumption. Fish consumption in pounds per day is in parentheses.

Metal	Fish species	Mean metal concentration	Action limit	Mean dietary intake	Maximum dietary intake	Suggested maximum fish consumption
cadmium	bridgelip sucker	0.12	0.30	0.05	0.60	4.58 (10.11)
	northern squawfish		0.30	0.05	0.60	11.0 (24.26)
	mountain whitefish	0.05	0.30	0.05	0.60	
	kokanee		0.30	0.05	0.60	
	rainbow trout		0.30	0.05	0.60	
copper	bridgelip sucker	1.05	20.0			
	northern squawfish	1.19	20.0			
	mountain whitefish	0.77	20.0			
	kokanee	2.26	20.0			
	rainbow trout	0.82	20.0			
lead	bridgelip sucker	0.18	2.0	0.29	0.35	0.33 (0.74)
	northern squawfish		2.0	0.29	0.35	
	mountain whitefish	0.22	2.0	0.29	0.35	0.27 (0.60)
	kokanee	0.10	2.0	0.29	0.35	0.60 (1.32)
	rainbow trout		2.0	0.29	0.35	
mercury	bridgelip sucker	0.13	1.0	0.01	0.63	4.74 (10.45)
	northern squawfish	0.46	1.0	0.01	0.63	1.34 (2.95)
	mountain whitefish	0.10	1.0	0.01	0.63	6.16 (13.58)
	kokanee	0.06	1.0	0.01	0.63	10.27 (22.64)
	rainbow trout	0.09	1.0	0.01	0.63	6.84 (15.09)

are affected by normal amounts of copper in the diet. This disorder is called Wilson's disease.

Insufficient data were available for establishment of a maximum no-observed-adverse-health-effect value. Based upon the recommended action limit of 20.0 mg/kg, copper should not cause adverse effects, however, it should be evaluated further.

Lead - Mean lead concentrations ranged from 0.10 mg/kg wet weight in kokanee to 0.22 mg/kg in mountain whitefish (Table 7-3). This represented five to eleven percent of the recommended action limit. Lead was below the method detection limit for northern squawfish and rainbow trout.

The National Academy of Sciences (1984) reported lead intake in humans from food varied from 0.10 mg/d for an adult female to 0.30 mg/d for an adult male. In addition, drinking water contributed 0.026 mg/d to the diet. Lead is also absorbed into the body through inhalation. About 0.06 mg/d is taken in by an adult breathing urban air. The World Health Organization recommended 0.35 mg/d as a safe dietary intake.

Based upon this information, lead concentrations would limit the amount of fish consumed from Pend Oreille Lake (Table 7-3). Slightly more than one-quarter kilogram or one-half pound of mountain whitefish or one-half kilogram or one and one-third pound of kokanee could be consumed per day. This conclusion may not be accurate as it was not based on statistically derived data and on very small samples. It does, however, warrant further investigation.

Mercury - Mean mercury concentration in northern squawfish was three to five times higher than the other fishes (Table 7-3). At 0.46 mg/kg wet weight, it was comparable to the mean international legal limit of 0.50 mg/kg reported by Nauen (1983) and represented 50% of the FDA action limit of 1.00 mg/kg.

The normal human diet was estimated to contribute about 0.014 mg/d of mercury (National Academy of Sciences 1984). The intake from food contributed about 0.01 mg/d while the remainder came from drinking water. Identifiable symptoms of mercury intoxication have been observed at ingestion rates of 0.28 to 0.98 mg/d (0.004-0.14 mg/kg body weight/d).

If northern squawfish were regularly consumed, they would have the potential of causing mercury intoxication. No risk should be expected from consuming any of the other fishes, even at the lower tolerance limits (*i.e.* 0.28 mg/d rate of ingestion).

Organic Compounds

Organic compounds screened are listed in Table 7-2. None of the samples from Clark Fork River or Pend Oreille Lake were found above the method detection limits.

CHAPTER 8

EFFECTS TO THE LAKE FISHERY

Water quality management goals can be in conflict with fishery management goals. A more productive fishery generally requires a more productive water body. Researchers have reported positive relations between total phosphorus concentration (Hanson and Leggett 1982; Jones and Hoyer 1982) and chlorophyll-*a* (Jones and Hoyer 1982) and fish yield. Mills and Schiavone (1982) reported a measure of productivity, such as Fee's Index, and chlorophyll-*a* were positively correlated ($P<0.05$) while secchi disc transparency depth was negatively correlated ($P<0.01$) with total planktivore weight.

Predictive models provide fishery and water quality managers the ability to project effects to the fishery from various water quality management goals. This is important in a water body like Pend Oreille Lake because of the economic significance of the sport fishery.

Water quality management goals for Pend Oreille Lake are to maintain the pelagic zone water quality while improving the water quality in the littoral zone (J. Skille, Idaho Department of Health and Welfare, Division of Environmental Quality, personal communication). Fishery management goals are to restore the fishery to past levels of production (N. Horner, Idaho Department Of Fish and Game, personal communication).

One objective of the Pend Oreille Lake Phase I Diagnostic and Feasibility Analysis was to determine the trophic status of Pend Oreille Lake (Beckwith 1989b). As commonly used, trophic status referred to the nutrient status of a water body. Woods (1991a) reported the trophic status of Pend Oreille Lake has not changed since the early 1950s.

The fishery management goal, restoration to past levels of production, was compatible with the water quality goal of maintaining high water quality in the pelagic zone of Pend Oreille Lake. It should be reminded during the 1950s and early 1960s the sport and commercial kokanee fishery yielded an average annual harvest of one million fish (Ellis and Bowler 1981).

Improvement of water quality in the littoral zone would likely not have an effect (*i.e.* change the trophic status) on the pelagic zone water quality. This was due to the type of nutrient-management action (*e.g.* removal of nutrient inputs from nearshore septic tank and wastewater treatment facilities, decreases in nonpoint source loads from developed drainages) targeted and their location in the shallower, developed, northern part of the lake. Woods (1991b) modeled the lake's pelagic zone response to various nutrient-management scenarios. He concluded removal of nutrient inputs from nearshore septic tanks and wastewater treatment facilities at Sandpoint and Priest River or a 25% reduction in loads from Pack River and Sand Creek would not affect the limnological response variables in the deep, southern segment (*i.e.* south of

Sheepherder Point and Camp Bay) of Pend Oreille Lake. The remainder of the lake showed small decreases in nutrient concentrations.

Obviously, the Pend Oreille Lake fishery must be limited by some other variable. Presently, the number of spawning fish may be limiting the number of large predators in the lake (Hoelscher and Bjornn 1989). Pratt (1985) and Hoelscher and Bjornn (1989) reported several tributaries having low if any juvenile rainbow trout. Several researchers have reported degraded habitat in the tributaries (Anderson 1971; Irving 1986; Hoelscher and Bjornn 1989). Tributaries are extremely important as rainbow trout, bull trout, and westslope cutthroat trout must spawn and rear in the tributaries before entering the lake. The single most likely variable limiting the Pend Oreille Lake fishery is the operation of Albeni Falls Dam (M. Maiolie, Idaho Department of Fish and Game, personal communication). It was speculated the changing of dam operation policy in 1967 forced kokanee to spawn in sub-optimum conditions. Typically, kokanee would spawn along wave swept shorelines. With the operation policy to stabilize water levels before kokanee spawning and incubation, kokanee were forced to spawn at depths not previously located in the wave action zone. These areas likely had higher percent fines and organic material resulting in higher egg mortality.

As part of the Section 525 Clark Fork/Pend Oreille Basin water quality study, Montana was also investigating sources of pollution in the Clark Fork River basin and recommending ways to control these sources (Ingman 1991). A ten percent reduction in nutrient loads from Clark Fork River was recommended as a realistic goal for nutrient management in Montana (G. Ingman, Montana Water Quality Bureau, personal communication). Woods (1991b) modeled a ten percent reduction in Clark Fork River nutrient loads and determined nutrient concentrations would decrease throughout the lake. In the southern segment of the lake, total phosphorus concentrations would decrease 0.5 μg/L from 7.4 to 6.9 μg/L, however, the trophic status would not change. Woods also modeled a 25% increase in Clark Fork River nutrient loads. This scenario likewise did not alter the lake's trophic status, although lakewide total phosphorus concentrations moved closer to the next more productive trophic state. In conclusion, the modeling showed that the lake's pelagic zone trophic state was relatively insensitive to small to moderate alterations in nutrient inputs.

In anticipation of nutrient reductions, we used a predictive model developed by Hanson and Leggett (1982) to model the effect on the Pend Oreille Lake fishery. Hanson and Leggett (1982) found a high correlation between mean epilimnetic total phosphorus concentration and fish yield (r^2=0.84; P<0.001). The mean epilimnetic total phosphorus concentration (based upon euphotic zone total phosphorus concentrations) for Pend Oreille Lake was calculated at 7.3 μg/L (Woods 1991a). Based on the equation by Hanson and Leggett (1982), fish yield was estimated at 1.32 kg/ha. Fish yield for Pend Oreille Lake, as estimated from 1991 creel census information, was 1.71 kg/ha (V. Paragamian, Idaho Department of Fish and Game, personal communication). Woods (1991b) simulated a ten percent nutrient reduction in Clark Fork River inflow. He calculated total phosphorus concentration would decrease 6.4%. Applying this rate to the mean epilimnetic total phosphorus concentration, we estimated a ten percent reduction in Clark Fork River nutrient loads would result in a mean epilimnetic total phosphorus concentration of 6.8 μg/L. This in turn related to a three percent reduction in fish yield (1.28 kg/ha). A 25% reduction in nutrient loads from Clark Fork River (mean epilimnetic total phosphorus concentration of 6.5 μg/L) would result in a 4.5% reduction in fish yield (1.26 kg/ha). Using kokanee sport fish harvest estimates from 1952 to 1965 (Appendix E-2 and E-3), a 4.5% reduction in fish yield would not be significantly different ($P>0.10$) and would support the fishery management goal.

