Flathead Drainage

789

Fraley F-07-27 #85071

**John J. Fraley** and **Bradley B. Shepard,** Montana Department of Fish, Wildlife and Parks
P.O. Box 67, Kalispell, Montana 59903

# Life History, Ecology and Population Status of Migratory Bull Trout (*Salvelinus confluentus*) in the Flathead Lake and River System, Montana

## Abstract

Life history, ecology, and population trends of migratory bull trout (*Salvelinus confluentus*) were investigated in the Flathead Lake and River system of northwest Montana and southeast British Columbia. We conducted these studies to obtain information to manage the species in light of threats posed by timber harvest, hydropower development, and a proposed coal mine. We estimated that about half the adult bull trout in Flathead Lake embarked on a spawning migration from May through July, swimming 88-250 km to reach tributaries of the North and Middle Forks of the Flathead River. Bull trout entered the tributaries when water temperatures dropped below 12°C, and spawned from late August through early October after water temperatures were below 9°C. They spawned in areas of tributaries with low gradient, loosely compacted gravel, groundwater influence, and cover. After spawning, females left the tributaries and returned to the lake sooner than males. Most spawners were six or seven years old and they averaged 628 mm in length. Juveniles were found close to the substrate in streams with summer maximum temperatures less than 15°C. Juveniles migrated out of the tributaries to the river system from June through August, at age I (18%), II (49%), III (32%), and IV (1%). Population status was monitored through redd counts and estimates of juvenile abundance in natal tributaries. The population may be limited by quantity and quality of rearing and spawning habitat, and spawning escapement. Specific requirements for spawning and rearing habitat, and general sensitivity of each life stage, make the bull trout an excellent indicator of environmental disturbance.

## Introduction

The bull trout (*Salvelinus confluentus*) is the largest species of fish native to the Flathead drainage, attaining a length of nearly one meter and a weight of 10 kg. The bull trout inhabiting the inland waters of northwestern North America is considered a separate species from the smaller, coastal Dolly Varden (*Salvelinus malma*) (Cavender 1978). The bull trout population in the Flathead system is largely migratory, growing to maturity in lakes and migrating through the river system and into the tributaries to spawn. Juveniles live in tributary streams from one to four years before migrating to the lakes.

Much information has been published concerning the life history of coastal Dolly Varden (e.g., Blackett 1968, Armstrong and Morton 1969, Armstrong and Morrow 1980, Balon 1980). Published information on the bull trout is limited. McPhail and Murray (1979), Leggett (1969), and Allan (1980) studied various aspects of the life history of bull trout in British Columbia and Alberta. Gould (1987) described the characteristics of larval bull trout.

The Montana Department of Fish, Wildlife and Parks has studied the bull trout population in the Flathead drainage since 1953 (Block 1955, Hanzel 1976). More intensive work was undertaken from 1979-1984 during the EPA-sponsored Flathead River Basin Studies (Graham *et al.* 1980, Fraley *et al.* 1981, Shepard *et al.* 1982, 1984b, Graham *et al.* 1982, Fraley and Graham 1982, Graham and Fredenberg 1982, Leathe and Graham 1982). We studied bull trout age and growth both in the lake and in the river system, harvest by anglers, the adult spawning migration, spawning site selection and use, and the densities, habitat selection, and emigration of juveniles growing in tributaries. Methods included tagging, gillnetting, stream trapping and electrofishing, creel survey, otolith and scale analysis, redd counts, and substrate analysis (Graham and Fredenberg 1982, Shepard and Graham 1983).

In this paper we summarize our findings on the life history, ecology, and population status of adfluvial bull trout in the Flathead Lake and inlet river system and compare our information to the results of other investigators.

## Study Area

The Flathead Lake and River system is a headwater drainage of the Columbia River Basin (Figure 1). Flathead Lake is a large oligomesotrophic lake with a surface area of 476 km$^2$ and a mean depth of 32.5 m (Potter 1978). The upper 3 m of Flathead Lake is regulated by Kerr Dam, constructed on the outlet in 1938. The Flathead River enters the north end of the lake. This study

