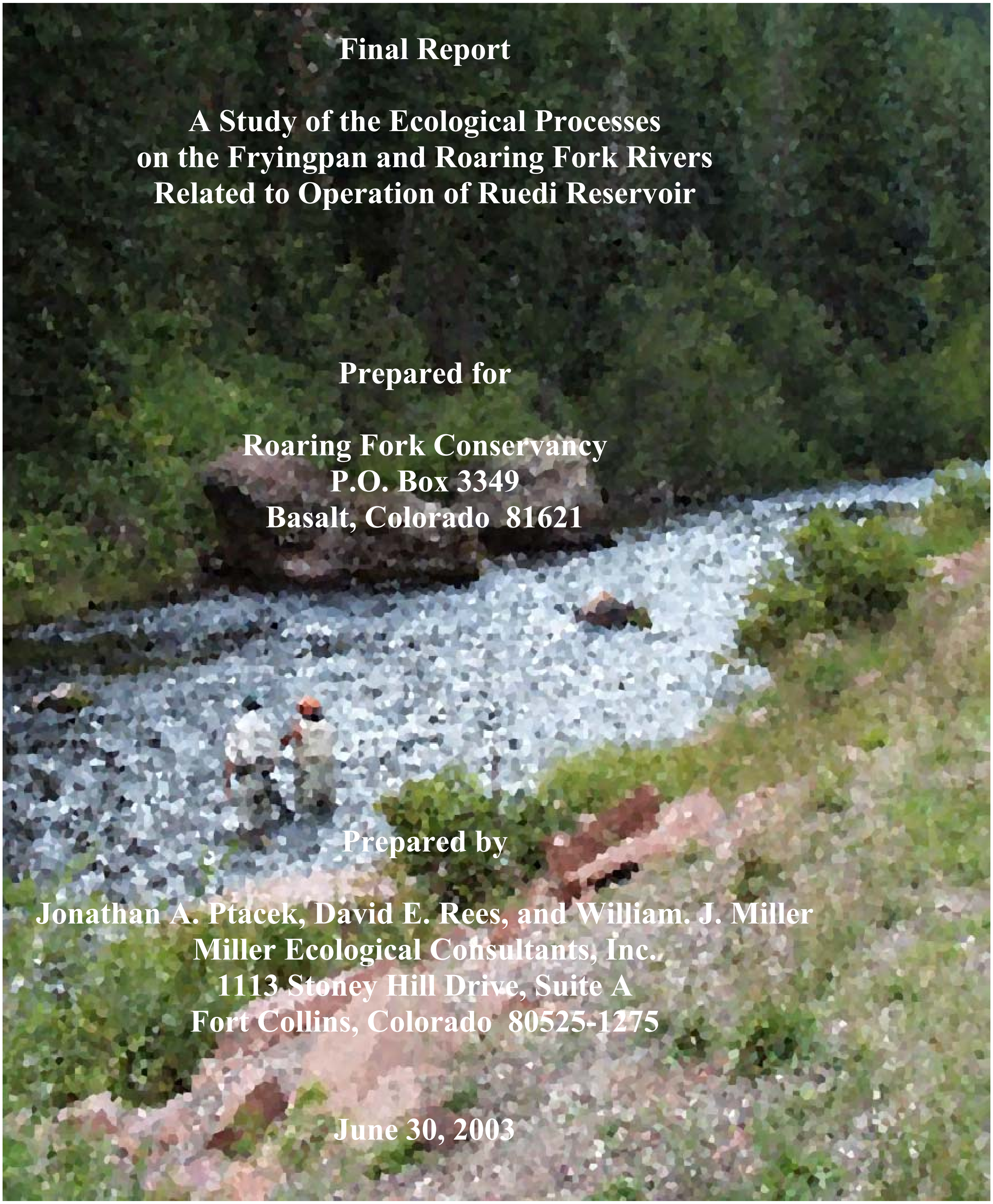

Final Report

A Study of the Ecological Processes on the Fryingpan and Roaring Fork Rivers Related to Operation of Ruedi Reservoir

Prepared for

Roaring Fork Conservancy
P.O. Box 3349
Basalt, Colorado 81621

Prepared by

Jonathan A. Ptacek, David E. Rees, and William. J. Miller
Miller Ecological Consultants, Inc.
1113 Stoney Hill Drive, Suite A
Fort Collins, Colorado 80525-1275

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MILLER ECOLOGICAL CONSULTANTS, INC.

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EXECUTIVE SUMMARY

Introduction

This study was conducted on the Fryingpan and Roaring Fork rivers to characterize the physical habitat and aquatic biota related to the operation of Ruedi Reservoir. The study components included instream habitat and flow relationships, thermal regime of reservoir releases, characterization of spawning habitat, and investigations into benthic macroinvertebrate populations and fish populations.

The study area for the fisheries evaluation consisted of the Fryingpan River from Ruedi Dam downstream to its confluence with the Roaring Fork, and the Roaring Fork River downstream of the Fryingpan River. The objective of the investigation and emphasis of this study is to provide current information on the biological and physical characteristics of the river and update information from the 1980s during a previous evaluation of operation of Ruedi Dam.

The intent of this executive summary is to provide a brief synopsis of this research study conducted on the Fryingpan and Roaring Fork rivers. For a more detailed and in-depth discussion of this study and its many subcomponents, please refer to the main body of this report.

Methods

The study approach to determine instream habitat and flow relationships relied on the Instream Flow Incremental Methodology (IFIM) and USGS hydrology data. The IFIM uses measurement cross-sections at a range of flow regimes and then combines hydraulic modeling with habitat suitability criteria. Species of interest for this study were brown and rainbow trout. The USGS hydrology data was used to determine changes in flow prior to and after Ruedi Dam was constructed on the river.

Thermal regimes were characterized by instream measurement with constant recording thermographs placed at four locations. These locations were the Fryingpan River below Ruedi Dam, Fryingpan River upstream of the confluence, Roaring Fork River upstream of its confluence with the Fryingpan River, and Roaring Fork River downstream of the Fryingpan River.

Spawning habitat was assessed using artificial redds constructed in the fall to approximate brown trout spawning, and spring to evaluate rainbow trout spawning. Artificial redds were constructed using a shovel to excavate a redd similar to the technique that a trout uses to move the gravel by fanning close to the substrate. After excavation, a thermograph and standpipe were placed in the redd and the redd was backfilled from upstream just as a spawning trout would do. Monthly measurements were taken during the course of the spawning and incubation period to determine intragravel characteristics for dissolved oxygen and water temperature.

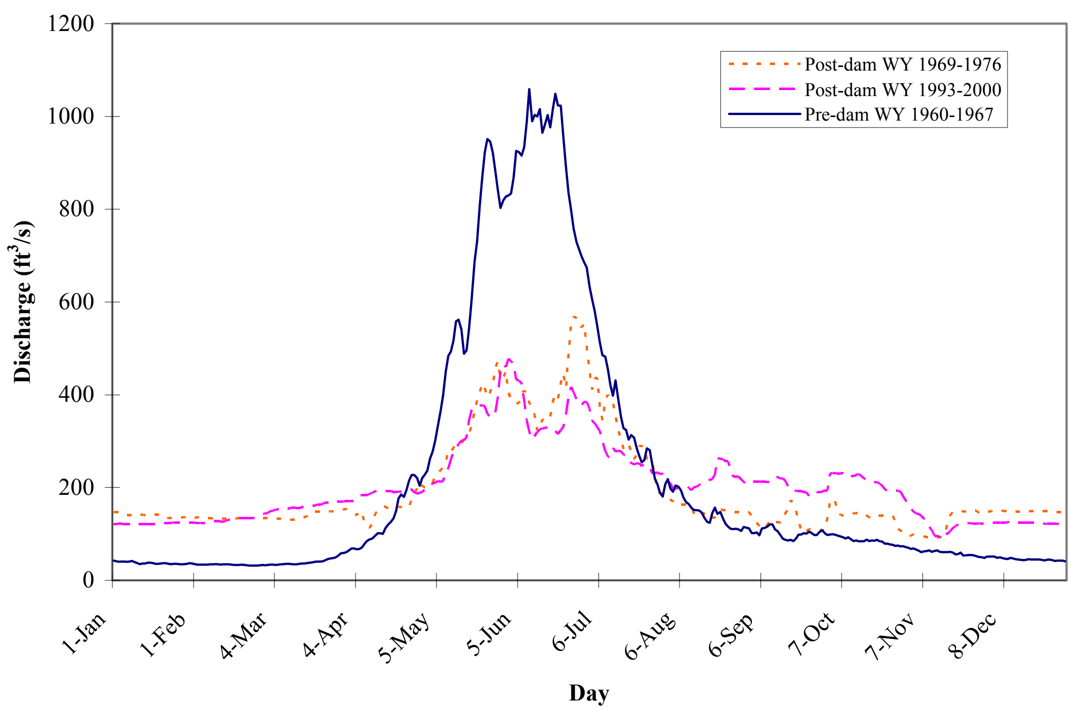
Benthic macroinvertebrate populations were evaluated using quantitative sampling in spring and fall at two locations in the Fryingpan River and two locations in the Roaring Fork River. Quantitative sampling consisted of a modified Hess sampler used to collect three replicate samples at each location. Invertebrate samples were collected in the Fryingpan River downstream of Ruedi Dam, just downstream of Taylor Creek in the Fryingpan River, and at two locations downstream of the Fryingpan River confluence in the Roaring Fork River. Macroinvertebrates were identified to lowest practical taxon and quantitative evaluations were made of population statistics.

Fish populations were evaluated using existing data from Colorado Division of Wildlife (CDOW) electrofishing data on the Fryingpan and Roaring Fork rivers. In addition to recent CDOW data, historical information for the Fryingpan River prior to the construction of Ruedi Reservoir was also included in the evaluation.

Results

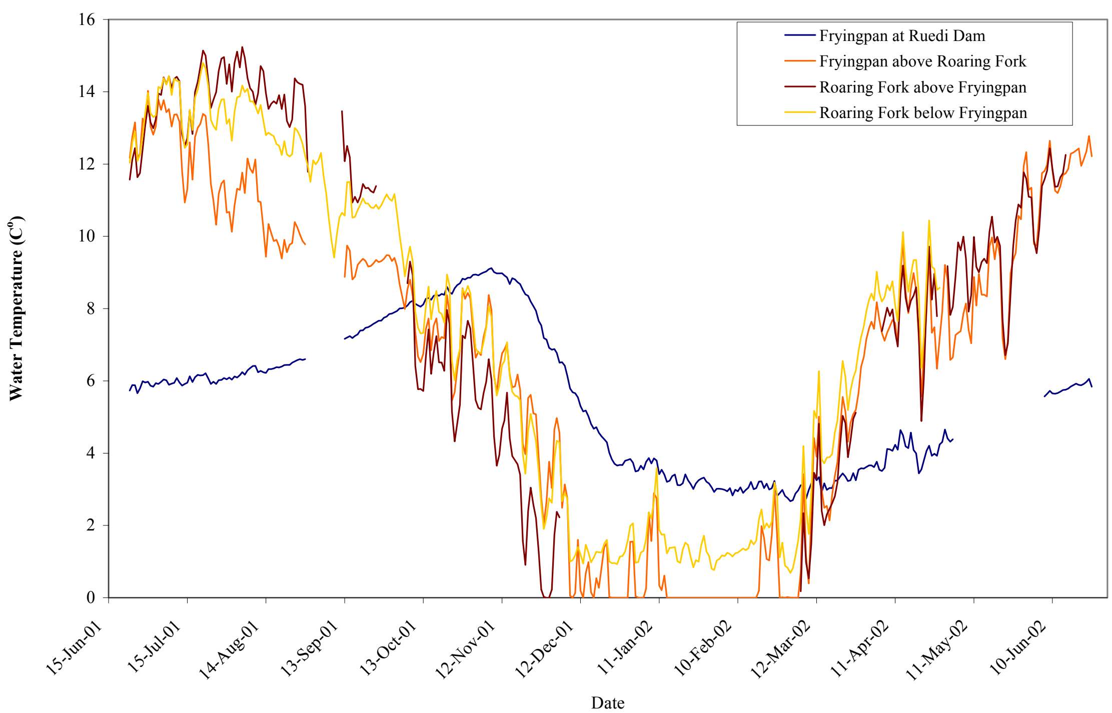
The physical attributes for this study included hydrology, thermal regime, spawning habitat, and habitat suitability or weighted useable area. Pre-dam and post-dam flow regimes show a significant difference in the shape of the hydrograph. The pre-dam hydrograph was characterized by a high snowmelt runoff in May, June and July, and low fall and winter baseflows. The pre-dam hydrograph for the Fryingpan River is typical of a snowmelt runoff system. The post-dam hydrograph shows a significant reduction in the peak flows in May and June with considerably elevated baseflows during the fall and winter. A comparison of these hydrographs is shown in Figure ES-1. Since 1989, a fairly common occurrence is an observed shift in the timing of the yearly peak flow. Prior to construction of Ruedi Reservoir and after completion until 1989, peak flows typically occurred in May or June. Recently, due to water releases intended to aid downstream endangered fishes, peak flows have been occurring during the late summer and early fall. This shift in the peak flow may have implications on the biological system in the Fryingpan River.

Figure ES-1. Average daily discharge pre and post Ruedi Dam construction.



Thermal monitoring in the Fryingpan River below Ruedi Reservoir shows that water temperatures are warmer in the winter and cooler in the summer due to the effects of Ruedi Reservoir. During the winter, water temperatures decrease with distance downstream of the reservoir. In the summer, the opposite occurs, with water temperatures increasing with distance downstream. Fryingpan River temperatures come close to ambient temperature downstream near the confluence with the Roaring Fork. In general, water temperatures are low throughout most of the year with the warmest temperatures occurring in the late fall during reservoir turnover (Figure ES-2). In an unregulated, snow melt runoff system, maximum water temperatures would typically occur during the late summer base flows.

Figure ES-2. Average daily water temperature (C^o) for two sites on the Fryingpan River and two sites on the Roaring Fork River.



Monitoring of brown and rainbow trout spawning habitat included intragravel temperature monitoring and sediment surveys. Brown trout spawning typically commences in mid to late October in the Fryingpan River. During this time, water temperatures are elevated in the upstream sections due to Ruedi Reservoir turning over (Figure ES-3). Although water temperatures are suitable for successful spawning and egg incubation throughout the Fryingpan River at this time, this data suggests that the highest brown trout spawning success would likely occur in the upstream reaches. Due to lower temperatures in the downstream reaches, the incubation period is extended and results in later emergence. Rainbow trout redd temperatures show the opposite characteristic (Figure ES-4). Rainbow trout spawning generally occurred in March and April with emergence in June and July. Water temperatures at the onset of spawning are lower than those required for successful incubation and there is likely high mortality at both sites. Due to the previously discussed thermal characteristics, the upstream site exhibits colder average intragravel water temperatures than the downstream site. The downstream site also has more daily variation and higher daily maximum temperature. Successful rainbow trout reproduction has been noted in the fish collections in the Fryingpan River near the Seven Castles Creek confluence. It is likely that extremely high egg mortality rates exist throughout the majority of the Fryingpan River below Ruedi Reservoir due to low water temperatures at the onset of spawning.

Sediment characteristics within both rainbow and brown trout artificial redds show that the substrate itself, once cleaned by the fish, is adequate for successful emergence of the fish. There was no significant input of fine sediment during the monitoring period for either brown or rainbow trout.

Results of the IFIM analysis show that the brown trout weighted useable area and rainbow trout weighted useable area show a response similar to the results of Nehring (1988b). Optimal flows for adult rainbow trout are approximately 250 ft^3/s in the low gradient sections and 200 ft^3/s in the higher gradient riffle sections. Brown trout adults show a similar response. Juvenile brown trout show a maximum weighted useable area corresponding to a flow of approximately 150 ft^3/s. Spawning habitat peaks at approximately 100 ft^3/s for both species (Table ES-1).

Figure ES-3. Average daily water temperature (C°) from two artificial redds during brown trout spawning at two locations on the Fryingpan River.

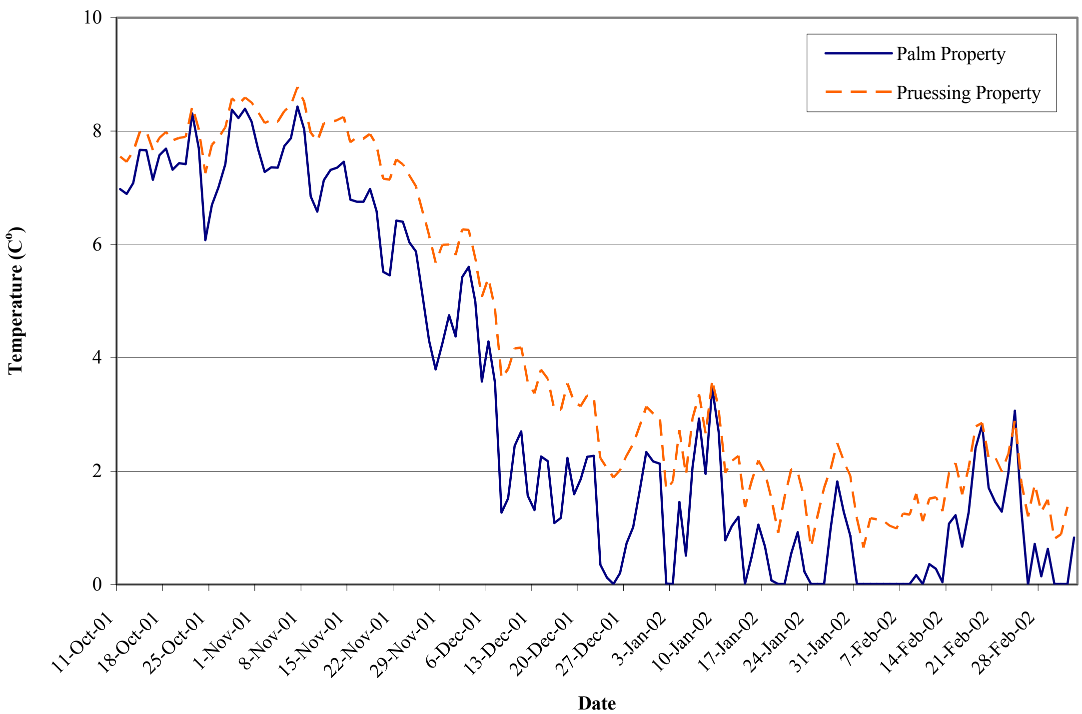


Figure ES-4. Average daily water temperature (C°) from two artificial redds during rainbow trout spawning at two locations on the Fryingpan River.

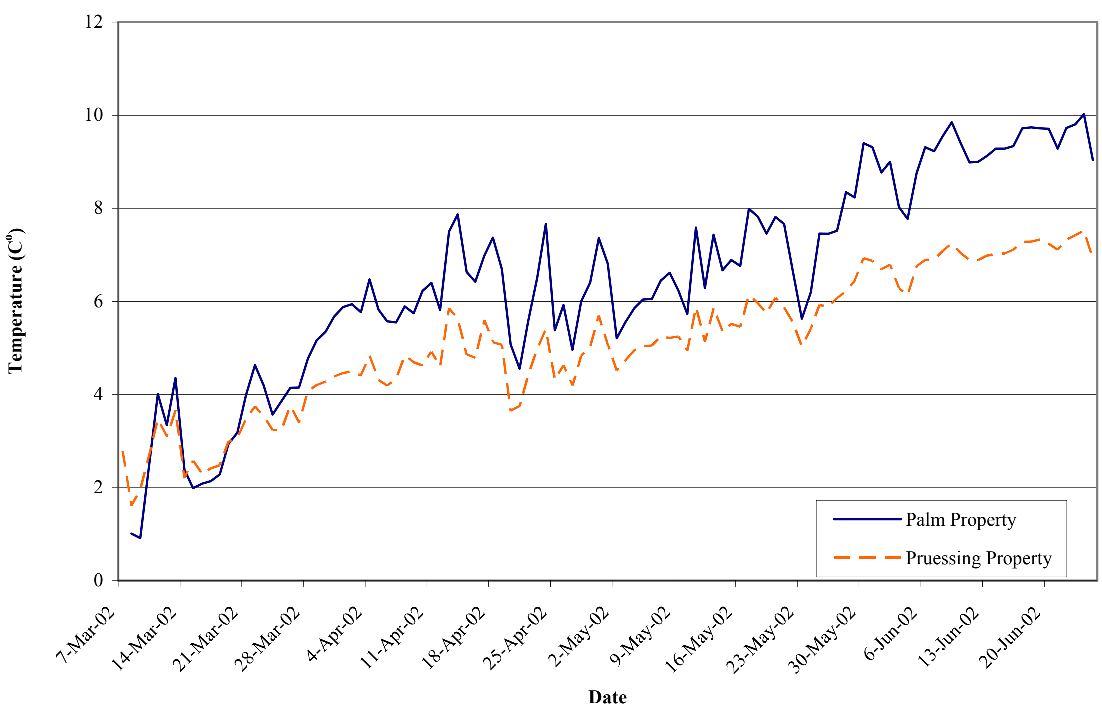


Table ES-1. Maximum weighted usable area (ft^2 per 1,000 ft) by lifestage and site. Discharge associated with maximum WUA is in parentheses. Overall maximum WUA for each lifestage is shaded yellow.

	Maximum Weighted Usable Area (ft^2 per 1,000 ft) by Site		
Species-Lifestage	**FPR-BP**	**FPR-HG**	**FPR-LG**
Brown-Juvenile	4452 (258)	5142 (150)	7404 (150)
Brown-Adult	25357 (400)	11218 (200)	26468 (246)
Rainbow-Juvenile	5645 (258)	5762 (100)	9042 (120)
Rainbow-Adult	34334 (600)	12068 (200)	29784 (246)
Spawning	10124 (100)	608 (60)	6332 (108)

One concern for the study is the impact of reducing late fall and winter baseflows. A low gradient riffle cross-section shows that the wetted area of the cross-section decreases by about six feet on a sixty foot cross-section or about 10% loss in wetted area. Implications of this decrease are the possible stranding of redds if flows drop after brown trout spawning is initiated. There is also a loss of wetted area and likely loss of macroinvertebrates and periphyton that provide food for the fish in the stream. The cross-sectional areas for those flows are shown in Figure ES-5.

The biological community investigations included macroinvertebrate sampling at two locations in the Fryingpan River and two locations in the Roaring Fork River over a three year period. The macroinvertebrate populations show high diversity in the Fryingpan River near Taylor Creek and in the Roaring Fork River (Figure ES-6). Diversity is reduced in the Fryingpan River immediately below Ruedi Reservoir. This is typical of regulated rivers due to alterations to the thermal regime and food sources. Fewer species are able to tolerate and flourish amid the alterations to the environment caused by dam operations. The system begins to recover natural function as it flows toward the Roaring Fork River and in turn, diversity increases.

Figure ES-5. Bed profile and modeled water surface elevations for run cross section at FPR-LG upper. Elevation is relative elevation based on a vertical base of 100 ft.

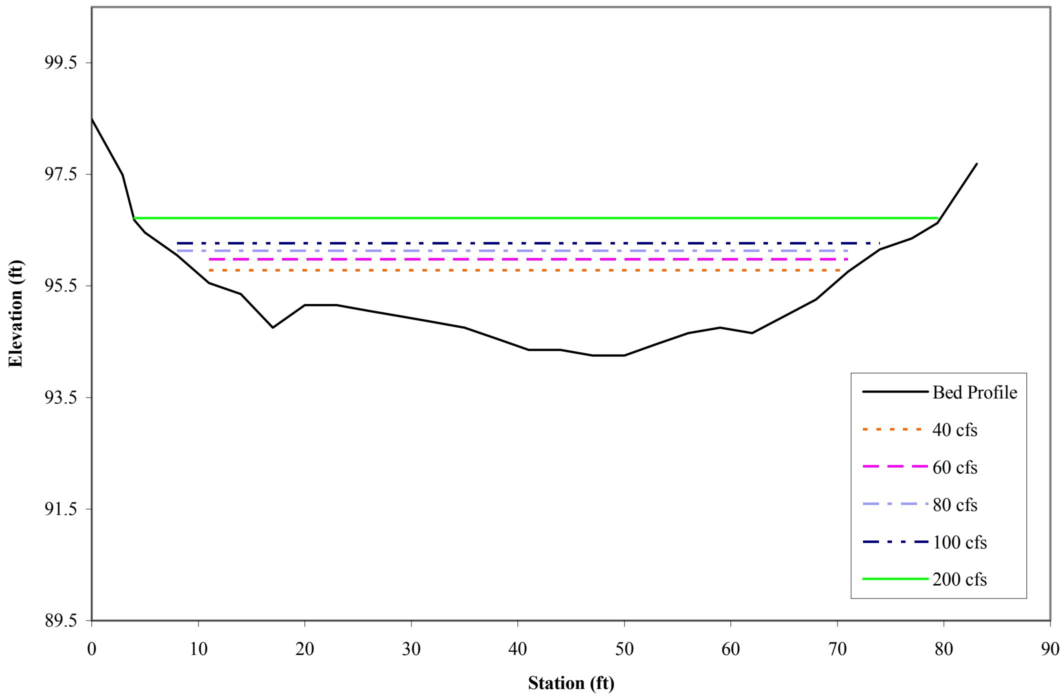
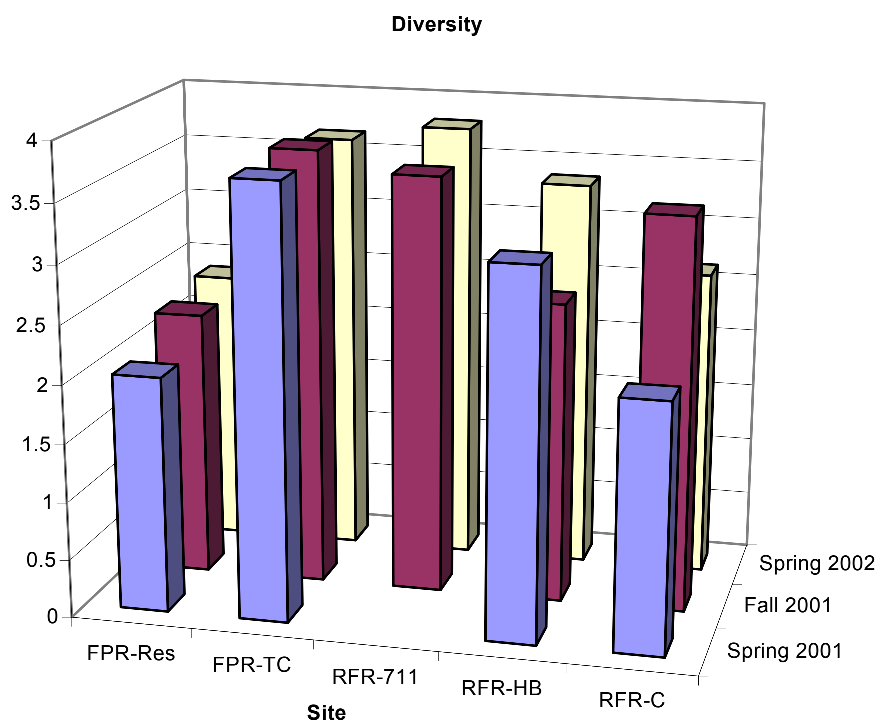


Figure ES-6. Diversity values obtained from sites on the Fryingpan River and Roaring Fork River, Colorado.



Macroinvertebrate densities are fairly similar between sites, with extremely high densities found in the spring of 2000 samples. The Fryingpan River downstream of the reservoir has some of the highest densities in the river. This is due to the stable environment and nutrient rich water provided by Ruedi Reservoir. Typical values in Colorado streams for good macroinvertebrate density are in the 5,000/m^2 range for unregulated streams. Both the Fryingpan and Roaring Fork rivers show macroinvertebrate numbers that are over 10,000/m^2 and in several instances over 20,000/m^2 at the sampling sites. This indicates that the benthic fauna are doing extremely well in both the Fryingpan and Roaring Fork rivers.

Fish populations were assessed using data from the CDOW, which has intensively monitored Fryingpan River populations since the late 1970s. Pre-dam fisheries data from the 1940s and 1960s were also evaluated (Figure ES-8). The trout population in the Fryingpan River immediately below Ruedi Reservoir has shown a shift from being dominated by rainbow trout in the late 1970s and 1980s to a salmonid community dominated by brown trout today. This may be due to several factors. The Fryingpan River was heavily stocked with rainbow trout from the 1970s until the late 1980s. No stocking occurred from 1994 through 1997 but has resumed in the past few years. There is also an indication that whirling disease is impacting the rainbow trout population. Steps were taken in 2002 to eliminate spores entering the river by installing a filter on the outflow from a known whirling disease source location from off-channel ponds. Brook trout and Colorado River cutthroat trout are either extirpated from the system or considered to be rare.

Overall, trout populations in the Fryingpan River are high. Total numbers and overall size has increased dramatically in the last 25 years. Fish over 4.5 kg (10 pounds) are caught by anglers and fish up to 10 kg (22 pounds) have been captured from the Fryingpan River below Ruedi Reservoir.

Figure ES-7. Density values obtained from sites on the Fryingpan River and Roaring Fork River, Colorado.

