MONTANA FISH, WILDLIFE AND PARKS
FISHERIES DIVISION

JOB PROGRESS REPORT

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Project Title: **STATEWIDE FISHERIES MANAGEMENT PROGRAM** | **Job Title:** **UPPER BIGHORN RIVER INVESTIGATIONS**

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ABSTRACT

Flow conditions in the Bighorn River were generally favorable for the fishery during the period of this report. Only one low water year occurred between 1989 and 1997 while several high flow years were experienced during this period. High river discharges resulted in a new record water temperature in the upper Bighorn River in 1995. A wetted perimeter flow analysis conducted on the upper Bighorn in 1997 helped reinforce the requested flow regime under which the Bureau of Reclamation has been managing the river.

Rainbow trout and brown trout populations in both the upper and lower shocking sections which had been impacted by the severe drought conditions between 1987 and mid-1989, responded favorably to the improved flow conditions. Recruitment of age 1 brown trout reached new record levels in both shocking sections in 1994, and age 1 estimates increased again in the lower section in 1995. These strong year classes have resulted in increasing populations of older brown trout in recent years.

Rainbow trout populations recorded major increases in both the upper and lower river thanks to two very strong year classes produced in 1993 and 1994. It appears that these year classes may raise Bighorn rainbow populations to a new level. As the rainbow population has increased, the ratio of rainbow to brown trout in the Bighorn has also changed. Total brown trout numbers have suffered as rainbow comprise more of the trout biomass in the river.

Recruitment of both rainbow and brown trout has increased substantially in the lower shocking section in recent years, possibly due to the scouring effects of higher flows experienced since 1989. Based on observed movement of both rainbow and brown trout, it appears the lower river may be becoming more important in maintaining the trout fishery in the upper river.

Angler satisfaction on the Bighorn has remained high, and should continue to remain high based on observed trout population trends.

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The study area, consisting of the Bighorn River in south central Montana from Yellowtail Afterbay Dam downstream to Two Leggins Fishing Access Site, has been described previously (Fredenberg 1984) (Figure 1). River miles (RM) denoted in this report refer to distance downstream from the Afterbay Dam.

Electrofishing on two sections (Figure 1) of the Bighorn River was conducted during daylight using a fixed-boom electrofishing boat powered by an outboard jet engine. The electrofishing apparatus was a Coffelt VVP-15 powered by a 6,500 watt Onan generator. Beginning in 1992, all electrofishing on the upper Bighorn River has been conducted using straight DC current producing about 2,000 W of power at an output of 200 V and 7 to 10 amps.

In the past, mark/recapture estimates were conducted in the fall (September and October) in both shocking sections. Warm water temperatures in the fall of 1991 forced shocking to be postponed on both sections until December. Due to the shorter daylight period at this time of year, only 2.5 miles of the normal 4.2 mile long standard shocking section was worked. Only one day of survey shocking was conducted on the lower St. Xavier shocking section in 1991 with no attempt to do a mark/recapture estimate. Beginning in 1992, mark/recapture efforts on the standard electrofishing section were shifted to late June and early July in order to avoid the warm water problem experienced in 1991, and to take advantage of a period when angling pressure normally drops off on the Bighorn. Mark/recapture estimates on the lower shocking section have continued during the normal late September, early October period.

All fish were measured to the nearest 0.1" and weighed to the nearest .01 pounds on a standard spring platform scale. Ten scale samples were taken per 2" size group, from an area above the lateral line posterior to the dorsal fin. Samples were mounted on acetate sheets, and the impressions were read on a microfiche reader.

Population estimates were obtained using a computer program developed by Montana Fish, Wildlife and Parks (FWP). Prior to 1990, a mark/recapture program had been used which based estimates on standard Peterson's mark-recapture calculations. During 1992 a new mark/recapture program was developed by FWP that used a log-likelihood method to calculate estimates. This method was more accurate than the old, especially in estimating numbers of small and very large fish. All mark/recapture estimates presented in this report were run using this new program, including data from years prior to 1992, which were rerun using this updated program.

Bighorn River water temperatures were monitored with a Taylor 30-day recording thermograph located in the U.S. Geological Survey (USGS) gage house on the right bank 200 yards downstream from the Afterbay Dam. River flow data were from USGS and Bureau of Reclamation (BOR) records measured at the Afterbay Dam and the USGS gage house.

A wetted perimeter (WETP) discharge relationship was developed for three key side channels in the upper river (Figure 2). Side Channel 1 is located on the left side of the river, looking downstream, approximately 0.6 miles downstream of the Afterbay Dam. Side Channel 5 is located on the right side of the river approximately 2.3 miles below the Afterbay Dam. The Three-Mile Side Channel is located on the right side of the river at the upstream end of the Three-Mile Fishing Access Site island complex, approximately 3.1 miles below the Afterbay Dam. All three side channels are important spawning and rearing areas for both rainbow and brown trout.

WETP field data were collected based on procedures outlined by Nelson (1984). Five riffle cross sections were established in each of the three side channels. Channel profiles were measured for each cross section, and water=s edge elevations were surveyed for three different calibration flows for each side channel.

All field data were sent to FWP's Research and Technical Service Bureau in Bozeman for data entry. Proofed data were entered into FWP's wetted perimeter predictive computer model and used to generate wetted perimeter-flow relationships for each individual cross section as well as a composite of all cross sections from a side channel. Composite data were plotted to identify an inflection point for each side channel.

River cross sections with permanent benchmarks tied back to known elevations at the Afterbay Dam were established near each side channel. River flows were measured at each cross section by the USGS to develop a relationship between flows at each site and flow measurements at the USGS gage house located immediately below the Afterbay Dam. A relationship between main-river and side-channel flows was also developed for each site so that side-channel flows could be related directly to gage house readings.

RESULTS AND DISCUSSION

Wetted Perimeter Analysis

River flows have always been a major factor controlling trout population levels on the Bighorn River. The mechanisms by which flows control fish populations are discussed in detail by Leathe and Nelson (1986).

Flow levels on the Bighorn River have been managed under an informal agreement with the Bureau of Reclamation since 1986. This agreement attempts to provide adequate flows for river trout populations while allowing the BOR the flexibility to deal with changing water availability and other management considerations. When water is available, the BOR attempts to maintain year-round flows at or above the optimum target flow of 2,500 cfs. At this flow, all major side channels in the upper Bighorn River have enough water to provide for good spawning, rearing and cover. During years when flows are below normal, but not critically low, a standard year-round target flow of 2,000 cfs is maintained. It is expected that this flow would be met or exceeded on an average of 8 out of 10 years. A flow of 2,000 cfs provides adequate spawning and rearing conditions in most side channels, but cover for adult fish would be limited. During drought conditions, the BOR attempts to prevent flows from dropping below a minimum target level of 1,500 cfs. Nearly all important side channels in the upper Bighorn River are dewatered at 1,500 cfs. River trout populations can be seriously impacted when flows reach this level.