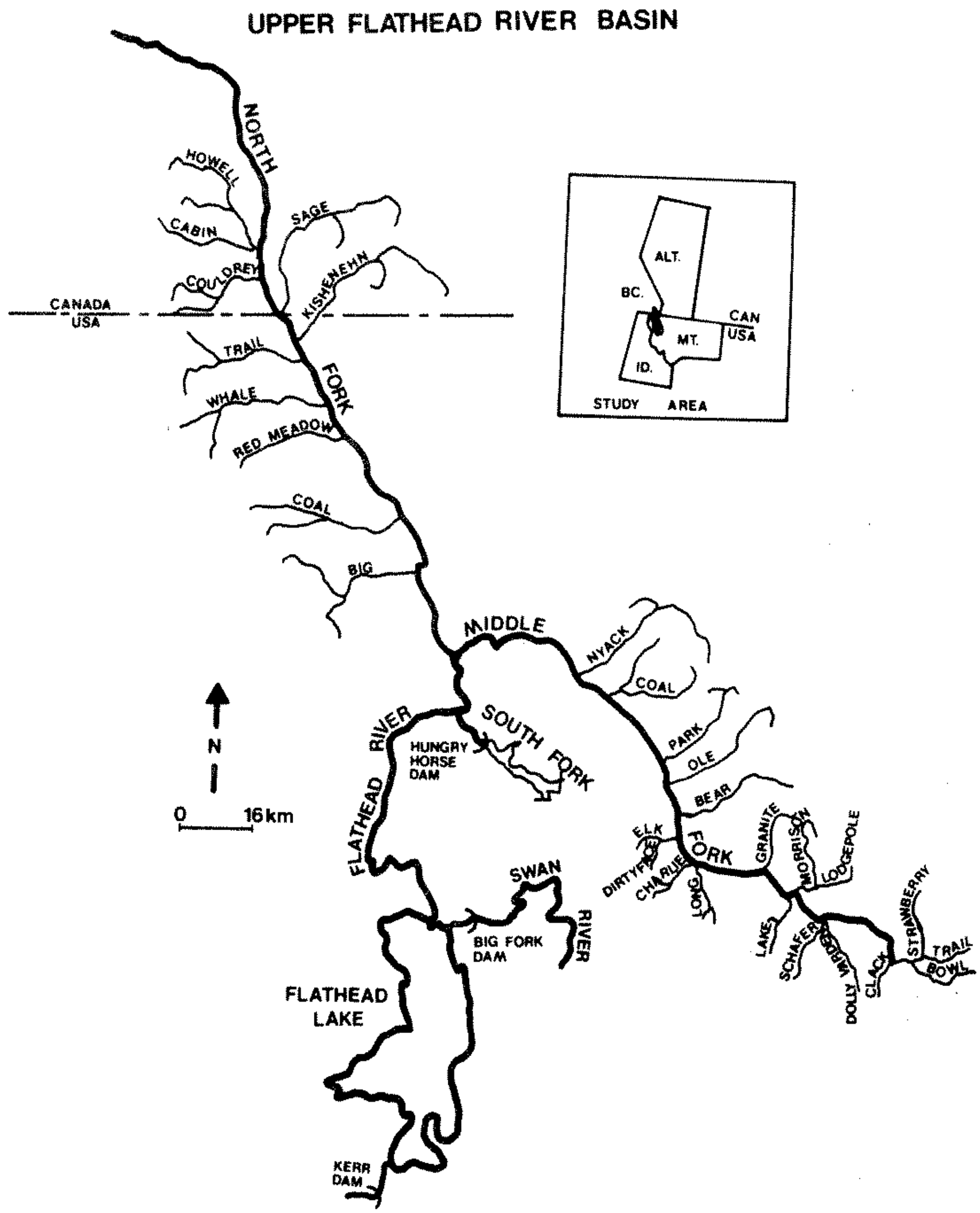


Figure 1. The upper Flathead River Basin. The 28 tributaries shown were used by spawning bull trout.

was conducted in the upper Flathead Basin which includes Flathead Lake and the river system upstream from Flathead Lake.

The South, Middle and North forks drain areas of approximately equal size in portions of the Great Bear and Bob Marshall wildernesses, Glacier National Park and the Flathead National Forest. The upper North Fork drains southern British Columbia. The South Fork is regulated by Hungry Horse Dam, located 8 km above its mouth. The Swan River enters Flathead Lake near the mouth of the Flathead River. Bull trout coexist with 23 other species of fish in the Flathead Lake and River system (Leathe and Graham 1982).

Most bull trout that spawn in the North and Middle Fork drainages mature in Flathead Lake, but fish maturing in large lakes of Glacier National Park may spawn in some tributaries. There are a few populations of bull trout in tributaries of the North Fork that spend their entire lives in the streams.

Bull trout originally used the tributaries of all forks of the Flathead and the Swan rivers. The construction of Bigfork Dam in 1902 blocked bull trout migrations into the Swan River. Limited numbers of bull trout move downstream from the Swan drainage via a marginal fish ladder, as evidenced by tag returns. Hungry Horse Dam, a 164.6-m structure which was closed in 1951, blocked all movements of bull trout into the South Fork drainage and probably resulted in a substantial reduction of the population in Flathead Lake.

The 28 tributaries used by spawning bull trout in the North and Middle Fork drainages (Figure 1) are characterized by gravel-rubble substrate, low flows of 0.057-1.70 $m^3/sec$, and maximum summer water temperatures less than 15°C.

## Results and Discussion

### Life History

#### *Lake Residence*

Bull trout populations residing in Flathead Lake were found to include recently arrived juveniles from the Flathead River system, subadult fish less than about 450 mm in length, and mature fish five to six years or more in age. Most bull trout in Flathead Lake matured at age VI. A similar age of maturity was reported for bull trout in Arrow Lakes, British Columbia (McPhail and Murray 1979).

The diet of bull trout in the lake consisted almost exclusively of fish. Whitefish species and yellow perch (*Perca flavescans*) were the most important food items, followed by kokanee (*Oncorhynchus nerka*) and nongame species (Table 1). Small bull trout have been found to feed incidentally on *Mysis* in Flathead Lake. *Mysis relicta* was discovered in Flathead Lake in 1981 and densities increased dramatically through 1986. Kokanee were the major food item for bull trout in Pend Oreille Lake, Idaho (Jeppson and Platts 1959), while whitefish were the major food in Upper Priest Lake (Bjornn 1961).