CHAPTER 9

CONCLUSIONS

- The native sport fishes in Pend Oreille Lake are westslope cutthroat trout, bull trout, and mountain whitefish. Due to reduced numbers, westslope cutthroat trout and bull trout are listed as federal sensitive species and state species of special concern. Other sport fishes have been stocked or found their way into the lake over the years: kokanee, rainbow trout, Gerrard rainbow trout, lake whitefish, brook trout, brown trout, lake trout, yellow perch, black crappie, largemouth bass, brown bullhead, pumpkinseed, and northern pike.

- From 1951 to 1965, the Pend Oreille Lake kokanee fishery was the most popular kokanee fishery in Idaho. The sport and commercial fishery yielded an average annual harvest of about one million fish. A world record rainbow trout, weighing 16.8 kg (37 lb), was caught in 1947, and the current world record bull trout, weighing 14.5 kg (32 lb), was caught in 1949. In 1952, seven of the ten largest trout caught in the continent came from Pend Oreille Lake.

- Fishing success for most salmonids saw dramatic declines between the 1950s and 1980s. Kokanee harvest began to decline during the 1960s. It reached a low in 1986 and has increased in recent years. Bull trout harvest initially declined and has stabilized at a depressed level. The westslope cutthroat trout fishery has declined more dramatically than any other Pend Oreille Lake fishery. It is now very reduced and is being supported by fingerling stocking.

- Hydropower development on the inlet and outlet of the lake was likely the single most important contributor to the decline in sport fish numbers. Albeni Falls Dam, completed in 1952, fluctuated lake levels between summer and winter. Winter drawdown dewatered shoreline spawning areas and killed kokanee eggs in the gravel. Cabinet Gorge Dam on Clark Fork River has been a complete migration block to all fishes since 1951, eliminating hundreds of miles of tributary spawning and rearing areas available to Pend Oreille Lake fishes. Fluctuations of the river below the dam also killed kokanee eggs.

- Rainbow trout, bull trout, and westslope cutthroat trout must spawn and rear for several years in tributary streams before migrating to the lake. Improper land use practices and natural catastrophes have resulted in degraded habitat in the remaining accessible tributaries. These changes have resulted in fewer fish in the lake.

- Opossum shrimp were introduced into Pend Oreille Lake in 1966. They became abundant by 1976. This small shrimp competed with newly emerged kokanee fry for food sources, reducing the kokanee's survival during the first few weeks of life.

- The kokanee population has increased 80% since 1986 and should increase even more as output from Cabinet Gorge Hatchery increases. Bull trout populations have stabilized and Pend Oreille Lake remains the State's best bull trout fishery. Rainbow trout catch rates have improved from 44 hours per fish in 1985 to 18 hours per fish in 1990. Even more improvements are expected as the abundance of their primary food source (kokanee) increases.

- The Pend Oreille Lake fishery has been estimated to be worth $2 million annually and returns about $1 million to local communities (1990 dollars). The kokanee fishery had a gross economic worth of 0.71 million dollars. The rainbow trout fishery was worth 1.09 million dollars. The projected gross economic worth of the Pend Oreille Lake fishery if management goals are realized would be valued at 5.49 million dollars.

- Lead may limit the consumption of kokanee to 0.60 kg (1.32 lb) and mountain whitefish to 0.27 kg (0.60 lb) per day. If northern squawfish were regularly consumed, they would have the potential of causing mercury intoxication. These conclusions may not be accurate as they were not based on statistically derived data and very small samples.

- A ten percent reduction in the mean epilimnetic total phosphorus concentration would reduced the kokanee yield three percent. A 25% reduction would result in a 4.5% reduction in kokanee yield. A 4.5 % reduction in fish yield would not be significantly different ($P>0.10$) from 1952 to 1965 kokanee sport fish harvest estimates and would support the fishery management goal--restoration to past levels of production.

CHAPTER 10

RECOMMENDATIONS

- Protect riparian areas to provide filtering capabilities and recruitment of large organic debris to Pend Oreille Lake tributaries available to adfluvial fishes. In-stream habitat enhancement is necessary in Grouse and Lightning creeks, two streams with large expanses of rapid, shallow water.

- Lakeshore development and non-point source watershed activities should be conducted to limit the percent fines less than 6.35 mm in the substrate to 25%.

- Human health risks from fish consumption should be further evaluated using statistically valid sample sizes. Emphasis should be placed on lead and mercury contamination.

CHAPTER 11

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APPENDIX A

Kokanee Spawner Counts

Appendix A. Kokanee spawner counts made from 1972 to 1978 and 1985 to 1989 on Pend Oreille Lake, Idaho, and tributaries, excluding the Granite Creek drainage. Data were summarized by Bowles et al. (1989) and Hoelscher et al. (1990).

Area	Maximum single counts											
	1972	1973	1974	1975	1976	1977	1978	1985	1986	1987	1988	1989
Lakeshore												
Bayview	2,626	17,156	3,588	9,231	1,525	3,390	798	2,915	1,720	1,377[c]	2,100	875
Farragut	25	0	0	0	0	0	0	–	10	0	4	–
Idlewild Bay	13	0	25	0	0	0	0	–	–	–	–	–
Lakeview	4	200	18	0	0	25	0	4	127	59	0	0
Ellisport Bay and Hope	1	436	975	0	0	0	0	0	0	0	–	–
Trestle Creek resorts	0	1,000	2,250	0	115	75	138	2	35	350	2	2
Sunnyside	0	25	0	0	0	0	0	0	0	0	–	–
Fisherman Island	0	0	75	0	0	0	0	–	–	–	–	–
Anderson Point	0	0	50	0	0	0	0	–	–	–	–	–
Camp Bay	0	617	0	0	0	0	0	0	0	0	–	–
Garfield Bay	0	400	20	0	0	0	0	0	6	0	35	–
Subtotal	2,669	19,834	7,001	9,231	1,640	3,490	936	2,921	1,898	1,786	2,141	877
Percent of Total	29%	62%	25%	64%	33%	40%	19%	32%	10%	20%	14%	19%
Tributaries												
Gold Creek	1,030	1,875	1,050	440	0	30	–	235	1,550	2,761	2,390	830
North Gold Creek	744	1,383	1,068	663	130	426	–	696	1,200	2,750	880	448
Cedar Creek	0	267	44	16	11	0	0	–	–	–	–	–
Johnson Creek	0	0	1	0	0	0	0	–	182	0	0	0
Twin Creek	0	0	135	1	0	0	0	5	0	0	0	0
Mosquito Creek	0	503	0	0	0	0	0	–	–	–	–	–
Clark Fork River	539	3,520	6,180	0	–	–	–	–	–	–	–	–
Lightning Creek (lower)	350	500	2,350	995	2,240	1,300	44	127	165	75	6	–
Spring Creek	2,610	4,025	9,450	3,055	910	3,390	4,020	5,284	14,000	1,500[d]	9,000	2,400
Cascade Creek	–	–	–	–	–	–	–	–	–	0	119	48
Trestle Creek	1,293	18	1,210	15	0	40	0	0	0	0	0	0
Trestle Creek[a]	–	1,100	217	14,555	1,486	865	1,589	208	1,034	410	422	466
Garfield Creek	0	0	25	0	0	0	0	–	1	0	0	0
Subtotal	6,566	12,091	21,513	5,185	3,291	5,186	4,046	6,347	17,098	7,086	12,698	3,726
Percent of Total[b]	71%	38%	75%	36%	67%	60%	81%	68%	90%	80%	86%	81%
Total[b]	9,235	31,925	28,514	14,416	4,931	8,676	5,000	9,268	18,996	8,872	14,839	4,603

a early-run kokanee spawner count

b excluding early-run kokanee spawners in Trestle Creek

c represents a partial count because heavy wave action kept spawners offshore and uncountable

d count made third week of December because low flows in Lightning Creek resulted in a complete passage barrier during early December

APPENDIX B

Kokanee Year Class Abundance

Appendix B. Estimated year class abundance (millions) of kokanee made by midwater trawl in Pend Oreille Lake, Idaho, from 1977 to 1989. The two oldest age classes were combined for estimates from 1977 to 1985. Data were summarized by Bowles et al. (1988) and Hoelscher et al. (1990).