Recommendations for this agreement were developed by evaluating the relationship between river flow and available fisheries habitat in a number of key side channels on the Bighorn River (Fredenberg 1987). Side channel habitat provides important spawning and rearing habitat for both rainbow trout and brown trout on the Bighorn River, and is, therefore, a critical component in maintaining the exceptional trout fishery found in the Bighorn. Rivers naturally down-cut below a dam once all recruitment of sediment from upstream sources is stopped. The Bighorn River is still a relatively new tailwater system, so the down-cutting process is still quite active. High flows experienced since 1990 have helped intensify channel changes in the upper Bighorn in recent years. As the main river channel continues to downcut, it will take higher flows to maintain the same quality of fisheries habitat in key side channels. In an effort to determine if flow levels requested under the informal agreement were still valid, and to provide additional data for the BOR to use when setting flows, a WETP study was conducted on the Bighorn in 1997. Funding for this study was provided jointly by Western Area Power Administration (WAPA) and the BOR.

The wetted perimeter and discharge relationships for selected channel cross-sections are useful tools for deriving instream flow recommendations for rivers and streams in Montana (Nelson 1984). Wetted perimeter is the distance along the bottom and sides of a channel cross-section in contact with water (Figure 3). As the discharge in a stream channel decreases, the wetted perimeter also decreases, but the rate of loss of wetted perimeter is not constant throughout the entire range of discharges. Starting at zero discharge, wetted perimeter increases rapidly for a small increase in discharge up to the point where the stream channel nears its maximum width. Beyond this break or inflection point, the increase in wetted perimeter is less rapid as discharges increase. An example of a wetted perimeter-discharge relationship showing a well-defined inflection point is given in Figure 4. The instream flow recommendation is selected at or near this inflection point.

The wetted perimeter/inflection point method is presently the primary method being used by FWP for deriving low flow recommendations for streams. This method is based on the assumption that the food supply is a major factor influencing a stream's carrying capacity (the number and pounds of fish that can be maintained indefinitely by the aquatic habitat). The principal food of many of the juvenile and adult game fish inhabiting the steams of Montana is aquatic invertebrates, which are primarily produced in stream riffle areas. The method assumes that game fish carrying capacity is proportional to food production, which in turn is proportional to wetted perimeter in riffle areas.

The wetted perimeter-flow relationship can also provide an index of other limiting factors such as cover, spawning habitat, and fish passage, all of which can influence a stream=s carrying capacity. Because of Montana's experience with the WETP method, and because riffles do provide key spawning habitat in Bighorn River side channels, this method was chosen to calibrate minimum flow requirement for key side channels on the Bighorn.

The plot of wetted perimeter versus flow for riffle cross sections in natural streams often shows two inflection points, the uppermost being the most prominent. Beyond the upper inflection point, large changes in flow cause only minor changes in wetted perimeter. The area available for food production is considered near optimal beyond this point. At flows below the upper inflection point, the stream begins to pull away from the riffle bottom until, at the lower inflection point, the rate of loss of wetted perimeter begins to rapidly accelerate. The lower inflection point indicates the minimum flow necessary to maintain a low level of aquatic habitat potential. At the lower inflection point flow, a limited sport fishery could still be maintained at a low or marginal level (Nelson 1984).

The wetted perimeter versus flow curves generated during this study only showed single upper inflection points. As discussed below for Side Channel 5, some problems arise when applying the WETP method to a side-channel area rather than a natural stream channel. It appears that the profile of a side-channel area may be more conducive to a single upper inflection point rather than two inflection points.

For Side Channel 1, the WETP computer program was calibrated to field data collected at flows of 7.7, 83.5 and 265.0 cfs. A plot of wetted perimeter versus flow for a composite of the five riffle cross sections resulted in a single inflection point at a flow of approximately 50 cfs (Figure 5). When applied to the river/side-channel flow relationship developed by the USGS, an inflection point of 50 cfs corresponded to a river flow of 2,150 cfs.

For Side Channel 5, the WETP computer program was calibrated to field data collected at flows of 47.9, 139.2 and 259.3 cfs. A plot of wetted perimeter versus flow for a composite of the five riffle cross sections resulted in a single inflection point at a flow of approximately 40 cfs (Figure 6). This inflection point was below the range of flows used to calibrate the WETP computer program, making it impossible to relate this inflection point to a corresponding river flow.

Side Channel 5 provided a good example of a problem inherent in applying the WETP methodology to side-channel areas. The most extensive, and probably first riffle to be dewatered in Side Channel 5 was located at the uppermost end of the side channel. This side channel was formed behind a long narrow island with a gradual sloping gravel bar at the upstream end. At higher flows, this gravel bar became part of a large riffle upstream of the island. It was not possible to establish WETP transects at this riffle because a cross section that extended from the river bank to the upstream end of the island during low flows would have extended all the way across the river at higher flows when the upper end of the island became flooded. As a result of this problem, all riffle cross sections in Side Channel 5 were established on two riffles further downstream in the side channel. Most of this side channel is fairly entrenched having a relatively flat bottom profile contained between two nearly vertical banks. Riffle cross sections from this section of the side channel would be expected to produce a definite inflection point at a flow level just before a major portion of the riffle started to dry up. It is likely that an inflection point generated for the expansive shallow riffle at the top of Side Channel 5, if it could have been used, would have been higher and would have fallen within the range of calibration flows measured at this side channel.

For the Three-Mile Side Channel, the WETP computer program was calibrated to field data collected at flows of 84.6, 248.1 and 932.1 cfs. A plot of wetted perimeter versus flow for a composite of the five riffle cross sections resulted in a single inflection point at a flow of approximately 225 cfs

(Figure 7). When applied to the river/side-channel flow relationship developed by the USGS, an inflection point of 50 cfs corresponded to a river flow of 2,500 cfs.

The inflection point flows determined during this study verified the flow requests under which the BOR has been managing the Bighorn River since 1986. Based on the criteria of the wetted perimeter program, flows at or above the upper inflection point should provide optimum food production and should consistently produce abundant, healthy and thriving aquatic populations (Nelson 1984). Both high inflection point flows calculated by this study fell within the requested flow range of 2,000 to 2,500 cfs. Upper inflection point flows for the Three-Mile side channel were the same as the optimum target flows that the river is currently being managed for. Results of the wetted perimeter study indicated that no adjustments were currently needed in the flow levels being requested for the Bighorn River.

The WETP curves calculated for the side-channel habitat in the Bighorn River did not show a lower inflection point to indicate minimum flow requirements. The minimum target flow of 1,500 cfs, used in the informal agreement with the BOR, was based on the observed flow level below which almost all of the important side channel habitat in the upper Bighorn River would be dewatered and unusable. Based on current data, a flow of 1,500 cfs still provides a good absolute minimum flow limit for the Bureau. As the main channel continues to downcut and change, the flow levels necessary to maintain even a limited amount of side-channel habitat could increase.

Stream Flows

Despite extremes in high and low flows since 1990, flows in the Bighorn Drainage have generally been favorable for trout populations. When average river flows were broken down by different time periods for each year since 1990, there were only four periods when the flows did not remain above the standard target flow of 2,000 cfs.

Low flows in 1994 and early 1995 resulted from a very early runoff in the spring of 1994 when most of the snow melt was complete by late May, followed by below normal summer precipitation. These conditions caused 1994 June-July inflows into Bighorn Lake to drop to 27% of normal, the lowest June-July inflows on record. River flows were reduced below the preferred minimum flow of 2,000 cfs in early June to reduce the drawdown of Bighorn Lake. Flows remained below this level into early May, 1995 resulting in low flow conditions during fall brown trout spawning in 1994 and through most of the spring rainbow spawn in 1995.