The annual growth increment for bull trout in Flathead Lake, based on analysis of scales, ranged from 60-132 mm (Table 2). Back calculations of length at annulus formation were made from 1,813 scale samples. Aging was checked with otoliths from 451 of the fish. Agreement of aging between otoliths and scales ranged from 100 percent for fish zero to three years of age, to 52 percent for older, mature fish. Growth of lake-resident fish was relatively constant after age IV. Growth rates of bull trout in Flathead Lake were similar to those reported for Priest and Upper Priest Lakes, Idaho (Bjornn 1961).

Not all mature bull trout spawned annually. Adult-size fish were relatively less abundant in the lake during the summer and fall, as compared to the spring. It appeared that 38 to 69 percent (average 57%) left the lake each spring and summer to spawn. The frequency of successive year spawning varied by age and sex (Leathe and Graham 1982). Alternate year spawning has been reported for inland Dolly Varden char (Armstrong and Morrow 1980).

#### *Upstream Migration*

Bull trout maturing in Flathead Lake began their spawning migration into the river system during April and moved slowly upstream, arriving in the North and Middle forks during late June and July. They traveled more than 250 km to spawn in some North Fork tributaries in British Columbia. The shortest distance traveled from Flathead Lake was 88 km to the mouth of Canyon Creek in the North Fork drainage. Observations and tag returns from 1974-1982 indicated that adult bull

TABLE 1. Composition by number, weight, and frequency of occurrence and calculated index of relative importance (IRI, George and Hadley 1979) for major food items in the stomachs of 95 bull trout collected between November and January, 1979, 1980 and 1981 in Flathead Lake.

| Item | Number | (%) | Wet weight -g. | (%) | Index of Relative Importance (IRI) |
|---|---|---|---|---|---|
| Pygmy whitefish | 5 | (2.4) | 37.0 | (4.0) | 3.2 |
| Lake whitefish | 1 | (0.5) | 104.1 | (11.2) | 4.3 |
| Mountain whitefish | 1 | (0.5) | 24.3 | (2.6) | 4.4 |
| Unidentified whitefish | 11 | (5.3) | 281.2 | (30.3) | 15.0 |
| Total whitefish | 18 | (8.7) | 446.6 | (48.1) | 23.5 |
| Kokanee | 2 | (1.0) | 82.8 | (8.9) | 4.0 |
| Unidentified trout/salmon | 2 | (1.0) | 13.2 | (1.4) | 1.5 |
| Total trout/salmon | 4 | (1.9) | 96.0 | (10.3) | 5.1 |
| Sculpin | 3 | (1.5) | 7.6 | (0.8) | 1.8 |
| Redside shiner | 5 | (2.4) | 15.0 | (1.6) | 2.0 |
| Peamouth | 1 | (0.5) | 3.6 | (0.4) | 0.7 |
| Sucker | 2 | (1.0) | 74.4 | (8.0) | 3.7 |
| Yellow perch | 83 | (40.3) | 105.1 | (11.3) | 24.6 |
| Total nongame | 94 | (45.6) | 205.7 | (22.1) | 31.0 |
| Unidentified fish | 90 | (43.7) | 181.1 | (19.5) | 41.4 |

TABLE 2. Back calculated lengths at annulus formation of bull trout in the upper Flathead Basin (n in parentheses). Calculations were made based on methods in Hesse (1977).

| Drainage | Total length (mm) at annulus | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX |
| *Adults and Juveniles* | | | | | | | | | |
| Upper Flathead (1968-81) | 66<br>(1,813) | 121<br>(1,538) | 196<br>(1,161) | 292<br>(927) | 385<br>(669) | 475<br>(349) | 566<br>(129) | 657<br>(32) | 731<br>(4) |
| Flathead Lake (1968-81) | 68<br>(931) | 129<br>(931) | 204<br>(928) | 291<br>(853) | 384<br>(603) | 472<br>(291) | 566<br>(102) | 658<br>(28) | 731<br>(4) |
| North Fork of the Flathead River drainage (1975-81) | 73<br>(533) | 117<br>(306) | 165<br>(60) | 301<br>(12) | 440<br>(8) | 538<br>(7) | 574<br>(3) | —<br>— | —<br>— |
| Middle Fork of the Flathead River drainage (1980-81) | 52<br>(349) | 100<br>(300) | 165<br>(172) | 297<br>(61) | 399<br>(57) | 488<br>(50) | 567<br>(24) | 655<br>(4) | |
| *Juveniles Only* | | | | | | | | | |
| North Fork drainage | 73<br>(525) | 117<br>(298) | 155<br>(52) | 228<br>(4) | — | — | — | — | — |
| Coal Creek | 75<br>(145) | 124<br>(62) | 202<br>(23) | 323<br>(14) | — | — | — | — | — |
| Red Meadow Creek | 65<br>(145) | 113<br>(113) | 168<br>(29) | 360<br>(7) | — | — | — | — | — |
| Trail Creek | 74<br>(473) | 119<br>(264) | 158<br>(46) | 228<br>(4) | — | — | — | — | — |
| Whale Creek | 56<br>(52) | 98<br>(34) | 139<br>(6) | — | — | — | — | — | — |

trout remained at the mouths of spawning tributaries for two to four weeks during which time feeding was thought to be limited.