	Year estimated												
Year class	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
1988	4.48												
1987	1.17	7.31											
1986	1.20	1.66	3.55										
1985	0.45	0.51	0.78	1.66									
1984	0.37	0.38	0.84	1.15	1.79								
1983	0.04	0.35	0.43	0.68	1.03	2.63							
1982			0.42	0.54	1.24	1.51	2.14						
1981				0.24	0.37	1.21	2.28	3.84					
1980						0.27	0.50	2.77	2.31				
1979							0.29	0.64	1.36	1.69			
1978								0.87	0.79	1.00	2.01		
1977									0.74	0.96	1.31	1.82	
1976										1.03	1.70	0.71	2.01
1975											0.67	2.00	1.17
1974												1.29	2.95
1973													0.65
Total	7.71	10.21	6.01	4.27	4.47	5.62	5.21	8.12	5.20	4.68	5.69	5.82	6.78
Density (number per hectare)	341	450	266	189	198	249	230	358	230	207	251	257	299

APPENDIX C

1986 and 1987 Tributary Fish Densities

Appendix C. Mean fish densities (fish/100 m²) for 1986 and 1987 by species, size or age class (Age 2+ = Age 2 and older), habitat type, section, and stream and area sampled for selected tributaries to Pend Oreille Lake, Idaho. Data were summarized by Hoelscher and Bjornn (1989).

Stream / Section - Date / Habitat type	Habitat units snorkeled	Area sampled m²	Area sampled %	Mean width (m)	Salmo fry	Rainbow Age 1	Rainbow Age 2+	Cutthroat juveniles	Bull trout fry	Bull trout juv.	Bull trout adult	Brook trout	Unidentified salmonids	Other[a]	Total
Pack River															
Section 1 - 23 Aug. 1986															
run	5	1491	4	11.40	34.1	1.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.5	36.0
riffle	5	1319	6	11.10	33.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	39.9
pool	1	191	31	15.30	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	13.6
all types	11	3001	5	11.35	33.5	1.4	*	0.0	0.0	0.0	0.0	0.0	0.0	2.3	37.2
Section 2 - 24 Aug. 1986															
run	4	569	4	8.10	45.3	3.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	1.6	51.3
riffle	6	898	3	8.80	28.1	1.9	0.1	0.2	0.0	0.1	0.0	0.0	0.0	3.0	33.4
pool	1	76	5	8.20	54.2	18.5	10.6	2.6	1.3	0.0	0.0	0.0	0.0	2.6	89.9
pocketwater	2	132	6	8.70	34.0	4.5	1.5	0.8	0.0	0.0	0.0	0.0	0.0	1.5	42.3
all types	13	1675	3	8.60	33.6	3.0	0.6	0.3	*	0.1	0.0	0.0	0.0	2.6	40.2
Section 3 - 8 Sept. 1986															
run	3	177	2	7.05	36.7	2.2	0.6	0.0	0.0	0.6	0.0	0.0	0.0	0.0	40.1
riffle	6	545	2	6.25	21.6	1.1	0.7	0.0	0.2	0.0	0.0	0.0	0.0	0.0	23.7
pool	3	139	10	5.20	32.3	10.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.9
pocketwater	3	161	8	7.55	18.6	6.2	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.1
all types	15	1023	3	6.50	25.8	2.0	1.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	29.2
All sections - 1986															
run	12	2237	4		36.8	2.0	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.6	39.8
riffle	17	2762	3		27.6	1.5	0.3	0.1	*	*	0.0	0.0	0.0	2.8	32.3
pool	5	406	11		38.1	11.8	5.6	1.1	0.6	0.0	0.0	0.0	0.0	1.2	58.8
pocketwater	5	294	7		26.5	5.3	2.9	0.4	0.0	0.0	0.0	0.0	0.0	0.8	35.9
all types	39	5698	4	8.75	31.6	2.1	0.5	0.1	*	0.1	0.0	0.0	0.0	1.8	36.2
Grouse Creek															
Section 1 -12-13,20,22 Aug. 1986															
run	8	1518	8	8.20	92.2	6.8	2.0	0.1	0.0	0.3	0.0	0.3	0.0	3.6	105.4
riffle	19	3822	5	6.80	29.0	7.1	1.2	*	*	0.1	0.0	*	*	2.8	40.3
pool	6	390	8	7.75	86.5	22.6	3.1	0.5	0.0	0.0	0.2	1.0	0.2	29.0	143.2
pocketwater	5	150	9	7.95	81.3	34.0	8.0	0.7	0.0	0.0	0.0	0.7	0.0	4.0	128.7
all types	38	5879	6	7.10	44.0	8.1	1.5	0.1	*	0.2	*	0.1	*	4.1	58.2

Appendix C. (continued)

Stream Section - Date Habitat type	Habitat units snorkeled	Area sampled m²	Area sampled %	Mean width (m)	Mean fish densities (fish/100 m²) Salmo fry	Rainbow Age 1	Rainbow Age 2+	Cutthroat juveniles	Bull trout fry	Bull trout juv.	Bull trout adult	Brook trout	Unidentified salmonids	Other[a]	Total
Grouse Creek															
Section 2 - 12 Aug. 1986															
run	1	34	3	4.00	41.1	11.7	8.8	2.9	2.9	0.0	2.9	0.0	2.9	0.0	76.4
riffle	7	1141	5	5.55	24.4	1.3	1.5	0.3	1.8	1.7	0.4	0.1	0.6	0.0	32.0
pool	1	18	3	5.10	11.1	11.1	11.1	5.5	0.0	11.1	0.0	0.0	5.5	0.0	61.0
all types	9	1193	5	5.25	24.8	2.0	2.1	0.5	1.8	1.8	0.5	0.1	0.8	0.0	34.7
Section 1 - 29 Aug. 1987															
run	4	600	3	7.70	61.1	8.0	1.7	0.7	0.0	0.0	0.2	0.3	0.0	1.0	72.9
riffle	3	698	1	7.75	29.0	2.4	0.3	0.6	0.0	0.0	0.0	0.0	0.3	0.1	32.7
pool	3	328	7	7.10	64.7	16.2	5.2	2.1	0.0	0.0	0.3	0.0	0.0	0.6	89.2
all types	10	1626	1	7.70	36.6	4.1	0.8	0.6	0.0	0.0	*	0.1	0.2	0.3	42.8
Section 2 - 11,29-30 Aug. 1987															
run	5	517	32	5.25	33.1	2.5	1.2	1.5	0.2	0.2	0.0	0.2	0.0	0.2	39.1
riffle	4	568	3	5.25	21.1	0.7	1.4	0.9	0.2	1.2	0.0	0.0	0.4	0.0	25.9
pool	5	223	19	5.25	44.9	5.4	5.8	6.3	0.0	0.4	0.9	0.4	0.0	0.0	64.2
all types	14	1308	6	5.25	23.1	1.1	1.6	1.2	0.2	1.1	*	*	0.3	*	28.7
Section 3 - 27-28 Aug. 1987															
run	6	194	55	4.05	1.5	0.0	0.0	4.6	0.0	1.0	0.5	0.0	0.0	0.0	7.7
riffle	7	866	7	4.30	0.8	0.0	0.0	3.8	0.2	0.3	0.2	0.0	0.0	0.0	5.4
pool	8	204	15	4.45	2.0	0.0	0.0	10.8	0.5	0.5	7.4	0.0	0.0	0.0	21.1
all types	21	1264	9	4.30	0.9	0.0	0.0	4.5	0.2	0.4	0.9	0.0	0.0	0.0	7.0
All sections - 1987															
run	15	1311	6		58.2	7.5	1.6	0.8	*	*	0.2	0.3	0.0	0.9	69.6
riffle	14	2132	2		24.7	1.9	0.4	1.0	*	0.2	*	0.0	0.3	0.1	28.7
pool	16	755	10		50.2	11.6	4.3	4.4	0.1	0.2	1.7	0.1	0.0	0.4	72.9
all types	45	4198	3	7.05	31.1	3.2	0.8	1.1	*	0.2	0.1	*	0.2	0.2	37.1
North Fork Grouse Creek															
Section 1 - 7,9 Sept. 1986															
run	6	453	6	4.90	73.0	5.5	0.7	0.2	0.0	0.0	0.0	7.7	0.0	0.2	87.4
riffle	6	293	3	3.70	45.8	3.8	0.3	0.0	0.0	0.0	0.0	3.4	0.0	0.3	53.6
pool	4	132	3	6.15	74.2	23.4	3.8	0.0	0.0	0.0	0.0	9.8	0.0	0.0	111.2
all types	16	878	4	4.40	61.5	8.2	1.1	0.1	0.0	0.0	0.0	6.3	0.0	0.2	77.4

Appendix C. (continued)