In contrast, Bighorn River flows exceeded 7,000 cfs during five of the seven years since 1990, and flows exceeded 12,000 cfs during two of these years (Table 1). The first extreme high flows occurred

Table 1. Maximum daily water temperature, first date water temperatures reached 601F, mean summer discharge and peak summer discharge (July-September) measured below the Afterbay Dam on the Bighorn River 1980-1997.

Year	Max Summer Water Temp. 1F	1st date Water Temps reached 601F	Mean Daily Summer Discharge (cfs)	Peak summer Discharge (cfs)
1980	62	8/21	3,740	5,259
1981	60	9/1	2,751	5,497*
1982	65	8/7	4,747	5,205
1983	67	7/13	5,879	9,298
1984	64	8/12	3,876	5,931
1985	53	Max. on 9/24	1,999	1,882
1986	67	7/8	4,306	7,431
1987	60	9/12	2,112	2,567
1988	56	Max. on 10/7	1,766	2,013
1989	59	Max. on 10/7	1,572	1,768
1990	60	10/4	2,036	2,214
1991	66	7/1	3,988	12,179
1992	60	9/23	2,253	3,135
1993	62	Early Aug - Missing data	3,707	7,687
1994	61	10/13	1,554	1,716
1995	71	7/7	3,641	14,038
1996	63	Mid-July - Missing data	3,268	7,262
1997	66	7/17	5,667	7,084*

* 1981 peak flow occurred in mid-June at 9,826 cfs
1997 peak flow occurred in mid-June at 11,037 cfs

in 1991 when high spring runoff caused river releases to be increased above 10,000 cfs in early June. Flows remained above 10,000 cfs until July 4 with peak flows over 12,000 cfs during the end of June and early July. Flows remained above 5,000 cfs until mid-July.

The second extreme high flows occurred in 1995, immediately following the low flows in 1994. A combination of an above normal winter snowpack, a cold wet spring and transfer of management of Boysen and Buffalo Bill reservoirs to the Wyoming Area Office of the Bureau of Reclamation in Casper lead to the extreme flows experienced in the Bighorn in 1995. The operation of Bighorn Lake, Boysen, and Buffalo Bill reservoirs were managed jointly under the jurisdiction of the Montana Area Office of BOR until October, 1994. At that time the operation of the Wyoming reservoirs was transferred to the Wyoming Area Office. Despite a record mountain snowpack in both the Shoshone and Wind River drainages, the Wyoming Area Office was reluctant to increase winter releases from Boysen or Buffalo Bill dams. When a delayed spring runoff did occur, releases from both dams had to be increased substantially to handle natural inflows. Flows in the Bighorn River below Yellowtail Dam were increased above 7,000 cfs in early June, but this did not prevent levels in Bighorn Lake from pushing into the exclusive flood pool by June 30. Flow in the Bighorn River was increased above 10,000 cfs on July 11 and remained above this level until July 27. Daily flows exceeded 14,000 cfs for four days as water was spilled through the spillway at Yellowtail. Flows in the river did not drop below 7,000 cfs until August.

Flow also exceeded 7,000 cfs in the Bighorn River during 1993, 1996 and 1997. In 1993, flows increased above 5,000 cfs in mid-June and remained at this level until mid-July with peak flows of about 7,700 cfs. In 1996, flows exceeded 5,000 cfs in mid-March and remained above this level through mid-July with peak flows of about 7,200 cfs. In 1997, flows exceeded 5,000 cfs by mid-March and remained high through early May with a peak discharge of 7,022 cfs. In an effort to buffer the high flood flows occurring in the Yellowstone River, Bighorn discharges were cut back to almost 3,200 cfs in mid-May. Once peak flows were over in the Yellowstone River, Bighorn River discharges were again increased to evacuate water from Bighorn Lake. Discharges in the Bighorn River exceeded 10,000 cfs for almost two weeks in mid-June with a peak discharge of 11,037 cfs. Flows dropped below 5,000 cfs for a few days in early July, then increased above 6,000 cfs for the rest of the month. Flows exceeded 7,000 cfs for the entire month of August and did not drop below 5,000 cfs until the second week of September.

Flow levels peaked just under 7,000 cfs in 1998, but average flow levels remained quite high through the entire year. Fall flows remained above 4,000 cfs until early November when they were dropped to around 2,500 cfs for brown trout spawning. Flows increased back to over 3,000 cfs by the end of January and continued to climb slowly up to 5,000 cfs by early May. A delayed spring runoff and below normal spring precipitation caused flows to drop back to around 2,500 cfs in mid-May, where they remained through June. Peak flows occurred in July during 1998, exceeding 6,000 cfs for 14 days with a peak daily flow of 6,872 cfs. Bighorn flows fluctuated between 4,000 and 5,000 cfs for the rest of the water year, as above average inflows kept Bighorn Lake within a couple of feet of the exclusive flood pool.

Water Temperatures

Past reports have discussed the relationship between flow and water temperatures in the Bighorn River. A significant linear correlation (P<0.01) was found between flow and summer water temperatures (Fredenberg 1986).

Whenever possible, all water passed through Yellowtail Dam is pulled through the power plant penstock, located approximately 200 feet below the surface of the reservoir, and run through the turbines to generate electricity. This deep withdrawal results in cold water being run through the power plant and discharged into the river. Once discharges exceed the power plant capacity, which is somewhere between 7,500 cfs and 8,200 cfs depending on reservoir elevations (Tim Felchle, personal communications), excess water is normally passed through the spillway structure. The spillway pulls water from closer to the surface of the reservoir, so water passing through the spillway is much warmer than water run through the power plant. The greater the proportion of warm water passing through the spillway as compared to the power plant, the faster the river warms up. Also during high runoff years , when water is most likely to be spilled, the reservoir warms up faster due to an increased volume of warmer water entering as runoff. During drought or low flow years, no warm water is passed through the dam, so warming in the river is totally dependent on the gradual warming of the entire reservoir.

River water temperatures continued to follow these same patterns between 1990 and 1997 with the warmest water temperatures occurring during the high flow years of 1991, 1995 and 1997 (Table 1). Peak water temperatures in the upper river reached a new high in 1995 at 711F. Water temperatures reached 701F on July 20, one day after the peak discharge of 14,038 cfs and stayed at or above 701F until September 28. In 1994, the lowest flow year during this period, river temperatures did not reach 601F until mid-October, and they dropped back below 601F before the end of the month (Table 1).

Brown Trout

Standard Section

Past reports have discussed brown trout population trends in the upper shocking section since annual electrofishing began in 1981. The total number of age 1 and older brown trout estimated in the upper section in December, 1981 was 2,218 brown trout per mile (Frazer 1990). The brown trout population showed a steady increase until reaching a peak of almost 10,000 brown trout per mile in 1987. Low water levels in 1987, 1988, and 1989 caused a significant declines in brown trout numbers down to around 5,000 brown trout per mile (Figure 8). This decline was first expressed as poor recruitment of young brown trout into the population in 1988 and 1989. A combination of factors including poor spawning flows, heavy predation by large brown trout on young fish, and lack of rearing habitat likely contributed to this poor recruitment (Frazer 1990). The weak year classes produced during this period carried forward as lower populations of larger brown trout in subsequent years.