Based on observations at stream trapping sites, adult bull trout entered tributary streams at night from July through September; the majority entered in August. Because most bull trout moved through the traps in pairs, we believe bull trout formed pairs near the mouth of the spawning tributary. Bull trout which entered the spawning tributaries were generally not in final spawning condition, but held in the tributaries for up to a month or more in deeper holes or near log or debris cover before spawning. Similar prespawning behavior and spawning timing was reported for bull trout in Mackenzie Creek (McPhail and Murray 1979) and John Creek (Leggett 1969) in British Columbia.

Most bull trout spawners in the North and Middle Forks were six or seven years of age (Table 3) whereas most spawners in the Swan system were five or six years old (Leathe and Enk 1985).

TABLE 3. Age of bull trout spawners in the Flathead system.

| Stream | Percent by Age | | | | |
|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 |
| North Fork Flathead River 1954 (N = 41) | 24 | 39 | 34 | 3 | 0 |
| Middle Fork Flathead River 1981 (N = 31) | 10 | 48 | 35 | 10 | 0 |
| Swan River 1983 (N = 57) | 33 | 35 | 23 | 9 | <1 |
| Swan River 1984 (N = 76) | 43 | 37 | 17 | 3 | 0 |

*Spawning*

Most bull trout spawned during September and early October in the Flathead River system, as did adfluvial bull trout in Idaho (Heimer 1965) and British Columbia (McPhail and Murray 1979). Initiation of spawning in the Flathead appeared to be related largely to water temperature, although photoperiod and streamflow probably also played a part. Spawning began when water temperatures dropped below 9-10°C. McPhail and Murray (1979) reported that 9°C was the threshold temperature for the initiation of spawning in Mackenzie Creek, British Columbia.

Bull trout spawners selected areas in the stream channel characterized by gravel substrates, low compaction and low gradient (Table 4). Groundwater influence and proximity to cover also were important factors influencing spawning site selection. These relatively specific requirements resulted in a restricted distribution of spawning in the Flathead drainage. Bull trout from Flathead Lake spawned in only 28 percent of the 750 km of available stream habitat according to basin-wide surveys from 1980-1982.

TABLE 4. Mean measurements of physical habitat variables in 34 stream reaches where no redds were located, 29 reaches where redd frequency averaged 1.2 redds/km (low), and 31 reaches where redd frequency averaged 6.9 redds/km (high).

| Parameter | Redd frequency categories | | |
|---|---|---|---|
| | None | Low | High |
| Stream order | 3.0 | 3.1 | 3.6 |
| D-90 (cm; the size of material larger than 90% of the substrate) | 51 | 37 | 33 |
| Gradient (percent) | 3.2 | 1.8 | 1.5 |
| Boulder (percent of substrate) | 16 | 12 | 10 |
| Gravel-Cobble (combined percent of substrate) | 54 | 62 | 62 |
| High quality pool (percent of stream) | 5 | 7 | 8 |
| Overhang cover (percent) | 14 | 10 | 11 |
| Total cover (percent) | 16 | 15 | 13 |

Average length of adult spawners in the Flathead River system was 628 mm (Table 5). The female chose a spawning site and constructed the redd, while the male defended the area. Male bull trout in Trail Creek, a North Fork tributary,

TABLE 5. Average total lengths of adult bull trout spawners in the Flathead drainage.

| Stream | Year | Average Length (mm) | Number of Fish |
|---|---|---|---|
| North Fork | 1979 | 638 | 36 |
| | 1977 | 645 | 32 |
| | 1953 | 617 | 165 |
| Middle Fork | 1980 | 618 | 35 |
| | 1957 | 622 | 87 |
| Both Forks | 1975 | 628 | 46 |

remained near the redd an average of two weeks after spawning. Bull trout redds in the Flathead drainage averaged 2.0 m long x 1.0 m wide, and sometimes overlapped. Block (1955) observed one male spawn with three females in succession; the size of the redd expanded each time. McPhail and Murray (1979), Leggett (1969), and Block (1955) provided detailed descriptions of spawning behavior and spawning site activities. After spawning, the spent adults moved out of the tributaries and downstream to the lake, possibly feeding on mountain whitefish (*Prosopium williamsoni*) during the journey.

Fecundity varied with fish size, averaging 5,482 eggs per female for a sample of 32 adults averaging 645 mm. One female bull trout weighed 15 pounds and contained 12,000 eggs. Bull trout in Arrow Lakes, British Columbia, were smaller and contained fewer than 2,000 eggs per female (McPhail and Murray 1979). The sex ratio of bull trout spawners averaged 1.4 females per male in Trail Creek in the North Fork drainage, and 1.37 females per male in the Swan drainage.

### *Incubation and Emergence*

After deposition by early October, bull trout embryos incubated in the redd for several months before hatching in January. The alevins then remained in the gravel and absorbed the yolk sac, with the first fry appearing in electrofishing samples in mid April. Emergence occurred approximately 200 days after egg deposition. Newly emerged fry averaged 23-28 mm and more than doubled their length during the first summer of growth (see Table 2).