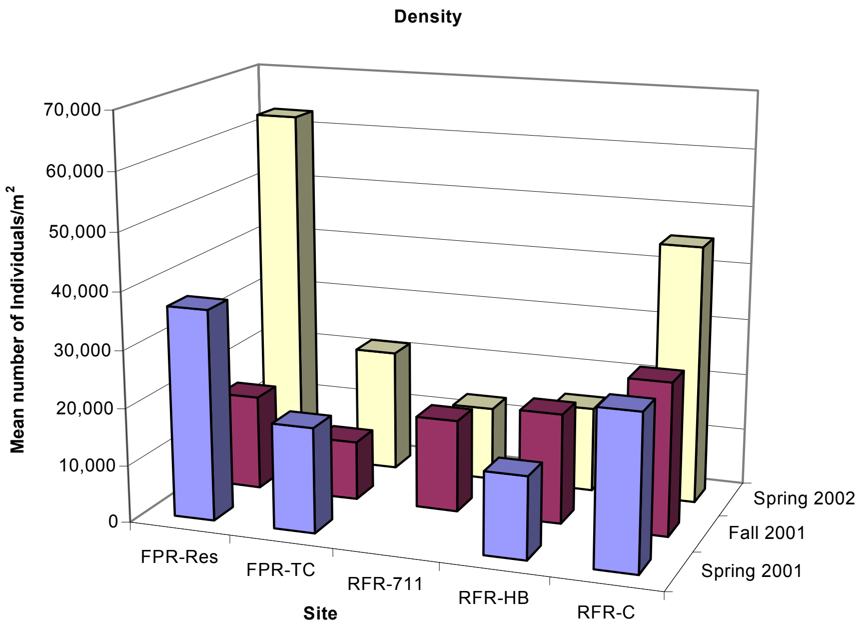
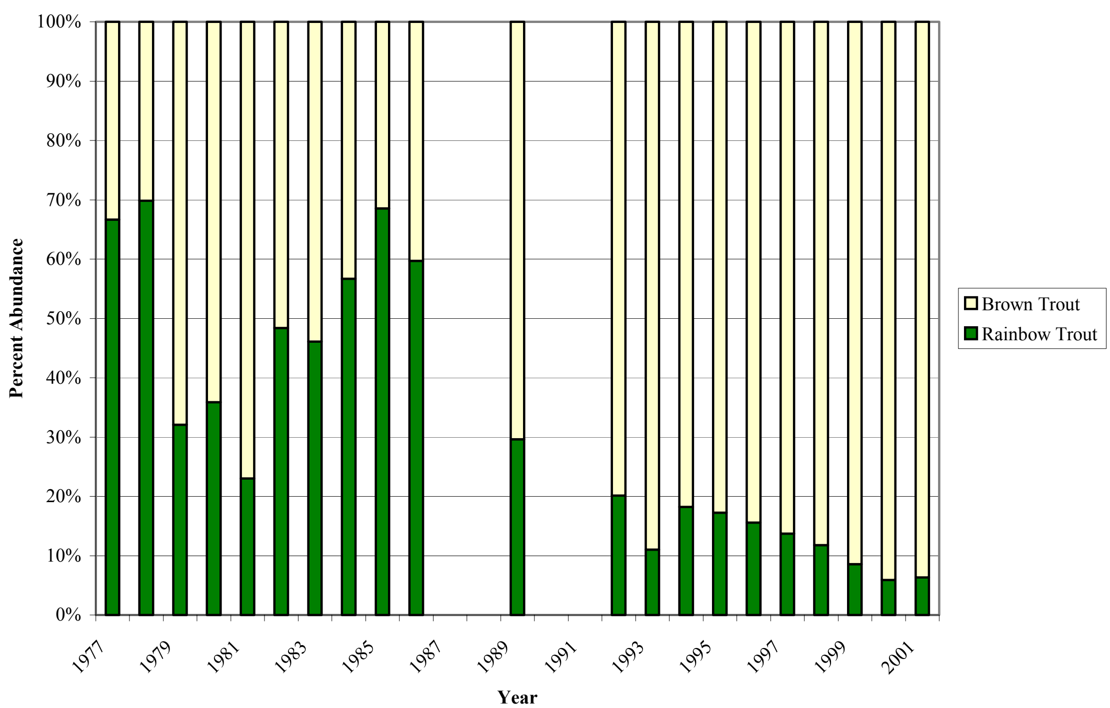


Figure ES-8. Fryingpan River trout percent abundance at the Ruedi sampling site. All data is from fall sampling, except 1989 and 1992, which are from spring sampling. Data source: Nehring and Thompson (2002).



Conclusions

In this section we provide the main conclusion points of this study in bullet format. Please refer to the main document for detailed discussion.

IFIM

- The amount of suitable trout habitat has increased with post-dam conditions as compared to habitat available pre Ruedi Dam construction.
- The CDOW Catch and Release section contains the best combination of active foraging and refuge/resting habitat in the Fryingpan River.

Macroinvertebrate Community

- Hypolimnetic releases and regulated flows in the Fryingpan River are responsible for maintaining extraordinarily high densities and biomass.
- Densities were highest in the Fryingpan River immediately below Ruedi Dam and in the Roaring Fork River near Carbondale.
- Benthic communities display longitudinal changes in structure.

Spawning

- Rainbow trout spawning success is temperature limited on the Fryingpan River.
- Rainbow trout spawning success may be further reduced by whirling disease.

Trout Populations

- Relative abundance of brown trout has significantly increased over the past 20 years.
- Maximum size and overall biomass has increased dramatically since dam construction.
- The portion of the trout community most affected by reservoir construction and operation is located immediately below the dam.

Thermal Regime

- The annual maximum temperature is shifted from late summer to late fall/early winter.
- Released water has reduced diel and annual temperature fluctuation.
- Water released is warmer than normal in the fall and winter and cooler than normal in the late spring and summer.
- The amount of influence the Fryingpan River has on the Roaring Fork River is dependant upon the proportion of Fryingpan River flow as compared to Roaring Fork River flow.

Hydrology

- Since dam construction, baseflows are augmented by reservoir releases and spring peak flows are reduced.
- Since 1989, reservoir releases have been significantly increased during the late summer/fall (August through October).
- In four of the last nine years maximum yearly flow occurred during September.
- Extreme fluctuations in reservoir releases occur fairly frequently on the hourly and daily level.

INTRODUCTION

During the mid-1900's the U.S. Bureau of Reclamation built numerous dams and reservoirs across the western United States. These dams and reservoirs were built to control floods, provide water for agricultural irrigation, and supply growing municipalities with needed water resources.

Dams affect rivers by regulating streamflows (Bain et al. 1988; Munn and Brusven 1991; McKinney et al. 2001), altering the thermal regime (Hauer and Stanford 1982; Voelz and Ward 1989; Vinson 2001) and reducing sediment input (Andrews 1986). Changes to the physical environment caused by dams have profound impacts on the aquatic biota downstream. Macroinvertebrate densities and community structure are often significantly altered (Munn and Brusven 1991, Moog 1993). Salmonid populations may significantly increase due to effects of dam operations (McKinney et al. 2001). Trout communities in the Blue River below Dillon Reservoir, Fryingpan River below Ruedi Reservoir, Green River below Flaming Gorge Reservoir, San Juan River below Navajo Reservoir, South Platte River below Cheesman Dam, and Taylor River below Taylor Park Reservoir are examples of western salmonid populations which are affected by the altered environment created by dam construction.

Ruedi Dam was completed in 1968 (U.S. Bureau of Reclamation 1975), inundating a portion of the Fryingpan River and creating Ruedi Reservoir, which is a large (102,373 af [Finnell 1972]) federally owned, Fryingpan-Arkansas Project storage reservoir. The primary objective of Ruedi Reservoir is to compensate senior West Slope water users for water diverted to the Arkansas basin through the Fryingpan-Arkansas Project. Ruedi Reservoir is also used to provide water for municipal/industrial uses, agriculture, recreation, conservation of fish and wildlife, as well as to provide a measure of flood control. Beginning in 1989, Ruedi Reservoir has provided additional releases in the late summer to offset impacts to endangered fish species in the Colorado River. Since 1968, the salmonid fishery in the Fryingpan River and to a lesser extent in the Roaring Fork River has been affected by operation of Ruedi Dam.

The Fryingpan River has developed into a world class fishery in part due to the altered physical environment, and special angling regulations that began in 1978 (Nehring and Anderson 1984). The introduction of the non-native opossum shrimp (*Mysis relicta*) into Ruedi Reservoir in 1970 provided a tremendous supplemental prey source for trout populations below the dam (Nehring 1991).

Objectives

The purpose of this study conducted by Miller Ecological Consultants, Inc., (MEC) is to evaluate impacts of the current and potential future operating conditions of Ruedi Reservoir on resident salmonid populations in the Fryingpan River and the lower Roaring Fork River by means of the following specific objectives:

- Quantify the relation between flow level and available salmonid habitat using an Instream Flow Incremental Methodology (IFIM) approach.
- Determine if fluctuations in brown and rainbow trout populations are related to flows that occur during various life stages.
- Determine the relationship between flow levels and other biological and physical processes, including macroinvertebrate populations, water quality parameters, and spawning habitat.
- Determine the relationship between trout populations and fish habitat elements, including macroinvertebrate populations, water quality parameters, and spawning habitat.

In order to provide a document which is clear but remains scientifically valid to both scientific and non-scientific communities, this report deviates from standard scientific writing practices regarding unit consistency. Data presented for hydraulic simulations and discharge is in English units, whereas the remainder of the document uses metric units.

Some terminology exists within this document that is scientific and technical; therefore, a glossary of selected scientific terms exists at the end of the document.

Study area

The study area for this project includes the Fryingpan River from Ruedi Reservoir downstream to the confluence with the Roaring Fork River, and the Roaring Fork River from immediately above its confluence with the Fryingpan River downstream to Carbondale, Colorado (Figures 1, 2, 3 and 4).

Within the study area, the Fryingpan River is a tailwater stream with flows controlled by releases from Ruedi Reservoir (Figure 5). In 1973, the Colorado Water Conservation Board appropriated a minimum instream flow of 39 ft^3/s from 1 November through 30 April, and 110 ft^3/s from 1 May through 31 October for the Fryingpan River (Colorado Water Conservation Board 2001). Several tributaries join the Fryingpan River in the study area, with some of the most important being Rocky Fork Creek, Downey Creek, Taylor Creek, and Seven Castles Creek. The 22.5 km section of the Fryingpan River below Ruedi Reservoir is a patchwork of public and private land.

The Colorado Division of Wildlife (CDOW) and U.S. Forest Service (USFS) manage lands that offer recreational access to the Fryingpan River below Ruedi Reservoir. The U.S. Geological Service (USGS) operates a real-time streamflow gage (USGS gage 09080400) approximately 0.4 km miles below the dam. The section from Ruedi Dam downstream to the confluence has been designated as "Gold Medal Water" by the CDOW and offers important recreational opportunities as well as economic value to the region (Crandall 2002). Historically, the native fishery was composed of Colorado River cutthroat trout (*Oncorynchus clarki pleuriticus*), mottled sculpin (*Cottus bairdi*), and possibly bluehead sucker (*Catostomus discobolus*). Mountain whitefish (*Prosopium williamsoni*) are native to the upper Colorado Basin (Behnke and Benson 1980); however, this species is not native to the Roaring Fork and Fryingpan rivers. Mountain whitefish were stocked into the Roaring Fork River prior to 1970 (Finnell 1972) and established a self-sustaining population. Currently, the fishery is composed of brown trout (*Salmo trutta*), rainbow trout (*Oncorhynchus mykiss*), and occasionally brook trout (*Salvelinus fontinalis*) and cutthroat trout (*Oncorhynchus* sp.).

The Roaring Fork River is a primarily unregulated river with a hydrograph typical of snowmelt controlled systems (Figure 5). Peak flows occur in early summer, mid-flows in late summer, and base flows throughout the late fall, winter and early spring. The Fryingpan River enters the Roaring Fork River in the town of Basalt. The Roaring Fork River continues approximately 45 km downstream, adding another major tributary (Crystal River) near Carbondale, before it empties into the Colorado River near Glenwood Springs. The USGS operates two real-time streamflow gages (USGS 09081000 and USGS 09085000) in this section. From the confluence of the Crystal River downstream, the Roaring Fork River is considered "Gold Medal Water" by the CDOW. The Roaring Fork River supports a coldwater fishery consisting of brown trout, rainbow trout, cutthroat trout, and mountain whitefish.

Figure 1. Satellite image of Roaring Fork and Fryingpan valleys from Carbondale upstream to Ruedi Reservoir.

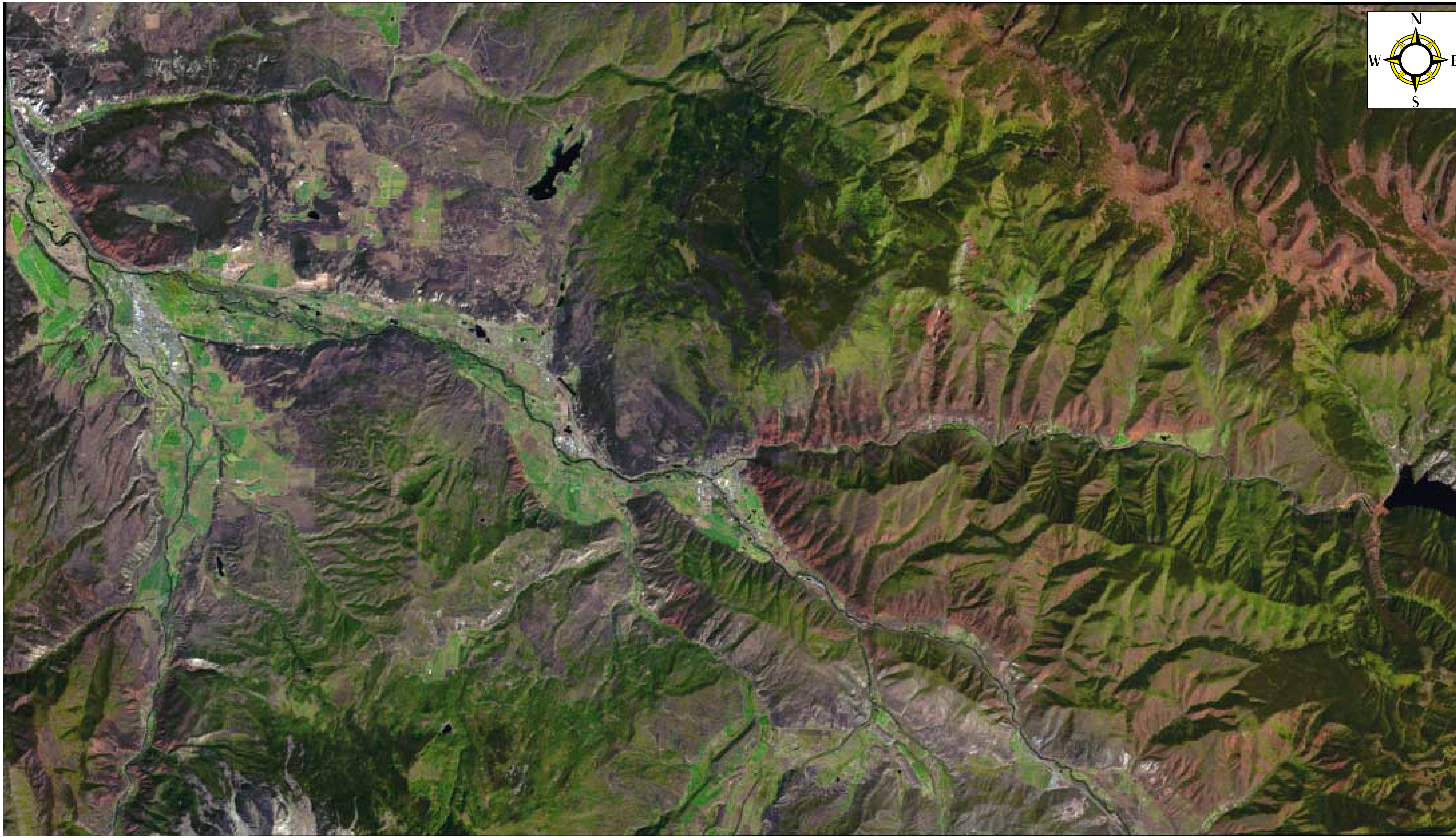


Figure 2. Satellite image of Roaring Fork River study area and sampling sites (Macroinvertebrates: red, IFIM: yellow).

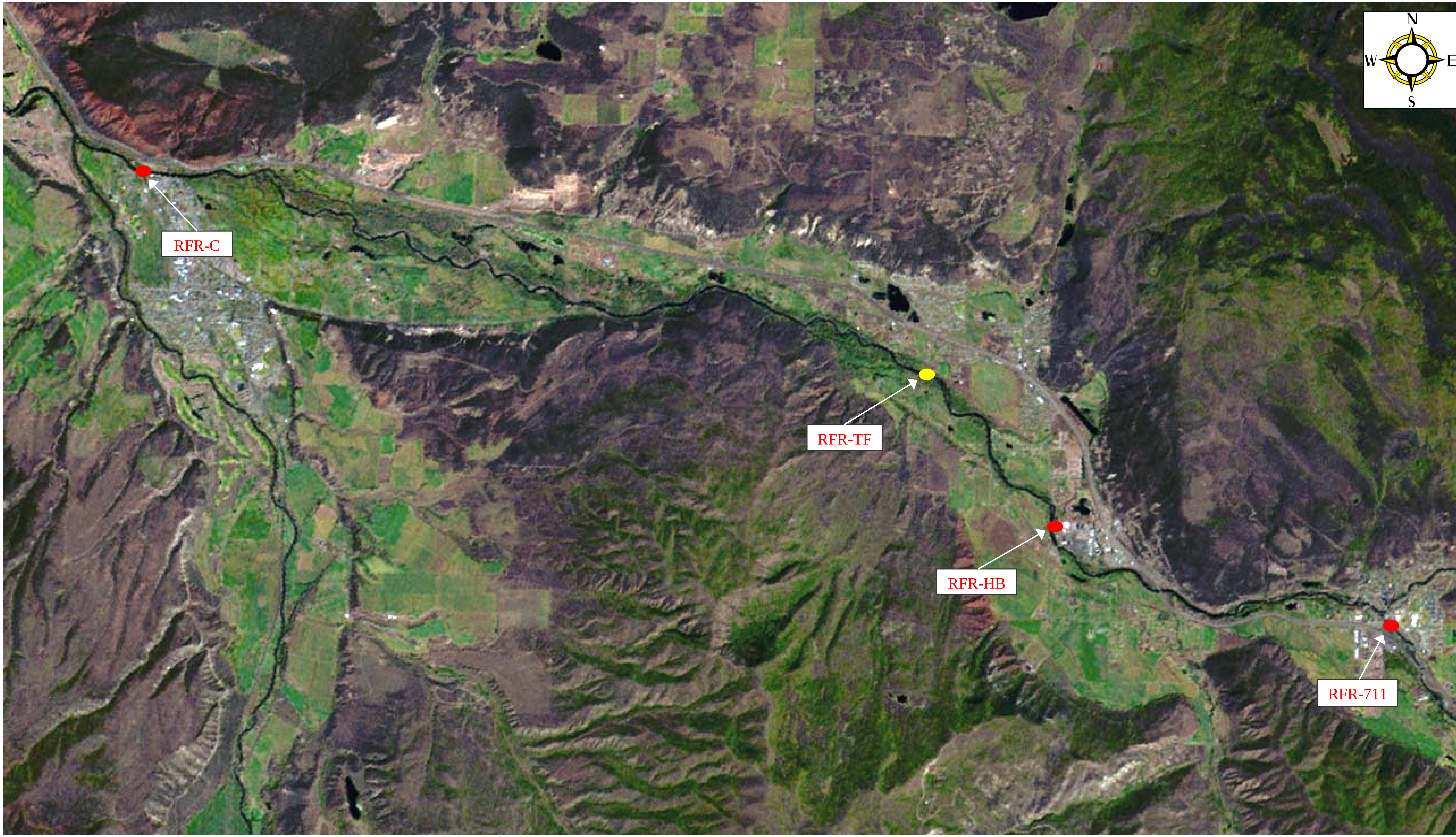


Figure 3. Satellite image of Fryingpan River study area from Ruedi Reservoir downstream to below Downey Creek (Macroinvertebrates: red, IFIM: yellow, Artificial Redds: purple).

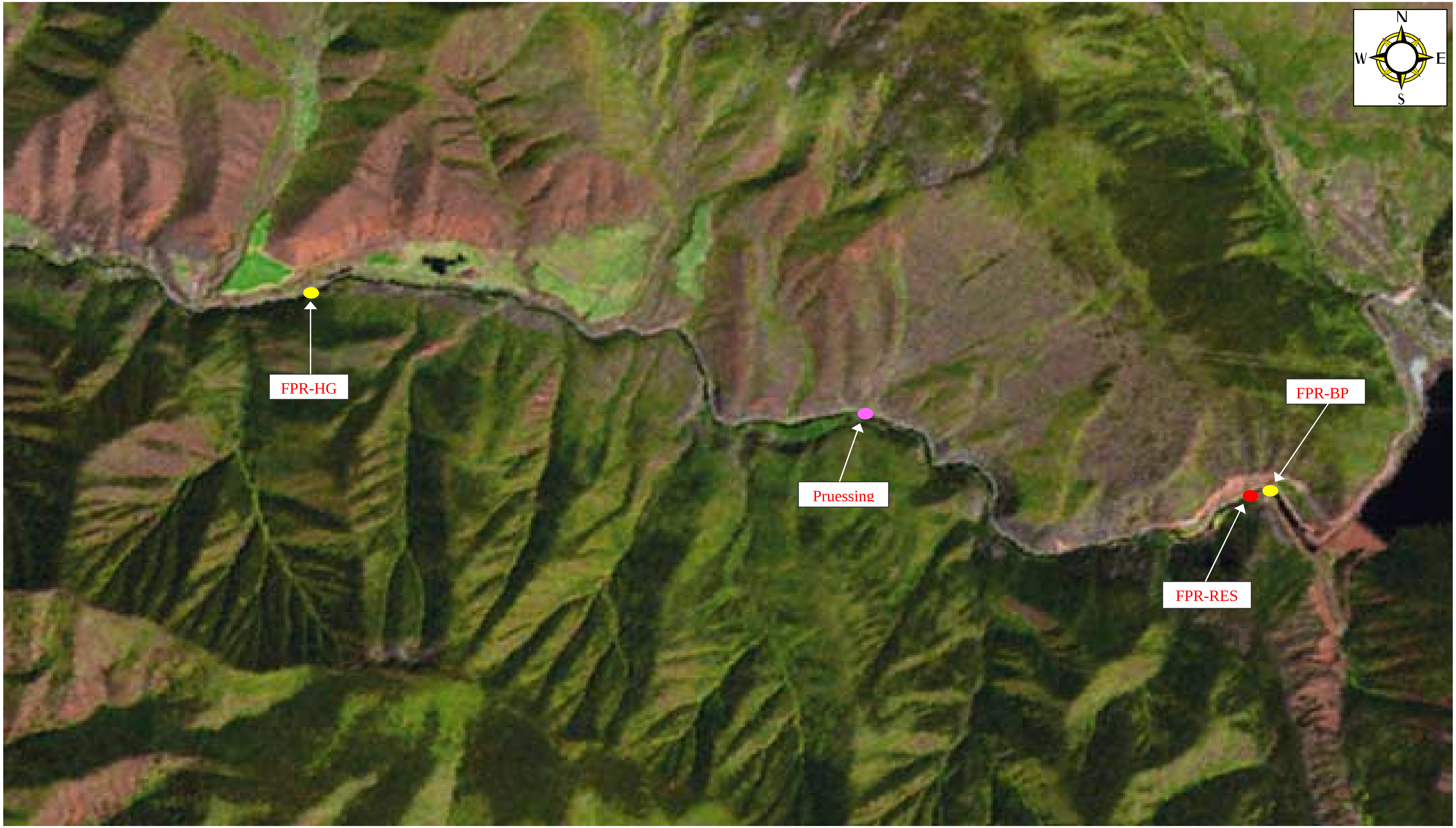
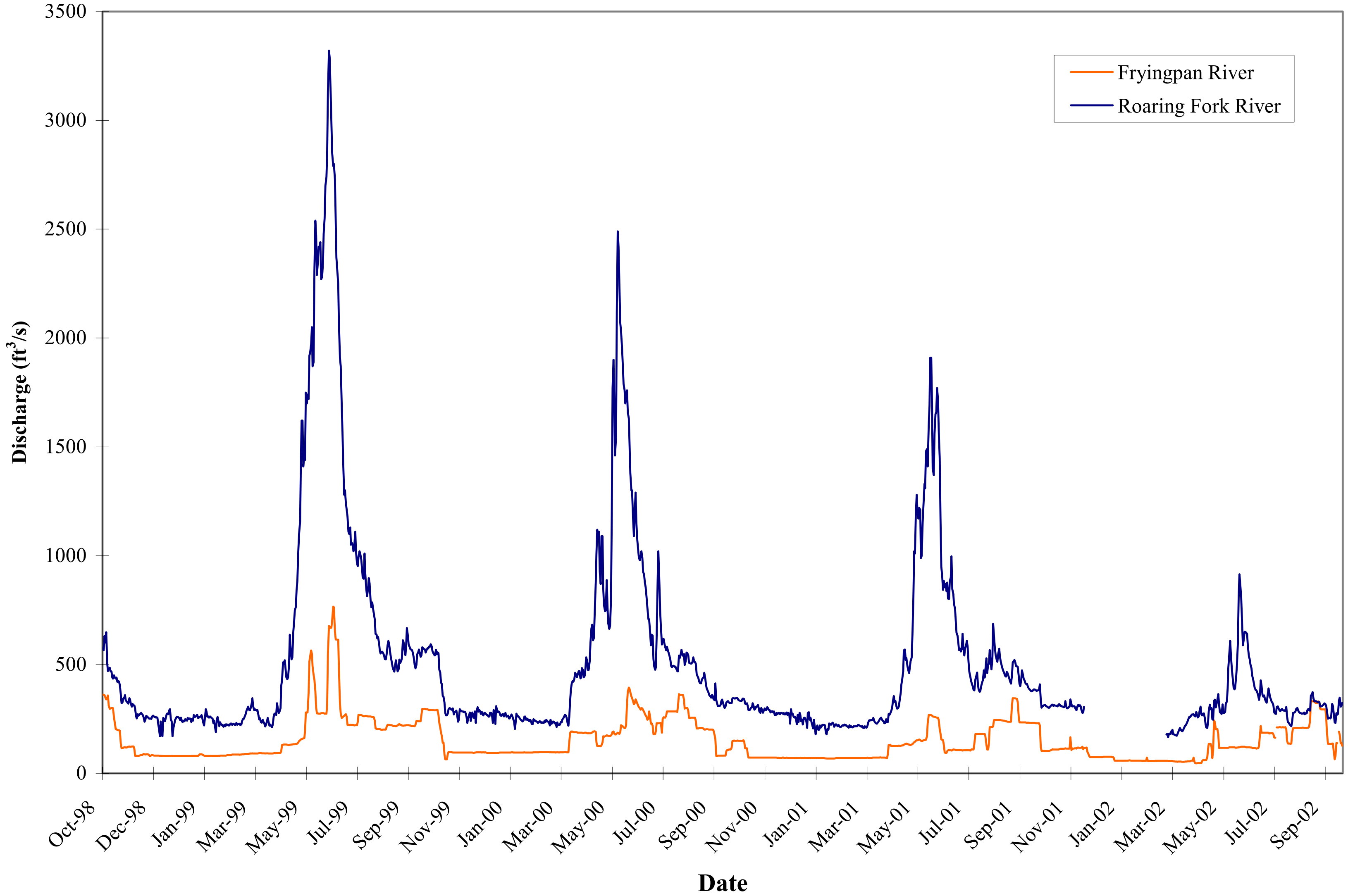


Figure 4. Satellite image of Fryingpan River study area from Downey Creek to Basalt (Macroinvertebrates: red, IFIM: yellow, Artificial Redds: purple).

Figure 5. Average daily discharge for Fryingpan River at Ruedi Dam (USGS gage 09080400) and Roaring Fork River at Emma (USGS gage 09080100) during water years 1999 through 2002. Data from WY 2002 is provisional.



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METHODS

IFIM Site Selection

Fryingpan River

During a site visit to the Fryingpan River on 21 June 2001, visual inspection noted three key hydraulically distinct channel types. To completely describe the aquatic habitat in the Fryingpan River below Ruedi Reservoir, IFIM and habitat mapping sites were established in each of the three main channel types.

The first channel type, which is scattered throughout the 22.5 km section below the dam, is characterized by high gradient, steep banks and large substrate. High gradient pocket water riffles dominate the habitat in these sections. Plunge, trench and lateral scour pools provide refuge from high velocities associated with the high gradient habitats. Run habitat is minimal. This channel type will be referenced as Fryingpan River High Gradient (FPR-HG). An IFIM site was located downstream from the Downey Creek confluence on USFS land approximately nine km below the dam to represent this channel type (Site location: Figure 3; Site picture: Figure 6).

The second channel type is characteristic of portions in the middle to upper reaches of the river. The river channel in these areas is lower gradient, typically shallower, with substrate consisting of gravel and cobble. Run and riffle habitat dominate this section of river with few pools. This channel type will be referenced as Fryingpan River Low Gradient (FPR-LG). Roy Palm graciously provided access to the Fryingpan River on his property where an IFIM site to represent this channel type was established approximately 11 km below the dam (Site location: Figure 4; Site pictures: Figures 7 and 8).

The third key channel type is restricted to the section immediately downstream of the Ruedi Reservoir in the CDOW's Catch and Release area. The channel in this section is controlled by man-made structures placed in the river channel and along the banks. This area is an extremely popular angling location accumulating over 24,500 estimated visitor days during 2001 (Crandall 2002). This section is referenced as Fryingpan River Bend

Pool (FPR-BP). The IFIM site to represent this channel type in this section was located approximately 0.4 km miles below the dam in the "Bend Pool" and associated upstream run (Site location: Figure 3; Site pictures: Figure 9).

Figure 6. Site FPR-HG on the Fryingpan River, August 2001, at 239 ft^3/s. Reported discharge is from USGS gaging station 09080400.

Figure 7. Site FPR-LG upper on Fryingpan River, August 2001, at 239 ft^3/s. Reported discharge is from USGS gaging station 09080400.

Figure 8. Site FPR-LG lower on Fryingpan River, August 2001, at 239 ft^3/s. Reported discharge is from USGS gaging station 09080400.

Figure 9. Site FPR-BP on the Fryingpan River, August 2001, at 239 ft^3/s. Reported discharge is from USGS gaging station 09080400.

Roaring Fork River

On 22 June 2001, we conducted a site visit on the Roaring Fork River to determine placement of IFIM sites based upon channel morphology and hydraulic conditions. The Roaring Fork River from the confluence of the Fryingpan River downstream through the town of Carbondale consists of a fairly uniform mixture of riffle/run habitats. Pool habitat is relatively uncommon throughout this reach. Our original intent was to select two locations for IFIM sites; however, due to the relatively consistent channel morphology throughout the reach, we opted to use only one site. This channel type is referenced as Roaring Fork River Tree Farm (RFR-TF). This representative site was established on the "Tree Farm" USFS land (Site location: Figure 2; Site picture: Figure 10).