Stream Section - Date Habitat type	Habitat units snorkeled	Area sampled m²	Area sampled %	Mean width (m)	Salmo fry	Rainbow Age 1	Rainbow Age 2+	Cutthroat juveniles	Bull trout fry	Bull trout juv.	Bull trout adult	Brook trout	Unidentified salmonids	Other[a]	Total
					Mean fish densities (fish/100 m²)										
North Fork Grouse Creek															
Section 1 - 14-16 July 1987															
run	8	414	5	4.00	143.8	5.3	1.9	0.2	0.0	0.0	0.0	9.7	0.0	0.7	161.6
riffle	8	522	6	4.40	81.0	2.7	0.6	0.0	0.0	0.0	0.0	4.0	0.0	1.7	90.0
pool	7	471	12	6.10	103.7	5.5	3.4	0.4	0.0	0.0	0.0	16.1	0.0	1.1	130.2
pocketwater	8	124	12	5.15	65.8	7.2	5.6	0.0	0.0	0.8	0.0	11.2	0.0	0.0	90.7
all types	31	1531	7	4.60	107.2	4.4	1.8	0.2	0.0	*	0.0	8.6	0.0	1.2	123.4
Section 2 - 14,16 July 1987															
run	10	328	17	3.40	68.5	1.2	1.2	7.0	0.0	0.3	0.0	6.1	0.0	1.8	86.2
riffle	10	398	17	3.35	28.1	0.5	0.0	2.8	0.0	0.0	0.0	1.2	0.0	2.2	34.9
pool	9	315	42	4.30	57.4	0.6	0.3	5.7	0.0	0.0	0.0	4.1	0.0	0.0	68.2
pocketwater	2	24	47	3.65	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	25.1
all types	31	1066	21	3.50	47.5	0.8	0.5	4.8	0.0	0.1	0.0	3.5	0.0	1.8	59.0
All sections - 1987															
run	18	742	8		129.0	4.5	1.8	1.6	0.0	*	0.0	9.0	0.0	0.9	146.8
riffle	18	921	8		69.6	2.2	0.4	0.6	0.0	0.0	0.0	3.4	0.0	1.8	78.1
pool	16	786	17		96.2	4.7	2.9	1.3	0.0	0.0	0.0	14.2	0.0	0.9	120.2
pocketwater	10	148	13		63.6	6.9	5.4	0.0	0.0	0.8	0.0	10.7	0.0	0.4	87.7
all types	62	2597	10	4.35	95.7	3.7	1.6	1.0	0.0	*	0.0	7.7	0.0	1.3	111.0
South Fork Grouse Creek															
Section 1 - 6 Sept. 1986															
run	8	206	24	4.00	42.2	9.2	0.0	1.4	0.0	0.5	0.0	0.0	0.5	0.0	53.8
riffle	8	141	4	2.75	34.0	2.8	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	39.0
pool	6	96	19	4.20	24.0	16.7	14.6	7.3	0.0	2.1	0.0	1.0	3.1	0.0	68.8
pocketwater	5	56	15	3.90	25.1	12.5	1.8	0.0	0.0	1.8	0.0	1.8	0.0	0.0	43.0
all types	27	499	10	3.20	33.7	6.1	1.7	2.4	0.0	0.4	0.0	0.2	0.4	0.0	45.0
Section 2 - 3 Aug. 1986															
run	4	62	11	3.55	69.3	4.8	0.0	8.0	0.0	1.6	0.0	0.0	0.0	0.0	83.8
riffle	2	54	8	2.05	24.1	3.7	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	29.6
pool	5	64	21	3.30	20.3	10.9	14.1	3.1	0.0	4.7	0.0	1.6	0.0	0.0	54.7
all types	11	180	12	2.85	39.8	5.6	2.8	4.4	0.0	1.5	0.0	0.3	0.0	0.0	54.4
All sections - 1986															
run	12	268	19		52.8	7.5	0.0	4.0	0.0	0.9	0.0	0.0	0.3	0.0	65.5
riffle	10	195	5		32.3	3.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0	37.3
pool	11	160	20		22.6	14.5	14.4	5.7	0.0	3.0	0.0	1.2	2.0	0.0	63.5
pocketwater	5	56	15		25.1	12.5	1.8	0.0	0.0	1.8	0.0	1.8	0.0	0.0	43.0
all types	38	679	11	3.10	35.2	6.0	1.9	2.8	0.0	0.7	0.0	0.3	0.3	0.0	47.2

Appendix C. (continued)

Stream Section - Date Habitat type	Habitat units snorkeled	Area sampled m²	Area sampled %	Mean width (m)	Mean fish densities (fish/100 m²) Salmo fry	Rainbow Age 1	Rainbow Age 2+	Cutthroat juveniles	Bull trout fry	Bull trout juv.	Bull trout adult	Brook trout	Unidentified salmonids	Other[a]	Total
South Fork Grouse Creek															
Section 1 - 21,30 Aug. 1987															
run	6	250	21	3.90	58.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	60.4
riffle	4	351	8	4.55	18.5	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.3	0.0	22.2
pool	6	227	32	5.35	47.5	0.0	0.4	15.0	0.0	0.4	0.0	0.0	0.4	0.0	63.8
all types	16	828	12	4.50	29.2	0.0	*	4.5	0.0	*	0.0	0.0	0.2	0.0	34.0
Rapid Lightning Creek															
Section 1 - 7 Sept. 1986															
run	4	473	5	6.20	60.8	2.7	0.2	0.6	0.0	0.0	0.0	0.0	1.0	4.0	69.5
riffle	3	252	3	6.95	32.1	1.2	0.0	0.4	0.0	0.4	0.0	0.0	0.4	3.6	38.1
pool	2	119	13	5.30	106.1	5.0	0.8	1.7	0.0	0.0	0.0	0.0	0.8	11.8	126.3
all types	9	844	5	6.50	51.3	2.2	0.2	0.6	0.0	0.2	0.0	0.0	0.8	4.2	59.4
Section 2 - 18 Aug. 1987															
run	8	1149	67	7.80	6.3	0.1	0.0	2.8	0.0	0.0	0.0	0.6	0.1	0.0	9.8
riffle	8	1612	8	7.20	2.8	0.0	0.0	0.9	0.0	0.0	0.0	0.2	0.2	0.0	4.2
pool	8	674	100	7.60	2.7	0.0	1.5	12.2	0.0	0.0	0.0	1.5	0.0	0.0	17.8
pocketwater	4	83	6	7.05	3.6	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	4.8
all types	27	3518	14	7.25	3.1	*	*	1.3	0.0	0.0	0.0	0.3	0.2	0.0	4.9
Section 3 - 18,24-25 1987															
run	8	823	12	5.50	24.4	0.0	0.0	11.5	0.0	0.0	0.0	17.5	0.0	0.0	53.4
riffle	7	804	4	4.70	11.6	0.0	0.0	5.1	0.0	0.0	0.0	5.3	0.0	0.2	22.3
pool	8	620	12	5.75	18.5	0.0	0.0	17.2	0.0	0.0	0.0	14.0	0.0	0.0	50.2
pocketwater	1	62	46	7.10	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6
all types	24	2310	8	5.10	15.7	0.0	0.0	8.7	0.0	0.0	0.0	9.6	0.0	0.1	34.2
Trestle Creek															
Section 1 - 24 July 1987															
run	8	478	34	5.90	0.6	0.2	0.8	2.5	0.2	0.8	0.0	0.0	0.0	0.6	5.8
riffle	7	651	4	6.50	0.2	0.5	0.2	0.9	0.0	0.8	0.0	0.0	0.0	0.3	2.8
pool	8	387	22	4.75	0.5	2.3	3.6	7.5	0.5	1.3	0.0	0.0	0.0	1.0	17.0
pocketwater	4	75	7	6.20	0.0	1.3	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	5.3
all types	27	1592	8	6.30	0.2	0.6	0.5	1.6	*	1.0	0.0	0.0	0.0	0.4	4.4
Section 2 - 25-26 July 1987															
run	8	629	72	5.65	0.3	0.6	0.0	5.1	0.0	0.3	0.5	0.0	0.0	0.2	7.0
riffle	13	1212	7	4.95	0.0	0.4	0.0	2.2	0.0	0.2	0.0	0.0	0.0	0.2	3.0
pool	20	650	24	5.70	0.0	0.2	0.2	10.3	0.0	0.9	3.1	0.0	0.2	0.0	14.8
pocketwater	1	14	2	4.65	0.0	0.0	0.0	13.9	0.0	0.0	0.0	0.0	0.0	0.0	13.9
all types	42	2505	11	5.05	*	0.4	*	3.7	0.0	0.3	0.4	0.0	*	0.1	5.0

Appendix C. (continued)