Weaver and White (1985) found that incubation time was dependent on temperature. Bull trout eggs required 113 days (340 temperature units) to 50 percent hatch in Coal Creek, a tributary of the North Fork of the Flathead River. The fry emerged from the gravel 223 days (635 temperature units) after egg deposition. Intergravel temperatures during the incubation period (October-March) in Coal Creek ranged from 1.2-5.4°C. Survival to emergence in Coal Creek averaged 53 percent. McPhail and Murray (1979) reported the best survival of bull trout embryos at 2-4°C.

### *Juvenile Occurrence and Emigration*

Juvenile bull trout were present in about half of the stream reaches surveyed during studies in the upper Flathead River Basin. Juveniles were present in many reaches that were not used by adult spawners; they apparently swam upstream to these sections to grow. Distribution also was influenced by water temperature as juvenile bull trout were rarely observed in streams with summer maximum temperatures exceeding 15°C. Oliver (1979), Allan (1980) and Pratt (1984) also reported that bull trout distribution was affected by temperature.

Young-of-the-year bull trout were generally found in side channel areas and along the stream margins in Flathead tributaries. Blackett (1968) reported a similar habitat preference for juvenile Dolly Varden char in southeast Alaskan streams. McPhail and Murray (1979) found young-of-the-year bull trout in areas of low velocity near stream edges.

Densities of bull trout juveniles in Flathead tributaries were greatest in pools, and lower but generally similar in runs, riffles and pocketwater habitat. Juvenile bull trout were found closely associated with stream substrate. Pratt (1984) studied microhabitat preferences in the Flathead drainage and reported that juvenile bull trout (less than 100 mm) usually remained near the stream bottom, close to streambed materials and submerged fine debris. Juveniles 100 mm or longer also remained near cover, including larger instream debris. As the juvenile bull trout grew, they became less associated with the streambed.

During stream residence, juvenile bull trout were opportunistic feeders, mainly ingesting aquatic invertebrates (especially Diptera and Ephemeroptera) in similar percentages as they were available in the stream (Fraley *et al.* 1981). Bull trout larger than 110 mm also ate small trout and sculpin.

Snorkeling estimates of juvenile bull trout densities in Flathead drainage tributaries averaged 1.5 fish/100 $m^2$ of stream surface area (range: 0.1-7.1). Juvenile bull trout are difficult to observe because of their close association with the stream bottom, so these numbers are probably underestimates. Electrofishing estimates ranged as high as 15.5 fish/100 $m^2$ in certain streams.

Most juvenile bull trout in the Flathead drainage remained in the tributaries for one to three years before emigrating to the river system. Of 246 juvenile bull trout captured in downstream migrant traps placed in three tributaries to the North and Middle forks, about half (49%) were age II, a third (32%) age III, and 18 percent age I (Table 6). Only 1 percent of the emigrants were age IV. The ages of emigrating juveniles were similar in Idaho and British Columbia (Bjornn 1961, Oliver 1979, McPhail and Murray 1979). The average lengths at annulus formation of Age I, II, and III juvenile bull trout in tributaries of the North Fork Flathead were 73, 117 and 155 mm, respectively (Table 2).

TABLE 6. Percent and number of age I, II, III and IV bull trout emigrating from tributary streams.

| Location | Years of migration sampling | Age Classes I | II | III | IV |
|---|---|---|---|---|---|
| Red Meadow Cr. | 1973, 79 | 6 (3) | 76 (42) | 18 (10) | 0 (0) |
| Trail Creek | 1977, 79 | 34 (41) | 43 (52) | 19 (23) | 3 (4) |
| Geifer Creek | 1981 | 0 (0) | 37 (26) | 63 (45) | 0 (0) |
| All Sites | (%) (number) | 18 (44) | 49 (120) | 32 (78) | 1 (4) |

Emigration of juveniles from the tributaries into the Flathead River system took place largely from June through August (Table 7), similar to the emigration period reported for the Wigwam drainage, British Columbia (Oliver 1979). After juvenile bull trout entered the river system they appeared to move rapidly downstream into the main stem Flathead River, arriving below the South Fork during August and September. Although juvenile bull trout were captured by electrofishing in the main stem throughout the year, their numbers peaked during the fall months (McMullin and Graham 1981). Snorkel observations indicated that some juveniles lived along the shallow margins of the Middle and North forks. Residence in the lower Flathead River before entry into Flathead Lake has not been well documented.

## Trends in Spawner Abundance

Drainage-wide counts of bull trout redds in 1980 (568), 1981 (714), 1982 (1138), and 1986 (814) were used to index the number of adfluvial bull trout which successfully spawned in the river-tributary system. We converted the redd counts to approximate fish numbers by making the following assumptions: 1) 75 percent of all redds were located, and 2) an average of 3.2 spawners entered the tributary for each completed redd. From partial trapping results on several tributaries in 1977-1981, we estimated a spawner:redd ratio of 3.2:1. In 1953, 55 bull trout entered Trail Creek and constructed 18 redds for a spawner:redd ratio of 3.2:1 (Block 1955). During 1954, 160 bull trout constructed 48 redds in Trail Creek, yielding a ratio of 3.3:1. Based on these assumptions, we calculated that an average of 3,450 bull trout successfully spawned annually in the Flathead drainage during our period of record.