Figure 10. Site RFR-TF on the Roaring Fork River, June 2001, at 876 ft^3/s. Reported discharge is from USGS gaging station 09081000.

IFIM Data Collection

The following methodology applies to specific techniques applied to the three IFIM sites on the Fryingpan River and one on the Roaring Fork River.

Transect placement followed the criteria proposed by Bovee (1982) and Bovee (1997). Transects were placed (marked with wooden stakes) in all habitats that represented over five percent of the total available habitat, except at FPR-BP. The intent of the FPR-BP site was to specifically model the response of the "Bend Pool" to flow variations and therefore only transects required to model this particular habitat were installed. The number of transects placed in each habitat type depended on the physical and hydraulic features of each location. Transects were placed in homogeneous habitat types. Additional transects were placed at key hydraulic locations within the habitat type to ensure better model calibration and simulation. Transects were located in contiguous habitats at three of the four sites. To accurately represent the available habitat in the low gradient channel type, transects were split between two sections at the FPR-LG site (designated FPR-LG upper and FPR-LG lower). Figures 11 and 12 show transect placement at this site and in a typical manner for all sites.

Data required by IFIM includes a full set of hydraulic measurements (bed and velocity profiles, water surface elevations, and discharge) and several stage-discharge measurements. Vertical elevations were established throughout each habitat type by establishing a primary benchmark and at least two secondary benchmarks at each study site. At each habitat and hydraulic transect, a measuring tape was stretched across the river and attached to the wooden stake representing the end of that specific transect. Linear distance (stationing) between stakes was recorded for all measured parameters. Streambank and water surface elevations were surveyed using a standard auto level and differential leveling. All surveys followed general guidelines listed by Bovee (1997). Within the stream channel, depth and mean column velocity were measured every 1-3 ft. across the wetted portion of the river. A Swoffer Model 2100 velocity meter and topset rod were used for all discharge and velocity profile measurements. Along the transect line at each interval where depth and mean column velocity were measured, dominant and subdominant substrate (following codes from Bovee (1997)) and cover type were also recorded. On two instances (pool cross section at FPR-BP, and run cross sections at RFR-TF) depths and/or velocities were either too deep or too fast to allow safe measurements at some point locations. For those locations, data was gathered only at points where safe measurements could be taken.

Hydraulic Simulations

All field data were entered into a spreadsheet program and checked for accuracy. The windows based PHABSIM version 1.10 software (USGS Mid-continent Ecological Science Center 2001) was used to create the hydraulic modeling runs. PHABSIM combines hydraulic modeling programs with a habitat suitability subroutine, allowing the user to predict changes in physical habitat due to alterations in flow.

Figure 11. Aerial view of FPR-LG lower with transect placement and location of artificial redd construction.

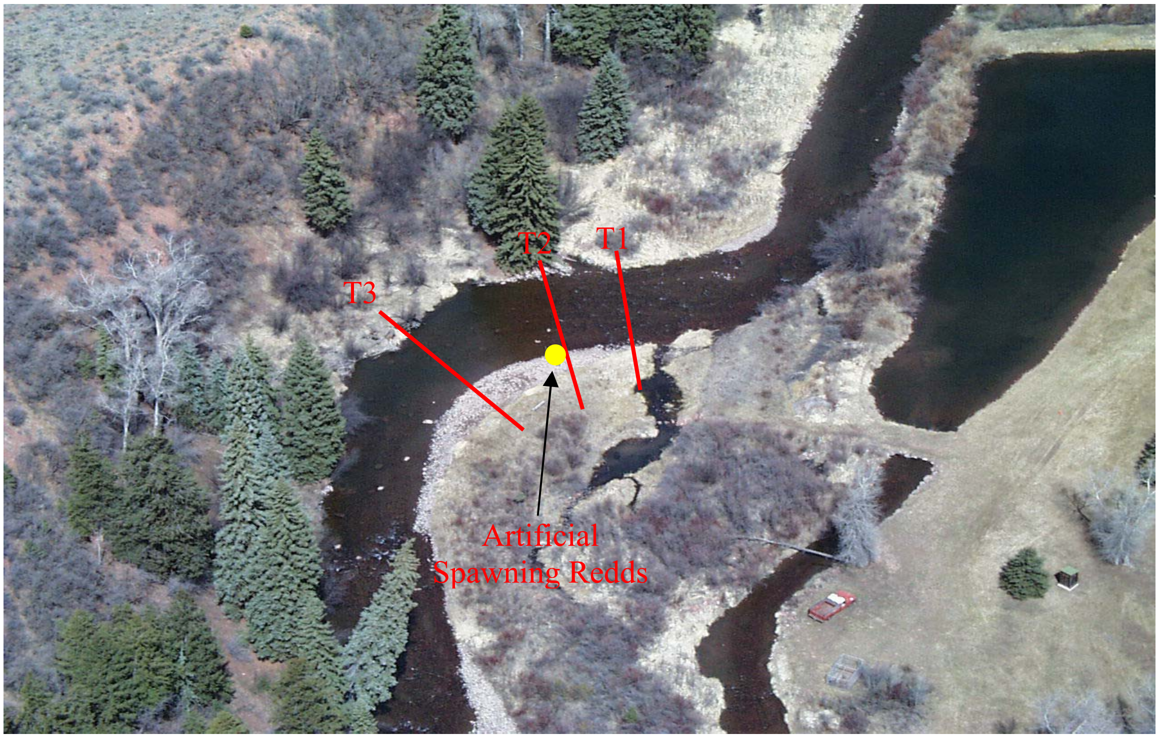

Figure 12. Aerial view of FPR-LG upper with transect placement.

In addition to the field data collected, PHABSIM requires the input of reach slope and habitat weighting factors. Slope was calculated for each reach using the water surface elevations and distance from the most upstream transect to the most downstream transect. Selected sites rarely contain individual habitat types in the same proportion as the reach total (Morhardt et al. 1983). Therefore, reach length and habitat weighting factors were determined using the "habitat typing" technique, which is the preferred technique (Bovee 1989). The habitat mapping protocol is described later in this section.

Each site was calibrated to measured water surface elevations and velocity distributions. Water surface elevations and velocities were modeled for simulated flows using the calibration corrections. Specific flows simulated varied a little by site but ranged from 40 ft^3/s to 800 ft^3/s for the Fryingpan River sites and from 150 ft^3/s to 876 ft^3/s on the Roaring Fork River. The computer programs Avparm and Avdepth (submodels of PHABSIM) were run to determine wetted perimeter, average depth and average velocity for each cross section at each simulated flow.

Using the PHABSIM submodel HABTAE, habitat suitability curves were run to determine weighted usable area (WUA) for rainbow trout and brown trout spawning, fry, juveniles and adults. Weighted usable area values are reported as $feet^2$ per mile of river or $feet^2$ per 1,000 feet of river to allow direct comparison between modeled sites. Adult and juvenile habitat suitability curves were developed by CDOW and USGS on the South Platte River below Cheesman Dam, near Deckers, Colorado. These curves are for active fish and do not adequately represent refuge habitat suitability. The South Platte River in this area is a tailwater stream with a large salmonid population composed of naturally reproducing brown and rainbow trout. The spawning curve was developed from brown trout spawning surveys conducted on Colorado streams (Chadwick & Associates, Inc 1987). The brown trout spawning curve was used as a surrogate curve for rainbow trout spawning in the Fryingpan River. Spawning data output is presented in brown trout figures but spawning is treated together for both species in the text.

Several analysis techniques were used to interpret the PHABSIM output. Habitat time series (Bovee 1982), WUA versus discharge (Bovee 1982), and wetted perimeter (Wesche and Rechard 1980; Leathe and Nelson 1986) techniques were used to analyze the effect of flow regime modification on trout habitat. Each technique was employed at all sites except for FPR-BP, at which habitat time series analysis was not conducted since the channel type associated with FPR-BP was directly related to dam construction and strongly influenced by man-made features.

Habitat time series analysis allows the direct comparison of multiple flow regimes on the trout habitat quality. Pre-dam and post-dam habitat was compared at FPR-HG and FPR-LG.

The wetted perimeter technique evaluates the decline in wetted perimeter as a function of discharge. Based upon this relationship, an "inflection" point was determined for riffle transects. Because a riffle transect was not modeled at FPR-BP, an inflection point is reported for the run transect at FPR-BP. Below the inflection point threshold, wetted perimeter declines rapidly for relatively small reductions in discharge (Annear and Condor 1984). The inflection point method provides another tool in the process of analyzing the affects of particular flow regimes on the aquatic communities.

Macroinvertebrates

Benthic macroinvertebrate sampling was conducted during spring (30 April) and fall (11 October) of 2001, and spring (1 May) 2002. Four sites were sampled in spring 2001 while five sites were sampled on later dates. Site locations in the Roaring Fork River are provided in Figure 2. Figures 3 and 4 provide site locations on the Fryingpan River. These sites consisted of two locations on the Fryingpan River and three locations on the Roaring Fork River. The sites on the Fryingpan River were located less than a kilometer below Ruedi Dam and downstream of the confluence of Taylor Creek. These locations were chosen to determine the influence of the dam and potential for recovery downstream. Sites in the Roaring Fork River consisted of a site immediately above and below the confluence with the Fryingpan River and a site near Carbondale. These sites were also chosen to elucidate dam related influences that may occur downstream of the confluence of the Fryingpan and Roaring Fork rivers. At each location, three samples were taken in riffle habitat using a Hess Sampler with 500 μm mesh in order to provide quantitative macroinvertebrate data. All samples were taken in areas of similar size substrate and similar depth to avoid bias that may be directly related to habitat. Depth at each sample location ranged between 24.4 cm and 33.5 cm. Substrate within the Hess Sampler was thoroughly disturbed and individual rocks were scrubbed by hand to dislodge all benthic organisms.

Benthic macroinvertebrates were preserved in ethanol and transported to the lab where they were sorted, enumerated and identified to the lowest practical taxonomic level (Merritt and Cummins 1996; Ward et al. 2002). Identification to the "lowest practical taxonomic level" means that all specimens were identified down to the level that is permitted by the available morphological characteristics. Early life stages of many species sometimes lack certain anatomical characteristics that allow the specimen to be identified to the genus or species level. In these cases the "lowest practical taxonomic level" may mean only the family level; however, if the available characteristics are consistent with a species that has been previously confirmed during this study then the individual may be included as a member of that taxa. In these cases the species name is provided in parentheses.

As a means of quality assurance, qualified personnel inspected each sample after sorting and a minimum of 20% of all identified taxa were reviewed. Dr. Boris Kondratieff (Professor of Entomology at Colorado State University) confirmed identifications in all cases where the identification of a specimen was difficult or questionable.

In instances where proper identification was possible, the Orders Ephemeroptera, Plecoptera, and Trichoptera were identified to genus (and many down to the species level). Most specimens of other Orders, including Diptera, were identified to the genus level; however, members of the family Chironomidae were only identified to subfamily or tribe. Data collected were used in various indices recommended by the Rapid Bioassessment

Protocols (Plafkin et al. 1989) to provide information regarding macroinvertebrate community structure, function, and general aquatic conditions. Population densities and species lists were developed for each sampling site. Indices used included Shannon-Weaver diversity (diversity) and evenness (evenness), Hilsenhoff Family Biotic Index (FBI), Ephemeroptera Plecoptera Trichoptera index (EPT), taxa richness (richness), and description of functional feeding groups.

Benthic macroinvertebrate production at each site was estimated by measuring macroinvertebrate density and biomass. Density was reported as the mean number of macroinvertebrates/m^2 found at each location. Densities were compared among sites for each sampling occasion. Biomass values were obtained by drying the benthic macroinvertebrates from each sample in an oven at 100°C for 24-hours or until all water content had evaporated. Biomass is reported as the mean dry weight of macroinvertebrates/m^2 at each site location.

Spawning

Artificial redds were constructed at two sites on the Fryingpan River (Figures 3 and 4) in order to describe intragravel conditions during the brown trout and rainbow trout spawning and egg incubation period. The most upstream site was established on the Pruessing Property just below the CDOW Catch and Release section (Figure 13). Another site was established upstream of Taylor Creek confluence on Roy Palm's property (Figure 11). This location corresponded to FPR-LG—an IFIM site. A third site in the town of Basalt was initially chosen but abandoned due to sub-marginal spawning habitat and difficulty with equipment maintenance.

On 10 October 2001, two artificial redds were constructed at each site. Areas chosen were based upon professional judgment regarding typical salmonid spawning locations. Specific redd locations are shown in Figures 14 and 15. Redds were excavated by mimicking a salmonids' natural substrate "cleaning" behavior using a shovel. This action disrupts the hydraulic conditions on the stream bottom and removes fine sediments and

Figure 13. Aerial view of Pruessing property with location of artificial redd construction.

Figure 14. Artificial redds at Palm property.

Figure 15. Artificial redds at Pruessing property.

creates a “bowl” in the gravel-cobble matrix. Once the initial redd bowl was created, an aluminum standpipe was pounded into the redd substrate. Holes had been pre-drilled into the standpipe to allow water circulation from the substrate into the standpipe. A Stowaway® Tidbit® temperature logger (accuracy ±0.2^{o}C) encased in a small (10 cm) section of pvc pipe was placed in the redd as well. Each thermograph was set to record temperature every hour. After the standpipe and thermograph were installed, substrate was dislodged upstream of the redd and allowed to cover the thermograph and holes of the standpipe. Once construction of the artificial redds was completed, the area was not disturbed until March. Active brown trout spawning was observed within 1 m of the artificial redds at both sites.

Due to an unexpected high release from Ruedi Reservoir (see Hydrology results) on 14 November 2001, standpipes in both redds at the Palm property were dislodged. There appeared to be little disturbance to the actual redd so standpipes were reinstalled without creating a new redd. The artificial redds at the Pruessing property were protected from the high pulse flow due to their location in the channel.

From October through March, five dissolved oxygen (DO) measurements were taken from each standpipe. Water was pumped out of the standpipe and intragravel water allowed to infiltrate in before a DO measurement was taken.

On 5 March 2002, freeze core samples were taken to describe the substrate composition within each artificial redd. A control sample was taken at each site as well. The freeze core apparatus generally followed the procedures and premises of Walkotten (1976) and Everest et al. (1980). A hollow spike, which had one end fully closed with a point, was pounded 25 cm deep into the center of the redd. Liquid CO_2 was used as the freezing media and pumped into the spike for 15 minutes to allow the substrate surrounding the spike to freeze to it (Figure 16). Once frozen, the spike and attached substrate were pulled from the streambed and placed in a bucket to thaw. Substrate gradations were performed by Earth Engineering Consultants, Inc. of Fort Collins, Colorado.

Figure 16. Freeze core sampler setup.

Rainbow trout artificial redds were constructed on 5 March 2002 at both Pruessing Property and Palm Property sites. Locations of rainbow trout artificial redds were in the same general location (20 m^2) as brown trout redds. Sampling methodology followed those outlined from brown trout artificial redds. Rainbow trout were observed actively spawning within 2 m of artificial redds at each site. Freeze cores were collected on 27 June 2002.

Fish Community

The evaluation of fish populations in the Fryingpan River relied on a literature review of Colorado Division of Wildlife (CDOW) reports and data that date to the early 1940s. Information extracted from the reports and summarized here included fish abundance records, fish stocking records, and recent investigations on whirling disease. The main reports for pre-dam fish population data came from Hunter and Parson (1943) and Burkhard (1966). Post-dam information relied on reports from Hoppe and Finnell (1970), Finnell (1972), Finnell (1977), Nehring (1980), Nehring and Thompson (1996), Nehring (1998), and Nehring and Thompson (2002). Data presented in these reports include relative abundance, information on length frequency, length at age, and comparisons of population numbers and stocking numbers over time.

Thermal Regime

The purpose of this portion of the study was to describe the thermal regime of the Fryingpan River and document its effects upon the Roaring Fork River. On 21 June 2001, we installed instream temperature thermographs, which were set to begin recording on 23 June 2001, at two sites in the Fryingpan River (gaging station and upstream of the confluence) and two sites on the Roaring Fork River (upstream of the Fryingpan River and downstream of the Fryingpan River at USFS "Tree Farm"). The lower Roaring Fork River site (USFS "Tree Farm") location was selected to insure adequate mixing of Fryingpan River water.

We used Stowaway® Tidbit® temperature loggers (accuracy ±0.2^{o}C) encased in a small (10 cm) section of pvc pipe for protection. Capsules were placed in the river and attached to a permanent object by aircraft cable. Each capsule was drilled with holes to ensure adequate water circulation. Each thermograph was set to record water temperature every hour and was downloaded every few months using a Stowaway® Optic Shuttle™.

If possible, capsules were placed in out-of-the-way and inconspicuous locations; however, during the year several instances of intentional or unintentional disturbance occurred. Most thermograph disturbances appeared to be caused by humans, although during December 2001, an ice dam ruptured, encasing the thermograph on the Roaring Fork River above the Fryingpan River above the water level in ice (Figure 17). In all instances where thermographs were disturbed, loggers were redeployed or new ones reinstalled.

Figure 17. Picture of Roaring Fork River looking downstream toward Fryingpan River confluence after ice flow. Ice remnants can be seen along right bank of river.

Collected data was downloaded and imported into a spreadsheet program and checked for accuracy. To alleviate any bias in water temperatures due to diel variability, data was averaged by day for all days with 20 or more hourly readings. Data collected during days and time periods when a thermograph was disturbed were removed from analysis. The Roaring Fork River upstream of the Fryingpan River had the most days eliminated (136) followed by the Roaring Fork River at "Tree Farm" (58), Fryingpan River at gaging station (48), and Fryingpan River above Roaring Fork River confluence (14). Due to the generalized type of analysis conducted and the structure of data points and values, it was possible to formulate robust conclusions regarding the thermal regime of the Fryingpan and Roaring Fork rivers.

Habitat Mapping

A quantified description of aquatic habitat is useful in determining the general condition of habitats affecting fish and macroinvertebrate communities. Using a protocol developed for the Pike & San Isabel National Forest (Winters and Gallagher 1997), the aquatic habitat was mapped at each of the four IFIM sites. Total length mapped per site was partially dependent upon access (public land or landowner permission) to the particular site. All aquatic habitats within the reach were observed and measured. Data collected during mapping by the field crew included habitat type, length, width, structural association, substrate type as a percentage of stream bottom, bank erodability, bank rock content and presence of large organic debris. Field data were input into a computer spreadsheet and analyzed using the Pike & San Isabel National Forest's Basin-wide program.

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RESULTS

IFIM Hydraulic Modeling

During 2001, we collected IFIM survey information for five discharges on the Fryingpan River (Table 1) and four on the Roaring Fork River (Table 2). A total of 19 transects were established at the Fryingpan River and Roaring Fork River sites (Table 3); however, the run control transect at FPR-LG upper was removed due to a mid-study change in the channel at that location. At FPR-LG, the river right transect pin was originally placed on a cobble/boulder point immediately downstream of a headgate. During mid-study, the point was altered to allow more efficient flow at the headgate.

Riverwide

Overall, FPR-LG (upper and lower combined for WUA calculations) had the highest WUA values for three (brown trout-juvenile, brown trout-adult, and rainbow trout-juvenile) of the four main species/lifestage combinations (Table 4). The FPR-BP site had the highest spawning and rainbow trout adult WUA values. Both spawning and adult lifestage WUA values were low at FPR-HG as compared to FPR-BP and FPR-LG (Table 4). FPR-HG contained less than half of rainbow and brown trout adult habitat that the other two sites had. On a riverwide basis, the Fryingpan River had the potential for more suitable habitat for rainbow trout juveniles and adults as compared to brown trout juveniles and adults. The Roaring Fork River contained similar juvenile and slightly lower adult WUA values compared to FPR-BP and FPR-LG. On both rivers and at all sites, juvenile habitat was low compared to adults, averaging less than 30 percent of adult habitat maximum WUA values.

Table 1. IFIM measurements conducted during 2001 on the Fryingpan River.

Date	Discharge (ft^3/s)	Measurement
21-22 June 2001	94	Transect placement, Water surface elevations, Habitat mapping
9 July 2001	106	Water surface elevations
30-31 July 2001	181	Bed profiles, Water surface elevations
30 August 2001	239	Water surface elevations
12 September 2001	342	Water surface elevations

Note: Reported discharges are from USGS gaging station 09080400.

Table 2. IFIM measurements conducted during 2001 on the Roaring Fork River.

Date	Discharge (ft^3/s)	Measurement
22 June 2001	876	Water surface elevations, Habitat mapping
9 July 2001	571	Water surface elevations
31 July 2001	379	Water surface elevations
11 October 2001	302	Bed profiles, Water surface elevations

Note: Reported discharges are from USGS gaging station 09081000.

Table 3. Instream Flow Incremental Methodology (IFIM) transect designations for sites on the Fryingpan and Roaring Fork rivers, Colorado.

Site	Transect	Habitat Type
FPR-BP (three transects)	1	Pool control
	2	Pool
	3	Run
FPR-HG (six transects)	1	Riffle
	2	Pool control
	3	Pool
	4	Pool transition
	5	Run
	6	Pocket-water riffle
FPR-LG, lower (three transects)	1	Riffle
	2	Pool control
	3	Pool
FPR-LG, upper (three transects)	1	Riffle control
	2	Run
	3	Run
RFR-TF (four transects)	1	Riffle
	2	Run control
	3	Run
	4	Riffle control

Table 4. Maximum weighted usable area (ft^2 per 1,000 ft) by lifestage and site. Discharge associated with maximum WUA is in parentheses. Overall maximum WUA for each lifestage is shaded yellow.

	Maximum Weighted Usable Area (ft^2 per 1,000 ft) by Site		
Species-Lifestage	**FPR-BP**	**FPR-HG**	**FPR-LG**
Brown-Juvenile	4452 (258)	5142 (150)	7404 (150)
Brown-Adult	25357 (400)	11218 (200)	26468 (246)
Rainbow-Juvenile	5645 (258)	5762 (100)	9042 (120)
Rainbow-Adult	34334 (600)	12068 (200)	29784 (246)
Spawning	10124 (100)	608 (60)	6332 (108)

FPR-BP

At FPR-BP, brown and rainbow trout habitat was greatest at high discharges. The majority of maximum WUA values occurred at discharges over 250 ft^3/s (Figures 18 and 19). The average discharge for maximum WUA values was 323 ft^3/s. However, all life stages showed declining habitat as flows exceeded those corresponding to the maximum WUA value. This site had the highest suitable spawning habitat of all reaches modeled. The upstream run cross section (T3) accounted for the majority of suitable spawning habitat. This area has a relatively uniform bottom consisting of gravel/cobble substrate (Figure 20). The maximum spawning WUA value occurred at a discharge of 100 ft^3/s with a corresponding average velocity of 1.23 ft/s and average depth of 0.86 ft. This area also provides prime foraging habitat at mid to upper discharge levels. The pool habitat at this site provides refuge cover during periods of inactivity or low flows. At 40 ft^3/s the maximum depth in this pool is greater than 3 ft (Figure 21).

Wetted perimeter remains relatively uniform at high flows with the inflection point for the run cross section occurring at 117 ft^3/s (Figure 22). Appendix A includes pictures of FPR-BP at four different flow levels (Figures A1-A4).

Figure 18. Weighted usable area (ft^2 per 1,000 ft) for brown trout versus discharge (ft^3/s) for FPR-BP.

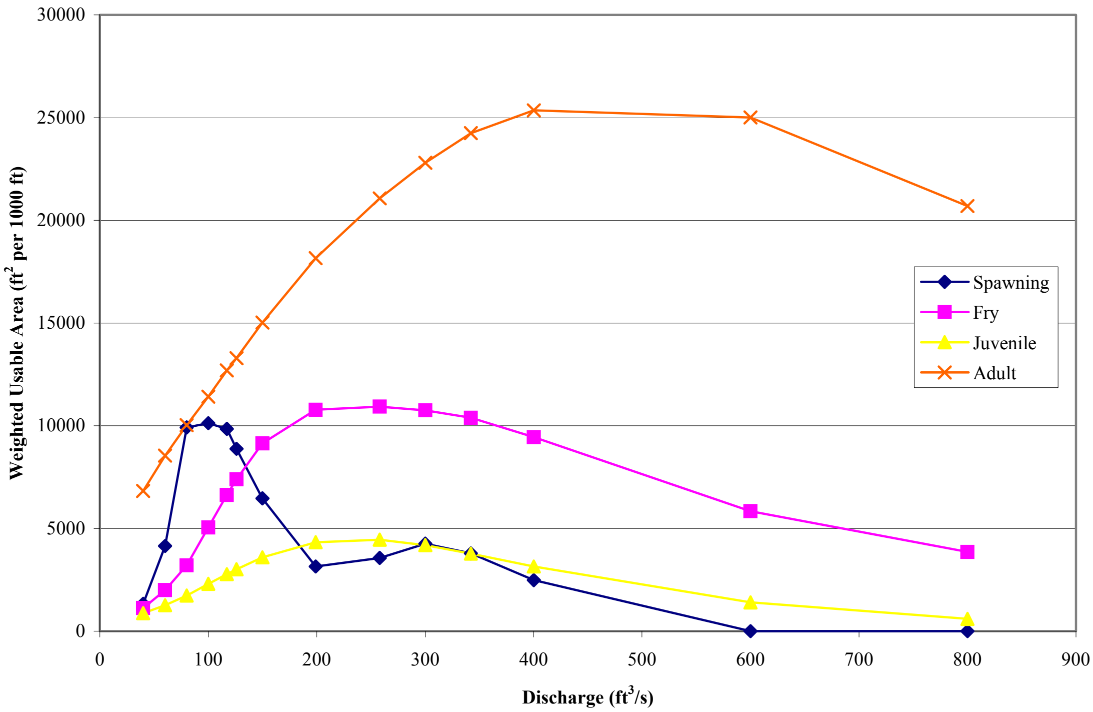


Figure 19. Weighted usable area (ft^2 per 1,000 ft) for rainbow trout versus discharge (ft^3/s) for FPR-BP.

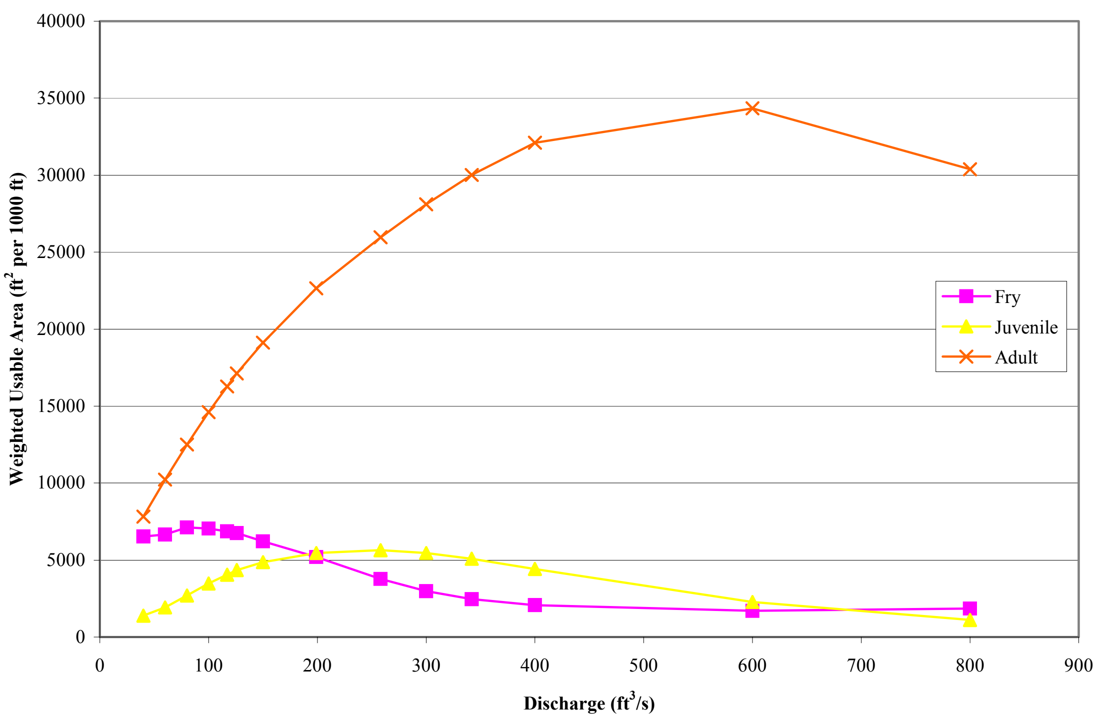


Figure 20. Bed profile and modeled water surface elevations for run cross section at FPR-BP. Elevation is relative elevation based on a vertical base of 100 ft.

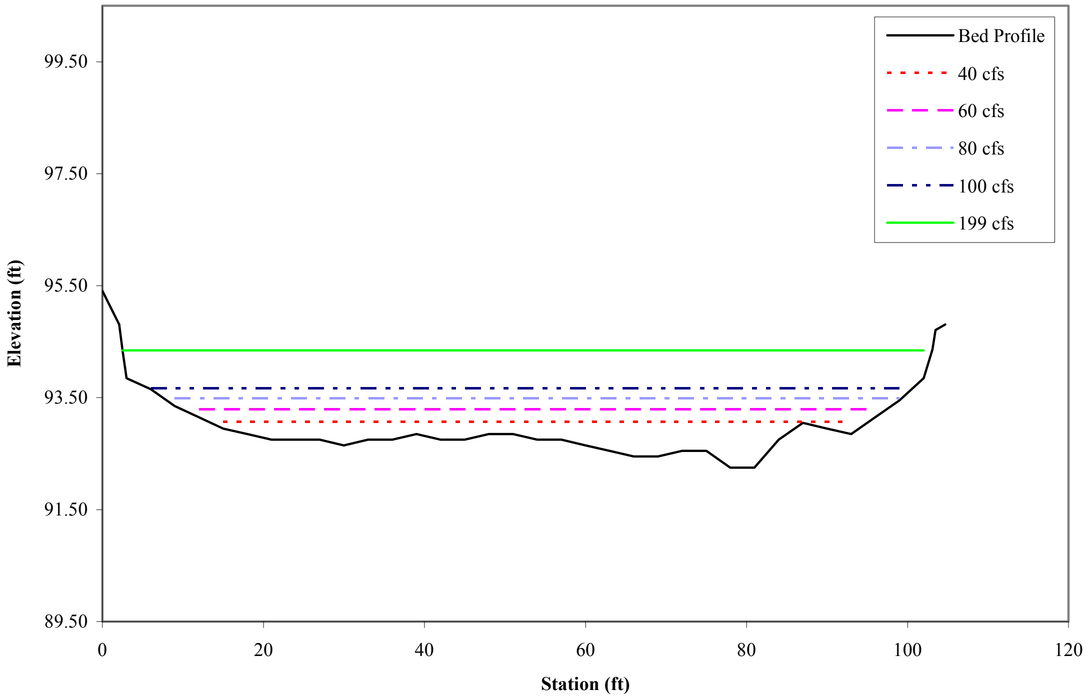


Figure 21. Bed profile and modeled water surface elevations for pool cross section at FPR-BP. Elevation is relative elevation based on a vertical base of 100 ft.