In 1993 the estimated number of age 1 and older brown trout in the upper Bighorn River dropped below 4,000 fish per mile for the first time since the early 1980s (Figure 8). Because almost 50% of the 1993 population was composed of three-year-old brown trout, anglers on the stream did not really notice this population decline. The estimated brown trout population in 1994 increased substantially to 6,238 age 1 and older fish per mile. However, much of this increase was due to a very strong 1993 year class of brown trout which comprised almost 83% of the 1994 population. This was the strongest age 1 year class seen in the upper river since annual shocking began in 1981. At the same time, the number of two-year-old and older brown trout declined to 1,067 fish per mile which was the lowest estimated population of older brown trout in the upper river since sampling began in 1981.

Low flows during the brown trout spawning period in 1994 resulted in a weak age 1 year class in the upper shocking section in the spring of 1995. The total brown trout estimate for the upper river dropped below 3,000 fish per mile for the first time since sampling was initiated in 1981. Despite this decline, the number of two-year-old and older brown trout increased by 79% (from 1994 levels) to 1,907 per mile. The increase in numbers of older brown trout helped mask the lower population numbers, and the extremely high flow levels experienced in 1995 reduced the number of anglers on the river. Satisfaction for the anglers that did fish the river seemed to remain high. In 1996 the brown trout population in the upper section increased again to 3,403 age 1 and older fish per mile with three-year-old fish from the strong 1993 year class making up 43% of the population (Table 2). The number of two-year-old and older brown trout in 1996 increased to 2,519 per mile, which was almost equal to the total estimated population in 1995 (Figure 8).

The brown trout population in the upper section continued its upward trend in 1997 with an estimated population of 4,029 age 1 and older brown trout per mile. The 1997 population consisted almost entirely of older fish with three-year-old brown trout again comprising almost 65% of the population. The 1997 estimate of one-year-old brown trout was the lowest number seen in the upper section since 1986 (Figure 8).

Combined annual mortality was quite high for all age groups of brown trout on the upper Bighorn between 1991 and 1995, ranging from 53% to 73% (Table 3). Part of this observed mortality was due to movement of brown trout out of the shocking section between sampling periods. A fairly consistent pattern of brown trout movement in and out of the upper shocking section became evident following the return to higher flow patterns in the early 1990s. Populations of age 1 brown trout showed 78% to 92% declines between age 1 and 2 (Table 2). This was only a temporary loss, however, as fish from these groups reappeared as three-year-old fish the next year. For example, the 1990 year class of brown trout was estimated at 1,892 age 1 fish in 1991. In 1992 the estimate for this year class declined to only 409 age 2 brown trout per mile for a 78.4% decline in the population. In 1993 the number of three-year-old brown trout estimated from the 1990 year class jumped back up to 1,721 brown trout per mile, a 320.8% increase. This same pattern of major declines between age 1 and 2, followed by a rebound in population numbers as age 3 was apparent for several years (Table 3). Brown trout from other sections of the river may also have moved into the shocking section as three-year-old fish.

Table 2. Estimated number of brown trout per mile, by age, in the standard electrofishing section (RM 3.8-8.0) of the Bighorn River.

Date	Age					
	I	I	III	IV	V+	Total
6/97	132	1,295	2, 493	104	4	4,029
6/96	884	1,027	1,472	18	2	3,403
6/95	776	705	1,000	201	1	2,683
6/94	5,171	143	849	75	C	6,238
6/93	1,241	295	1,721	329	10	3,596
6/92	3,806	409	600	172	4	4,991
12/91	1,892	1,523	807	112	C	4,334
9/90	3,314	936	958	15	C	5,223
9/89	1,294	1,023	2,558	166	4	5,045
9/88	1,008	1,858	2,507	116	8	5,497
9/87	3,109	3,606	2,913	280	25	9,933
9/86	3,354	2,781	1,098	265	62	7,566

Brown trout movement patterns in the upper river changed again in 1995. The weak 1994 and 1995 year classes increased in total population size as age 2 fish, and increased again as age 3 fish, indicating movement of younger fish into the shocking section. This influx of younger brown trout into the shocking section more than made up for the continued high mortality recorded for older brown trout. As a result, the combined annual mortality rate for all ages of brown trout dropped to 6.1% between 1995 and 1996. This was the second lowest combined mortality rate observed for brown trout in the upper section since sampling began in 1981. The combined population of age 1 and older brown trout estimated in 1996 actually increased by over 100% into 1997, with one-year-old fish making up less than 4% of the 1997 population (Table 3).

Table 3. Comparison of estimated annual mortality rates (percent change) for brown trout in the standard electrofishing section (RM 3.8-8.0) of the Bighorn River from 1991 to 1997.

Age Class*	12/91-7/92	7/92-7/93	7/93-7/94	7/94-7/95	7/95-7/96	7/96-7/97
1	-78.4	-92.2	-88.5	-86.4	+32.3	+146.5
2	-60.6	+320.8	+187.8	+599.3	+108.8	+242.7
3	-78.7	-45.2	-95.6	-76.3	-98.2	-92.9
4 & older	-96.4	-94.2	-100.0	-98.7	-99.0	-77.8
Total	**-72.6**	**-52.8**	**-70.3**	**-69.4**	**-6.1**	**+109.0**

* **Age class indicated is age at beginning of time interval.**

The biomass of brown trout in the upper river has never recovered to the level seen before the drought of the late 1980s. The peak biomass recorded in the standard section in 1987 was 9,953 pounds per mile. As discussed above, the first fish impacted by the low flows in 1987 and 1988 were young fish. Populations of two-year-old and older brown trout, which constituted a major part of the biomass, did not drop off significantly until 1990 (Figure 8). In 1991 fall shocking was postponed until December due to high water temperatures in late September (Frazer 1993). This change meant that trout were collected right at the end of a very warm season when growth rates were exceptionally good. As a result, the biomass of brown trout recorded in 1991 was higher than would have been expected for the same brown trout population had sampling been conducted during the normal sampling period in late September. Since 1992, shocking in the standard section has been conducted in late June and early July, at the start of the summer growing season on the Bighorn. This has resulted in a general decline of trout biomass present during sampling. Between 1992 and 1996 the total brown trout biomass in the upper section range between about 2,000 and 3,700 pounds per mile (Table 4). This trend changed in 1997 with the increased brown trout population dominated by larger three-year-old fish. The 1997 brown trout biomass jumped to 5,333 pounds per mile.

Average lengths of various age classes of brown trout have remained fairly consistent since the sampling period for the standard section was shifted to early summer in 1992 (Table 5). Past reports have discussed the relationship between flow, water temperature and growth rates in the Bighorn when sampling was conducted in the fall near the end of the growing season (Fredenberg 1986). These influences were not nearly as evident when fish were collected in June and July, at the start of the growing season.

Table 4. Total Biomass (pounds per mile) of age 1 and older brown trout estimated in the standard electrofishing section (RM 3.8-8.0) of the Bighorn River from 1992 to 1997.