Bull trout spawned in 28 tributaries to the North and Middle forks (see Figure 1), but only a small percentage of the stream reaches were used for spawning. Important spawning tributaries in the North Fork were Howell, Trail, Whale, Big and Coal creeks. Major spawning tributaries in the Middle Fork were Morrison-Lodgepole, Granite, Ole, Trail and Dolly Varden creeks. The portion of the drainage in Canada supported 23-31 percent (mean 29%) of the spawning in the North Fork drainage during the 1980-82 period. Howell Creek supported 13-19 percent (mean 16%) of all North Fork spawning.

Monitoring of bull trout spawning at selected sites indicated that escapement was highest in 1982 (Table 8). These sites are considered representative of the drainage, and comprised 32, 30, 31, and 43 percent of the total drainage-wide counts in 1980, 1981, 1982, and 1986, respectively. Monitoring areas reflected drainage-wide trends.

Juvenile bull trout densities have been used as an index of population status. Juvenile bull trout populations in sections of Coal and Morrison creeks have been monitored for a six-year period (Table 9). Numbers of juvenile bull trout in these sections were highest in 1987 for both streams. Continued population estimates in these streams will provide valuable baseline information for future monitoring.

Sampling for bull trout in Flathead Lake indicated that the population had been relatively stable through 1981. Average catches of bull trout in sinking nets were 1.2 to 2.1 fish per net

TABLE 7. Number of stream trapping days, number of juvenile bull trout passed downstream through traps, and number of trapped juvenile bull trout per trap day by month from North Fork tributaries during 1976 to 1980 and Middle Fork tributaries during 1981.

| | June | July | August | September | October |
|---|---|---|---|---|---|
| *North Fork tributaries (1976-1980)* | | | | | |
| Trap days | 42 | 443 | 424 | 264 | 131 |
| Number of fish | 42 | 709 | 340 | 116 | 6 |
| Fish/trap day | 1.00 | 1.60 | 0.80 | 0.44 | 0.04 |
| *Middle Fork tributaries (1981)* | | | | | |
| Trap days | 43 | 74 | 62 | 14 | — |
| Number of fish | 60 | 28 | 19 | 8 | — |
| Fish/trap day | 1.40 | 0.38 | 0.26 | 0.57 | — |

TABLE 8. Bull trout redd counts for selected areas of tributaries chosen for monitoring in the Flathead Drainage.

| | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|---|---|
| North Fork: | | | | | | | | | | |
| Big | 10 | 20 | 18 | 41 | 22 | 9 | 9 | 12 | 22 | 19 |
| Coal | 38 | 34 | 23 | 60 | 73 | 61 | 40 | 13 | 48 | 52 |
| Whale | 35 | 45 | 98 | 211 | 141 | 133 | 94 | 90 | 143 | 136 |
| Trail | 34[a] | 31[a] | 78 | 94 | 56 | 32 | 25 | 69 | 64 | 62 |
| Total North Fork | 117 | 130 | 217 | 406 | 292 | 235 | 168[b] | 184 | 277 | 269 |
| Middle Fork: | | | | | | | | | | |
| Morrison | 25[a] | 75 | 32[a] | 86 | 67 | 38 | 99 | 52 | 49 | 50 |
| Granite | 14 | 34 | 14[a] | 34 | 31 | 47 | 24 | 37 | 34 | 32 |
| Lodgepole | 32 | 14 | 18 | 23 | 23 | 23 | 20 | 42 | 21 | 19 |
| Ole | | 19 | 19 | 51 | 35 | 26 | 30 | 36 | 45 | 59 |
| Total Middle Fork | 71 | 142 | 83 | 194 | 156 | 134 | 173[b] | 167 | 149 | 160 |
| Total Drainage Monitoring Areas | 188 | 272 | 300 | 600 | 448 | 369 | 341 | 351 | 426 | 429 |

[a]Counts may be underestimated due to incomplete survey.
[b]High flows may have obliterated some of the redds.

TABLE 9. Juvenile bull trout densities in sections of a North Fork tributary (Coal Creek) and a Middle Fork tributary (Morrison Creek) from 1980-1985.

| | Date | Population Estimate (Number/150 m section) | 95% Confidence Interval |
|---|---|---|---|
| Coal Creek (at Deadhorse Bridge) | 08/05/82 | 130 | ±36 |
| | 03/23/83 | 99 | ±33 |
| | 08/31/84 | 89 | ±27 |
| | 08/26/85 | 167 | ±66 |
| | 08/12/86 | 149 | ±45 |
| | 09/01/87 | 179 | ±55 |
| Morrison Creek | 09/23/80 | 91 | ±48 |
| | 09/01/82 | 93 | ± 5 |
| | 08/18/83 | 62 | ±11 |
| | 09/25/85 | 93 | ±27 |
| | 08/27/86 | 114 | ±15 |
| | 08/25/87 | 138 | ±10 |
| | 08/30/88 | 126 | ±23 |

in 1967-1970, 2.2 to 2.9 fish per net in 1980-81 (Leathe and Graham 1982). Average length of bull trout sampled in Flathead Lake increased by 24 mm from 1967 to 1980. A larger percentage of the fish were greater than 500 mm in the 1980-81 sampling period. The percentage of trophy fish (greater than 634 mm) was similar in both sampling periods. Migrating spawners, captured in the river system, were similar in size from 1953 through 1981 (see Table 5).