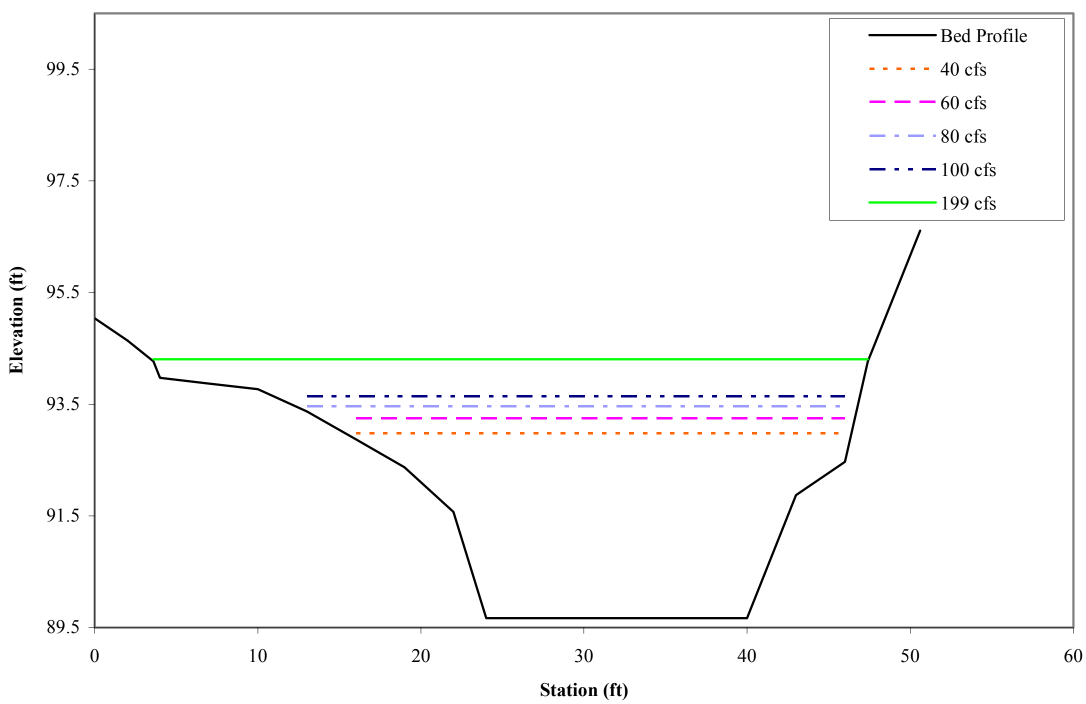
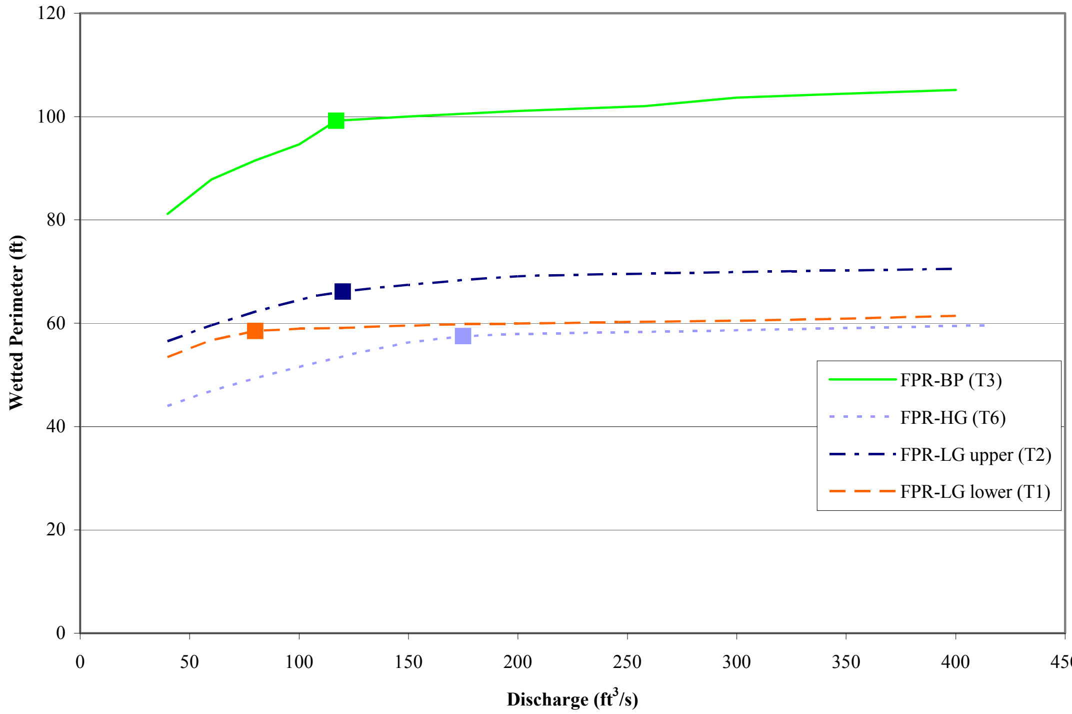


Figure 22. Wetted perimeter (ft) as a function of discharge (ft^3/s) for all sites on the Fryingpan River. Inflection point is denoted by square.



FPR-HG

Site FPR-HG had low WUA values for all species and lifestages as compared to the other two Fryingpan River sites (Table 4). All lifestages exhibited declining WUA values at flows higher than the discharge corresponding to the maximum WUA value (Figures 23 and 24). This site had an extremely low suitability of spawning habitat. This is due to a high percentage of large substrate (large cobble-boulder) and high water velocities (maximum measured: 4.98 ft/s at 227 ft^3/s) associated with this high gradient reach. Of all Fryingpan River sites, FPR-HG had the lowest average discharge (142 ft^3/s) at which maximum WUA values occurred.

At low flows, pools provide refuge habitat with depths exceeding 2.7 ft. at 40 ft^3/s (Figure 25). However, the average depth in run and riffle cross sections is only 0.8 ft. and average maximum depth is only 1.31 ft at 40 ft^3/s. At low flows, riffle and run habitats contain only a small portion of the overall WUA at this site.

Figure 23. Weighted usable area (ft^2 per 1,000 ft) for brown trout versus discharge (ft^3/s) for FPR-HG.

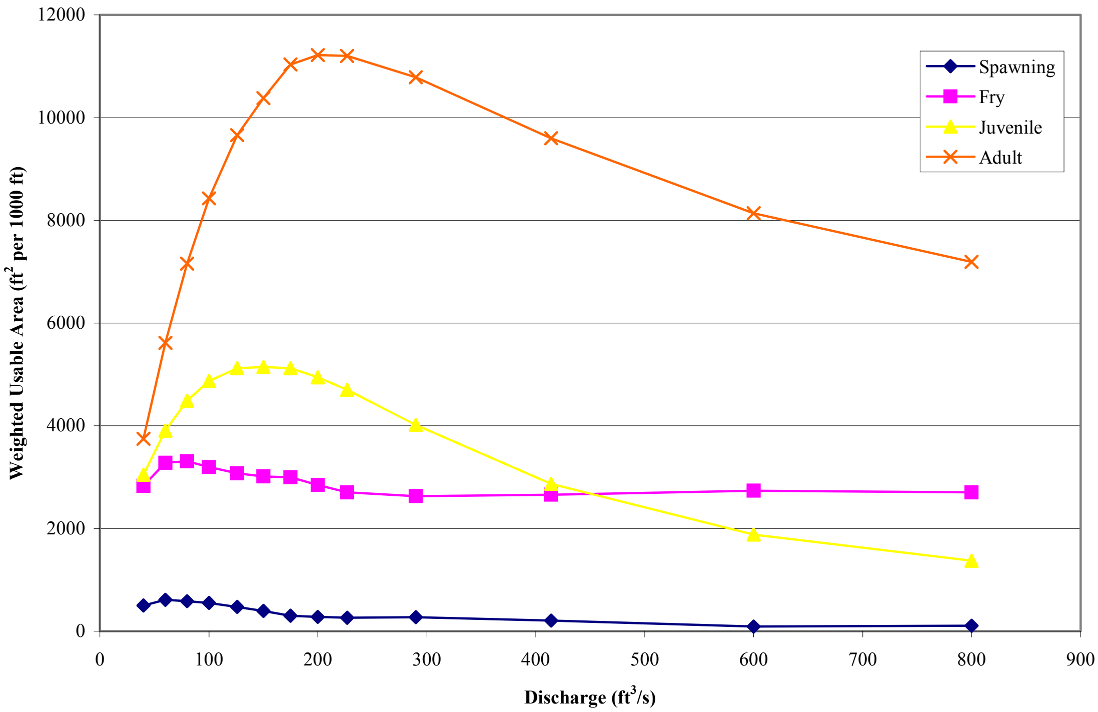


Figure 24. Weighted usable area (ft^2 per 1,000 ft) for rainbow trout versus discharge (ft^3/s) for FPR-HG.

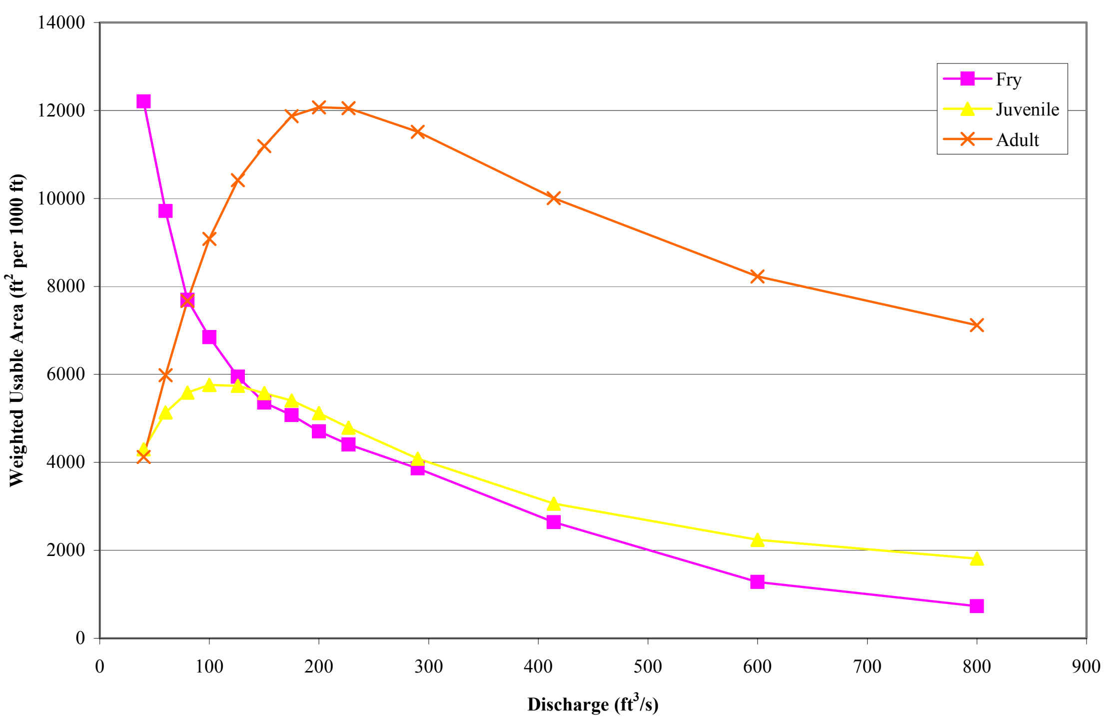
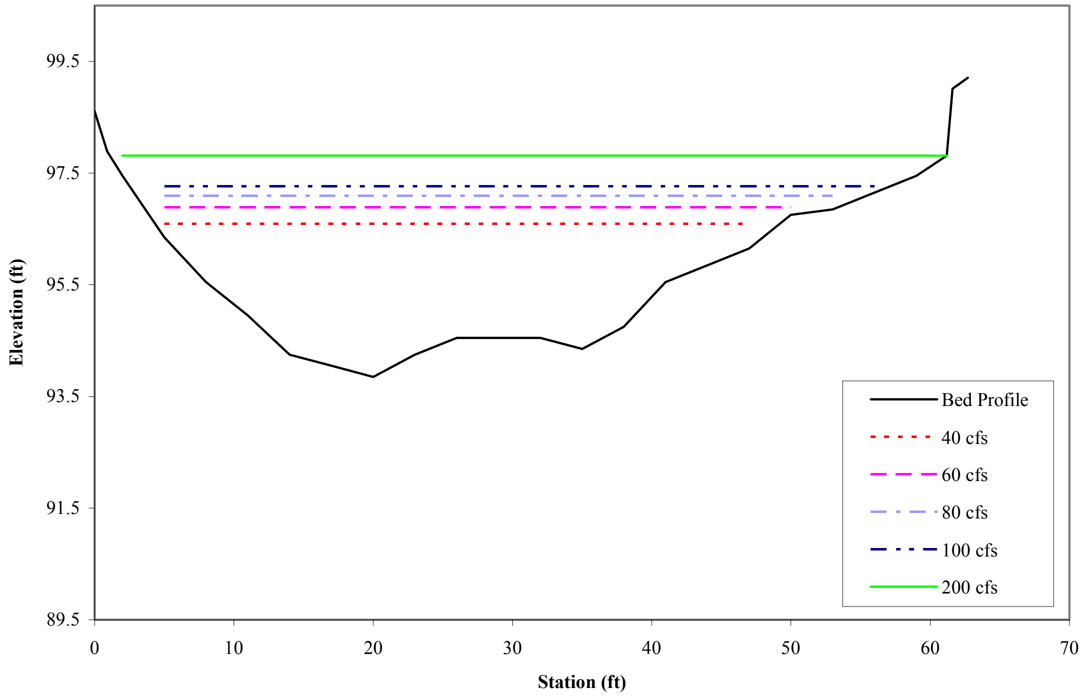


Figure 25. Bed profile and water surface elevations for pool cross section at FPR-HG. Elevation is relative elevation based on a vertical base of 100 ft.



Wetted perimeter remains relatively uniform at high flows with the inflection point for the riffle cross section (T6) occurring at 150 ft^3/s (Figure 22). Appendix A includes pictures of FPR-HG at three different flow levels (Figures A5-A7).

An analysis of the WUA output using a habitat time series approach, indicates that rainbow and brown trout had more suitable habitat after dam construction than before at site FPR-HG (Figures 26 and 27). Only during a couple of short duration (1-2 week) occasions did pre-dam habitat meet or exceed post-dam habitat. Significant increases in habitat from pre-dam to post-dam conditions were observed during the baseflow period. A reduction in overall habitat during the spring peak flows is evident for all species-lifestage combinations at this site (Figures 26 and 27).

Figure 26. Habitat time series for rainbow trout at site FPR-HG. Flows modeled were average daily discharges for 1960-1967 (pre-dam) and 1993-2000 (post-dam).

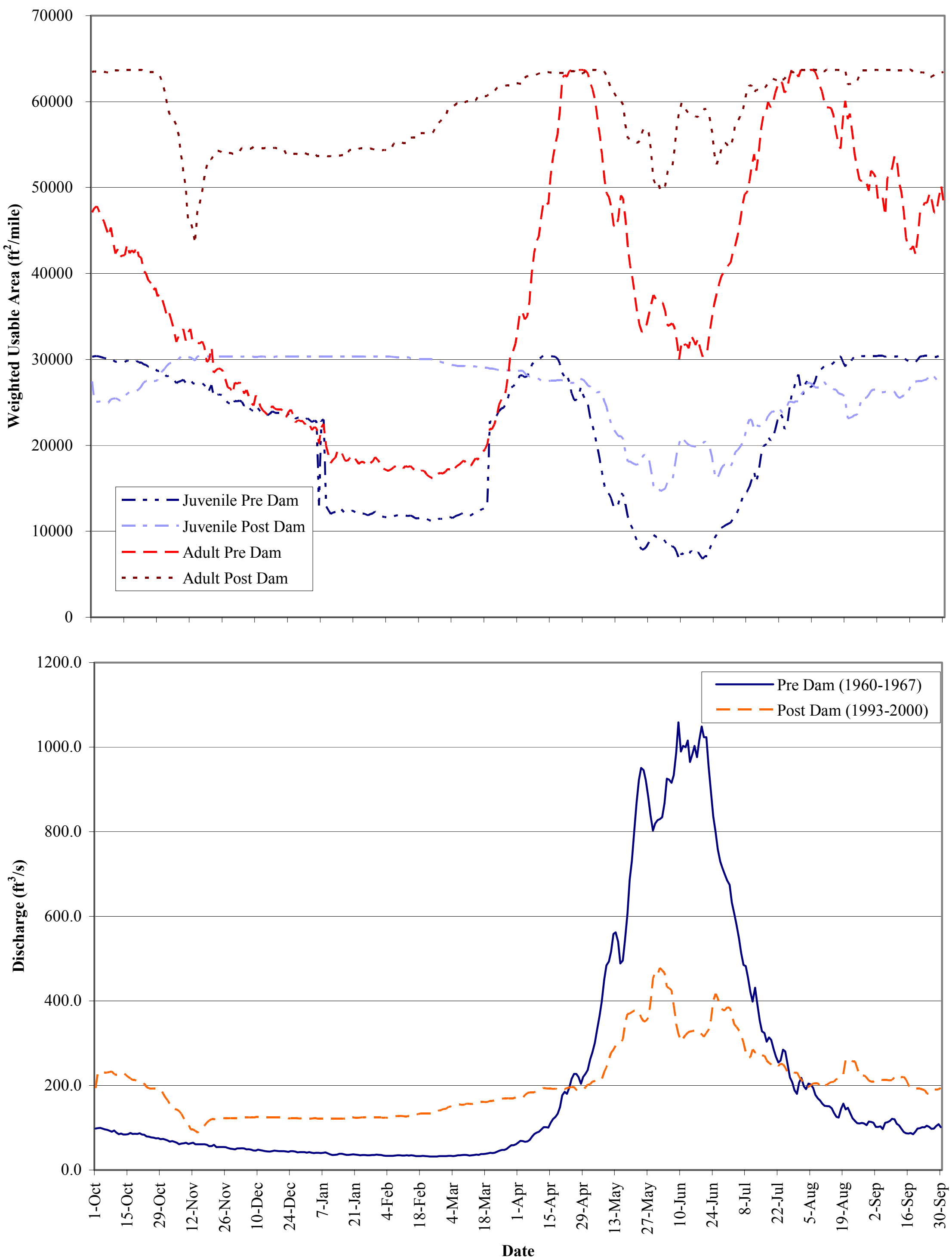
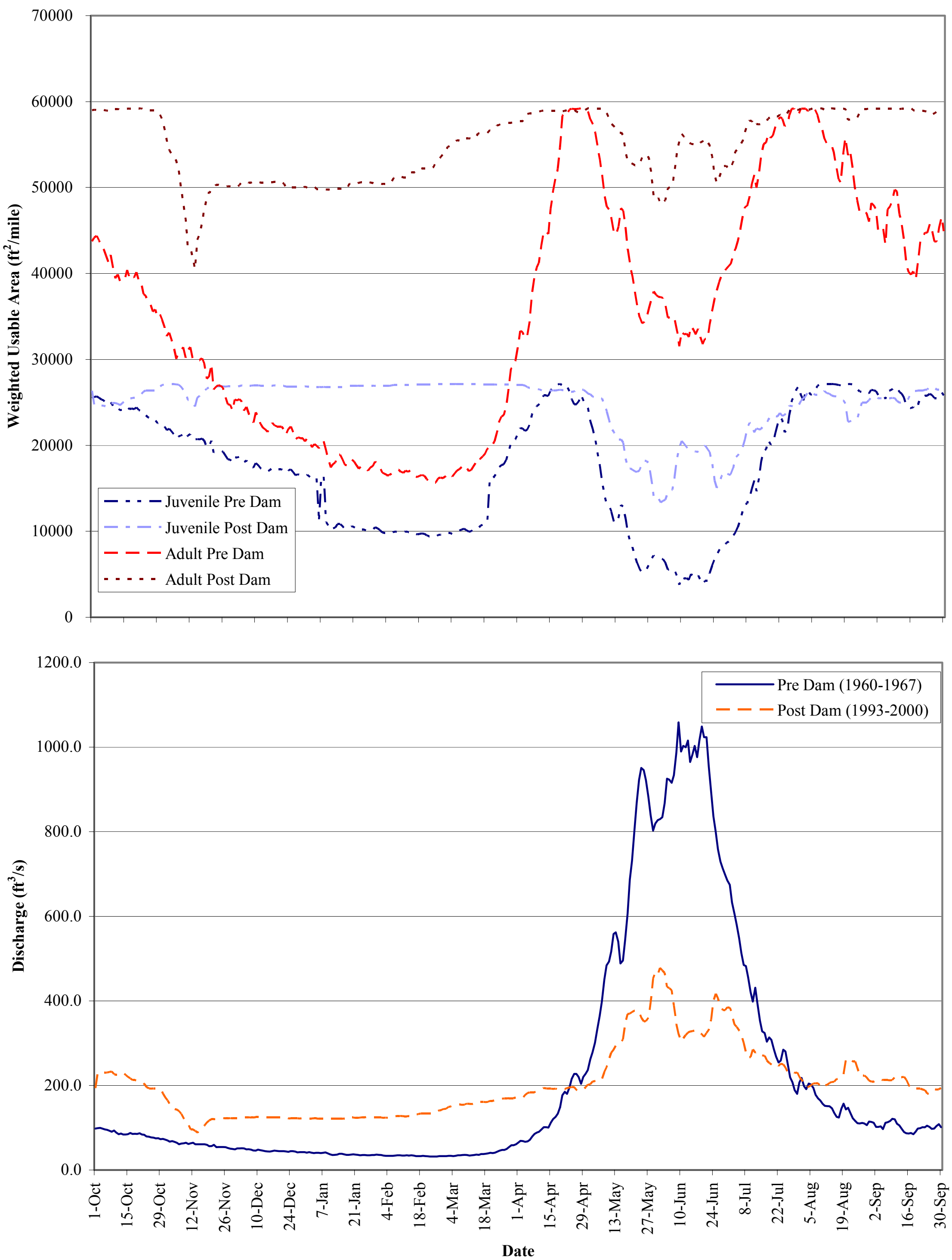


Figure 27. Habitat time series for brown trout at site FPR-HG. Flows modeled were average daily discharges for 1960-1967 (pre-dam) and 1993-2000 (post-dam).



FPR-LG

The low gradient reach (represented by FPR-LG) of the river had the highest overall WUA values of all three reaches. The average discharge for maximum WUA values was 174 ft^3/s. This value is intermediate between sites FPR-HG and FPR-BP. However, as with FPR-HG and FPR-BP, all life stages showed declining habitat suitabilities as flows exceeded those corresponding to the maximum WUA value (Figures 28 and 29).

As with the other sites, pool habitat acts as refuge habitat (Figure 30). Maximum pool depth was 2.2 ft at 40 ft^3/s.

Spawning suitabilities were high in riffle and shallow run habitats at FPR-LG. Maximum spawning WUA occurred at a discharge of 108 ft^3/s. The pool control cross section (T2) provides high quality spawning habitat at this flow, with an average depth and velocity of 0.95 ft and 1.83 ft/s, respectively. Artificial redds were placed at the pool-riffle interface during the spawning study. Natural redds and active brown trout spawning were observed within 1 m of this cross section.

At riffle cross section T1 at FPR-LG lower, wetted perimeter remained very stable until flows dropped below 80 ft^3/s (Figure 22). At the run cross section at FPR-LG upper (Figure 31), the wetted perimeter inflection point was around 120 ft^3/s. Appendix A shows the upper and lower FPR-LG sites at four different flow levels (Figures A8-A13).

Overall, adult habitat increased post-dam construction at site FPR-LG (Figures 32 and 33). Brown and rainbow trout adult habitat was significantly higher during late summer through baseflow period in post-dam as compared to pre-dam conditions. Juvenile habitat was similar between pre- and post-dam conditions.

RFR-TF

The IFIM site on the Roaring Fork River (RFR-TF) had a higher suitability for rainbow trout habitat than brown trout habitat. Most maximum WUA values occurred at flows less than 302 ft^3/s (Figures 34 and 35).

Figure 28. Weighted usable area (ft^2 per 1,000 ft) for brown trout versus discharge (ft^3/s) for FPR-LG (data from lower and upper sections combined).

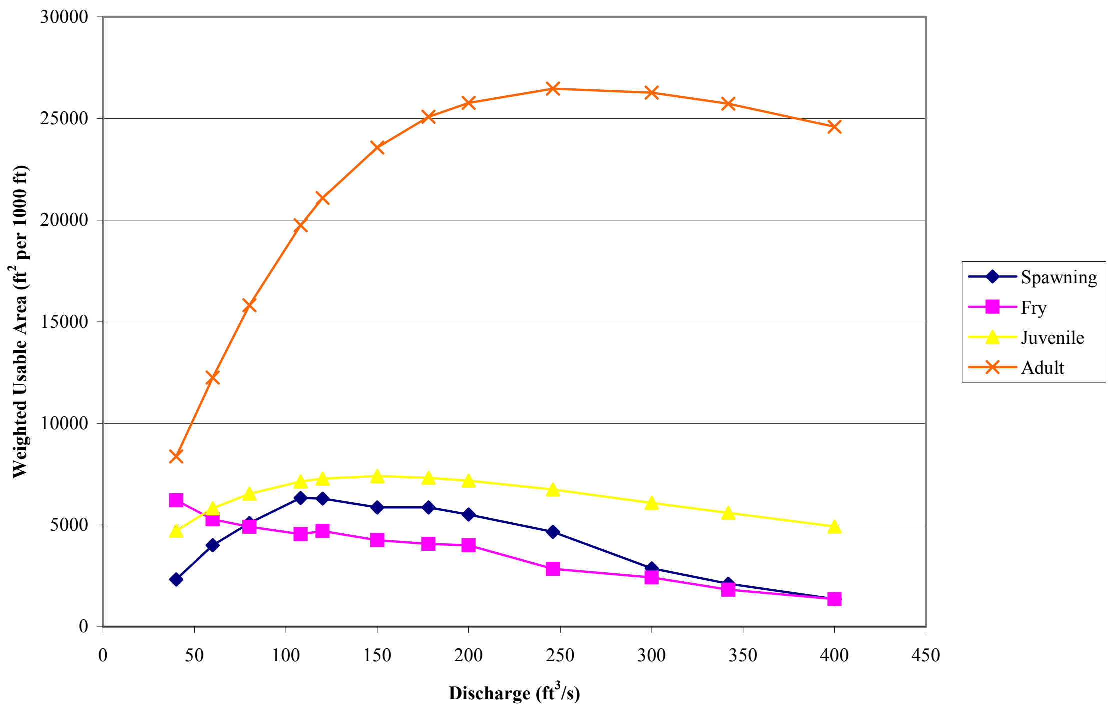


Figure 29. Weighted usable area (ft^2 per 1,000 ft) for rainbow trout versus discharge (ft^3/s) for FPR-LG (data from lower and upper sections combined).

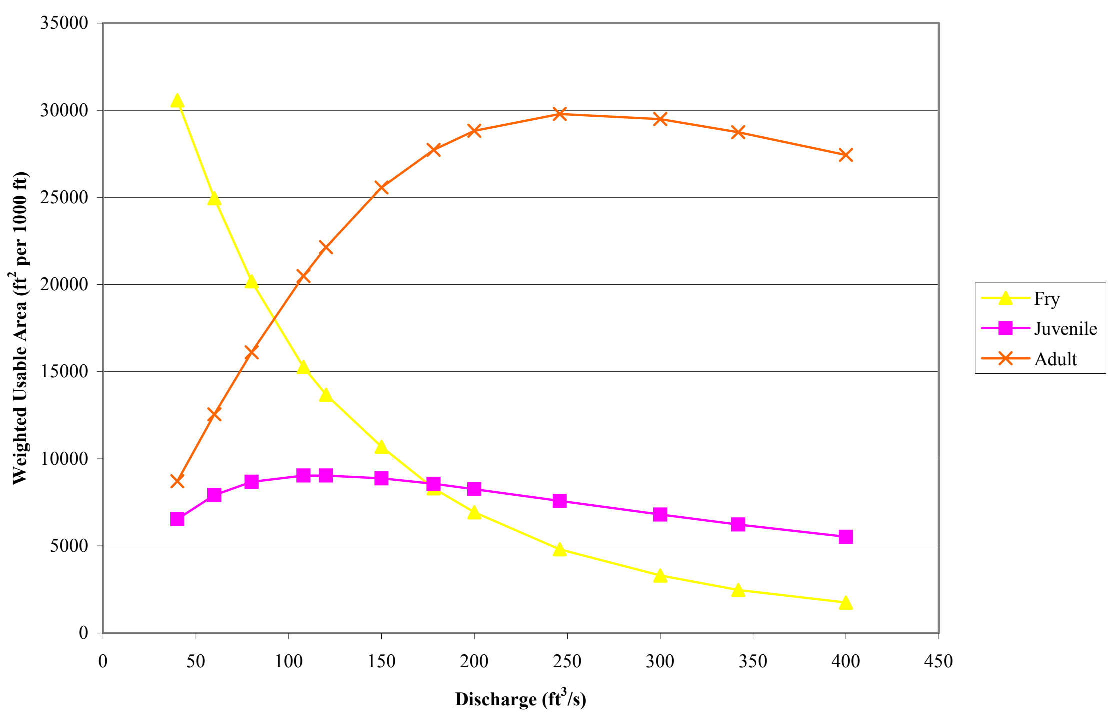


Figure 30. Bed profile and water surface elevations for pool cross section at FPR-LG lower. Elevation is relative elevation based on a vertical base of 100 ft.