Stream Section - Date Habitat type	Habitat units snorkeled	Area sampled m²	Area sampled %	Mean width (m)	Salmo fry	Rainbow Age 1	Rainbow Age 2+	Cutthroat juveniles	Bull trout fry	Bull trout juv.	Bull trout adult	Brook trout	Unidentified salmonids	Other[a]	Total
					Mean fish densities (fish/100 m²)										
Trestle Creek															
Section 3 - 24-25 July 1987															
run	7	184	96	3.60	2.2	0.0	0.0	6.5	0.0	1.6	2.2	0.0	0.0	0.0	12.5
riffle	8	722	8	3.85	2.2	0.0	0.0	4.7	1.4	1.2	0.7	0.0	0.0	0.0	10.2
pool	18	311	26	4.10	3.2	0.0	0.0	10.0	0.0	1.6	15.7	0.0	0.0	0.0	30.8
pocketwater	5	31	13	3.50	3.2	0.0	0.0	6.5	0.0	3.2	0.0	0.0	0.0	0.0	13.0
all types	38	1248	11	3.85	2.3	0.0	0.0	5.4	1.2	1.3	2.3	0.0	0.0	0.0	12.6
All sections - 1987															
run	23	1292	53		0.6	0.3	0.5	3.7	0.1	0.7	0.3	0.0	0.0	0.4	6.8
riffle	28	2584	6		0.5	0.3	*	2.3	0.3	0.6	0.2	0.0	0.0	0.2	4.5
pool	46	1348	24		0.8	0.8	1.2	9.4	0.2	1.2	4.8	0.0	0.1	0.3	18.9
pocketwater	10	120	6		0.4	0.7	0.0	5.8	0.0	2.5	0.0	0.0	0.0	0.0	9.3
all types	107	5345	10	5.10	0.6	0.4	0.2	3.2	0.3	0.8	0.6	0.0	*	0.2	6.3
Lightning Creek															
Section 1 - 18 Aug. 1986															
run	4	1744	7	14.55	70.2	1.8	*	0.0	0.0	0.0	0.0	0.0	0.0	*	72.1
riffle	8	2470	3	10.30	39.4	4.4	1.0	0.0	0.0	*	0.0	0.1	*	0.1	45.1
pool	1	172	3	9.85	109.8	11.6	1.7	0.0	0.0	0.0	0.0	1.2	0.0	0.0	124.4
all types	13	4387	4	11.25	49.4	4.1	0.8	0.0	0.0	*	0.0	0.1	*	0.1	54.6
Section 2 - 21 Aug. 1986															
run	5	1098	12	9.40	61.8	2.6	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.0	64.8
riffle	9	2009	4	8.65	18.2	2.7	0.4	0.0	0.0	*	0.0	0.1	0.0	0.0	21.4
pool	2	112	6	5.85	117.8	20.5	7.1	0.0	0.0	0.0	0.0	3.6	0.0	0.0	149.0
pocketwater	4	231	5	11.10	44.1	3.9	1.7	0.4	0.0	0.0	0.0	0.4	0.0	0.0	50.6
all types	20	3450	5	8.85	28.0	3.2	0.6	*	0.0	*	0.0	0.2	0.0	0.0	32.1
Section 3 - 6,9 Sept. 1986															
run	5	524	62	6.80	20.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.2
riffle	4	234	3	5.05	6.4	0.8	0.4	0.0	0.0	0.0	0.8	0.0	0.0	0.4	9.0
pool	2	118	41	5.95	25.5	0.8	0.8	0.0	0.8	0.0	0.0	0.0	0.8	0.0	29.7
pocketwater	1	196	18	11.65	13.3	0.5	0.0	1.5	1.0	0.5	0.0	0.0	0.0	0.0	16.8
all types	12	1072	11	6.00	9.0	0.8	0.4	0.2	0.1	*	0.6	0.0	*	0.3	11.5
All sections - 1986															
run	14	3366	10		66.6	2.0	*	0.0	0.0	*	0.0	0.1	0.0	*	68.8
riffle	21	4714	3		29.2	3.6	0.8	0.0	0.0	*	*	0.1	*	0.1	33.8
pool	5	402	6		108.4	13.5	3.1	0.0	*	0.0	0.0	1.7	*	0.0	126.8
pocketwater	5	427	7		38.6	3.3	1.4	0.6	0.2	0.1	0.0	0.4	0.0	0.0	44.5
all types	45	8909	5	11.95	39.1	3.6	0.7	*	*	*	*	0.1	*	0.1	43.8

Appendix C. (continued)

Stream Section - Date Habitat type	Habitat units snorkeled	Area sampled m²	Area sampled %	Mean width (m)	Mean fish densities (fish/100 m²): Salmo fry	Rainbow Age 1	Rainbow Age 2+	Cutthroat juveniles	Bull trout fry	Bull trout juv.	Bull trout adult	Brook trout	Unidentified salmonids	Other[a]	Total
East Fork Lightning Creek															
Section 1 - 12,22,26 Aug. 1987															
run	8	756	72	6.00	15.7	0.1	0.0	0.4	0.0	0.0	0.0	0.0	0.1	0.0	16.4
riffle	8	1437	21	6.25	15.0	0.2	0.4	0.3	0.0	0.0	0.0	0.1	0.1	0.0	16.0
pool	5	493	70	6.65	21.5	0.6	2.8	2.2	0.0	0.0	0.0	0.4	0.6	0.0	28.2
all types	21	2687	31	6.25	15.6	0.2	0.6	0.4	0.0	0.0	0.0	0.1	0.1	0.0	17.0
Section 2 - 9,12 Aug. 1987															
run	8	829	55	6.15	25.3	0.1	0.2	0.7	0.1	0.1	0.0	0.0	0.0	0.0	26.6
riffle	8	1409	12	6.25	9.4	0.0	0.5	0.8	0.1	0.4	0.0	0.0	0.0	0.0	11.1
pool	8	554	23	5.85	9.0	0.2	2.0	2.2	0.4	0.9	0.9	0.0	0.7	0.2	16.6
pocketwater	4	83	10	5.50	12.1	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	15.7
all types	28	2875	17	6.15	10.9	*	0.6	1.1	0.1	0.4	0.1	0.0	0.1	*	13.5
Section 3 - 9 Aug. 1987															
run	7	295	81	4.70	3.0	0.0	0.0	3.7	0.0	0.7	0.0	0.0	0.0	0.0	7.5
riffle	8	534	16	4.35	1.9	0.4	0.4	1.5	0.0	0.6	0.0	0.0	0.4	0.0	5.0
pool	7	362	22	5.45	0.8	0.3	0.8	3.9	0.8	1.1	1.9	0.0	0.3	0.0	10.2
all types	22	1190	22	4.70	1.6	0.3	0.5	2.4	0.2	0.7	0.6	0.0	0.3	0.0	6.8
All sections - 1987															
run	23	1880	64		19.1	0.1	0.1	1.0	0.1	0.1	0.0	0.0	*	0.0	20.6
riffle	24	3380	15		9.9	0.1	0.4	0.7	*	0.3	0.0	*	0.1	0.0	11.6
pool	20	1410	30		8.0	0.3	1.7	2.8	0.5	0.8	1.1	0.1	0.5	0.1	16.1
pocketwater	4	83	7		11.8	0.1	0.2	2.8	*	0.1	*	*	*	0.0	15.1
all types	71	6753	22	5.85	10.6	0.1	0.6	1.2	0.1	0.3	0.2	*	0.1	*	13.3
Johnson Creek															
Section 1 - 25 Aug. 1987															
run	4	228	30	5.10	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.4
riffle	6	829	20	4.95	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
pool	6	237	39	5.95	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4
all types	16	1294	22	5.05	0.0	0.0	0.0	0.0	0.1	0.0	*	0.0	0.0	0.0	0.2
Twin Creek															
Section 1 - 20-21 July 1987															
run	8	1635	68	8.95	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	4.8
riffle	8	985	13	5.00	0.3	0.1	0.3	0.0	0.0	0.0	0.0	0.5	0.1	2.8	4.2
pool	8	1269	71	7.70	2.4	0.1	0.6	0.0	0.0	0.0	0.0	0.2	0.0	0.0	3.2
all types	24	3889	32	6.10	1.4	0.1	0.3	0.0	0.0	0.0	0.0	0.4	0.1	2.0	4.2

Appendix C. (continued)

Stream Section - Date Habitat type	Habitat units snorkeled	Area sampled m²	Area sampled %	Mean width (m)	Salmo fry	Rainbow Age 1	Rainbow Age 2+	Cutthroat juveniles	Bull trout fry	Bull trout juv.	Bull trout adult	Brook trout	Unidentified salmonids	Other[a]	Total
Twin Creek															
Section 2 - 20-21,26 July 1987															
run	8	270	36	3.55	140.8	1.5	2.2	6.3	0.0	0.0	0.0	38.5	0.0	0.0	189.4
riffle	8	401	11	3.15	40.2	0.0	0.7	2.2	0.0	0.0	0.0	7.2	1.5	0.0	51.9
pool	8	156	40	4.50	139.6	1.9	6.4	33.9	0.0	0.6	0.0	40.3	1.9	0.0	226.0
pocketwater	8	57	28	3.55	26.1	5.2	8.7	7.0	0.0	0.0	0.0	12.2	0.0	0.0	59.2
all types	32	884	18	3.30	63.1	0.6	1.8	5.6	0.0	*	0.0	14.9	1.2	0.0	87.5
All sections - 1987															
run	16	1905	60		37.1	0.4	0.5	1.5	0.0	0.0	0.0	9.2	0.0	0.0	48.6
riffle	16	1386	12		12.7	0.1	0.4	0.7	0.0	0.0	0.0	2.6	0.5	2.0	19.0
pool	16	1425	62		40.2	0.6	2.2	9.4	0.0	0.2	0.0	11.2	0.5	0.0	64.6
pocketwater	8	57	28		26.1	5.2	8.7	7.0	0.0	0.0	0.0	12.2	0.0	0.0	59.2
all types	56	4773	25	4.85	20.1	0.2	0.7	1.7	0.0	*	0.0	4.8	0.4	1.4	29.4
Granite Creek															
Section 1 - 20 Aug. 1987															
run	8	816	25	5.55	1.6	0.0	0.0	3.3	0.0	1.0	0.0	0.0	0.0	0.6	6.5
riffle	8	1077	15	5.60	4.5	0.0	0.0	0.6	0.1	0.7	0.0	0.0	0.0	0.3	6.3
pool	7	413	14	6.90	4.6	0.0	0.0	5.1	0.7	2.7	0.0	0.0	0.0	0.2	13.5
all types	23	2306	17	5.85	3.8	0.0	0.0	2.3	0.2	1.2	0.0	0.0	0.0	0.4	8.0
Section 2 - 19-20 Aug. 1987															
run	8	357	62	4.70	2.0	0.0	0.0	5.0	0.0	3.1	0.0	0.0	0.0	0.3	10.4
riffle	8	1139	23	5.20	3.4	0.0	0.0	3.0	0.2	2.7	0.1	0.0	0.0	0.1	9.6
pool	10	497	52	5.05	2.6	0.0	0.2	12.5	0.0	4.0	0.4	0.0	0.0	0.2	20.5
all types	26	1993	30	5.10	3.2	0.0	*	4.6	0.1	2.9	0.1	0.0	0.0	0.1	11.2
Section 3 - 19 Aug. 1987															
run	5	263	40	5.30	0.0	0.0	0.0	1.5	0.0	1.5	0.0	0.0	0.0	0.0	3.0
riffle	8	950	13	5.05	0.0	0.0	0.0	1.4	0.0	0.6	0.1	0.0	0.0	0.0	2.1
pool	8	302	33	4.60	0.0	0.0	0.0	4.6	0.0	1.0	1.6	0.0	0.0	0.0	8.0
all types	21	1514	16	5.00	0.0	0.0	0.0	1.7	0.0	0.7	0.2	0.0	0.0	0.0	2.8
All sections - 1987															
run	21	1435	32		1.4	0.0	0.0	3.3	0.0	1.3	0.0	0.0	0.0	0.5	6.5
riffle	24	3166	16		2.5	0.0	0.0	1.5	0.1	1.2	0.1	0.0	0.0	0.1	5.5
pool	25	1212	25		3.3	0.0	*	6.5	0.4	2.6	0.4	0.0	0.0	0.2	13.9
all types	70	5814	20	5.40	2.4	0.0	*	2.6	0.1	1.4	0.1	0.0	0.0	0.2	7.0