Year	Total Biomass
1992	2,010
1993	3,675
1994	2,024
1995	2,756
1996	2,771
1997	5,333

Table 5. Average length (inches), by age class, of brown trout from the standard electrofishing section (RM 3.8-8.0) of the Bighorn River during late June - early July* 1991-1997.

Year	Age				
	1	2	3	4	5+
1991*	10.6	16.0	18.0	18.3	C
1992	5.8	12.8	17.0	18.1	19.6
1993	5.2	12.4	15.9	17.8	19.6
1994	5.3	12.5	17.0	18.3	C
1995	4.8	12.3	16.7	18.9	20.6
1996	5.5	11.6	15.7	19.6	20.5
1997	5.5	12.5	16.1	17.8	19.7

* 1991 fish were sampled in December.

Lower Section

Brown trout populations in the lower (St. Xavier) shocking section have shown substantial increases during recent years (Figure 9). Brown trout populations in the lower river were impacted by the same low flows that affected population levels in the upper river in the late 1980s. These flow conditions caused the brown trout population in the lower section to drop to very low levels in 1992 and 1993, with age 1 fish comprising most of the population (Table 6). A strong 1993 year class helped the brown trout population rebound from 643 7 inch and longer brown trout per mile in 1993 to over 2,000 per mile in 1994 (Figure 9). Age 1 brown trout comprised almost 83% of the 1994 estimated population. At 1,675 age 1 brown trout per mile, this was the strongest age 1 year class seen in the lower shocking section since sampling began in 1984. This strong age 1 year class in the lower section corresponded to the record age 1 year class seen in the upper section in 1994. The number of age 2 and older brown trout estimated in 1994 also increased by over 90% from 1993 level (Table 6).
Brown trout populations continued to grow in 1995 with the total brown trout population increasing to a record 2,807 age 1 and older brown trout per mile. Again age 1 brown trout comprised almost 85% of this population with an estimated 2,374 age 1 brown trout per mile in this section of river. The age 1 population in 1995 was equal to the total brown trout population estimated in the lower shocking section in 1984, which was the previous record brown trout population level estimated in the lower shocking section (Table 6). The population of two-year- old and older brown trout increased again between 1994 and 1995 with most of the increase due to two-year-old fish from the strong 1993 year class. The dominant two-year-old year class averaged about 12.3 inches in length. Few larger brown trout were present in the lower shocking section in 1995. Only 39 brown trout 18 inches long and longer were handled during four days of marking and three days of recapture shocking.

The brown trout population in the lower section decreased by almost one-third between 1995 and 1996 to 1,909 brown trout per mile. Most of the decline was due to fluctuations in the number of one-year-old fish in the estimate (Table 6). The number of two-year-old and older brown trout declined by 8.5% during this period with two-year-old browns dominating this group. Again, only 32 brown trout 18 inches long and longer were handled during the entire mark/recapture effort in the lower section.

Brown trout numbers declined again in 1997 to 1,692 age 1 and older brown trout per mile. All of the decline was in the number of one-year-old brown trout in the population. The number of two-year-old and older brown trout increased by 88% from 1996 to 745 per mile. Two-year-old brown trout again comprised most of this population, but the population of three-year-old brown trout also increased. The number of 18 inch and longer brown trout handled during 7 days of mark/recapture efforts in 1997 increased to 65, and the estimated population of 18 inch and longer brown trout increased by 30% to 43 per mile.

Table 6. Estimated number of brown trout per mile, by age, in the lower electrofishing section (RM 17.6-21.6) of the Bighorn River.

Date	Age				
	I	I	III	IV+	Total
9/97	947	606	136	3	1,692
9/96	1,309	345	70	3	1,727
9/95	2,374	404	29	C	2,807
9/94	1,675	292	47	9	2,023
9/93 [1/]	461	122	52	8	643
9/92[2/]	507	52	9	1	569
12/91[3/]	C	C	C	C	C
9/90	634	35	230	24	924
9/89	182	147	181	76	586
9/88	885	309	196	81	1,471
9/87	757	361	194	78	1,389
9/86	1,201	415	196	53	1,866

[1/] 7 inches and longer
[2/] 7 to 16 inches
[3/] No trout estimate was conducted in the lower section in 1991

Brown trout movement was evident in data from the lower section, but movement patterns were different than those discussed for the upper section. Even though the strong age 1 year classes estimated in 1994, 1995, and 1996 all carried through as stronger age 2 year classes the following year, losses of these age 1 fish before their second year were still high. Observed brown trout mortality rates between ages 1 and 2 were 76%, 86%, and 60% for 1994, 1995 and 1996 age 1 year classes respectively. Much of this apparent loss was a result of movement of young fish out of the shocking section between sampling periods.

This pattern also reflects another change that has been observed on the Bighorn in recent years. Historically most of the brown trout spawning in the Bighorn River has occurred in the upper 9 miles of river upstream of Soap Creek, with very limited spawning further downstream. The distribution of brown trout spawning areas has changed with the recent high water years on the Bighorn. High flow events have apparently scoured and cleaned spawning gravel farther downstream from the Afterbay Dam. The improved spawning habitat has resulted in more brown trout spawning below Soap Creek, which has been reflected in the large populations of young-of-year (YOY) and age 1 fish observed in the lower section since 1994 (Figure 9).

Both the upper and lower shocking sections had very strong age 1 populations in 1994. Since that time, the estimated age 1 populations in the upper section have been poor while they have been strong in the lower section (Figures 8 & 9). Based on these data it appears the upper section of the river may be depending on upstream movement of young fish to help maintain a strong brown trout population.

Brown trout biomass peaked in the lower shocking section at 1,491 pounds per mile in 1994. Even though the total brown trout population increased substantially in 1995, the total brown trout biomass declined by 370 pounds per mile. This observed difference was due to a lower average condition factor for the 1995 fish following the cold water temperatures seen in 1994. The average condition factor for brown trout declined from 46.34 in 1994 to 42.76 in 1995, which was enough to lower biomass numbers despite higher population numbers. With more larger fish in the population in 1997, and an improved condition, total brown trout biomass increased to 1,217 pounds per mile.

Summary and Discussion - Brown Trout

Brown trout populations on the Bighorn entered the 1990s on a decline due to the lingering impacts of drought flows experienced in the late 1980s. Population levels continued to decline in both the upper and lower shocking sections as the weak year classes of brown trout, produced during low flow conditions, became the primary spawning population.

Despite a reduced number of spawners, brown trout populations responded immediately once flow conditions improved beginning in 1989. Three increasingly strong age 1 year classes of brown trout were estimated in the upper shocking section in 1990, 1992 and 1994. The record age 1 year class estimated in the upper river in 1994 corresponded to a record age 1 brown trout population estimate in the lower river the same year. Recruitment of brown trout dropped off in the upper river after 1994, but the population of older brown trout continued to increase as the strong year classes produced prior to 1994 matured. Recruitment of young brown trout in the lower river increased to produce another record one-year-old year class in 1995. Age 1 year classes in the lower river dropped below record levels in 1996 and 1997, but recruitment still remained strong.