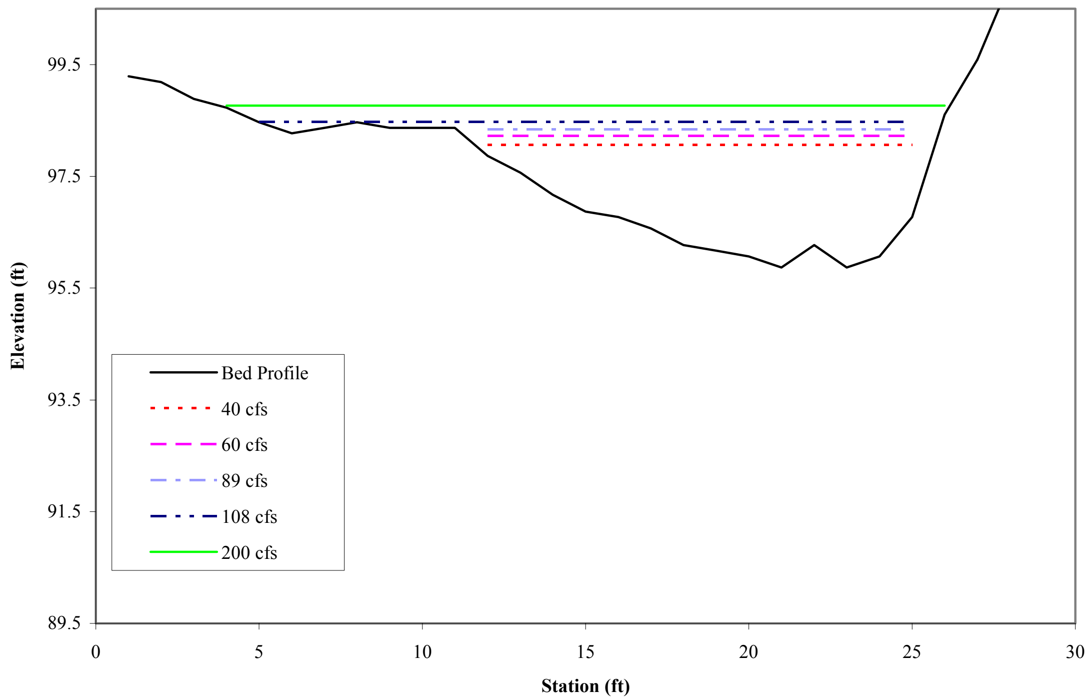


Figure 31. Bed profile and modeled water surface elevations for run cross section at FPR-LG upper. Elevation is relative elevation based on a vertical base of 100 ft.

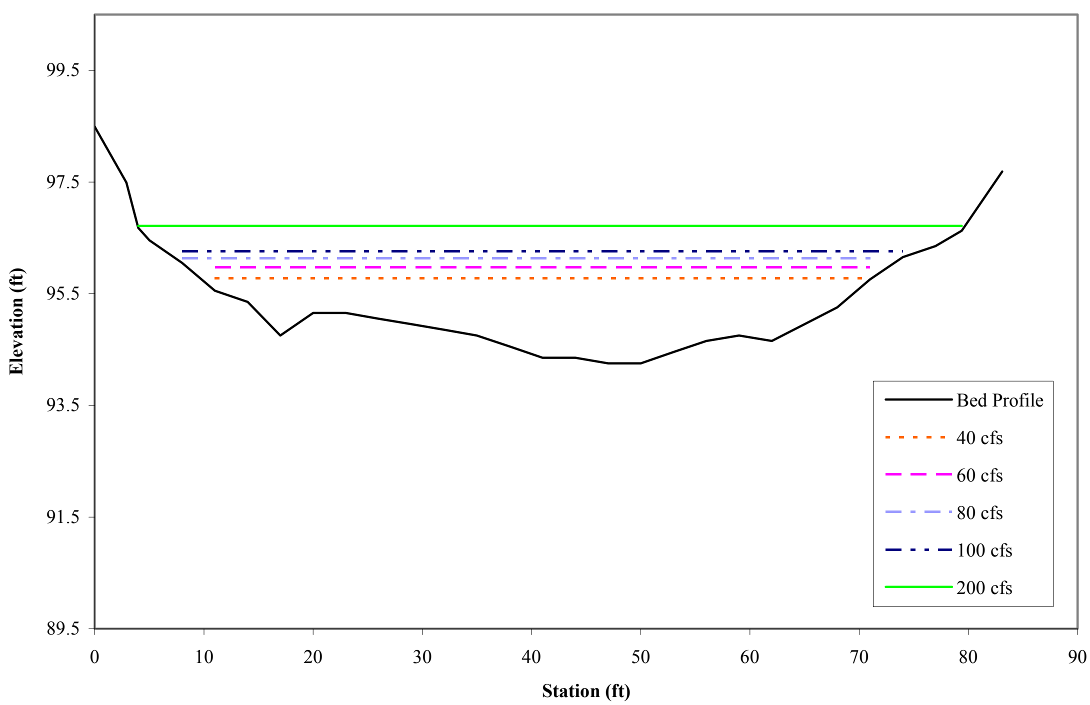


Figure 32. Habitat time series for rainbow trout at site FPR-LG. Flows modeled were average daily discharges for 1960-1967 (pre-dam) and 1993-2000 (post-dam).

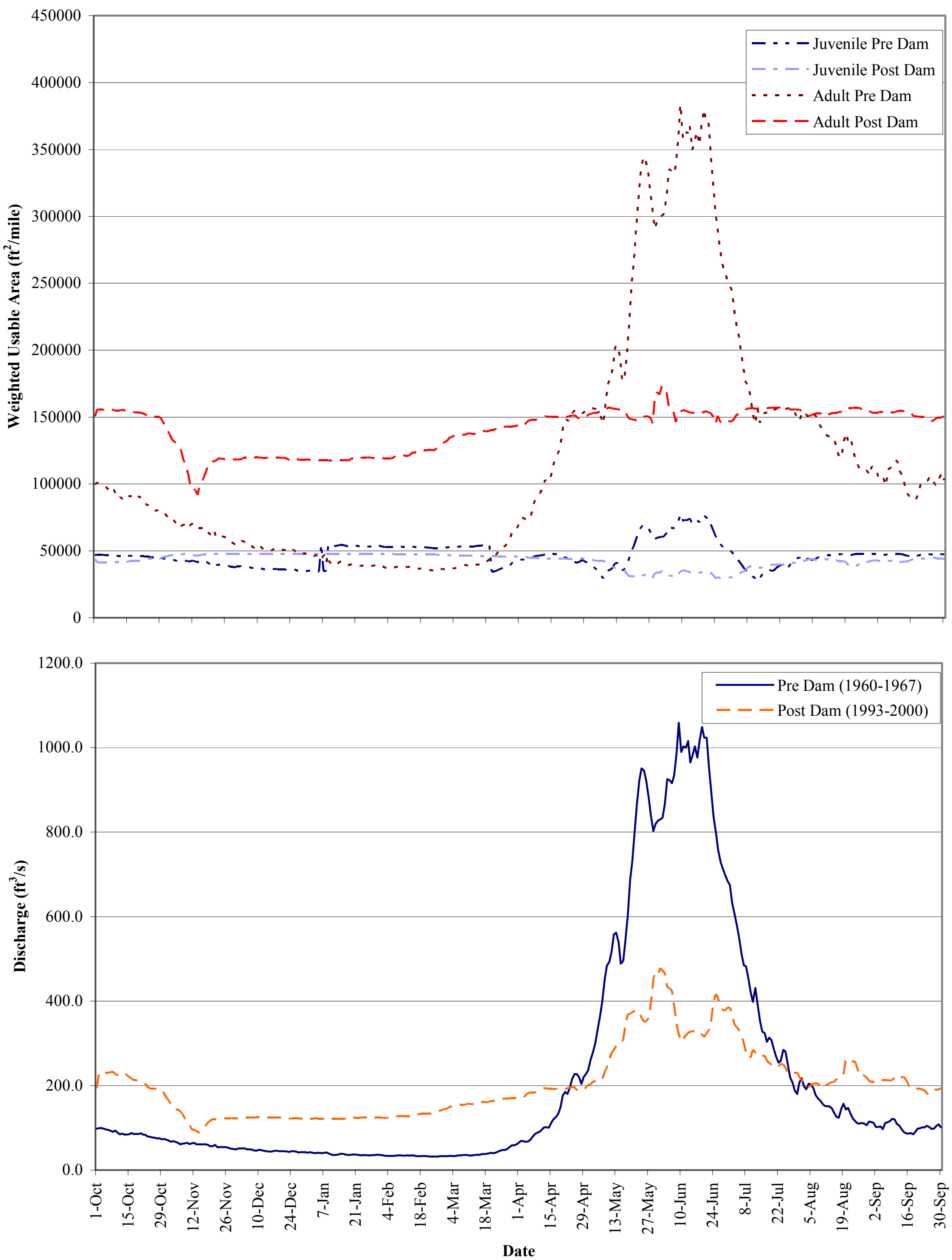


Figure 33. Habitat time series for brown trout at site FPR-LG. Flows modeled were average daily discharges for 1960-1967 (pre-dam) and 1993-2000 (post-dam).

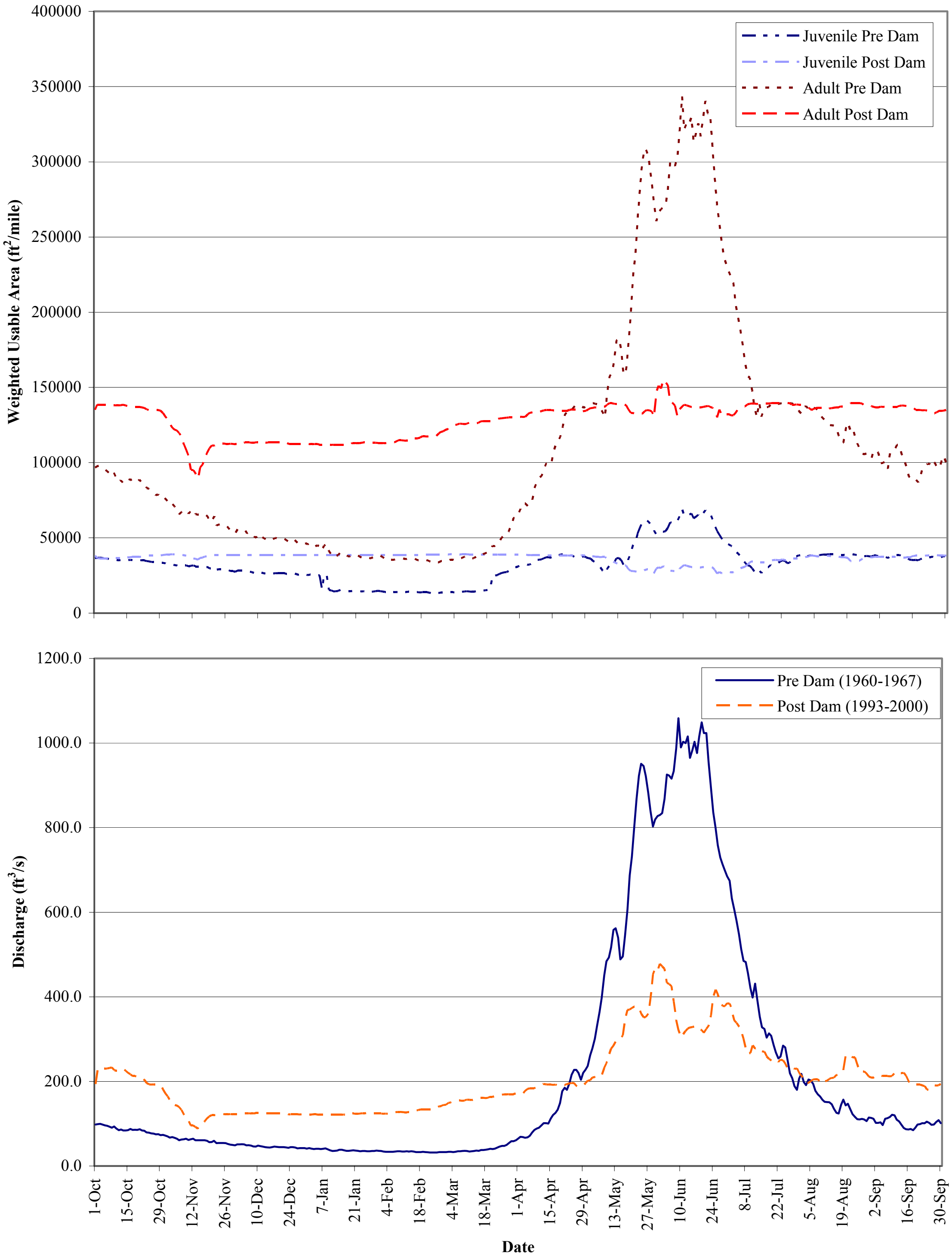


Figure 34. Weighted usable area (ft^2 per 1,000 ft) for brown trout versus discharge (ft^3/s) for RFR-TF.

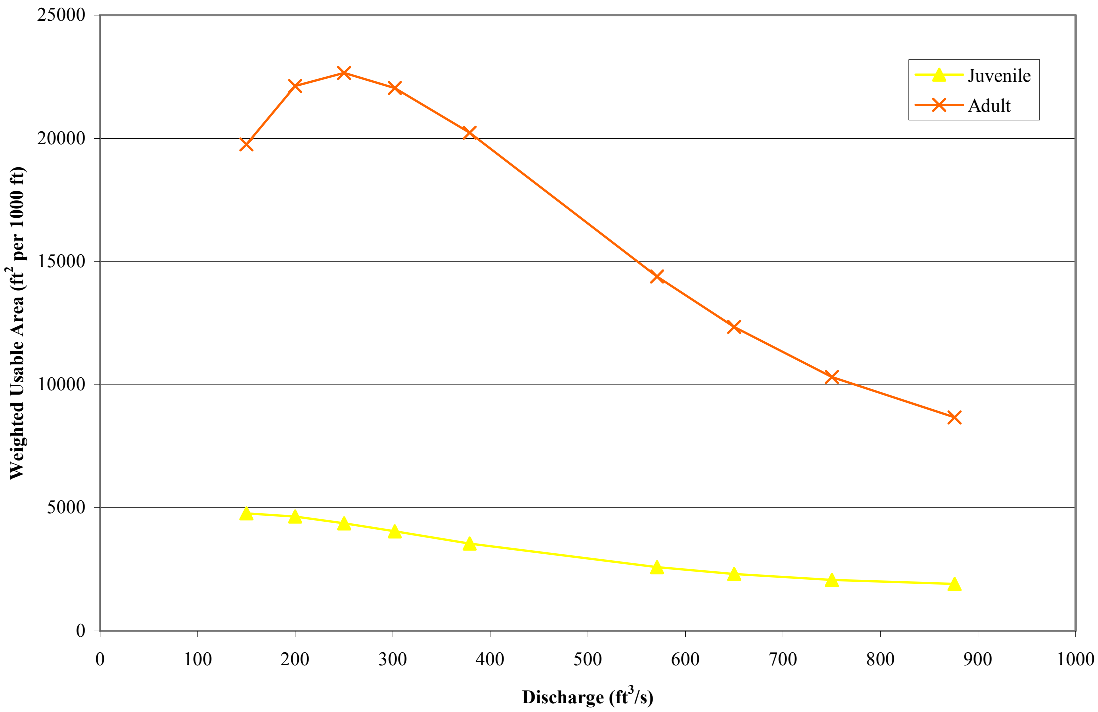
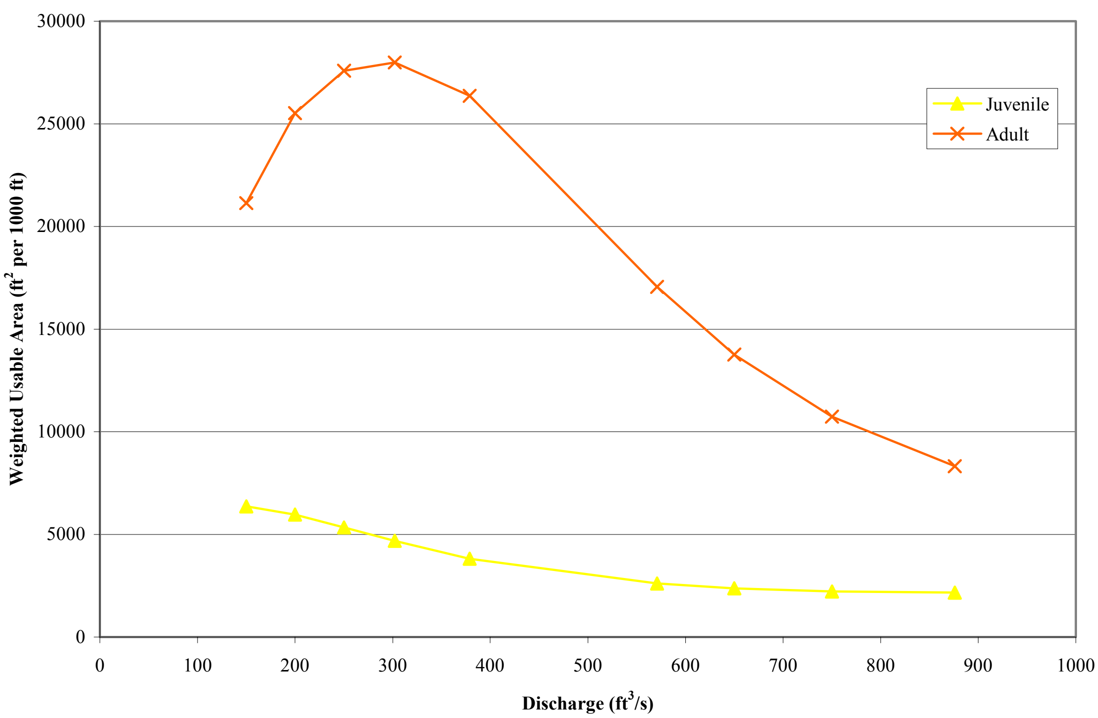


Figure 35. Weighted usable area (ft^2 per 1,000 ft) for rainbow trout versus discharge (ft^3/s) for RFR-TF.



Macroinvertebrates

Macroinvertebrate sampling and analysis were conducted at four sites in the spring of 2001 and five sites in the fall of 2001 and spring 2002. The results provided by the applied metrics are presented in Table 5. Complete species lists are provided in Appendix B. The results from the applied metrics provided a measure of longitudinal changes in macroinvertebrate communities as well as a seasonal comparison. The following section describes the range and results of the applied metrics. These results will be further evaluated in the discussion section.

Diversity and evenness values were evaluated for each site on each sampling date. These metrics are influenced by similar processes and often indicate similar trends. Diversity and evenness values were used to detect changes in macroinvertebrate community structure. In unpolluted waters diversity values typically range from near 3.0 to 4.0. In polluted waters this value is generally less than 1.0. The evenness value ranges between 0.0 and 1.0. Values lower than 0.3 are generally considered indicative of organic pollution (Ward et al. 2002). Diversity ranged from 2.03 to 3.80 during this study, while evenness ranged from 0.406 to 0.707. On each sampling occasion the lowest values for both metrics were obtained at FPR-RES. Some decline in these values was also observed at RFR-C during the spring sampling events. A comparison of diversity values between spring sampling events indicated a similar spatial trend (Figure 36). This pattern was also observed for evenness values (Figure 37).

Diversity and evenness values exhibited some fluctuation between sites and sampling events, but remained within a range suggesting good or excellent water quality at most locations. These metrics are designed to indicate different types of disturbance, and are often used as indicators of pollution. Low values that were observed at the site below the dam were likely a result of the restraints imposed by regulated releases from the dam.

The FBI is often used in macroinvertebrate studies as a means of detecting organic enrichment. In this study it was useful for monitoring differences between the sites that may

Table 5. Metrics and comparative values for macroinvertebrate samples collected from riffle habitat in the Fryingpan River and Roaring Fork River, Colorado.

Spring 2001	Diversity	Evenness	FBI	EPT	Taxa Richness	Density (#/m^2)	Biomass (g/m^2)
FPR-RES	2.03	0.406	5.72	17	32	36,770	7.4108
FPR-TC	3.71	0.707	3.97	21	38	18,366	8.7948
RFR-HB	3.15	0.615	3.54	20	35	14,331	6.7219
RFR-C	2.13	0.411	5.78	19	36	26,997	8.0786
Fall 2001							
FPR-RES	2.29	0.453	5.86	19	33	16,509	1.3820
FPR-TC	3.76	0.701	4.76	23	41	10,318	2.4338
RFR-711	3.59	0.649	2.69	29	46	16,137	2.5485
RFR-HB	2.58	0.475	1.53	24	43	19,237	2.5405
RFR-C	3.37	0.629	4.47	22	41	26,625	7.9478
Spring 2002							
FPR-RES	2.37	0.471	6.06	20	33	62,996	9.2919
FPR-TC	3.66	0.683	4.86	22	41	21,458	4.3774
RFR-711	3.80	0.700	3.70	22	43	12,988	7.2225
RFR-HB	3.46	0.634	3.36	25	44	14,906	6.9187
RFR-C	2.64	0.502	5.46	19	38	45,171	16.8719

Figure 36. Diversity values obtained from sites on the Fryingpan River and Roaring Fork River, Colorado.

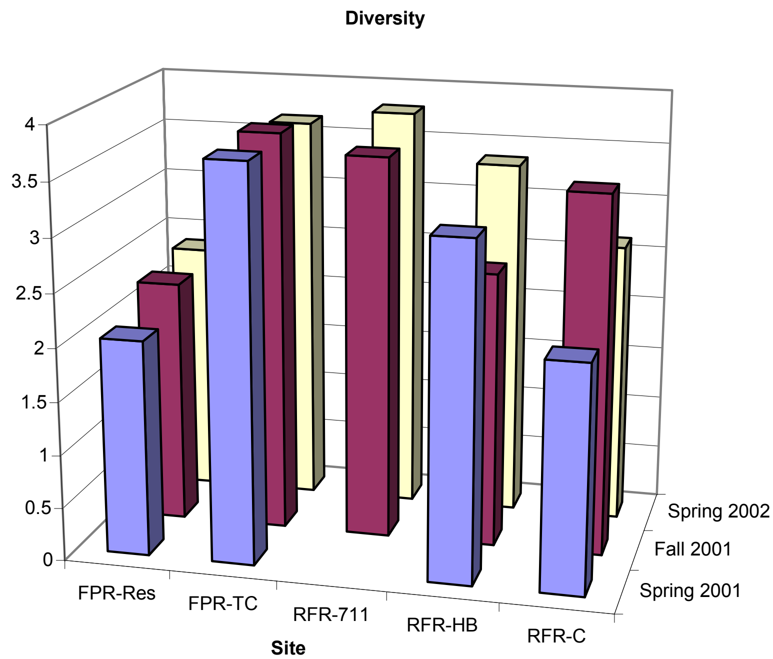
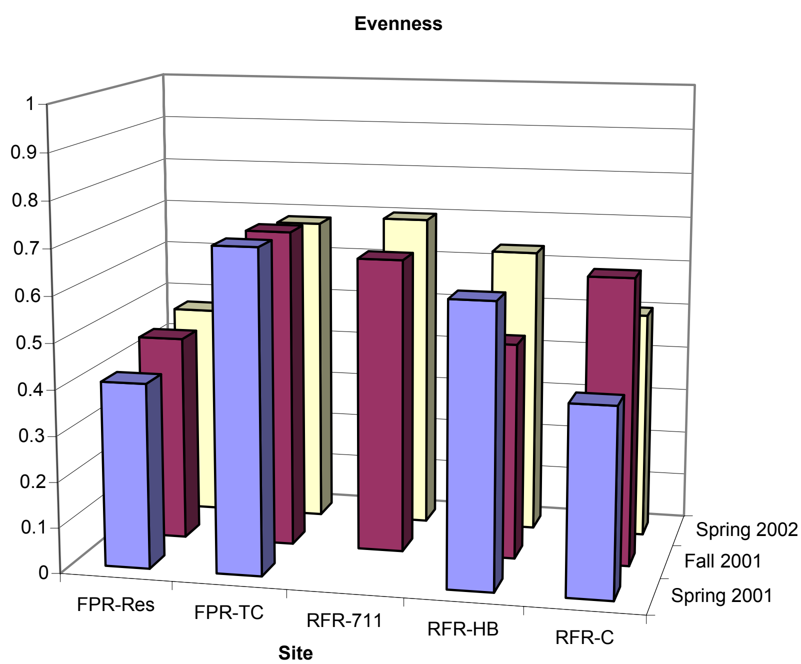


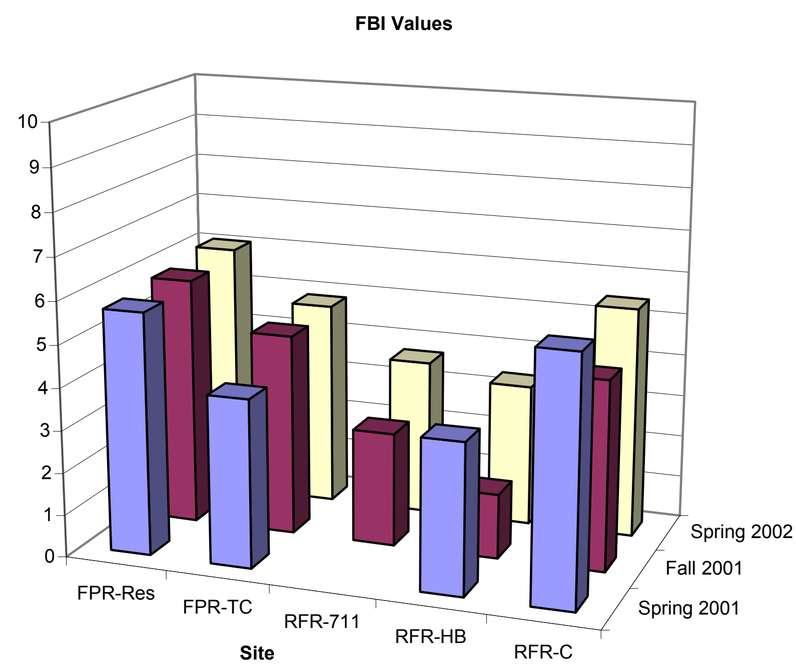
Figure 37. Evenness values obtained from sites on the Fryingpan River and Roaring Fork River, Colorado.



not be attributed to discharge. Because the FBI requires modification for use in many areas, the number indicating a certain water quality rating will vary among regions. Comparison of the values produced within a given system should, however, provide information regarding difference in sites based on nutrient enrichment. Values for the FBI range from 0.0 to 10.0, and increase as water quality decreases (Plafkin et al. 1989).

FBI values varied seasonally and among sites in the study area (Figure 38). These values ranged from 1.53 at RFR-HB in October 2001 to 6.06 at FPR-RES in May 2002. On each sampling occasion the highest values were obtained at FPR-RES. This is likely an effect of the physical processes imposed by the dam. Other relatively high values were reported from RFR-C. Although values obtained from RFR-C do not exceed 5.78 (in a possible range of 1.0 to 10.0), the values represent a consistent relative increase from FBI values reported for upstream sites on the Roaring Fork River. The available data suggests that some organic enrichment occurs upstream of RFR-C.

Figure 38. FBI values obtained from sites on the Fryingpan River and Roaring Fork River, Colorado.



The EPT index was employed to assist in the analysis of the data. It is a direct measure of taxa richness among species that are typically considered more sensitive to pollution or other perturbations. This measurement is simply given as the total number of identified taxa in the orders Ephemeroptera, Plecoptera and Trichoptera found at each station. The EPT and richness metrics were used to measure numbers of taxa present at each location. The difference between EPT and richness values is that the EPT only includes taxa from Orders that are considered to be sensitive to disturbances, and richness includes all taxa. Results obtained by these metrics provide a description of changes in community complexity throughout the study area. These results are most valuable when compared among sites within the same system.

Taxa richness was also reported for each sampling event during the study. This measurement is reported as the total number of different taxa collected on each date from each sampling location. It is similar to the EPT index, except that it includes all different identifiable benthic macroinvertebrate species. It is useful for describing differences in habitat complexity or aquatic conditions between rivers or site locations. Taxa richness and EPT index values indicated similar trends among the sites on each sampling occasion (Figure 39 and 40). Overall, major aquatic macroinvertebrate groups were well represented at all sites in the study area. Values were generally lower immediately below the reservoir and increased at sites downstream. A slight decline in these metric values occurred at RFR-C. As expected, changes in the physical environment resulted in the loss and replacement of certain taxa along a longitudinal gradient.

Biomass values provide information in terms of weight of macroinvertebrates produced by habitat at each site. Benthic macroinvertebrate density and biomass were used as an indication of production at each site location. Although these measurements are closely related they do not always indicate the same trends. The density value is based on the mean number of individuals that were collected by quantitative sampling, whereas biomass is a function of the number and weight of individuals.

Figure 39. EPT values obtained from sites on the Fryingpan River and Roaring Fork River, Colorado.