Mean fish densities (fish/100 m²) span the columns Salmo fry through Total.

a sculpin, longnose dace, shiner, mountain whitefish
* area weighted mean fish densities less than 0.1 fish/100 m²

APPENDIX D

1983 and 1984 Tributary Fish Densities

Appendix F. Summary of fish distribution and relative abundance (fish/100 m^2) data collected during the 1983 and 1984 field seasons in tributaries to the eastern and northern shores of Pend Oreille Lake, Idaho.

Stream	Reach	Date	Water Temp. ° C	Unidentified salmo	Rainbow	Cutthroat	Brown trout	Unidentified salvelinus	Bull trout	Brook trout	Other	Total
Eastside tributaries												
Falls		9-7-83	9.5	-.-	-.-	-.-	—	-.-	-.-	2.3	-.-	2.3
Cedar		9-7-83	12.0	-.-	-.-	-.-	—	-.-	-.-	5.8	-.-	5.8
Granite		8-14-84	9.5	2.8	2.1	1.4	—	0.7	5.5	-.-	-.-	12.5
		8-27-83	12.0	-.-	14.4	2.0	—	-.-	7.6	-.-	-.-	24.0
		9-7-83	8.5	-.-	0.5	1.6	—	-.-	1.6	-.-	-.-	3.7
		8-14-84	14.0	-.-	33.4	0.4	—	-.-	0.9	0.4	-.-	35.1
		8-14-84	9.0	1.5*	41.2	0.7	—	-.-	5.9	0.4	2.2	51.9
Sullivan Springs		8-14-84	8.0	-.-	6.2	-.-	—	-.-	1.1	-.-	2.6	9.9
North Gold		8-12-83	9.0	-.-	-.-	55.6	—	-.-	-.-	-.-	-.-	55.6
		8-8-84	8.0	1.2	-.-	0.6	—	-.-	0.6	-.-	-.-	2.4
		8-8-84	8.0	0.6	1.1	-.-	—	-.-	5.0	-.-	-.-	6.7
South Gold		8-26-84	8.5	-.-	2.9	2.3	—	-.-	5.2	-.-	-.-	10.4
		8-8-84	11.0	-.-	5.5	1.1	—	-.-	8.8	-.-	5.5	20.9
		8-12-83	11.0	2.1	-.-	-.-	—	-.-	2.8	-.-	-.-	4.9
		8-8-84	11.0	0.8	2.0	2.3	—	-.-	-.-	-.-	0.5[a]	5.6
West Gold		8-12-83	8.0	-.-	-.-	43.1	—	-.-	-.-	-.-	-.-	43.1
Northside tributaries												
Trestle		8-11-83	11.0	-.-	-.-	-.-	—	-.-	-.-	-.-	-.-	0.0
		7-17-84	10.0	0.6	2.2	-.-	—	-.-	7.3	-.-	-.-	10.1
		7-17-84	9.0	-.-	-.-	3.4	—	-.-	5.0	-.-	-.-	8.4
		8-16-83	12.0	-.-	-.-	1.5	—	-.-	1.5	-.-	-.-	3.0
Tributary		7-17-84	-.-	-.-	-.-	-.-	—	-.-	17.3	-.-	-.-	17.3
Tributary		7-17-84	10.0	-.-	-.-	-.-	—	-.-	-.-	-.-	-.-	0.0
Tributary		7-17-84	10.0	-.-	-.-	-.-	—	-.-	-.-	-.-	-.-	0.0
Sandpoint Creek		9-6-83	15.0	4.4	4.4	2.9	—	-.-	-.-	23.3	19.0[a,b]	54.0
Spring Jack		8-24-83	15.0	-.-	-.-	-.-	—	-.-	-.-	-.-	-.-	0.0
Schweitzer		9-6-83	10.0	1.3	15.4	3.8	—	-.-	-.-	5.1	-.-	25.6
Little Sand		9-6-83	11.0	1.0	10.1	1.0	—	-.-	-.-	-.-	-.-	12.1
		9-6-83	11.0	6.7	15.7	17.9	—	-.-	-.-	-.-	-.-	40.3
Riser		7-18-84	12.0	-.-	-.-	1.2	—	-.-	-.-	-.-	-.-	1.2
Strong		7-18-84	11.0	-.-	-.-	13.5	—	-.-	-.-	-.-	-.-	13.5

[a]Mountain whitefish

[b]Sucker squawfish

Appendix F. Summary of fish distribution and relative abundance (fish/100 m^2) data collected during the 1983 and 1984 field seasons in tributaries to the Clark Fork River, Pend Oreille drainage, Idaho.

Stream	Reach	Date	Water Temp. °C	Unidentified salmo	Rainbow	Cutthroat	Brown trout	Unidentified salvelinus	Bull trout	Brook trout	Other	Total
Clark Fork tributaries												
Mosquito		7-30-84	9.0	1.3[a]	2.6	2.6	—	—	—	13.2	—	19.7
		7-30-84	13.0	—	1.7	—	—	—	—	33.0	.3	35.0
Twin[a]		8-15-84	13.0	—	120.9	2.4	3.6	—	1.2	7.1	—	135.1
		9-8-83	11.0	—	92.6	1.5	—	—	4.6	128.1	—	274.6
		8-15-84	13.0	—	47.2	—	44.6	—	—	26.2	—	118.0
		9-8-83	10.0	—	58.0	9.7	34.1	—	17.0	204.4	—	321.2
		8-15-84	11.0	—	16.0	0.9	5.4	—	2.3	44.3	29.8	98.6
		7-19-84	13.0	1.8	10.2	2.4	3.0		2.4	32.3	2.4	54.5
Johnson		8-13-84	7.5	—	1.2	7.7	—	—	1.2	—	—	10.1
		8-31-83	10.0	—	2.6	0.6	—	—	4.5	—	—	7.7
Lightning	Quartz	8-18-83	10.0	—	—	2.2	—	—	—	—	—	2.2
	Pools	7-27-84	14.0	0.4*	—	3.5	—	—	2.1	—	1.8	7.8
	Above Rattle	8-18-83	12.5	0.2	4.0	5.0	—	—	0.2	0.2	—	9.6
		8-24-84	14.5	0.5	35.3	4.2	—	0.2	1.9	0.5	0.2	42.8
	Porcupine											
		8-9-83	15.0	—	2.6	—	—	—	0.2	0.1	—	2.9
		7-27-84	19.0	—	72.6=fry 1.8=juv.	0.2	—	—	1.2	0.7	0.4	76.9
		8-24-84	17.0	—	85.4	1.4	—	—	—	0.5	—	87.3
		8-22-83	15.0	—	8.9	—	—	—	—	0.4	0.5[a]	9.8
		7-16-84	18.0	—	4.7	—	—	—	—	2.3	1.8	8.8
		7-16-84	18.0	—	3.8	—	—	—	—	—	1.5	5.3
Spring	Run	7-10-84	11.0	—	77.0+	1.4	—	—	—	—	—	78.4
	Pool	7-10-84	11.0	—	18.2	2.2	0.3	—	—	0.2	1.8	22.7
Spawning channel		7-19-84	9.5	33.1	31.0	—	—	18.2	—	—	—	82.3
Cascade	Web Canyon	7-31-84	14.0	42.6	7.8	1.9	—	—	—	25.2	—	77.5
Horn's		8-31-83	—	1.8	14.1	6.2	—	—	—	—	—	22.1
East Fork		7-19-84	12.0	0.8*	2.2	2.2	—	—	16.1	—	—	21.1
		7-19-84	12.0	3.3*	—	3.3	—	—	13.6	—	—	20.2
		8-9-83	—	1.2	4.4	1.2	—	—	4.8	0.6	0.6[c]	12.8
		8-22-84	14.0	—	8.8	1.8			1.8	0.6	0.3[c]	13.3