The lower river section has become a more important contributor to the overall Bighorn trout population following the high flushing flows experienced in recent years. Populations of two year old and older brown trout were strong in both the upper and lower shocking sections in 1997, despite a continually increasing rainbow population. The trout population on the Bighorn appears to be shifting towards a new equilibrium where rainbow will make a stronger contribution to the total trout fishery.

Rainbow Trout

Standard Section

Rainbow populations in the upper river have remained fairly consistent at around 1,000 one-year- old and older rainbow per mile since the late 1980s (Figure 10). Two strong year classes of rainbow produced in 1985 and 1986, following the end of rainbow stocking, were responsible for much of the original increase seen in the rainbow population (Frazer 1990). The rainbow population remained above 1,000 age 1 and older fish per mile from 1992 through 1995 while the contribution of age 1 fish to these populations varied considerably (Table 7). The estimated population in 1992 was 1,014 rainbow per mile with age 1 rainbow comprising 22% of the population. The 1993 rainbow population increased slightly to 1,048 age 1 and older rainbow per mile with age 1 fish only contributing about 4% of the population.

In 1994, the estimated rainbow population reached a new record for the upper river at 1,324 age 1 and older rainbow per mile. However, due to the high standard deviation associated with this estimate, these numbers are somewhat questionable. No marked rainbow between 5.5 and 16.0 inches were recaptured in 1994, so the estimated population of rainbow in these size ranges was based entirely on an estimated efficiency curve generated by the computer using fish from both ends of this size range. The estimate accurately depicts the trend of increasing rainbow numbers, but the actual number values may not be entirely accurate.

Part of the observed increase in 1994 was due to a record age 1 year class from fish produced in 1993. This year class of fish comprised 45% of the 1994 population. Despite a record population level, the number of two-year-old and older rainbow actually declined by 283 rainbow per mile from the 1993 level. Another strong rainbow year class was produced in 1994. The 1995 age 1 year class was the second strongest one-year-old year class estimated in the upper river since stocking was discontinued in the early 1980s (Figure 10). The 1995 rainbow estimate decreased slightly to 1,205 rainbow per mile, while the number of age 2 and older rainbow increased from 1994 levels.

Table 7.Estimated number of rainbow trout per mile, by age, in the standard electrofishing section (RM 3.8-8.0) of the Bighorn River.

Date	Age					
	I	I	III	IV	V+	Total
6/97	57	86	1,601	516	58	2,318
6/96	33	370	302	202	50	957
6/95	427	102	292	290	94	1,205
6/94 [1/]	600	110	231	260	123	1,324
6/93 [1/]	41	5	426	289	287	1,049
6/92	224	490	187	102	11	1,014
12/91	C	C	C	C	C	C
9/90	54	13	488	321	36	912
9/89 [2/]	C	52	591	482	69	1,194
9/88	68	354	373	139	26	960
9/87	342	400	148	111	15	1,016
9/86	355	78	171	97	38	739

[1/] Poor estimates

[2/] Fish 13" and longer only

The estimated rainbow population in the upper shocking section dropped below 1,000 fish per mile for the first time in several years in 1996. However, this decline was due entirely to the lack of an age 1 year class. Only 33 age 1 rainbows per mile were estimated in the upper section in 1996. The number of age 2 and older rainbow actually increased by 19% over population levels estimated in 1995.

The rainbow population in the upper section took a huge jump in 1997 to an estimated record population of 2,318 1 year old and older rainbow per mile. Normally large fluctuations in population levels in the Bighorn have been a reflection of variations in recruitment of young fish as indicated by estimates for one-year-old fish. In 1997, one-year-old rainbow (at 57 per mile) comprised less than

3% of the population. Three-year-old rainbow from the strong 1994 year class comprised 69 % of the 1997 estimated population, and four-year-old fish from the 1993 year class constituted 22% of the population. The estimated population of 1,601 age 3 rainbow per mile in 1997 was greater than any previous total estimate for rainbow in the upper river. This strong three-year-old year class was produced during low flow conditions experienced in 1994. Some of the strongest rainbow year classes produced on the Bighorn have been produced during low flow years. The strong 1993 and 1994 year classes first showed up as near record one-year-old populations, and this trend was evident in both the upper and lower shocking sections (Figures 10 & 11). These two strong year classes of rainbow could help carry the Bighorn rainbow population to a new level, just as the 1985 and 1986 year classes did in the past.

The trend towards an increasing presence of rainbow in the Bighorn River trout population was evident when 1997 population levels were compared to historic population data. In 1987, when trout numbers reached record high levels in the Bighorn, the combined trout population of both rainbow and brown trout was 10,949 trout per mile in the upper river. At that time brown trout comprised 91% of the population with rainbow contributing less than 10%. In 1997 the combined population of rainbow and brown trout was 6,160 trout per mile, with brown trout comprising 62.4% of the population and rainbow comprising 37.6%.

Previous reports discussed movements of various age classes of rainbow into and out of the shocking section between annual sampling periods (Frazer 1990). This same type of movement has been evident almost every year, but there is no consistent pattern for certain age groups of rainbow (Table 8). One- and two-year-old classes, which were poorly represented in 1990, made strong contributions to the 1992 population as three- and four-year-old fish. Age 1 rainbow in 1992 and 1994 appeared to have moved out of the shocking section as age 2 fish and back into the section as age 3 fish. This same movement pattern was observed for brown trout in the upper section, but it did not hold consistent for rainbow. The 1994 year class, first seen as a strong age 1 population in 1995, did not follow this pattern. This year class showed a 12% mortality between 1995 and 1996, and then showed a 333% gain in 1997 where they represented 69% of the entire 1997 population. The strong age 1 year class observed in 1994 declined significantly in 1995, rebounded some as age 3 fish in 1996, and increased again to comprise 22% of the 1997 rainbow population (Figure 10). There was only a 14 % decline in this year class between 1994 and 1997.

Table 8. Comparison of estimated annual mortality rates (percent change) for rainbow trout in the standard electrofishing section (RM 3.8-8.0) of the Bighorn River from 1992 to 1997.

Age Class*	7/92-7/93	7/93-7/94	7/94-7/95	7/95-7/96	7/96-7/97
1	-97.8	+168.3	-83.0	-11.9	+160.6
2	-13.1	+4,520.0	+165.5	+196.1	+332.7
3	+54.5	-39.0	+25.5	-30.8	+70.9
4	+122.5	-68.9	-75.4	-82.8	-71.3
5 and older	+500.0	-85.5	-66.7	-100.0	-100.0
Total	**-1.5**	**-30.9**	**-41.2**	**-22.9**	**+123.7**

*** Age class indicated is age at beginning of time interval.**

There appeared to be high mortality of the 1991 year class of rainbow between 1992 and 1993. However, the estimated population of this same year class of rainbow increased over 4500% in the shocking section between 1993 and 1994 (Figure 10). Between 1992 and 1993 age 3, 4, and 5 rainbows all showed population increases. Numbers of one- and two-year-old rainbow from the 1993 population showed significant increases in 1994 while age 3, 4 and 5 fish from 1993 all declined in 1994. Between 1994 and 1995 increases occurred in populations of two and three-year-old fish while mortality was recorded for ages 1, 4 and 5 (Table 8).