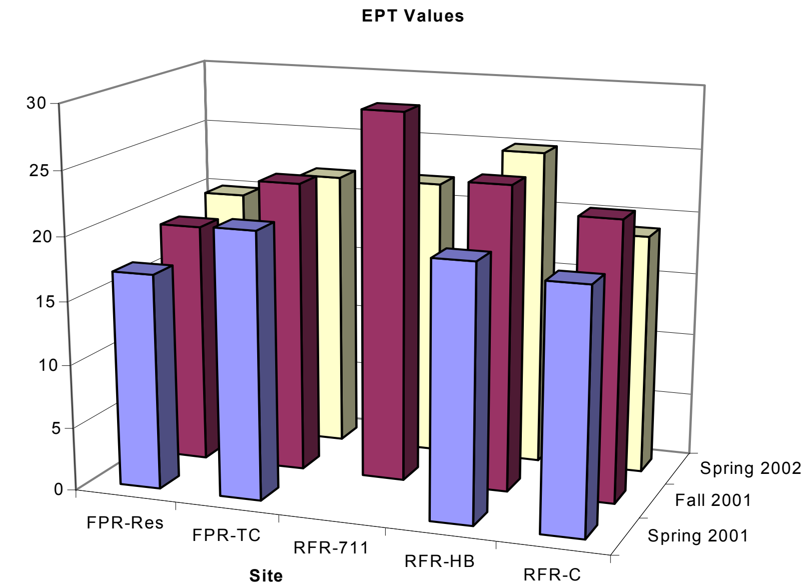
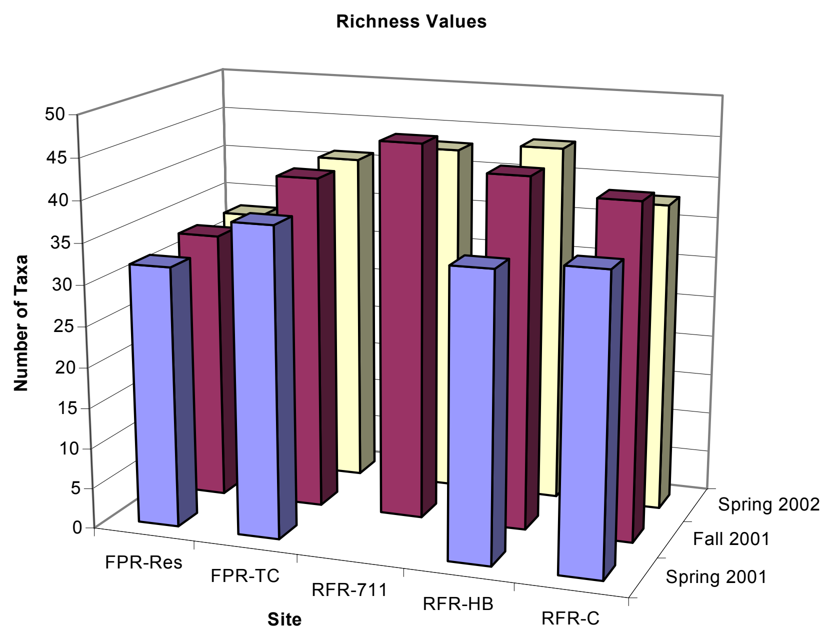


Figure 40. Richness values obtained from sites on the Fryingpan River and Roaring Fork River, Colorado.



Results provided by these metrics indicated that high densities of benthic macroinvertebrates occur in the Fryingpan River downstream of the reservoir during the spring and in the Roaring Fork River near Carbondale during the spring and fall (Figure 41). Biomass was generally greater during the spring with the highest values occurring at RFR-C during spring 2002 (Figure 42). Densities ranged from 10,318 individuals/m^2 at FPR-TC in the fall of 2001 to 62,996 individuals/m^2 at FPR-RES during the spring of 2002. Biomass ranged from 1.38 g/m^2 at FPR-RES in the fall of 2001 to 16.87 g/m^2 at RFR-C in the spring of 2002. The dissimilarity between these two metrics was apparent on several occasions. A difference in size and/or species composition is usually responsible for dissimilarities in trends between density and biomass. Specific life-history traits of each species result in seasonal changes in community composition. The relatively small size of the species that occurred below Ruedi Dam resulted in a relatively low associated biomass.

The previously described metrics were used to evaluate benthic macroinvertebrate communities in terms of structure. Separating invertebrate taxa into functional guilds based on food acquisition provided a measurement of macroinvertebrate community function. Aquatic macroinvertebrates were categorized according to feeding strategy to determine the relative proportion of various groups. The proportion of certain functional feeding groups in the macroinvertebrate community can provide insight to various types of stress in river systems (Ward et al. 2002).

An examination of the function of benthic macroinvertebrate communities, in terms of food acquisition, can also provide insight into the overall health of the ecosystem. Results of functional feeding group analysis indicated some spatial and temporal changes (Figure 43). Communities immediately below the dam were consistently dominated by collector-gatherers, while other functional groups became more apparent downstream. The shredder and scraper guilds were well represented on each sampling occasion from FPR-TC downstream to RFR-HB. Collector-filterers and predators generally comprised a lower proportion of the functional group composition at most sites throughout the study period.

Figure 41. Density values obtained from sites on the Fryingpan River and Roaring Fork River, Colorado.

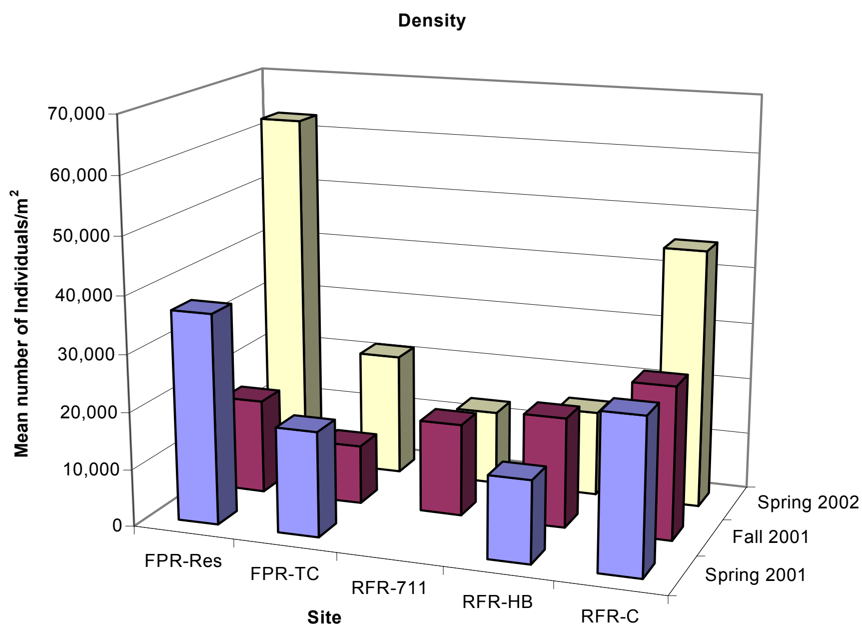


Figure 42. Biomass estimates obtained from sites on the Fryingpan River and Roaring Fork River, Colorado.

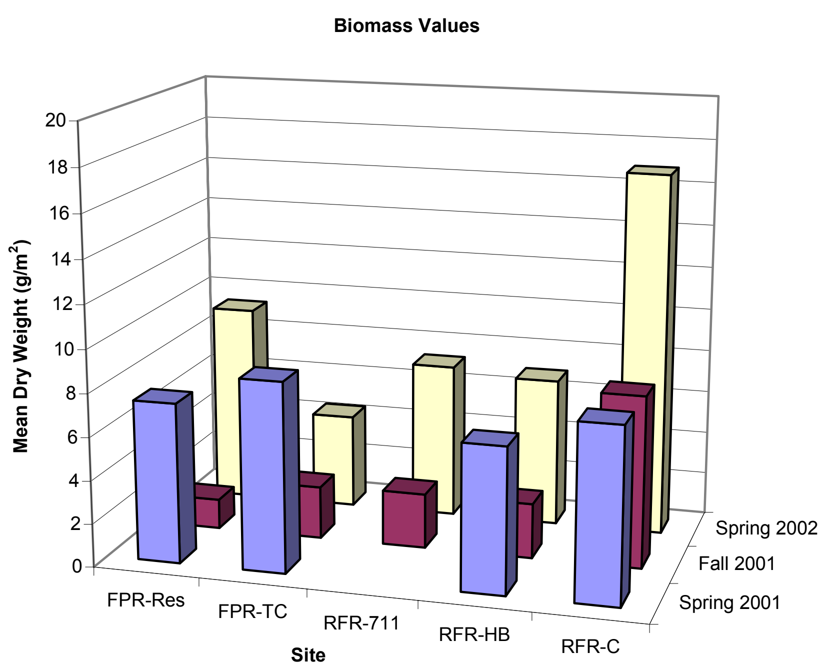
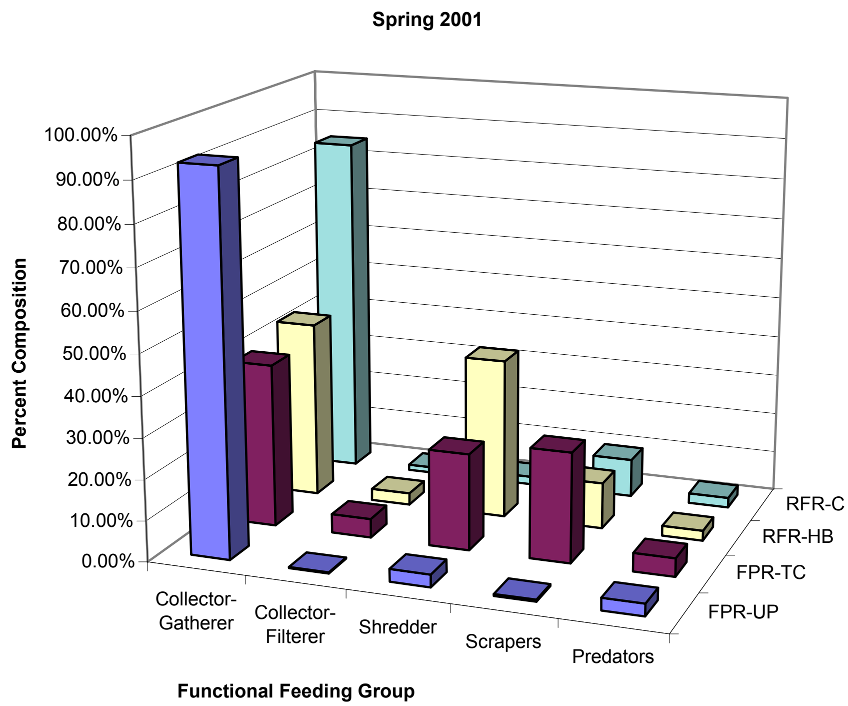


Figure 43. Functional feeding groups at sites on the Fryingpan River and Roaring Fork River, Colorado.



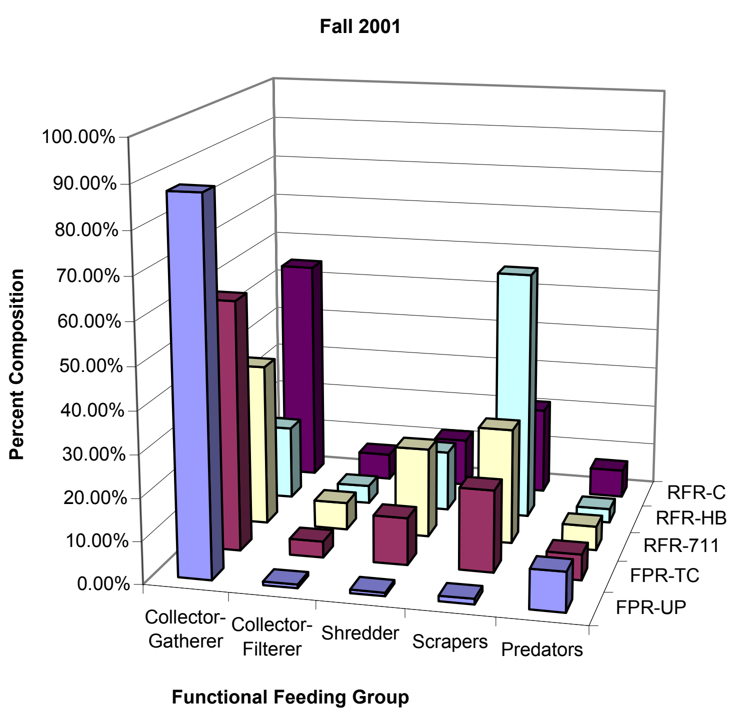
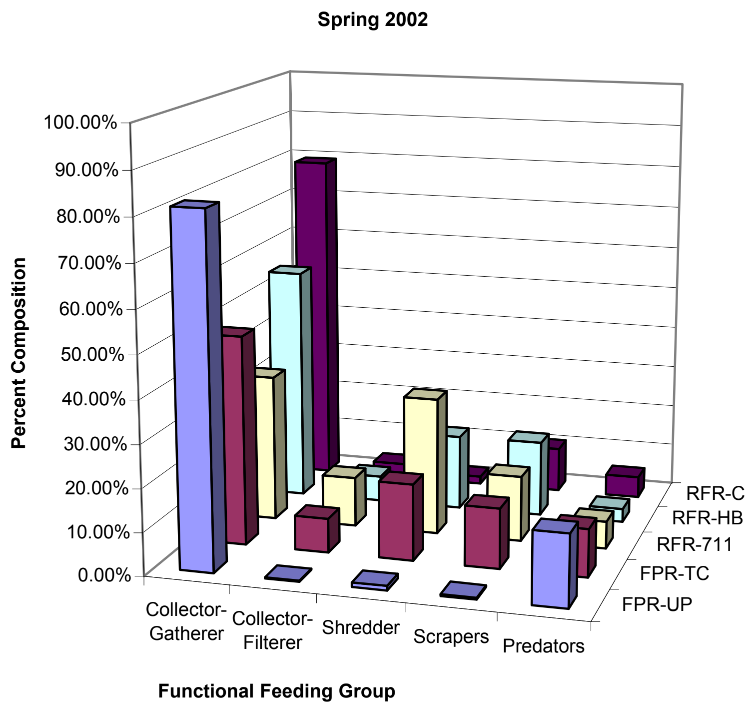


Figure 43 (continued). Functional feeding groups at sites on the Fryingpan River and Roaring Fork River, Colorado.



Spawning

Spawning investigations in the Fryingpan River included monitoring of intragravel and ambient conditions at spawning locations. Data collected from the artificial redds show that both water temperature and dissolved oxygen concentrations are adequate for egg and embryo survival for brown trout (Table 6). Dissolved oxygen levels remain adequate throughout rainbow trout egg incubation (Table 7). Several factors affect water temperatures collected during the dissolved oxygen measurements, including the ambient water temperature influencing the temperature of the standpipe and subsequently affecting the small volume of water in the pipe. Water temperatures collected during dissolved oxygen measurements were to provide a general idea of temperatures within the redd. The most accurate water temperature data source is the intragravel thermographs. Figures 44 and 45 show intragravel water temperatures, collected by

Table 6. Intragravel water temperature and dissolved oxygen concentrations for constructed brown trout redds.

Brown Trout redds Temperature (C^o) Date	Pruessing property Redd 1	 Redd 2	 Ambient	Palm property Redd 1	 Redd 2	 Ambient
10 October 2001	10.0	9.5	9.5	9.7	9.7	9.7
6 November 2001	9.8	9.7	9.8	9.4	9.3	9.3
5 December 2001	5.4	5.2	5.4	3.3	3.3	3.3
11 January 2002	3.3	3.4		1.6	1.6	
5 March 2002	1.4	1.2	1.4			

Dissolved oxygen (mg/l) Date	Pruessing property Redd 1	 Redd 2	 Ambient	Palm property Redd 1	 Redd 2	 Ambient
10 October 2001	8.32	8.17	8.29	8.04	8.23	8.08
6 November 2001	8.96	9.02	9.13	8.67	8.97	9.13
5 December 2001	8.06	8.25	8.13	10.14	10.00	10.13
11 January 2002	6.66	6.27	6.79	8.01	8.20	8.19
5 March 2002	10.15	10.78	10.89			

Table 7. Intragravel water temperature and dissolved oxygen concentrations for constructed rainbow trout redds.

Rainbow Trout redds Temperature (C^o) Date	Pruessing property Redd 1	 Redd 2	 Ambient	Palm property Redd 1	 Redd 2	 Ambient
5 March 2002	3.7	3.4	3.8			
6 March 2002				0.8	0.7	0.9
5 April 2002	6.5	6.4	6.5	6.8	6.9	7.0
29 April 2002	7.9	8.2	7.8	10.6	11.0	11.2
6 June 2002	8.1	7.8	7.7	8.8	8.1	9.1
27 June 2002	8.1	8.2	8.1	10.7	11.1	12.1

Dissolved oxygen (mg/l) Date	Pruessing property Redd 1	 Redd 2	 Ambient	Palm property Redd 1	 Redd 2	 Ambient
5 March 2002	7.61	7.56	7.54			
6 March 2002				5.41	5.42	5.44
5 April 2002	11.12	11.18	11.32	11.38	11.10	11.52
29 April 2002	9.21	9.53	10.08	8.61	8.36	9.20
6 June 2002	8.77	9.89	10.56	9.78	8.56	10.53
27 June 2002	10.06	9.55	10.88	5.17	6.61	10.42

Figure 44. Average daily water temperature (C^o) from two artificial redds during brown trout spawning at two locations on the Fryingpan River.

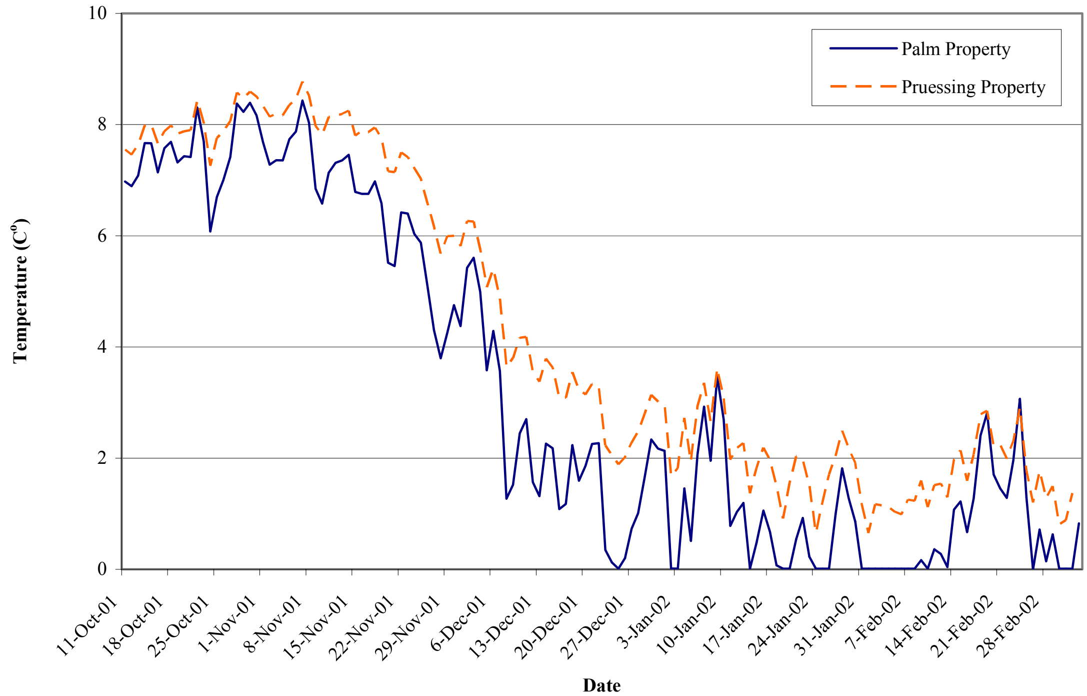
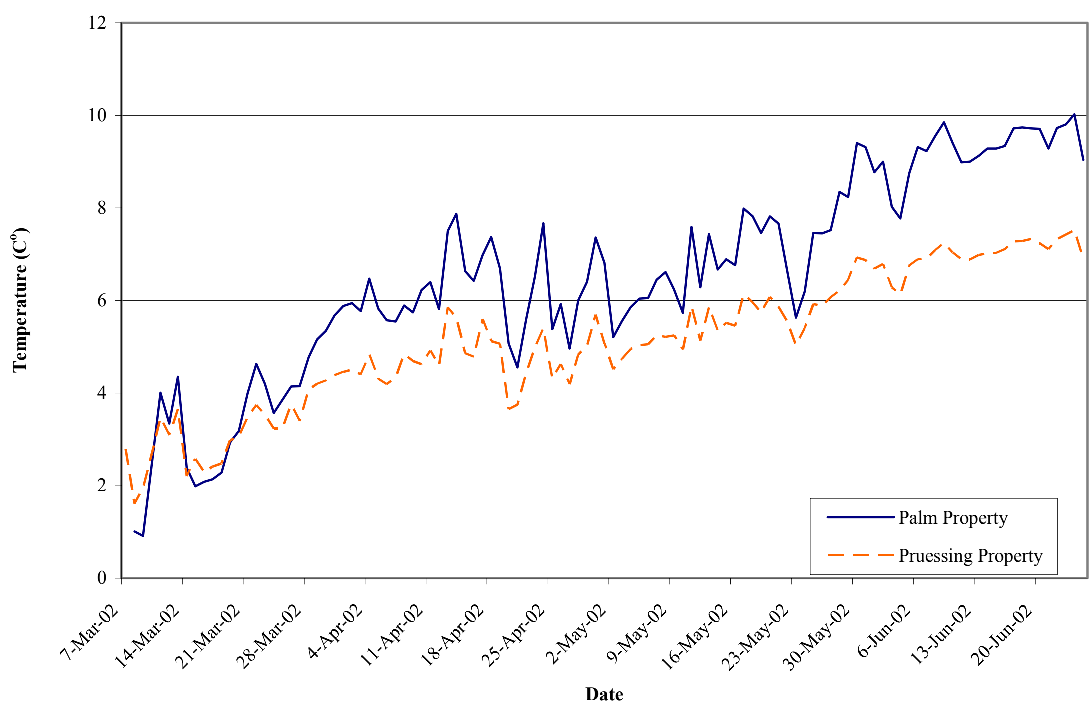


Figure 45. Average daily water temperature (C^o) from two artificial redds during rainbow trout spawning at two locations on the Fryingpan River.



Stowaway thermographs, during the brown and rainbow trout spawning and incubation periods. Intragravel water temperatures show the effects of the dam release at the Pruessing property. The downstream site (Palm) has lower winter water temperatures than the upstream site (Pruessing). Spring and early summer temperatures also reflect the release temperatures from the dam, with temperatures lower in the upper river than downstream reaches. This pattern is opposite of that expected on a natural stream where water temperatures at downstream locations should be colder in the winter and warmer in the summer when compared to upstream areas.

The result of the altered temperature regime shows up in the predicted emergence date of the species. Brown trout would be expected to emerge earlier at the Pruessing property (upstream) than at the Palm property (downstream) (Table 8). Conversely, rainbow trout would be expected to emerge later at the upstream locations and earlier at the downstream locations (Table 8). The temperature regime at the upstream location has a higher minimum temperature and more constant daily temperatures. The temperature regime in the downstream locations has lower minimum temperatures and more daily fluctuations when compared to the upstream locations. This results in a longer time needed to accumulate temperature units for fall spawning species but a shorter time to accumulate temperature units for spring spawning species in the lower river.

The sediment distributions for spawning areas range from clean, large cobble on the surface with a matrix supported structure underneath. The larger clean sediment near the surface and the additional removal of fine sediment during redd construction results in a redd that has very little fine sediment (Table 9). This is typical of suitable salmonid spawning areas. The predicted emergence values for the artificial redds and surface material range from 37% to 94% using the model of Miller (1988), which describes potential spawning success based only on available sediments. The lower values for rainbow trout spawning at the Pruessing site may be artificially low and related to sampling technique. The freeze cores were not vertically stratified for analysis and a higher proportion of the fine sediments may have been below the area used by a trout for spawning. The actual values are probably closer to the surface estimates.

Table 8. Predicted emergence dates based on degree days.

Location	Brown Trout	Rainbow Trout
Pruessing property	22 April 2002	22 June 2002
Palm property	11 May 2002	8 June 2002

Table 9. Sediment size classes for artificial redds and surface sediments.

Sediment size (mm)	Pruessing surface	Pruessing brown 1	Pruessing brown 2	Pruessing rainbow 1	Pruessing rainbow 2	Palm surface	Palm brown 1	Palm brown 2	Palm rainbow
152.400	100		100			100	100	100	
127.000	100		100			100	100	57	
101.600	92		100			100	64	57	
76.200	46	100	55	100	100	53	39	45	100
50.800	37	73	51	100	100	30	34	13	58
38.100	29	52	41	86	100	18	29	12	58
25.400	21	43	37	60	100	14	19	9	52
19.050	16	35	34	52	100	11	16	7	46
12.700	11	28	29	45	100	8	11	5	32
9.660	9	25	27	41	87	7	9	4	26
4.750	5	19	22	32	65	5	6	2	21
2.360	3	15	17	24	40	3	5	2	17
1.120	2	12	13	17	22	2	4	1	14
0.600	1	10	10	12	11	1	3	1	10
0.425	1	8	9	10	7	1	2	1	8
0.300	1	7	7	7	6	1	2	1	7
0.150	1	4	4	4	3	1	1	1	4
0.075	0.2	2.9	2.9	2.6	1.2	0.2	0.8	0.2	2.9
Estimated percent emergence	94%	70%	68%	49%	37%	94%	92%	94%	69%

Note: Data is presented as “percent finer than”. The value indicates the percent of the sediment that is finer than the sediment size. I.e. for Pruessing shovel, 9% of the sediment is finer (smaller) than 9.660 mm.

Fish Community

The Fryingpan River fish populations have been studied since the early 1940s. Some of the earliest information on the fish community is reported by Hunter and Parson (1943). Burkhardt (1966) also provides fisheries data for the Fryingpan River prior to Ruedi Dam construction. Post-dam investigations of fish populations began in the late 1960s after completion of Ruedi Dam (Hoppe and Finnell 1970; Finnell 1972; Finnell 1977). Those data are summarized in reports through the 1970s and 1980s. The most recent report is Nehring and Thompson (2002), which includes a summary of fisheries data collected in the Fryingpan River below Ruedi Reservoir from 1977 through 2001.

Brook Trout

Brook trout are a common species in tributary streams to the Fryingpan River both above and below Ruedi Reservoir; however, their status in the mainstem Fryingpan River below Ruedi Reservoir has been much less successful. Brook trout populations showed a consistent decline in population numbers from the mid 1980s until the mid 1990s (Nehring and Thompson 2002). Population numbers remained low but stable from 1993-1998; however, since 1998 this population has been significantly reduced and brook trout are nearing extirpation in the Fryingpan River below Ruedi Reservoir (Nehring and Thompson 2002). Several theories have been postulated regarding the observed decline throughout the 1980's in brook trout numbers. The most plausible hypothesis is that brook trout recruitment has been severely decreased due to intense predation by brown trout (Nehring and Thompson 1996). Nehring and Thompson (2002) postulate that the increase in whirling disease infection during the late 1990's has pushed the brook trout to the brink of extirpation.

Colorado River Cutthroat Trout

Historically, the Colorado River cutthroat trout was the only trout species native to the Fryingpan River drainage. However, due to the introduction of competitor trout species (brook, rainbow and brown trout), cutthroat populations were extirpated from the Fryingpan River drainage except for a few small tributary streams. A population of A+ strain Colorado River cutthroat trout exists in Rocky Fork Creek, which is tributary that enters the Fryingpan River immediately below Ruedi Reservoir (Nehring 1998). Colorado River cutthroat trout have been found in a tributary to the Fryingpan River upstream of Ruedi Dam (Finnell 1977). In 1993, the CDOW began stocking Colorado River cutthroat trout in an effort to reestablish a viable population in the Fryingpan River. Due to hatchery problems, Colorado River cutthroat have not been stocked into the Fryingpan River since 1993 and few, if any Colorado River cutthroat remain in the system.

Brown and Rainbow Trout

Since studies began in the 1940s on the Fryingpan River fishery, brown and rainbow trout have dominated the salmonid community. Hunter and Parson (1943) reported the earliest findings on the fishery. These evaluations included sampling data from the lower and upper Fryingpan River, both above and below the current location of Ruedi Reservoir. Length frequency information from this study showed that the majority of the fish were less than 24 cm in length with few fish over 33 cm long (Figure 46). Burkhard (1966) also found a similar distribution of fish throughout the length of the river.

Finnell (1972) reported on the length at age information for Fryingpan River trout downstream of Ruedi Dam. Both rainbow trout and brown trout show similar growth increments by year and are very similar in size for each age class (Figure 47). Age 5, for both species, were between 35 and 40 cm in length.

Brown and rainbow trout relative abundances have shifted over time in the Fryingpan River below Ruedi Reservoir. Early post-dam studies reported that rainbow trout accounted for 66-80% of the trout population and brown trout only made up 20-29% (Hoppe and Finnell 1970; Finnell 1972; Finnell 1977) (Figure 48). During the late 1980s and early 1990s, the dominate species shifted from rainbow trout to brown trout (Figure

49). Currently, brown trout account for over 90% of the trout population in the Fryingpan River immediately below Ruedi Reservoir (Nehring and Thompson 2002).

Figure 46. Length frequency of Fryingpan River trout circa 1940s. Data source: Hunter and Parson (1943).

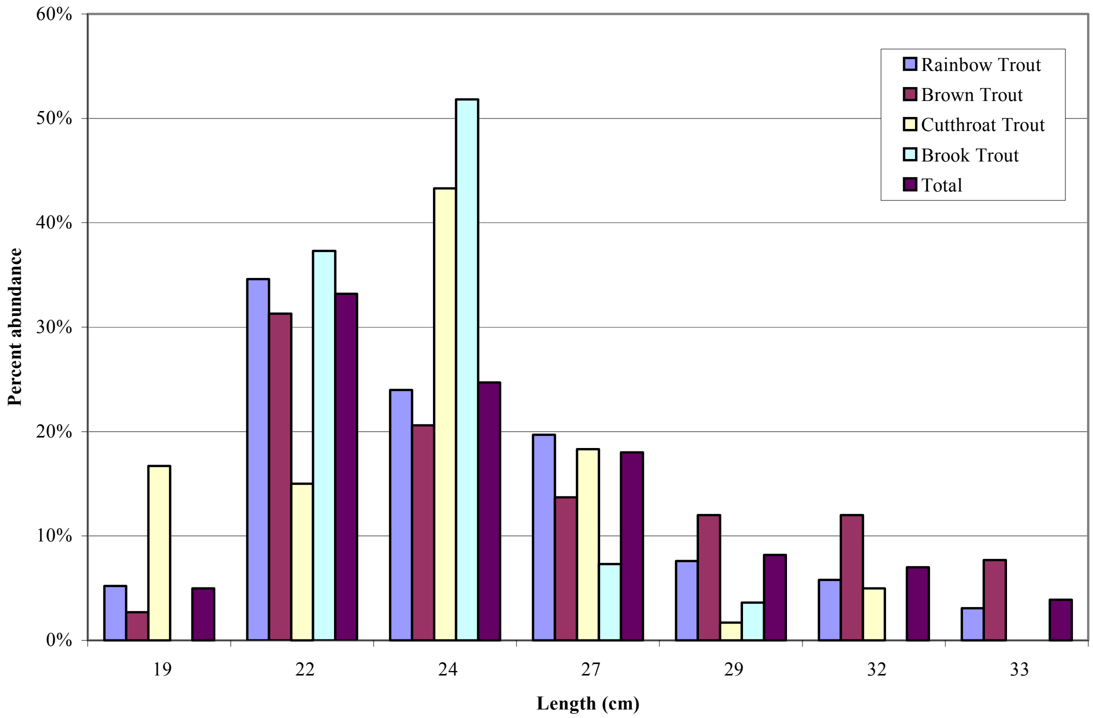


Figure 47. Length at age data for Fryingpan River trout downstream of Ruedi Dam. Data source: Finnell (1972).