Appendix F. (Continued)

Stream	Reach	Date	Water Temp. ° C	Unidentified salmo	Rainbow	Cutthroat	Brown trout	Unidentified salvelinus	Bull trout	Brook trout	Other	Total
Charr		7-19-84	9.0	1.2*	1.2	0.6	—	—	8.0	—	—	11.0
Savage		8-31-83	—	1.2	3.3	4.6	—	—	0.4	—	—	9.5
		7-19-84	12.0	—	3.2	—	—	—	1.9	—	—	5.1
Porcupine		7-31-81	13.0	—	—	—	—	—	—	13.0	—	13.0
		7-31-84	13.0	—	—	—	—	—	—	18.8	—	18.8
		8-10-83	14.0	1.1	2.5	1.4	—	—	1.4	0.4	0.3[c]	7.1
		7-31-84	14.0	1.6	1.8	0.9	—	—	7.1	—	0.8	12.1
Wellington		7-27-84	14.0	0.5*	0.3	12.8	—	—	—	—	0.3[c]	13.9
		8-18-83	12.0	—	2.1	2.4	—	—	2.1	2.1	—	8.7
		7-26-84	14.0	0.5*	1.9	0.3	—	—	2.8	1.1	1.8[a,c]	8.3
Rattle		8-5-83	—	—	—	3.1	—	—	—	—	—	3.1
		8-16-83	10.0	—	—	51.8	—	—	—	—	—	51.8
		8-16-83	11.0	—	—	8.4	—	—	3.0	—	—	11.4
	Pool	7-26-84	13.0	—	—	17.3	—	—	14.4	—	—	31.7
	Run	7-28-84	14.0	—	—	5.0	—	—	6.2	—	—	11.2
		8-9-83	—	0.8	2.8	—	—	—	—	—	—	3.6
		7-28-84	16	—	1.3	—	—	—	2.4	—	0.3[c]	4.0
Benning Mt. tributary		7-28-84	13°	—	—	12.2	—	—	—	—	—	12.2

[a]Mountain whitefish
[b]Sucker/squawfish
[c]Sculpin
*Cutthroat /rainbow hybrid
+Difficult to distinguish between rainbow and cutthroat fry

RBA DH

App…dix F. Summary of fish distribution and relative abundance (f…/100 m^2) data collected during the 1983 and 1984 field season in the Pack River and its tributaries, Pend Oreille drainage, Idaho.

Stream	Reach	Date	Water Temp. °C	Unidentified salmo	Rainbow	Cutthroat	Brown trout	Unidentified salvelinus	Bull trout	Brook trout	Other	Total
Pack River drainage												
Pack River		8-17-83	11.0	0.3	0.3	6.7	—	—	—	—	—	7.3
		8-19-83	16.0	—	—	11.6	—	—	2.4	—	—	14.0
		7-25-84	12.5	0.7	—	7.0	—	—	3.5	—	—	11.2
		8-19-83	16.0	—	—	14.8	—	—	2.2	—	—	17.0
		8-23-83	15.0	—	19.2	0.2	—	—	—	0.2	1.0[a]	20.6
		8-23-83	15.0	—	55.3	0.4	—	—	—	0.7	9.3[b,c]	65.7
		7-25-84	22		121.2	—	—	—	—	0.2	15.1[d]	136.5
		7-25-84	15-22	—	45.4	0.1	—	—	—	—	7.5[b]	53.0
Trout		8-15-84	—	—	—	0.6	—	—	—	—	—	0.6
		8-16-83	14.0	41.9	—	2.3	—	—	—	—	—	44.2
Rapid Lightning		8-25-83	15.0	—	0.4	7.3	—	—	—	0.7	1.1[a]	9.5
		8-1-84	21.0	2.0	42.7	3.0	—	—	—	1.0	7.9	56.6
		8-1-84	21.0	—	110.9	—	—	—	—	0.4	13.4	124.7
Gold		9-8-84	15.0	—	1.1	—	—	—	—	—	13.9[a]	15.0
Grouse												
		7-24-84	15.0	—	1.0	3.8	—	—	5.4	0.3	—	10.5
		8-15-83	10.0	—	63.4	—	—	—	0.8	—	—	64.2
		8-15-84	16.0	—	18.9	—	—	—	0.2	0.6	1.2	20.9
		8-6-84	18.0	—	67.2					1.0	0.5	68.7
		8-9-84	19.0	0.5	56.6	—	—	—	—	0.6	2.7[f]	60.4
		8-15-83	22.0	—	38.4	0.2	—	—	—	—	1.6[f]	40.2
North Fork		8-24-84	10.0	—	99.0	—	—	0.7	—	4.2	2.1	106.0
		8-25-83	15.0	—	53.2	0.6	—	—	—	0.4	1.1[a]	55.3
		8-9-84	19.0	—	110.4	—	—	—	—	3.0	—	113.4
		8-6-84	—	—	126.4	—	—	—	—	1.2	0.6	128.2
Plank		7-24-84	14.0	0.7*	—	5.0	—	—	—	—	—	5.7
Chute		7-24-84	14.0	—	—	24.6	—	—	—	—	—	24.6
Sand		8-25-83	12.5	—	5.4	8.6	—	—	—	42.9	—	56.9
		8-25-83	15.0	—	—	—	—	—	—	—	32.0	32.0

Stream	Reach	Date	Water Temp. ° C	Unidentified salmo	Rainbow	Cutthroat	Brown trout	Unidentified salvelinus	Bull trout	Brook trout	Other	Total
Berry		8-30-83	15.0	—	12.5	4.0	—	—	—	1.1	—	17.6
Colburn		8-24-83	12.5	—	5.1	0.8	—	—	—	0.3	—	6.2
Caribou		8-30-83	13.0	—	4.4	12.7	—	—	—	—	—	17.1
		8-30-83	14.0	4.4	20.9	1.3	—	—	—	—	—	26.6
Hellroaring		8-30-83	14.0	—	9.8	—	—	—	—	—	—	9.8
Jaru		8-17-83	14.0	—	—	38.0	—	—	—	0.9	—	38.9
Youngs		8-17-83	18.0	—	—	32.2	—	—	—	—	—	32.2
McCormick		8-1-84	16.0	—	—	16.3	—	—	—	—	—	16.3
		8-17-83	17.5	—	—	0.9	—	—	—	—	—	0.9

[a] Mountain squawfish
[b] Squawfish/sucker
[c] Sculpin
[d] Unidentified fry/larval fish
[e] Redside shiners
[f] Mountain whitefish, squawfish, sucker, sculpin

APPENDIX E

Number of Anglers, Effort, and Harvest

Appendix E-1. Estimated minimum number of anglers, effort, and harvest by year, Pend Oreille Lake, Idaho, from 1951 to 1980 and 1985.

Year	Anglers	Hours	Kokanee	Rainbow trout	Bull trout	Cutthroat trout	Whitefish	Spiny-rayed[a]	Other game	Non-game	Total
1951	60,172	330,923	820,486	678	1,775	5,271	3,017	18,838			850,065
1952	57,814	308,850	514,913	535	2,393	5,850	1,172				524,863
1953	99,855	522,692	1,335,881	3,158	5,035	8,201	6,393	66,666	468	5,064	1,430,866
1954	90,566	459,271	1,232,916	2,534	3,660	5,322	8,146	44,216	845	7,915	1,305,554
1955	67,645	327,551	650,375	2,594	3,811	4,982	1,375	17,840	226	9,137	690,340
1956	87,813	406,538	1,092,651	3,251	3,288	5,343	9,121	17,274	804	15,421	1,147,153
1957	72,355	331,476	751,113	2,938	2,117	5,138	9,141	30,249	4,910	9,766	815,372
1958	88,453	400,683	1,197,426	5,286	1,348	5,881	1,678	91,567	4,573	16,465	1,324,224
1959	75,057	345,406	1,161,913	4,906	1,677	3,659	1,255	14,883	1,212	3,335	1,192,840
1960	77,162	372,266	1,039,200	9,626	2,616	3,730	959	7,236	1,208	1,891	1,066,466
1961	81,387	384,702	991,955	5,355	966	2,641	198	7,532	271	2,563	1,011,481
1962	59,379	274,554	650,960	6,556	1,434	2,615	780	16,824	289	3,031	682,489
1963	72,221	350,128	1,049,339	10,323	1,049	3,069	801	5,353	416	1,200	1,071,550
1964	66,225	314,220	1,162,625	4,942	929	1,757	408	1,896	0	485	1,173,042
1965	58,263	281,230	1,007,292	4,763	1,460	1,744	476	5,646	212	390	1,021,983
1966	65,340	295,781	808,744	4,978	1,199	2,040	320	2,184	85	6	819,556
1967	54,699	245,837	710,312	3,349	657	788	177	4,396	0	178	719,857
1968	55,414	242,859	618,405	4,169	624	782	153	1,374	66	0	625,573
1969	45,025	197,202	483,292	3,297	862	954	685	2,314	7	7	491,418
1970	61,815	261,785	654,848	4,419	640	1,256	829	3,857	31	1,239	667,119
1971	60,137	265,514	590,058	4,462	967	965	2,320	2,306	62	1,190	602,330
1972	50,506	222,908	521,048	3,384	928	1,114	2,368	439	20	255	529,556
1973	46,582	211,034	328,739	4,422	751	973	1,170	1,413	35	71	337,574
1974	49,206	226,973	319,286	4,337	847	500	1,582	582	20	148	327,302
1975	58,323	262,605	438,382	3,671	838	1,250	677	977	59	212	446,066
1976	53,705	241,736	218,639	5,868	1,253	814	333	193	111	280	227,491
1977	50,554	228,512	238,548	5,861	1,251	896	257	334	74	122	247,343
1978	48,470	226,453	167,640	6,878	1,469	813	234	914	76	111	178,135
1979	57,674	253,518	198,844	10,133	1,218	666					
1980	53,219	250,812	184,139	8,157	1,729	724	268	1,580	186	192	196,975
1985	36,446	179,229	72,358	6,048	915	664	628	401	437	95	81,546

a 1953 to 1970 values based on the harvest of yellow perch, black crappie, and largemouth bass

Appendix E-2. Estimated minimum number of resident sport anglers, effort, and harvest by year, Pend Oreille Lake, Idaho, from 1952 to 1980 and 1985.