Movement of various age groups of fish into and out of the shocking section from one sampling period to the next affects the reliability of the presented population data. It becomes difficult to accurately calculate annual mortality rates for rainbow from year to year. Total mortality rates calculated from 1992 through 1996 ranged from 1.5% to 41.2% while the combined population of age 1 and older rainbow increased by almost 124% between 1996 and 1997 (Table 8). These calculated mortality rates were comparable to estimated annual mortality rates calculated in the past (Frazer 1991).

Movement also affects the accuracy of the population numbers presented. The population estimates generally underestimate the total population present in the river as a whole because certain age groups appear to be under represented in the shocking section at any given time. These same factors would also result in an underestimation of the total trout biomass present in the river.

Rainbow trout biomass in the upper river climbed to 2,504 pounds per mile in 1993, about 300 pounds less than the record rainbow biomass recorded in 1989. Despite higher total population numbers in 1994 and 1995, rainbow biomass dropped to just over 1,500 pounds per mile, as the number of larger rainbow comprised a smaller portion of the population. Rainbow biomass declined further to 1,329 pounds per mile in 1996. The record rainbow trout population estimated for the upper section in 1997 resulted in a new biomass record of 4,471 pounds of rainbow per mile.

Biomass data further exemplify the increasing importance of rainbows in the Bighorn trout population. The combined biomass of rainbow and brown trout in the upper shocking section in 1997 was 9,804 pounds per mile, or 1,002 pounds per mile less than the record combined biomass measured in the Bighorn in 1987. In 1987 brown trout comprised 89% of the estimated biomass while rainbow only contributed 11%. The balance shifted in 1997, with brown trout contributing 54% of the biomass, and rainbow contributing 46%.

Changes in biomass were highly correlated with the number of "trophy-sized" 18 inch and longer rainbow present in the population. Numbers of "trophy-sized@ rainbow reached a new high in 1993 at 779 per mile. These numbers declined to 429 and 373 18 inch and longer rainbow per mile in 1994 and 1995 respectively. Part of the decline observed in 1995 may have been due to slower growth rates in older fish resulting from cold water temperatures in 1994. In 1996 the number of 18 inch and longer rainbow declined again to 277 per mile. The trend reversed in 1997 as the estimated number of 18 inch and longer rainbow jumped back up to a new record level of 877 per mile.

Most rainbow in the upper river reach 18 inches in length as three-year-old fish. Some variations in rainbow growth rates were evident from year to year, but average sizes of various age classes of rainbow have remained quite consistent since 1992 (Table 9). These growth data can not be compared directly to older growth rates because the sampling period was shifted from September to June on the upper shocking section in 1991. Effects of varying water temperatures on growth rates were most evident in the one-year-old fish. Low flow conditions in 1994 resulted in cold water temperatures on the Bighorn throughout the summer. Average lengths of one-year-old rainbow from the 1994 year class measured in 1995 were the smallest measured between 1992 and 1997 (Table 9). Water temperatures in 1995 were very warm due to high flows and a spill of warmer water from near the surface of the reservoir. One-year-old rainbow in 1996 were 1.2 inches longer than one-year-old fish measured in 1995. Effects of varying water temperatures were not nearly as evident in older age classes of rainbow. The poor growth seen at age 1 in the 1994 year class carried over in the two-year-old rainbows in 1996, but by 1997 the average size of the three-year-old fish from this year class was back up within the normal range (Table 9).

Table 9. Average length (inches) by age class of rainbow trout from the standard electrofishing section (RM 3.8-8.0) of the Bighorn River during late June - early July 1992-1997.

YEAR	AGE					
	1	2	3	4	5	6+
1992	5.6	13.7	17.2	19.3	21.1	21.7
1993	4.3	13.6	18.1	19.9	20.0	20.2
1994	4.7	13.1	17.5	19.3	19.9	19.9
1995	3.8	13.5	16.8	18.8	20.2	20.1
1996	5.0	12.1	16.7	18.9	20.0	C
1997	4.8	13.2	17.0	19.0	19.4	C

Lower Section

Rainbow population levels in the lower (St. Xavier) shocking section showed a pattern similar to that seen for brown trout in the lower section, with several strong year classes of fish being produced since 1990. The presence of strong age 1 year classes of rainbow helped push total population numbers to new record highs (Figure 11).

The estimated population of age 1 rainbow in the lower section reached a new record of 649 per mile in 1990, which helped raise the total estimated population to a new record of 892 rainbow per mile. No population estimate was conducted in 1991 due to high fall water temperatures. One day of survey shocking indicated another strong year class was produced in 1990, and that the strong 1989 year class was still an important part of the population (Frazer 1993). Few smaller fish were captured in the lower section in 1992 making it impossible to calculate a good estimate for fish less than 13 inches in length. The estimated population of age 1 rainbow reached another record level in 1993 while the number of two-year-old and older fish dropped to only 119 per mile, slightly less than the previous low seen in 1986 (Table 10).

The total rainbow population in the lower section reached another record high at 945 age 1 and older rainbow per mile in 1994. The 1994 age 1 year class was still strong, although slightly smaller than the one-year-old year classes estimated in 1990 and 1993. Two-year-old rainbows from the strong 1992 year class comprised 25% of the 1994 population (Table 10).

Table 10. Estimated number of rainbow trout per mile, by age, in the lower electrofishing section (RM 17.6-21.6) of the Bighorn River.

Date	Age					
	I	I	III	IV	V+	Total
9/97	763	92	317	4	C	1,176
9/96	243	490	171	14	C	919
9/95	984	114	68	20	10	1,196
9/94	600	241	69	33	2	945
9/93	745	4	84	30	1	864
9/92 1/	C	128	42	7	C	178
12/91 2/	C	C	C	C	C	C
9/90	649	43	138	62	C	892
9/89	111	84	46	55	34	330
9/88	233	76	126	18	2	455
9/87	185	276	19	31	C	511
9/86	345	25	71	14	2	457

1/ 13 inches and longer only

2/ No trout estimate was conducted in the lower section in 1991

The 1995 rainbow population estimate set another record for both the total population at 1,196 age 1 and older rainbow per mile, and for the estimated age 1 year class at 984 per mile (Figure 11). The 1995 age 1 estimate was greater than any previous total rainbow population estimated for the lower section (Table 10).

The 1995 brown trout population in the lower section also reached record levels for both total population and for the age 1 year class in 1995 (Figure 9). Part of the record population levels seen in the fall of 1995 may have been the result of extreme high flows that occurred in the Bighorn during the spring and summer of 1995. High flows may have flushed smaller fish down from the upper river with many concentrating in the lower shocking section during fall sampling. Rainbow estimates obtained for the upper section in 1995 contained good numbers of all age classes of fish (Figure 11), but these estimates were completed before the highest flushing flows occurred during mid-July.

Regardless of where they came from, the strong 1994 year class remained a dominant part of the rainbow population in the lower section in 1996 and 1997. The 1996 rainbow population declined by 23% from 1995 levels, but the total population of 919 age 1 and older rainbow per mile was still better than any lower section rainbow estimate prior to 1994 (Table 10). The decline seen in 1996 was due entirely to a weak age 1 year class produced by poor recruitment in 1995. This weak year class corresponded to a poor age 1 year class seen in the upper shocking section in 1996. Just as the low flows experienced in 1994 resulted in strong rainbow recruitment in both the upper and lower river, the high flows in 1995 appeared to limit recruitment.