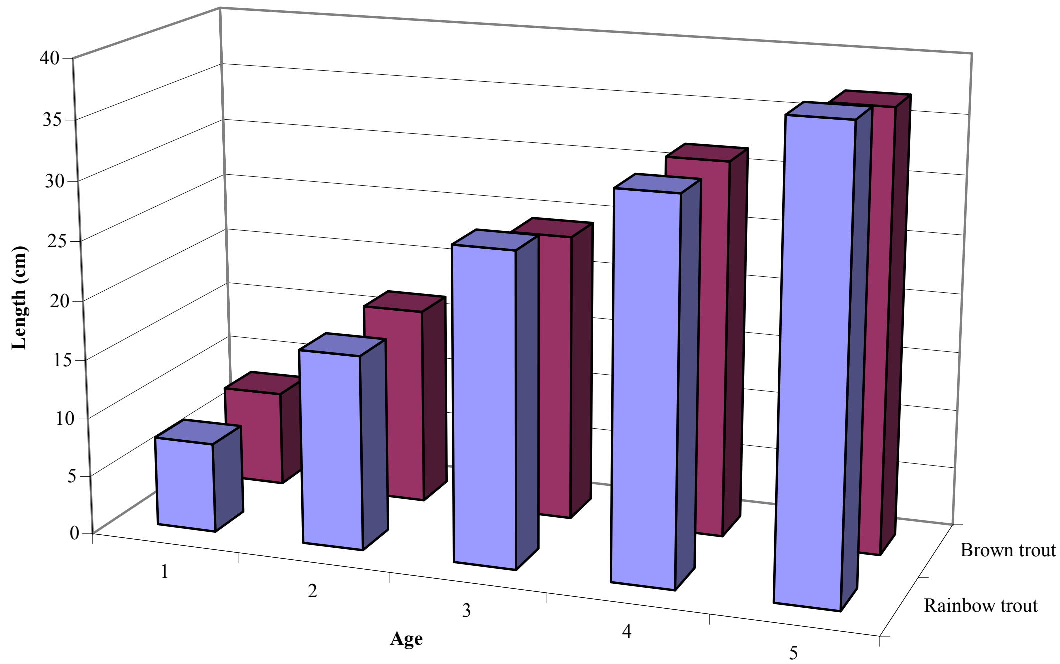


Figure 48. Fryingpan River trout percent abundance at Ruedi sampling site 1972 and 1973. Data source: Finnell (1977).

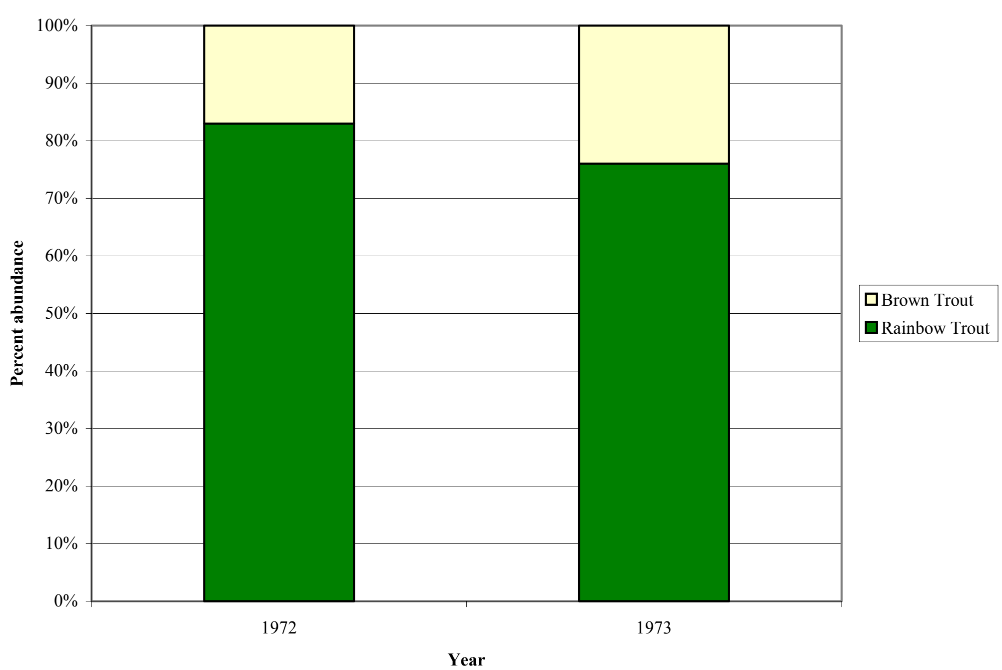
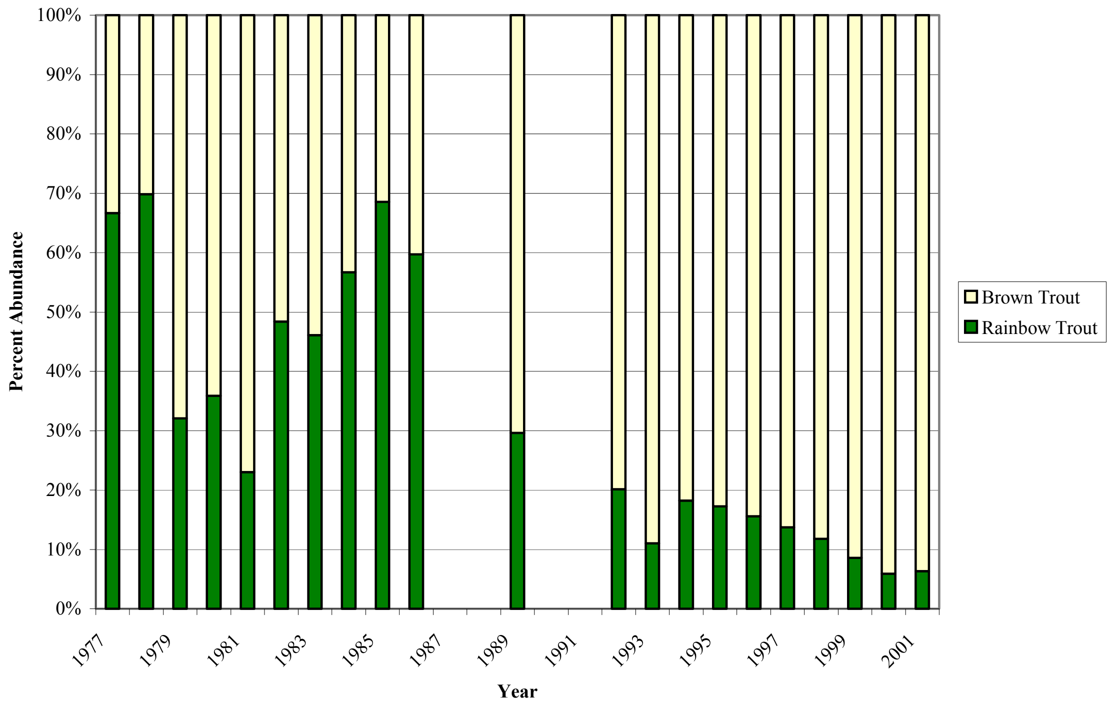


Figure 49. Fryingpan River trout percent abundance at the Ruedi sampling site. All data is from fall sampling, except 1989 and 1992, which are from spring sampling. Data source: Nehring and Thompson (2002).



Trout populations in the lower Fryingpan River show a similar trend (Figures 50 and 51). Relative abundance of rainbow and brown trout at the Taylor Creek site were not as distinctly different in the 1970s; however, brown trout now dominate (Figure 51). As was shown with trout populations at the Ruedi site in the last ten years, brown trout now comprise over 90% of the relative abundance and rainbow trout comprise less than 10% of the abundance at the Taylor Creek site.

The observed shift in species relative abundance may be attributed to several factors, including successful brown trout spawning, lack of rainbow trout recruitment due to whirling disease and poor spawning success, predation by brown trout, and reduced rainbow trout stocking. Nehring (1980) does note that there is successful rainbow spawning from the Seven Castles area downstream but also states that very few young, wild rainbow trout have been collected. The presence and impact of whirling disease during the late 1990’s has exacerbated the problem with reduced rainbow trout recruitment rates.

Figure 50. Fryingpan River trout percent abundance at Seven Castles sampling site. Data source: Finnell (1977).

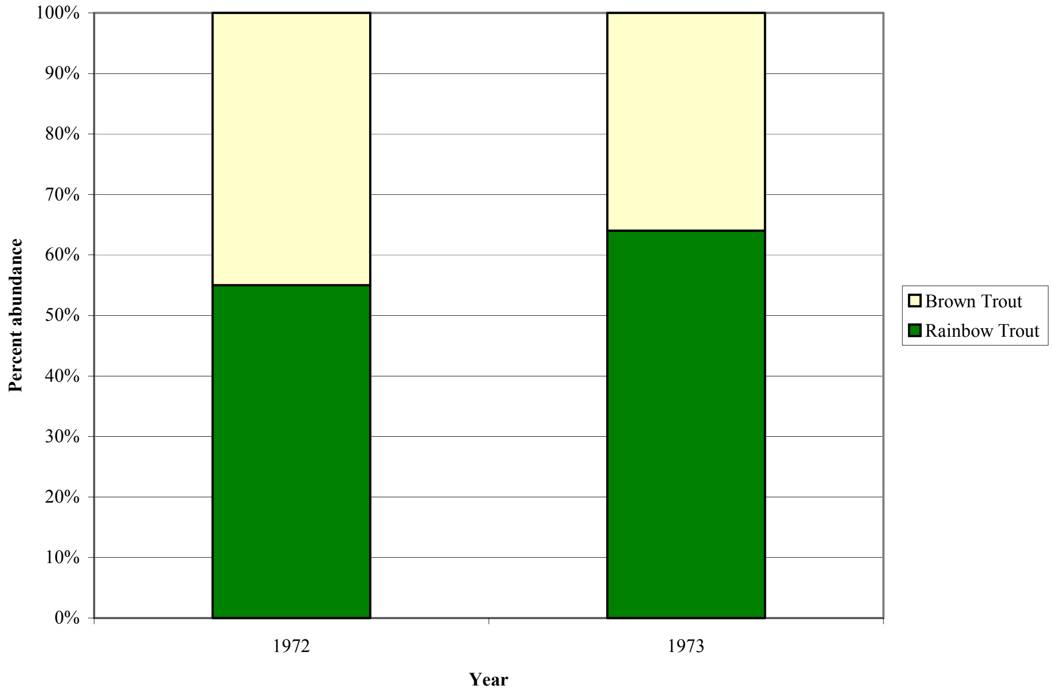
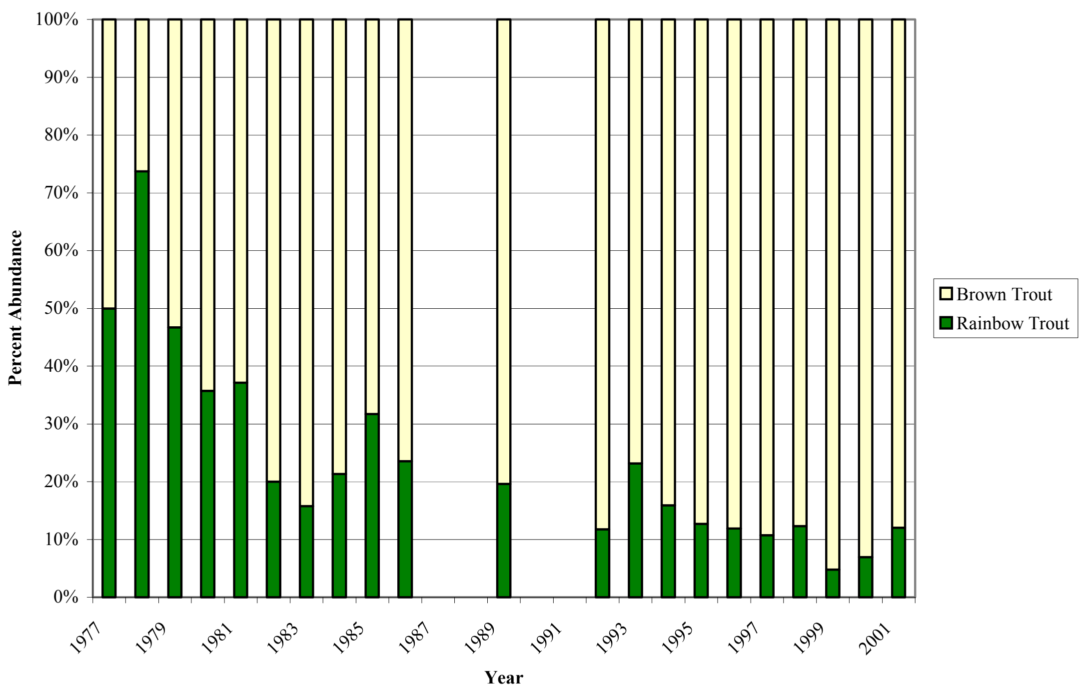


Figure 51. Fryingpan River trout percent abundance at Taylor Creek sampling site. All data is from fall sampling, except 1989 and 1992, which are from spring sampling. Data source: Nehring and Thompson (2002).



Stocking records show that even in the late 1930s, considerable stocking was taking place on the Fryingpan River (Figure 52). Records in the late 1930s and early 1940s show that over 20,000 fish per year were stocked annually in the Fryingpan River. At that time there was no limited catch or terminal tackle restrictions and most stocked fish were harvested by anglers. Hunter and Parson (1943) stated that nearly 65% of the fish stocked were harvested from the river. Fish stocking records reported by Nehring and Thompson (2002) show that approximately 10,000 rainbow trout were stocked per year from 1988 through 1993. Trout were not stocked in the Fryingpan River in 1994-1997, 1999, and 2000. During 1998, 2001 and 2002, over 20,000 rainbow trout were stocked per year. These stockings likely contribute to the fish community seen in the Fryingpan River today, but as noted, brown trout are still the dominant species.

The number of larger trout (<35 cm) in the Fryingpan River below Ruedi Reservoir has increased since the late 1970s (Figure 53). Number of trout over 35 cm remained relatively constant throughout the late 1970s and early to mid 1980s; however, during the mid to late 1980s a sharp increase was observed. Currently, large brown and rainbow trout are available to fisherman. Nehring (2000) reports that fish often exceed 4.5 kg (10 pounds) and fish up to 10 kg (22 pounds) occur in the Fryingpan River immediately below Ruedi Reservoir. The median size reported by Nehring (1980) shows that the same distributions as reported by Hunter and Parson (1943) generally applied to the Fryingpan River with the exception that there were fish over 40 cm long in the river during the 1970s. The same distributions of size continue today with fish over 40 cm noted being caught by fishermen.

Figure 52. Stocking records for Fryingpan River 1937 through 2002. Data source: Hunter and Parson (1943) and Nehring and Thompson (2002).

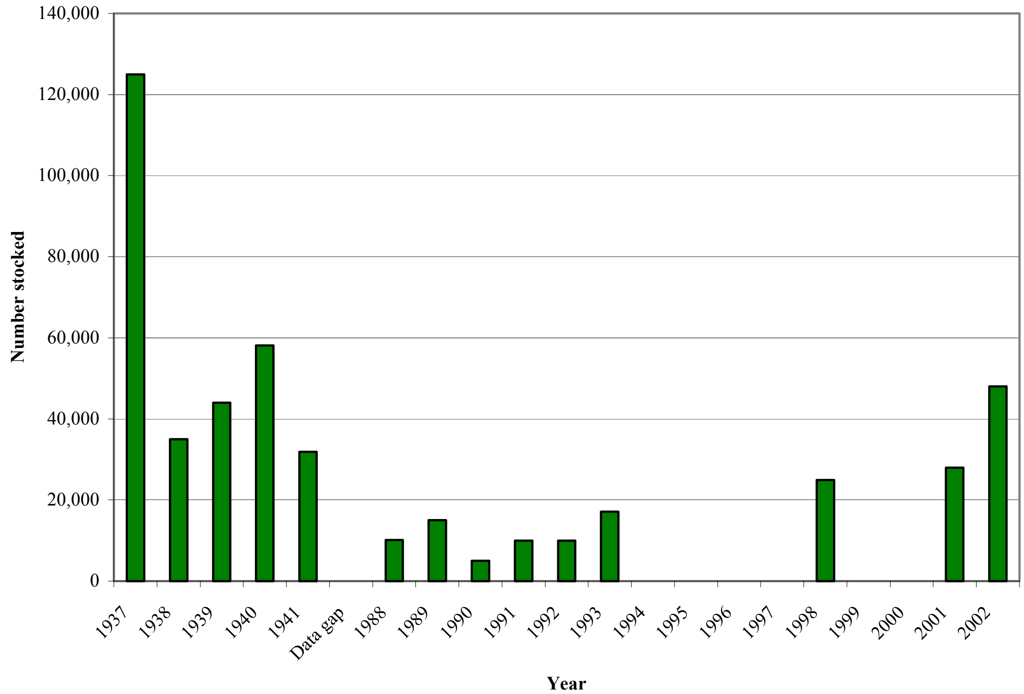
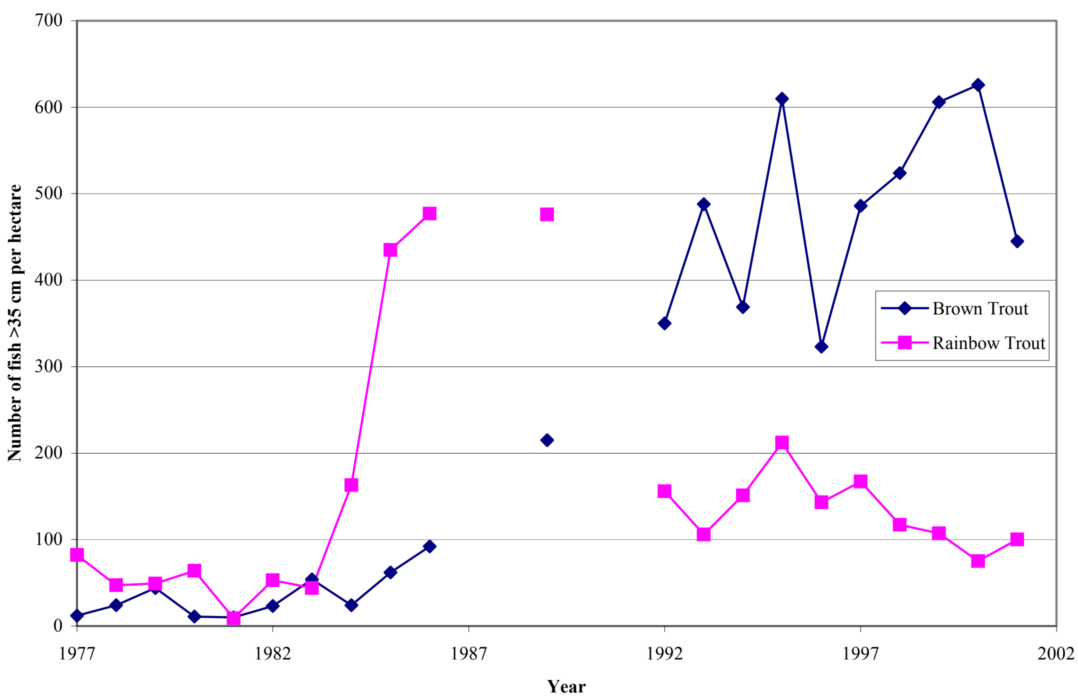


Figure 53. Number of trout larger than 35 cm in the Fryingpan River immediately below Ruedi Reservoir. All data is from fall sampling, except 1989 and 1992, which are from spring sampling. Data source: Nehring and Thompson (2002).



Whirling Disease

An additional factor that may be influencing trout populations on the Fryingpan River is the presence of whirling disease in the river. Whirling disease has come to the forefront throughout the western United States as one of the main parasitic diseases that affect wild trout populations. In the Fryingpan River, testing trout for whirling disease began in 1994. Water filtration studies started in 1998, testing for presence of spores in the water itself. Results of past whirling disease studies are summarized in Nehring and Thompson (2002).

Fryingpan River trout have tested positive for whirling disease since 1996 (Nehring and Thompson 2002). Originally it was thought that these fish were coming from the Roaring Fork River and migrating into the Fryingpan River. Additional testing with water filtration that started in 1998 identified the outflow from a series of ponds in the Fryingpan River valley as a significant source of whirling disease infectivity (Nehring and Thompson 2002). The Colorado Division of Wildlife has been working to isolate the source of infection and modify the outlet to remove that point of infectivity from the river. In 2001 and 2002, experiments were conducted to test a passive filter system to eliminate spores from the outflow water. Initial tests show that the passive sand filter system could be effective in eliminating the spores and reducing infectivity of that water (Nehring and Thompson 2002). In 2002, modifications began on the source pond's outlet to the Fryingpan River to install the sand filter.

With removal of this point source of infectivity, it is hypothesized that the overall infectivity in the Fryingpan River will be decreased. Presence of whirling disease in the Fryingpan River system may have contributed to the declines in rainbow, brown, and brook trout populations that were observed from 1999 through 2002.

Thermal Regime

The thermal regime of the Fryingpan and Roaring Fork rivers was monitored from 23 June 2001 through 25 June 2002 (Figure 54). The annual trend (Figure 54) for all sites except for the Fryingpan River below Ruedi Dam was: a period of low (0-3^{o}C) relatively constant temperatures from December through February; in March, water temperatures began to rise and continued to increase until approximately the beginning of August (peak 14-15^{o}C); temperatures then declined throughout the fall reaching the base level at the end of November.

Below Ruedi Dam, the thermal regime in the Fryingpan River is distinctly different. Variation in the annual thermal regime was significantly reduced. During the study, the maximum and minimum temperatures on the Fryingpan River below Ruedi Reservoir were 9.1^{o}C and 2.7^{o}C, respectively. Lowest temperatures occurred from January through March. Gradual warming occurred throughout the spring, summer and early fall, reaching a peak around mid-November. Water temperatures dropped sharply from mid-November until the beginning of January.

Water released from Ruedi Reservoir has very little variability in diel temperature characteristics (Figure 55). During most of the year, fluctuation between nighttime lows and daytime highs is usually less than 1.5^{o}C. Diel fluctuation is highest in the springtime, with temperature differences greater than 2.5^{o}C; however, differences are minimal overall.

The Fryingpan River above the confluence site and both Roaring Fork River sites exhibit similar patterns in diel fluctuation. During the winter months (December to February), very little variation in temperatures occurred. However, during the remainder of the year temperatures varied from 3-5^{o}C from day to night (Figure 56).

Figure 54. Average daily water temperature (C^o) for two sites on the Fryingpan River and two sites on the Roaring Fork River.

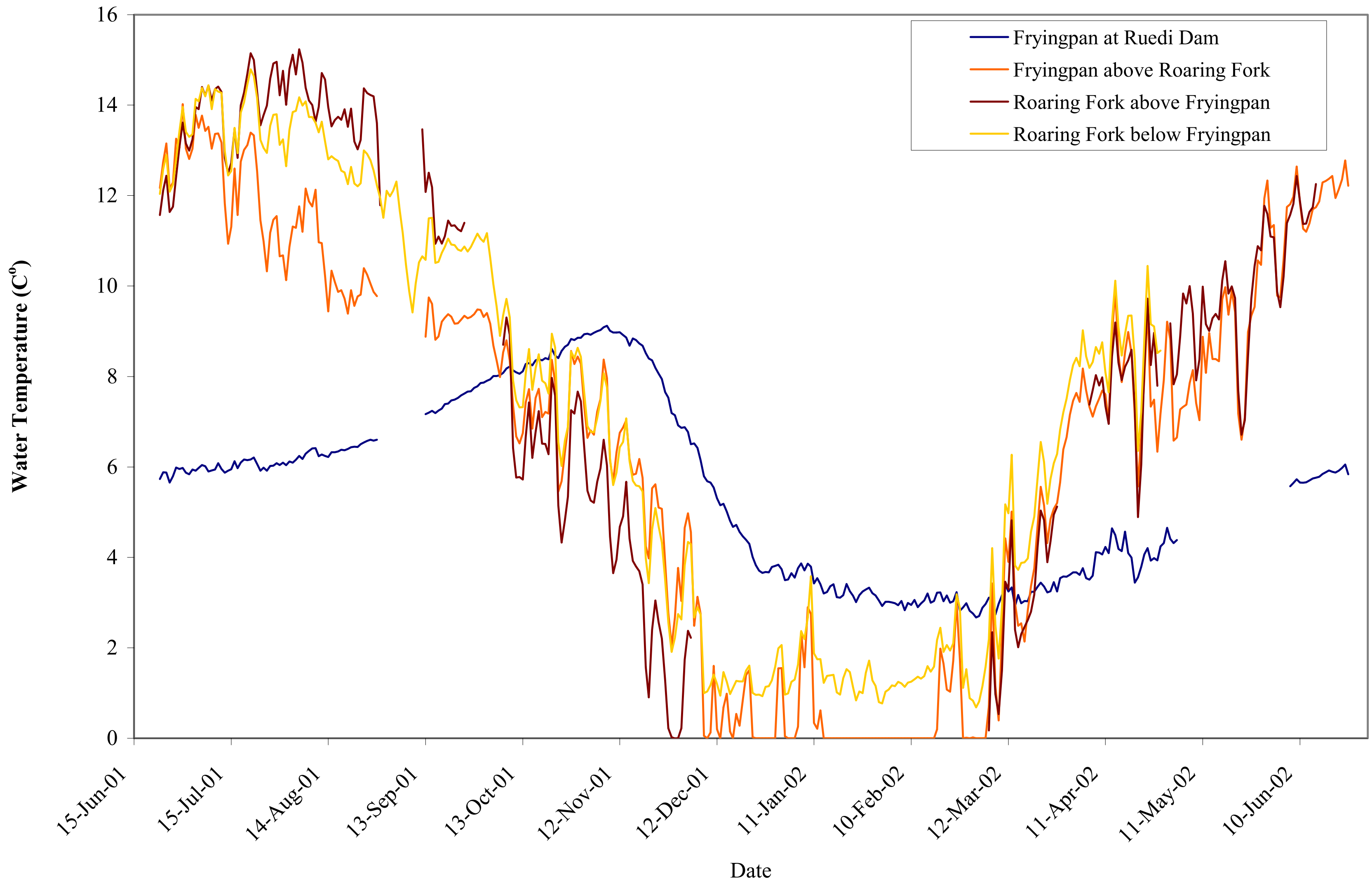


Figure 55. Diel temperature variation for the Fryingpan River below Ruedi Reservoir.

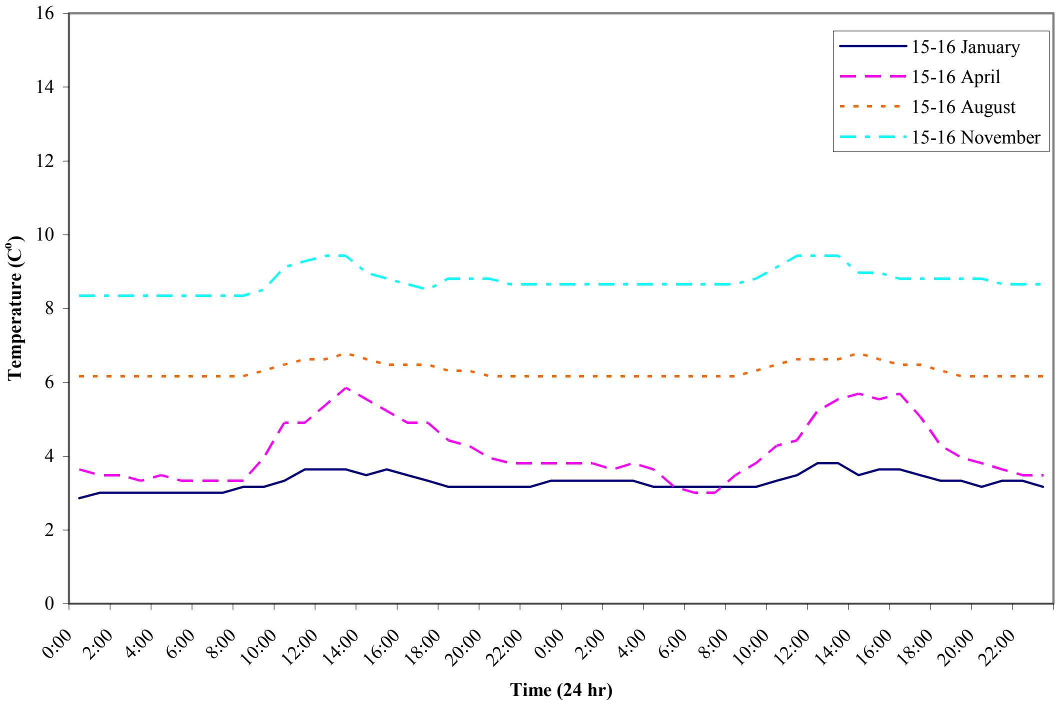
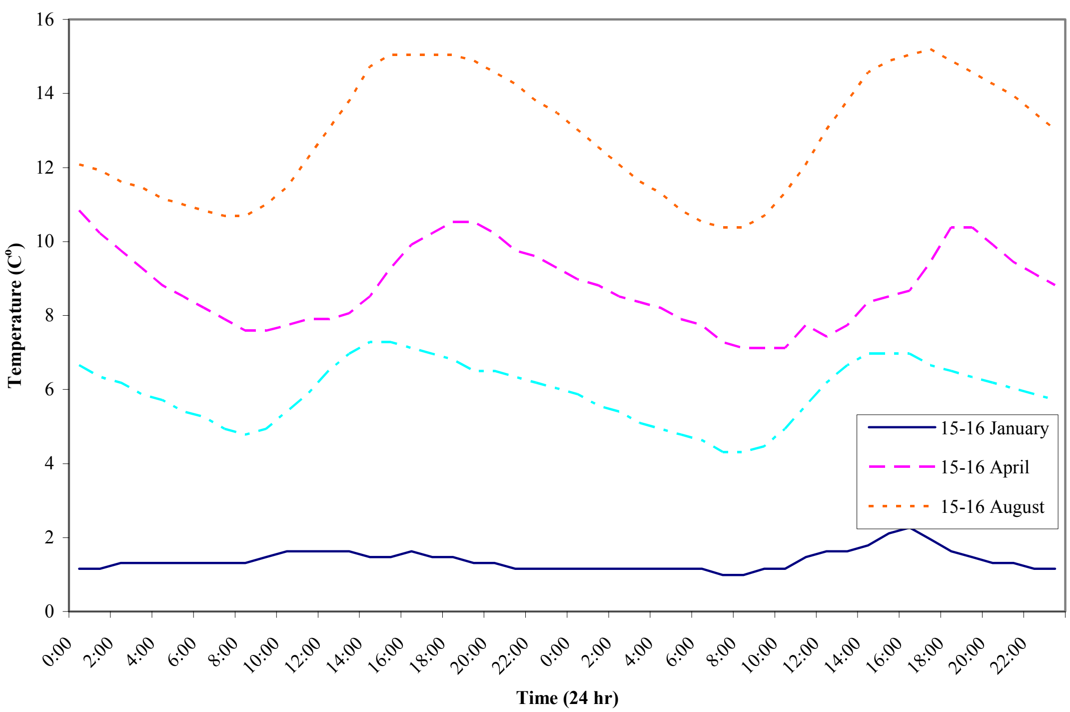


Figure 56. Diel temperature variation for the Roaring Fork River at USFS "Tree Farm".