Year	Anglers	Hours	Kokanee	Rainbow trout	Bull trout	Cutthroat trout	Whitefish	Spiny-rayed[a]	Other game	Non-game	Total
1952	26,836	133,539	183,657	265	1,475	2,486	642				188,525
1953	47,786	234,173	412,288	1,588	2,696	3,251	4,836	62,603	273	3,428	490,963
1954	40,956	189,920	326,568	1,431	1,780	1,964	6,314	42,641	414	5,551	386,663
1955	31,386	139,639	181,492	1,111	1,790	1,797	1,014	17,188	226	7,342	211,960
1956	45,432	196,226	423,092	1,431	1,599	2,233	8,029	16,158	744	12,810	466,096
1957	35,207	148,236	256,280	1,173	1,016	1,723	8,748	26,859	4,032	7,749	307,580
1958	45,532	192,199	365,082	2,570	819	2,377	1,148	89,068	4,408	13,499	478,971
1959	36,671	162,296	377,065	2,596	946	1,974	995	12,680	867	2,542	399,665
1960	35,564	162,531	320,041	4,450	1,752	1,529	641	6,232	868	1,177	336,690
1961	33,648	156,142	257,362	2,367	555	1,544	178	4,427	139	1,779	268,351
1962	23,656	108,380	168,847	2,725	954	992	621	13,871	254	1,852	190,116
1963	31,788	154,371	359,677	4,821	492	1,646	650	3,912	262	848	372,308
1964	26,703	125,842	357,152	2,090	382	699	345	1,419	0	205	362,292
1965	27,440	128,817	385,007	2,183	617	762	156	5,202	79	127	394,133
1966	24,710	113,085	220,317	2,823	504	833	226	1,784	85	0	226,572
1967	20,564	95,147	218,629	1,260	344	408	151	4,369	0	178	225,339
1968	18,379	83,200	207,058	2,078	285	427	30	694	36	0	210,608
1969	17,549	83,349	180,294	1,334	496	418	413	1,580	7	7	184,549
1970	21,944	91,878	173,672	1,778	321	432	611	3,534	18	1,108	181,474
1971	23,751	107,753	189,377	2,265	496	409	1,284	1,689	23	481	196,024
1972	21,214	96,097	172,952	1,677	437	584	1,378	255	9	117	177,409
1973	19,929	92,099	127,291	2,312	568	674	1,086	1,275	20	39	133,265
1974	22,124	104,936	132,981	1,948	465	210	1,417	485	14	122	137,642
1975	26,291	121,425	208,347	1,788	374	754	487	873	47	18	212,688
1976	20,179	92,724	67,932	2,146	653	430	246	146	18	153	71,724
1977	20,740	98,812	72,616	2,925	885	429	141	247	30	48	77,321
1978	22,163	108,167	62,100	3,471	1,167	481	156	416	57	89	67,937
1979	26,327	122,025	78,343								
1980	25,524	125,794	75,002	4,331	1,305	422	127	879	105	140	82,311
1985	20,302	104,890									

a 1953 to 1970 values based on the harvest of yellow perch, black crappie, and largemouth bass

Appendix E-3. Estimated minimum number of non-resident sport anglers, effort, and harvest by year, Pend Oreille Lake, Idaho, from 1952 to 1980 and 1985.

Year	Anglers	Hours	Kokanee	Rainbow trout	Bull trout	Cutthroat trout	Whitefish	Spiny-rayed[a]	Other game	Non-game	Total
1952	30,051	169,372	268,116	262	884	3,353	443				273,058
1953	44,877	242,764	382,593	1,570	2,339	4,950	472	4,063	195	1,636	397,818
1954	41,619	221,512	362,844	1,103	1,880	3,358	398	1,575	431	2,364	373,953
1955	32,257	163,819	228,610	1,483	2,021	3,185	162	652	0	1,795	237,908
1956	38,006	181,397	240,294	1,820	1,689	3,110	650	1,116	60	2,611	251,350
1957	34,229	165,556	277,699	1,765	1,101	3,415	151	3,390	878	2,017	290,416
1958	36,862	171,033	359,132	2,706	529	3,504	221	2,499	165	2,966	371,722
1959	34,914	162,830	332,001	2,310	731	1,685	214	2,203	345	772	340,261
1960	36,385	176,806	278,571	5,176	864	2,201	81	1,004	340	714	288,951
1961	42,453	192,610	305,361	2,988	411	1,097	20	3,105	132	628	313,742
1962	31,348	138,339	190,039	3,831	480	1,623	14	2,953	35	1,139	200,114
1963	35,805	165,126	314,291	5,502	557	1,423	25	1,441	154	6	323,399
1964	35,295	164,446	452,962	2,852	547	1,058	28	449	0	280	458,176
1965	26,256	126,334	319,034	2,573	747	982	119	437	133	73	324,098
1966	37,976	166,206	351,403	2,155	695	1,200	66	400	0	6	355,925
1967	31,559	133,442	290,081	2,082	306	380	26	27	0	0	292,902
1968	35,492	150,157	288,454	2,091	339	355	117	680	30	0	292,066
1969	26,606	109,106	242,109	1,957	366	536	248	716	0	0	245,932
1970	37,715	157,446	367,981	2,641	319	824	211	323	13	131	372,443
1971	33,790	141,844	242,383	2,156	456	544	299	594	39	76	246,547
1972	26,971	113,475	186,499	1,705	489	530	382	171	11	18	189,805
1973	25,873	115,292	195,767	2,110	183	299	84	138	15	32	198,628
1974	27,082	122,037	186,305	2,389	382	290	165	97	6	26	189,660
1975	32,032	141,180	230,035	1,883	464	496	190	104	12	194	233,378
1976	33,526	149,012	150,707	3,722	600	384	87	47	93	127	155,767
1977	29,814	129,700	165,932	2,936	366	467	116	87	44	74	170,022
1978	26,307	118,286	105,540	3,407	302	332	78	498	19	22	110,198
1979	31,347	131,493	120,501								
1980	27,695	125,018	109,137	3,826	424	302	141	701	81	52	114,664
1985	16,144	74,339									

a 1953 to 1970 values based on the harvest of yellow perch, black crappie, and largemouth bass

Appendix E-4. Estimated minimum number of commercial anglers, effort, and harvest by year, Pend Oreille Lake, Idaho, from 1951 to 1973. Commercial fishery was closed on 31 March, 1973.

Year	Anglers	Hours	Kokanee	Rainbow trout	Bull trout	Cutthroat trout	Whitefish	Spiny-rayed[a]	Other game	Non-game	Total
1951			170,500								170,500
1952	927	5,939	63,140	8	34	11	87				63,280
1953	7,192	45,755	541,000				1,085				542,085
1954	7,991	47,839	543,504				1,434				544,938
1955	4,002	24,093	240,273				199				240,472
1956	4,375	28,915	429,265				442				429,707
1957	2,919	17,684	217,134				242				217,376
1958	6,059	37,451	473,212				319				473,531
1959	3,472	20,280	452,847				46			21	452,914
1960	5,213	32,929	440,588				237				440,825
1961	5,286	35,950	429,232				0			156	429,388
1962	4,375	27,835	292,074				145			40	292,259
1963	4,628	30,631	375,371				126			346	375,843
1964	4,227	23,932	352,511				35	28			352,574
1965	4,567	26,079	303,251	7	96		201	7		190	303,752
1966	2,654	16,490	237,024			7	28				237,059
1967	2,576	17,248	201,602	7	7		0				201,616
1968	1,543	9,502	122,893				6				122,899
1969	870	4,747	60,889	6			24	18			60,937
1970	2,156	12,461	113,195				7				113,202
1971	2,596	15,917	158,298	41	15	12	737	23		633	159,759
1972	2,321	13,336	161,597	2	2		608	13		120	162,342
1973	780	3,643	5,681								5,681

a 1953 to 1970 values based on the harvest of yellow perch, black crappie, and largemouth bass