The 1996 rainbow population was dominated by two-year-old rainbow from the 1994 year class. Three-year-old fish from the 1993 year class were also an important part of the 1996 population (Table 10). The 1993 and 1994 year classes were the same year classes responsible for the tremendous rainbow increase seen in the upper shocking section in 1997. Due to the contribution of these two strong year classes the estimated population of two-year-old and older rainbow in the lower shocking section in 1996 was greater than any total rainbow population estimated for the lower section prior to 1990.

The 1997 rainbow estimate jumped back up to 1,176 age 1 and older rainbow per mile, just under the record population level seen in 1996. A strong age 1 year class comprised 65% of the 1997 population, indicating good recruitment in 1996. The strong age 1 year class in the lower river was in sharp contrast to the upper river, where age 1 rainbow comprised less than 3% of the estimated population. The contribution of the weak 1995 year class remained low in the 1997 population while the strong 1994 year class was still estimated at 317 three-year-old fish per mile. The strong 1993 year class of rainbow, which made a significant contribution to the 1996 population in the lower section as three-year-old fish, was almost nonexistent in the lower section in 1997. The estimated population of four-year-old and older rainbow in the lower section in 1997 was only 4 fish per mile (Table 10). It appears that these older fish moved out of the lower shocking section , probably moving upstream. This same year class of fish comprised 22% of the 1997 estimated rainbow population in the upper river.

Extensive movement of various age classes in and out of the lower shocking section between sampling periods has made it difficult to calculate annual mortality rates for rainbow in the lower river in the past (Frazer 1990). In contrast to recent data presented for the upper shocking section, evidence of movement in and out of the lower shocking section between sampling periods has been limited since 1992.

Total annual mortality for the lower section has ranged from about 43% to 78% since 1992 (Table 11). Only two cases of rainbow movement were obvious in these data. Two-year-old rainbow from the 1991 year class were estimated at only 4 fish per mile in 1993, yet in 1994 this same year class jumped to 69 fish per mile for a 1,600% increase (Table 11). The estimated population of rainbows from the 1993 year class increased 50% between 1995 and 1996. Movement out of the lower shocking section by 4 year old rainbow from the 1993 year class between 1996 and 1997 has already been discussed.

Table 11. Comparison of estimated annual mortality rates (percent change) for rainbow trout in the lower electrofishing section (RM 17.6-21.6) of the Bighorn River from 1992 to 1997.

Age Class*	7/92-7/93	7/93-7/94	7/94-7/95	7/95-7/96	7/96-7/97
1	C	-67.7	-81.0	-50.2	-62.1
2	-34.4	+1,625	-71.8	+50.0	-35.3
3	-28.6	-60.7	-71.0	-79.4	-97.7
4 & older	-85.7	-93.3	-72.7	-100.0	-100.0
Total	**-35.0****	**-60.1**	**-77.6**	**-43.5**	**-55.1**

*** Age class indicated is age at beginning of time interval.**

** Age 2 and older

The total biomass of rainbow present in the lower shocking section exceeded 1,000 pounds per mile for the first time in 1994, when the estimated biomass reached 1,063 pounds per mile. Total rainbow biomass dropped back to 636 pounds per mile in 1995. Although population numbers were at an all time high, one-year-old fish comprised 82% of the population. Rainbow biomass reached a new high in 1996 at 1,146 pounds per mile then declined slightly to 1,020 pounds per mile in 1997. Biomass is a direct reflection of the contribution larger fish make to the total population estimate.

The average lengths of various age classes of rainbow trout in the lower shocking section have remained fairly consistent from year to year (Table 12). It was not possible to compare growth rates in the upper and lower shocking sections due to differences in sampling times. The upper section is sampled at the beginning of the growing year, while the lower section is sampled closer to the end.

Table 12. - Average length (inches), by age class, of rainbow trout from the lower electrofishing section (RM 17.6-21.6) of the Bighorn River during September 1992-1997.

Year	Age				
	1	**2**	**3**	**4**	**5+**
1992	C	16.2	19.2	19.9	C
1993	9.7	11.2*	17.8	19.1	20.5
1994	10.5	16.3	19.2	20.7	20.8
1995	8.6	15.0	17.8	19.7	19.8
1996	10.3	14.7	17.9	19.1	C
1997	9.7	15.2	17.3	19.6	C

* Average based on 4 fish

Summary and Discussion - Rainbow Trout

The rainbow population in the Bighorn river received a major boost from two strong year classes produced in 1985 and 1986, following operational changes to reduce gas supersaturation problems and the elimination of trout stocking in the upper river. These two year classes helped build the rainbow population in the Bighorn to a new level, which in turn, produced a stronger spawning population. When the progeny of these spawners matured, they produced two new, strong year classes in 1993 and 1994. Fish from these two year classes have been a dominant part of the rainbow population in both the upper and lower river in recent years. It appears these two year classes may be carrying the rainbow population in the Bighorn to another new level.

Rainbow population data are showing the same pattern discussed for brown trout with an increase in recruitment and rearing of young fish in the lower shocking section. This increase began with the better flow conditions experienced in the early 1990's. Population estimates for the lower section showed that strong year classes of rainbow have been produced every year except one since 1992 (Figure 11). Even the poor year class produced in 1995 showed up much stronger in the lower section as an age 1 year class in 1996 than in the upper river. Upstream movement of rainbows produced downstream of Soap Creek may become an important factor in maintaining the rainbow fishery in the upper river.

One consequence of the recent strength seen in the Bighorn rainbow population has been to shift the balance in the Bighorn River trout population. When annual sampling was first initiated on the Bighorn in the early 1980's, the trout population was strongly dominated by brown trout. The expansion of the rainbow population in the Bighorn has, to some extent, been at the expense of the brown trout population. This shift should be good news for most anglers based on a survey of Bighorn River anglers conducted in 1992 and 1993. Responses to this survey showed that most anglers strongly favored management alternatives which would benefit rainbow over brown trout (Frazer & Brooks 1997). It remains to be seen whether the current increases in rainbow levels will eventually lead to a dominance of rainbow in the Bighorn River.

MANAGEMENT RECOMMENDATIONS

! Because WETP studies reinforce the traditionally requested flow releases, these should be used as the basis of negotiations as part of the Crow Compact settlement.

! Hydraulic studies on the river should be expanded further downstream, at least to Two Leggins Diversion. Work with BOR and WAPA to establish additional permanent cross sections and monitor changes in side channel and island configurations in this lower section of river.

! The importance of the Bighorn River fishery continues to warrant annual sampling at the upper and lower sections to closely monitor changes in fish populations.

! Whirling disease continues to present a serious threat to the Bighorn River fishery. Monitoring for whirling disease should continue in the Bighorn River through periodic sampling of fish and placement of test cages in the river.

! Increasing numbers of rainbow trout, and especially larger rainbow, may allow consideration of a future regulation change permitting harvest of a trophy rainbow trout in the special regulation section above Bighorn FAS.

! Public access is an important issue on the Bighorn River so all new real-estate offerings along the river should be evaluated as to their potential of providing additional public access.

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