### Sensitivity to Environmental Disturbance

All bull trout life stages are sensitive to environmental disturbances. The population in the Flathead system is threatened by several major forms of resource development. The proposed Cabin Creek coal mine in the North Fork drainage in British Columbia received preliminary approval by the Canadian government and was referred by the U.S. and Canadian governments to an International Joint Commission for review (Flathead International Study Board 1988). This mining activity could harm bull trout spawning and rearing habitat in the upper North Fork and in Howell Creek, the major spawning tributary in the Canadian portion of the drainage. The major concerns are increased sedimentation, alteration of flow and water quality degradation (Biological Resources Committee 1987). In addition, timber harvest and road construction in both the North and Middle Fork drainages are potential threats to bull trout spawning and rearing habitat.

Increased fishing pressure is often associated with resource development. Because of the restricted distribution of bull trout spawning in the basin and the limited size of the known annual escapement (3,000-4,000 individuals), harvest of fish by anglers could reduce the population. Any increase in harvest by anglers in a particular area or subbasin could result in a loss of recruitment from that site, in turn reducing the overall population in Flathead Lake.

The long overwinter incubation and development phase for bull trout embryos and alevins (223 days in Coal Creek) leaves them particularly vulnerable to increases in fine sediments and degradation of water quality. In laboratory experiments, survival was shown to be inversely related to the percent fine material (<6.35 mm) in the gravels (Weaver and White 1985). Survival to emergence ranged from nearly 50 percent in substrates which contained 10 percent fines, to zero percent in mixtures which contained 50 percent fines. Juvenile bull trout could be affected by streambed changes because of their close association with the substrate. Shepard *et al.* (1984a) found a significant relationship ($r^2 = 0.40$, $P < .01$) between substrate score (a measure of unimbedded instream rock cover) and juvenile bull trout densities in tributaries of the Swan River.

As our studies of bull trout in the Flathead River system continue, we hope to define more precisely the factors which negatively affect the population. It is not clear whether the tributaries are at carrying capacity for juvenile bull trout, nor whether juvenile densities are limited by spawner escapement levels. The answer to these questions will require monitoring of the escapement levels and resulting juvenile densities in the tributaries over a longer period of time. McPhail and Murray (1979) suggested that limitations in juvenile rearing habitat may form an "ecological bottleneck," greatly affecting overall population levels of bull trout.

Bull trout in the Flathead River system are dependent on habitat quality and management of the interconnected river, lake, and tributaries. Cumulative losses of spawning and rearing habitat would reduce the bull trout population in Flathead Lake.

## Acknowledgments

We thank Steve Leathe, Laney Hanzel, Tom Weaver, Karen Pratt, Don Read and Steve McMullin for their research efforts on bull trout in the basin. Pat Graham directed portions of the studies. Many technicians contributed directly to the study. The USDE Environmental Protection Agency, USDA Forest Service, USDI Bureau of Reclamation, and the USDE Bonneville Power Administration supplied funds and cooperation. Mark Gaub prepared the illustrations; Dennice Hamman and Frances Roe typed the manuscript. Harold Mundie, Loren Bahls, Alan Martin, Jim Vashro, Fred Holm, Karen Pratt, Tom Weaver, and Mark Gaub reviewed the manuscript.

## Literature Cited


Allan, J. H. 1980. Life history notes on the Dolly Varden char (*Salvelinus malma*) in the upper Clearwater River, Alberta. Alberta Energy and Natural Resources, Fish and Wildlife Division, Red Deer, Alberta, Canada.

Armstrong, R. H., and J. E. Morrow. 1980. The Dolly Varden Char *Salvelinus malma*. *In* E. K. Balon, (ed.) *Chars:* salmonid fishes of the genus *Salvelinus*. W. Junk. The Hague, The Netherlands. Pp. 99-140.

Armstrong, R. H., and W. M. Morton. 1969. Revised annotated bibliography on the Dolly Varden char. Research Report No. 7. Alaska Department of Fish and Game, Juneau, Alaska.

Balon, E. K. 1980. Comparative ontogeny of chars. *In* E. K. Balon, (ed.) *Chars:* Salmonid fishes of the genus *Salvelinus*. W. Junk. The Hague, The Netherlands. Pp. 703-720.

Biological Resources Committee. 1987. Predicted impacts of the proposed Cabin Creek coal mine on the aquatic and riparian resources of the Flathead River Basin, British Columbia and Montana. Report to the Flathead River International Study Board, Washington, D.C. 352. p.

Bjornn, T. C. 1961. Harvest, age structure, and growth of game fish populations from Priest to Upper Priest Lakes. Trans. Amer. Fish Soc. 90:27-31.

Blackett, R. F. 1968. Spawning behavior, fecundity, and early life history of anadromous Dolly Varden (*Salvelinus malma*) in southeastern Alaska. J. Fish Res. Board Can. 30:543-548.

Block, D. G. 1955. Trout migration and spawning studies on the North Fork drainage of the Flathead River. Montana State University, Missoula, Montana. M.S. Thesis.

Cavender, T. M. 1978. Taxonomy and distribution of the bull trout (*Salvelinus confluentus*), from the American Northwest. Calif. Fish Game 64:139-174.

Flathead River International Study Board. 1988. Board report to the International Joint Commission, Washington, D.C.

Fraley, J., and P. Graham. 1982. Physical habitat, geologic bedrock types and trout densities in tributaries of the Flathead River drainage, Montana. *In* N. B. Armantrout, (ed.) Acquisition and utilization of aquatic habitat inventory information. Proceedings of a symposium held October 28-30, 1981, Portland, Oregon. Pp. 178-185.

Fraley, J., D. Read, and P. Graham. 1981. Flathead River fishery study: April 1981. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana. 132 p.

George, E. L., and W. F. Hadley. 1979. Food and habitat partitioning between rock bass (*Ambloplites rupestris*) and smallmouth bass (*Micropterus dolomieui*) young-of-the-year. Trans. Amer. Fish. Soc. 108:253-261.

Gould, W. R. 1987. Features in the early development of bull trout (*Salvelinus confluentus*). Northw. Sci. 61:264-268.

Graham, P. J., and W. Fredenberg. 1982. Flathead Lake Fisherman Census. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana. 44 p.

Graham, P. J., D. Read, D. Leathe, J. Miller, and K. Pratt. 1980. Flathead River Basin fishery study. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana, 118 p.

Graham, P. J., B. B. Shepard, and J. J. Fraley. 1982. Use of stream habitat classifications to identify bull trout spawning areas in streams. *In* W. B. Armantrout, (ed.) Acquisition and utilization of aquatic habitat inventory information. Proceedings of a symposium held October 28-30, 1981, Portland, Oregon. Pp. 186-198.

Hanzel, D. A. 1976. The seasonal, area and depth distribution of cutthroat trout and Dolly Varden in Flathead Lake. Job Performance Report, Project No. F-33-F-10, Job I-a. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana. 3 p.

Heimer, J. T. 1965. A supplemental Dolly Varden spawning area. University of Idaho, Moscow, Idaho. M.S. Thesis.

Hesse, L. 1977. FIRE I, a computer program for the computation of fishery statistics. Nebraska Tech. Ser. No. 1, Nebraska Game and Parks Commission. Proj. No. F-10-R. Pp. 60.

Jeppson, P. W., and W. S. Platts. 1959. Ecology and control of the Columbia River squawfish in northern Idaho Lakes. Trans. Amer. Fish. Soc., 88:197-203.

Leathe, S. A., and M. D. Enk. 1985. Cumulative impacts of microhydro development on the fisheries in the Swan drainage, Montana. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana. 114 p.

Leathe, S. A., and P. J. Graham. 1982. Flathead Lake fish food habits study—Final report. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana. 137 p.

Leggett, J. W. 1969. The reproductive biology of the Dolly Varden char *Salvelinus malma* (Walbaum). University of Victoria, Victoria, British Columbia, Canada. M.S. Thesis.

McMullin, S. L., and P. J. Graham. 1981. The impact of Hungry Horse Dam on the kokanee fishery of the Flathead River. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana. 98 p.

McPhail, J. D., and C. B. Murray. 1979. The early life-history and ecology of Dolly Varden (*Salvelinus malma*) in the upper Arrow Lakes. Department of Zoology and Institute of Animal Resources, University of British Columbia, Vancouver, British Columbia. 113 p.

Oliver, G. 1979. A final report on the present fisheries use of the Wigwam River with an emphasis on the migration, life history and spawning behavior of Dolly Varden char, *Salvelinus malma* (Walbaum). Fisheries investigation in tributaries of the Canadian portion of Libby Reservoir, British Columbia Fish and Wildlife Branch, Victoria, British Columbia, Canada.

Potter, D. S. 1978. The zooplankton of Flathead Lake: An historical review with suggestions for continuing lake resource management. University of Montana, Missoula, Montana. Ph.D. Dissertation.

Pratt, K. L. 1984. Habitat selection and species interactions of juvenile westslope cutthroat trout (*Salmo clarki Lewisi*) and bull trout (*Salvelinus confluentus*) in the upper Flathead River Basin. University of Idaho, Moscow, Idaho. M.S. Thesis.

Shepard, B. B. and P. J. Graham. 1983. Fish resource monitoring program for the upper Flathead Basin. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana. 61 pp.

Shepard, B. B., J. J. Fraley, T. M. Weaver, and P. Graham. 1982. Flathead River fisheries study. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana. 86 p.

Shepard, B., S. Leathe, T. Weaver, and M. Enk. 1984a. Monitoring levels of fine sediments within tributaries to Flathead Lake, and impacts of fine sediment on bull trout recruitment. Paper presented at the Wild Trout III Symposium. Yellowstone National Park, Wyoming. 11 p.

Shepard, B., K. Pratt, and P. Graham. 1984b. Life histories of westslope cutthroat and bull trout in the upper Flathead River Basin, Montana. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana. 85 p.

*Received 14 March 1988*
*Accepted for publication 16 February 1989*

Weaver, T. M., and R. G. White. 1985. Coal Creek fisheries monitoring study number III. Quarterly progress report to United States Department of Agriculture, Forest Service, Montana State Cooperative Fisheries Research Unit, Bozeman, Montana. 94 p.