The Fryingpan River exhibits a distinct influence on the thermal characteristics of the Roaring Fork River below Basalt. During this study, the influence appeared to be the strongest during the late summer through the winter months.

In the late summer (July-September) of 2001, input of water from the Fryingpan River lowered the temperature of the Roaring Fork River below the confluence (Figure 57). During this time, water temperatures in the Fryingpan River above the confluence were roughly 3°C lower than the Roaring Fork River above the confluence. The Fryingpan River accounted for 40 percent (based on streamflow records from USGS gages 09080400 and 09081000) of the Roaring Fork River flow at this time.

During the late fall and winter, Ruedi Reservoir releases are warmer than the Roaring Fork River at either site. Fryingpan River water cools significantly before it enters the Roaring Fork River but is still warm enough to elevate water temperatures in the Roaring Fork River below the confluence near Basalt (Figure 58).

Figure 57. Average daily water temperature (C°) during July and August 2001 for two locations on the Fryingpan River and two sites on the Roaring Fork River.

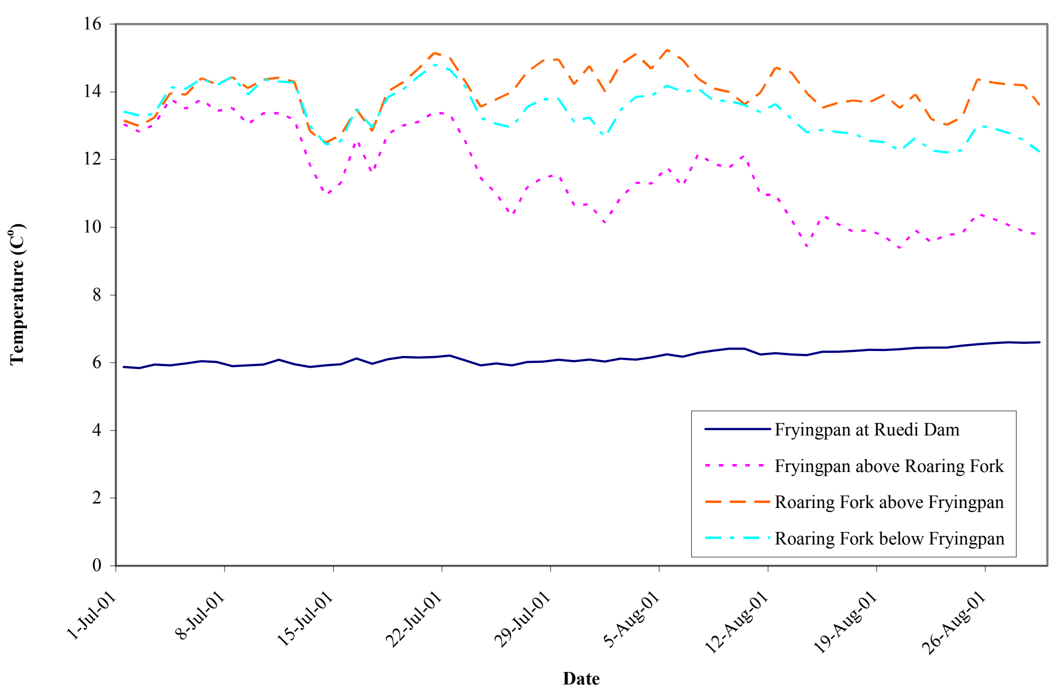
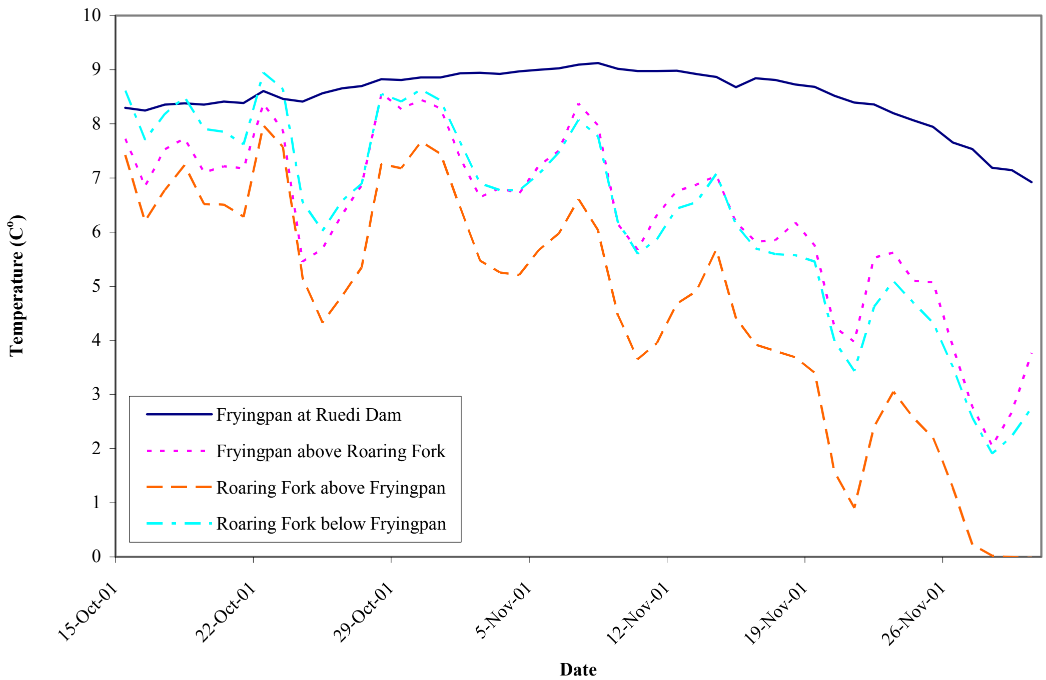


Figure 58. Average daily water temperature (C°) during October and November 2001 for two locations on the Fryingpan River and two sites on the Roaring Fork River.

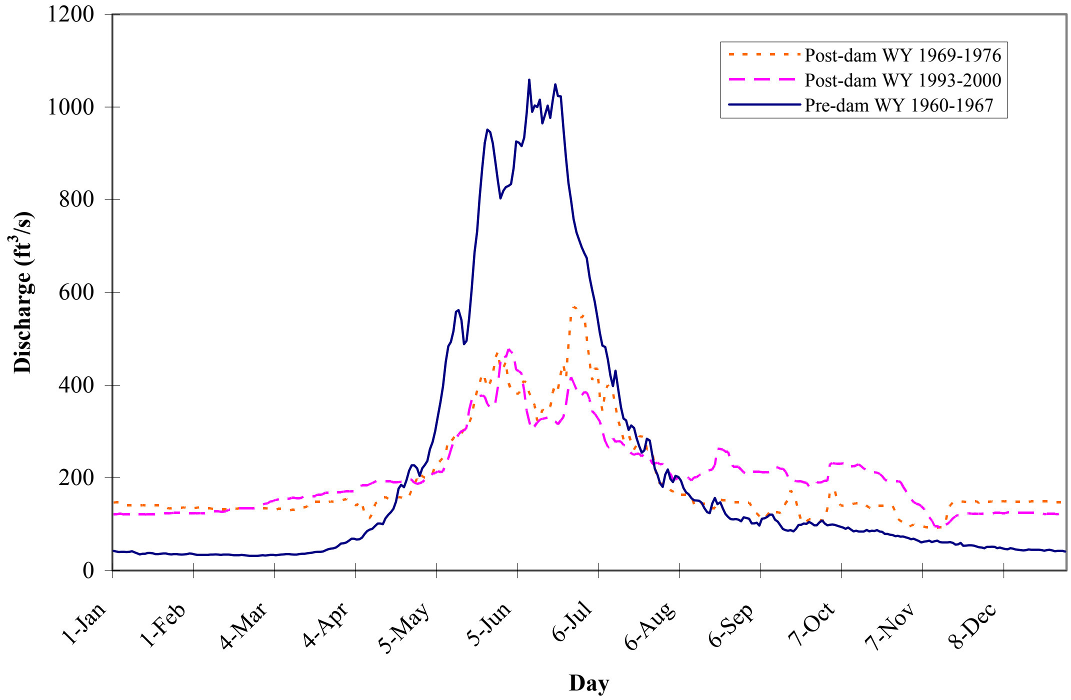


Hydrology

The hydrological characteristics of the Fryingpan River below Rocky Fork Creek (location just downstream of Ruedi Dam) have been altered significantly since Ruedi Reservoir was completed. Fall and winter baseflows have been augmented and spring peak flows have been reduced (Figure 59). Average baseflows (December through March) were 39.5 ft^3/s for the 8 years prior to dam completion and 137.7 ft^3/s for 2 post-dam periods (1969-1976 and 1993-2000). Post-dam spring peak flows were only 40 percent of the pre-dam period.

Much of the natural stochasticity of the system has been reduced or eliminated by the construction of the reservoir; however, man-made "flood" events do periodically occur. Occasionally, reservoir releases are increased dramatically over a short time frame (hour) and then gradually (several hours) dropped back to near original flow levels. This essentially becomes a man-made storm event. An example of this occurred on the evening of 14 November 2001 when outlet structure maintenance required abnormal

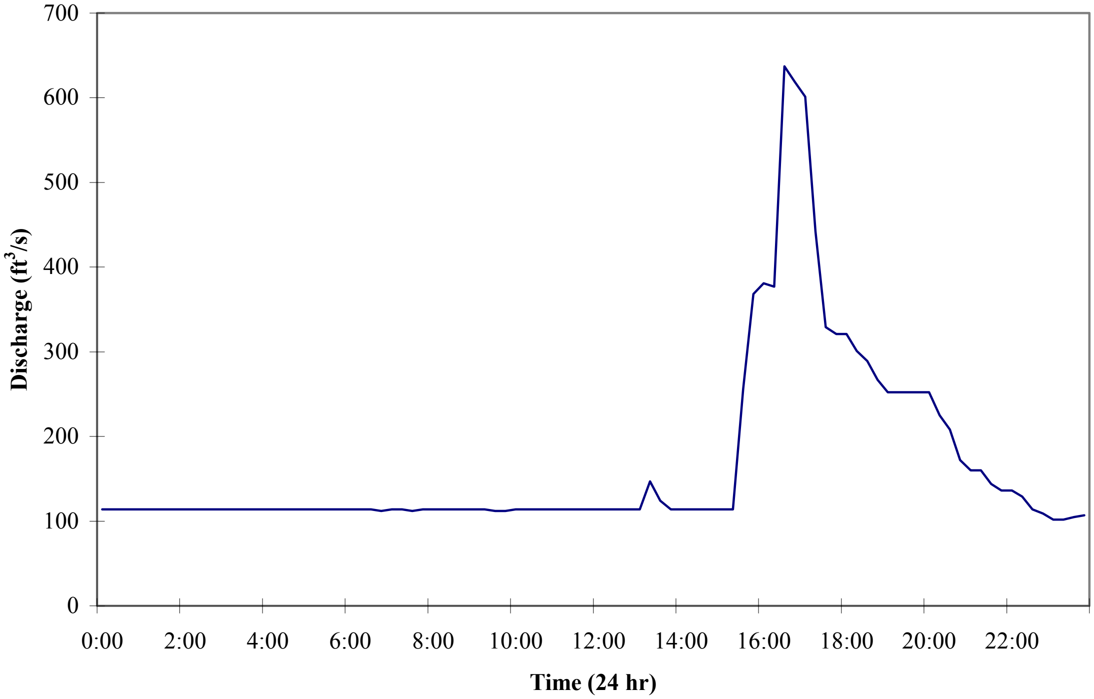
Figure 59. Average daily discharge pre and post Ruedi Dam construction.



releases (Figure 60). Flows were increased from approximately 106 ft^3/s to over 600 ft^3/s in just over an hour and reduced back to 106 ft^3/s 8 hours later. Dramatic changes in reservoir releases also occur on a daily and weekly level due to ever changing water "calls" coming on and going off.

Since 1989, Fryingpan River flows have been elevated from previous fall post-dam flows during the late summer and fall to meet downstream water demands for endangered fish species. The average daily flow during September and October was 132 ft^3/s from 1969-1976 and 207 ft^3/s from 1993-2000 (this data corresponds to September and October from Figure 59). In many instances since 1989, the yearly peak flow has occurred during September (Figure 5). Flows have remained elevated through October, finally dropping around the beginning of November. The latter portion of this time period encompasses a substantial portion of the brown trout spawning period in the Fryingpan River.

Figure 60. Discharge for Fryingpan River at Ruedi Dam (USGS gage 09080400) on 14 November 2001. Provisional data.



Habitat Mapping

Habitat mapping was conducted at three locations in the Fryingpan River in order to describe the three distinct geomorphological areas that were used in the instream flow portion of the study (Appendix C). Habitat mapping was used in the IFIM for the habitat typing technique. Only one site was used in the Roaring Fork River because much of the habitat was identified as a similar complex of riffles and runs. The Fryingpan River immediately downstream of Ruedi Reservoir (FPR-BP) was wider, and had a large area of run habitat that was not typical for most other reaches of the Fryingpan River. FPR-BP had the most pool habitat (20%) of all sites mapped. Habitat in the low gradient reach (FPR-LG) consisted of similar proportions of riffle (50%) and run (42%) habitat. The combination of these two types accounted for more than 90% of the available habitat in that reach. Habitat in the high gradient reach (FPR-HG) was defined by a decrease in run habitat (14%) and an increase in riffle habitat (76%). The quantity of pool habitat remained similar to the proportion that was reported for FPR-LG. The river banks in all reaches surveyed were generally stable and vegetated.

The Roaring Fork River site was entirely composed of riffle and run habitat; however, it was difficult to delineate the channel into clear habitat units due to the similarity of these two habitats within this river.

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DISCUSSION

IFIM

The application of the IFIM can be a valuable tool in examining the relationship between streamflow and habitat availability (Nehring and Anderson 1993). The use of habitat suitability curves to determine available habitat follows the premise that depth and velocity are primary components structuring fish distribution. This premise is supported by the findings of other researchers (Gorman and Karr 1978; Moyle and Vondracek 1985; Bain et al. 1988).

Several studies to quantify the relationship between streamflow and trout habitat have been conducted on the Fryingpan River since Ruedi Reservoir was created (Nehring 1979**;** Environmental Research and Technology, Inc. 1981; Nehring 1988b). Nehring and Anderson (1993) attempted to correlate streamflow and associated WUA values with measured trout population parameters. They concluded that factors other than habitat availability confounded the situation on the Fryingpan River and thus precluded a significant correlation. Environmental Research and Technology, Inc. (1981) conducted their study to assess impacts on trout habitat resulting from a water sale to the Exxon Company. Since the purpose of the ERT report was a quantification of impacts to trout habitat, information on minimum and optimum flows was not provided, therefore a direct comparison cannot be made.

Other researchers have provided qualitative estimates of minimum flow recommendations and reservoir operations (Hoppe and Finnell 1970). These estimates were based upon personal observations and not scientifically quantified. The authors recommended flows no lower than 100 ft^3/s and when changes in reservoir releases occurred, that ramping rates were as gradual as possible.

Nehring (1988b) recommended minimum flows ranging from 50 ft^3/s to 65 ft^3/s depending on life stage. He found optimum flows of 100 ft^3/s for brown trout spawning, fry, juvenile, adult, rainbow trout spawning, and rainbow trout fry. Rainbow trout juvenile and adults had optimum flows of 150 ft^3/s and 250 ft^3/s, respectively.

This (MEC) study found higher optimum flows than did Nehring (1988b) for brown trout and rainbow trout in the Fryingpan River. This difference is likely due to the use of different habitat suitability curves between this study and Nehring (1988b).

Many factors ultimately determine which area or reach contains the most suitable habitat and highest fish biomass. Refuge or resting habitat is an extremely important habitat feature. Pools are usually considered the typical resting habitat but any location with substantial depth and low velocities may act as a refuge habitat. These habitats gain importance during any periods of increased physiological stress on fish. During winter low flows, spring peak flows, post-spawning and after being caught and released by an angler, fish may utilize this type of habitat. Because we used habitat suitability curves that were constructed using active fish, any determination of which reach possessed the best habitat must take into account refuge or resting habitat. The section immediately below Ruedi Dam has high WUA values as well as a higher proportion of refuge or resting type habitat (pool) compared to either of the other two sites.

Alterations in the Fryingpan River flow regime due to Ruedi Reservoir operations result in different habitat time series for pre and post dam conditions. Overall, a greater amount of adult habitat exists today as compared to the pre-dam environment. In general, both FPR-LG and FPR-HG had similar trends during the base flow period. However, a comparison between these sites shows a distinctly different trend during the peak flow period. This is due to the channel morphology associated with each site. FPR-LG is characterized by a wider, shallower channel with a low gradient. The amount of wetted area increases with higher spring flows, while velocities only increase marginally. The channel at FPR-HG is constricted and as flows increase, little gain in wetted perimeter is realized but velocities increase and become unsuitable. Therefore, the channel morphology at FPR-LG makes this site more suitable for trout during higher spring flows.

Macroinvertebrates

Analysis of benthic macroinvertebrate samples has become a widely accepted tool used to monitor aquatic conditions in lotic environments (Winner et al. 1980; Plafkin et al. 1989; Cairns 1990; Cairns and Pratt 1992; Rosenberg and Resh 1992). Benthic macroinvertebrate community structure and function are products of the physical and biological influences present in the environment. The dominant force contributing to the structure of aquatic macroinvertebrate communities is dependent upon the time of year, adaptations of the given macroinvertebrates, and/or magnitude of disturbances (Poff and Ward 1989). The flow regime of a stream is usually considered to be one of the most important factors that influence aquatic communities (Poff et al. 1997).

Flow is particularly important because it is often correlated with numerous other factors that influence the aquatic community (Cushman 1985; Poff and Ward 1990). These factors include: depth, velocity, thermal changes, renewal of resources, etc. The macroinvertebrate community composition of a given stream is adapted to, and dependent on, the flow regime (as well as other variables) that exists in that stream.

Releases from the impoundment at Ruedi Reservoir directly influence the benthic macroinvertebrate and fish communities that exist downstream. In many ways, the impoundment and physical variables associated with discharge are responsible for the development of an exceptional trout fishery in the Fryingpan River. The influence of regulated discharge on the macroinvertebrate community results in an increase in thermal stability and extended periods of flow stability.

Aquatic macroinvertebrate communities were evaluated in this study to better understand the relationship between macroinvertebrate populations and flows and the role of macroinvertebrates as a food component for trout populations. The results, based on available data, provide a description of the composition of existing macroinvertebrate communities at the time and location of sampling. This information is useful because it describes seasonal and longitudinal changes in community composition, and the associated metrics indicate possible mechanisms that are responsible for structuring the macroinvertebrate community. The mechanisms that influence the community assemblages are numerous and include variables not related to flow manipulations. However, the direct and indirect effects of the regulated flow regime in the Fryingpan River provide a major influence on benthic macroinvertebrates. This study describes the contribution of various factors that influence the composition of macroinvertebrates assemblages in the Fryingpan and Roaring Fork rivers.

The Fryingpan River downstream from Ruedi Reservoir is a unique system. Stream size, elevation, gradient, regulated flow, reduction in sediment transport, and altered thermal regime are just a few of the physical processes responsible for structuring the macroinvertebrate community. Few other rivers in this region can be compared to the Fryingpan River for the purpose of providing reference information when determining what is “normal” for macroinvertebrate communities. Interpretation of these results must rely in part from research on other tailwaters and observations from other Colorado streams, but mostly on a spatial and temporal comparison of sampling conducted within the Fryingpan River. The Roaring Fork is influenced to a lesser extent by the dam at Ruedi Reservoir, and is therefore more typical of a western Colorado stream.

The compilation of metrics used in this study indicated that community composition was a function of various processes throughout the study area. Densities and often biomass were highest in the Fryingpan River below Ruedi Dam and in the Roaring Fork River near Carbondale. This trend was most evident in the spring, but proportionally high densities and biomass remained evident at RFR-C during October 2001. During the fall of 2001 density and biomass at FPR-RES were similar to other site locations. Most of the values obtained from the other metrics indicated that a more balanced community structure and function occurred at the sites in-between FPR-RES and RFR-C. Ward et al. (2002) indicates that optimum metric values range between 3.0 - 4.0 (for diversity), and 0.6 - 0.8 (evenness) in Colorado streams. During the spring sampling events, data from samples taken from FPR-TC, RFR-711 and RFR-HB consistently provided metric values in this optimal range. Values produced by samples taken from FPR-RES and RFR-C were consistently lower. In addition, the FBI and EPT values indicated that the proportion of taxa that are considered sensitive to perturbation or pollution was relatively greater in the Fryingpan River downstream of FPR-RES, and in the Roaring Fork River upstream of RFR-C. Interpretation of these trends will identify some of the processes that are responsible for influencing these communities.

Macroinvertebrate study results suggest that all sites have habitat that supports large numbers of aquatic organisms. In general, density and biomass estimates at all site locations were adequate for maintaining large and healthy fish populations. However, the metrics used to analyze this data exhibited some variation among stations and provided some noteworthy observations and trends. The decline in diversity, evenness and EPT values at RFR-C suggest that there was some impact from organic pollution at this site. This observation was supported by an increase in FBI values. The high density and biomass that was consistently observed at RFR-C was also consistent with an increase in nutrients that could be attributed to mild organic pollution. It is likely that runoff, from pasturelands or fertilized areas (golf courses or other developments), was responsible for influencing the macroinvertebrate community in the Roaring Fork River near Carbondale. Similar metric values were reported from FPR-RES and can be attributed to the effects of releases from the reservoir, which are discussed in more detail below.

Influence of Ruedi Dam

The alteration of aquatic macroinvertebrate communities by regulated flows has been well documented (Ward 1974; Ward and Stanford 1979; Hauer and Stanford 1982; Voelz and Ward 1989; Weisberg et al. 1990; Munn and Brusven 1991; Vinson 2001). This modification of benthic communities is dependant on natural physical, biological and climatic factors as well as dam operations and the limnological conditions that exist in the reservoir. Much of the reduction in diversity that has been observed in tailwaters has been attributed to the altered thermal regime (Lehmkuhl 1972; Ward and Stanford 1979; Voelz and Ward 1989).

An analysis of benthic macroinvertebrate collections from FPR-RES indicated that higher densities, but lower diversity occurred below the dam when compared to other sites in the study area. A comparison of data from FPR-RES and data from the other stations revealed that the observed differences in metric values could mostly be attributed to increased numbers of *Baetis* mayflies and chironomid midges (particularly Orthocladiinae) and reduced numbers of stoneflies. Other specific families of mayflies and caddisflies (Heptageniidae and Hydropsychidae, respectively) had representatives that were also reduced or eliminated below the dam. Description of the benthic macroinvertebrate assemblage from a functional perspective at FPR-RES indicated that the collector-gatherer group was dominant and most other groups were poorly represented. These trends were consistent with observations from other studies regarding the influence of deep-water releases in tailwaters.

A decrease in diversity is commonly reported immediately below dams on Colorado streams (Ward 1974). An increase in chironomids and certain mayflies (*Baetis* sp.) and general reduction in stoneflies are typical responses to the regulated flow and temperature regime that exist in tailwaters (Ward et al. 2002). Densities of other specific taxa that were found to be influenced by releases from Ruedi Dam have been the focus of research in other tailwaters. Munn and Brusven (1991) found that orthoclad chironomids became dominant in a regulated reach of an Idaho river. A reduction of net-spinning hydropsychid caddisflies was also reported by Hauer and Stanford (1982). They determined that the temperature constancy associated with deep releases from a dam did not provide the thermal cues necessary for successful completion of the life cycle of most hydropsychid caddisflies.

The absence of certain functional feeding groups at FPR-RES is at least partially a response to the availability of certain food types in the hypolimnetic releases from the reservoir. Ward and Stanford (1979) reported that a reduction in filter-feeding species was commonly observed below dams with hypolimnetic releases. Voelz and Ward (1989) found that an increase in the shredder group downstream from a Colorado reservoir was related to a downstream increase in leaf detritus biomass. However, they also suggest that a variety of biological interactions including competition among macroinvertebrates and influences of algal growth may be partially responsible for the composition of benthic macroinvertebrate communities in tailwaters.

Functional feeding groups at each site on the Fryingpan River reflect the availability of food resources. The temperature stability below Ruedi Reservoir creates an excellent environment for algal growth. A shift in functional feeding groups at downstream sites indicates that leaf litter produced by the riparian zone becomes much more important. As the influence of Ruedi Reservoir decreases, the function of the riparian zone becomes a more dominant factor in the maintenance of the high densities of benthic macroinvertebrates.

Historical research indicated that high densities of aquatic macroinvertebrates occurred in the Fryingpan River prior to the construction of Ruedi Dam (Hunter and Parson 1943; Burkhard 1966). Data collected and pooled from several habitat types near Ruedi by Burkhard (1966) reported quantitative (ft^2) macroinvertebrate densities. A conversion of Burkhard's data would estimate densities at approximately 2,423 individuals/m^2. This estimation is probably low because of the bias associated with pooling data from several habitat types. Description of macroinvertebrate communities in historical accounts lacks the detail necessary to determine changes that have occurred over time. However, the historical data does suggest that communities in the vicinity of FPR-RES were dominated by caddisflies prior to the construction of Ruedi Dam. The current reduction or absence of caddisflies at this location provides some evidence of the changes in benthic community structure that have occurred.

Studies that have been conducted since the closure of Ruedi Dam have consistently suggested that benthic macroinvertebrate communities have been altered due to the regulated effects of reservoir releases (Environmental Research and Technology 1981; Simons, Li and Associates 1983). This alteration becomes less evident with distance downstream of the dam. Simons, Li and Associates (1983) provide densities, diversities and species lists for sample sites within a study area that encompassed site locations used for this study. Overall, some similar trends could be observed when comparing MEC data to the data presented by Simons, Li and Associates. In both cases densities were highest below Ruedi Dam and decreased (while diversity increased) near Taylor Creek. Simons, Li and Associates (1983) estimated density at 4,035 individuals/m^2 near the dam during October 1982, but results of the present study indicated that density at this site was 16,509 individuals/m^2 in October 2001. Spring samples collected by MEC had density values that approached 63,000 individuals/m^2. Although biomass values suggest that these individuals were mostly small, this number was high even when compared to other tailwaters.

The Green River below Flaming Gorge Dam is another example of a tailwater trout fishery that was created in the Colorado River Drainage. Vinson (2001) provides a summary of changes that occurred in macroinvertebrate communities in the Green River after closure of Flaming Gorge Dam. Pre-dam macroinvertebrate data indicated that densities were approximately 1,000/m^2. Quantitative data from the reach immediately downstream of the dam, collected over three decades, indicated that densities had increased to ~10,000 individuals/m^2 after closure of the dam. Recent surveys report the actual densities range from 8,100 to 11,800/m^2.

A comparison of densities provided by Vinson (2001) to those reported in this study demonstrates the exceptional macroinvertebrate production that occurs in the Fryingpan and Roaring Fork rivers. Densities in the Fryingpan and Roaring Fork were at least equivalent to those reported in the Green River, and in some cases more than six times higher. Macroinvertebrate communities and populations should be sufficient to support healthy trout populations throughout the study area; however an important additional food source for trout occurs in the reach below Ruedi Dam.

Mysis relicta

The influence of *M. relicta* in the reach of the Fryingpan River immediately downstream from Ruedi Dam has received considerable attention (Nehring 1988a; Nehring 1991;

Nehring and Thompson 1994; Nehring 1999). *M. relicta* was stocked into Ruedi Reservoir in 1970, and first appeared in releases below the dam in 1985 (Nehring 1991). This species is poorly adapted for swimming in current velocities that are associated with swift running waters, and consequently provides an excellent food resource for trout in the river. Nehring (1991) determined that the presence of *M. relicta* in the Fryingpan River had resulted in a positive effect on rainbow trout condition, growth rate, and population size in the 5 km immediately below Ruedi Dam. The trout community below Ruedi Dam was believed to be partially dependent on this augmented food supply. Years with drought conditions and consequently low releases from the dam are thought to reduce the rate of entrainment of *M. relicta* (Nehring and Thompson 1994). Nehring and Thompson (1994) determined that declines in rainbow trout and brook trout biomass during a four-year period were directly related to a decrease in food supply resulting from low flows associated with drought conditions.

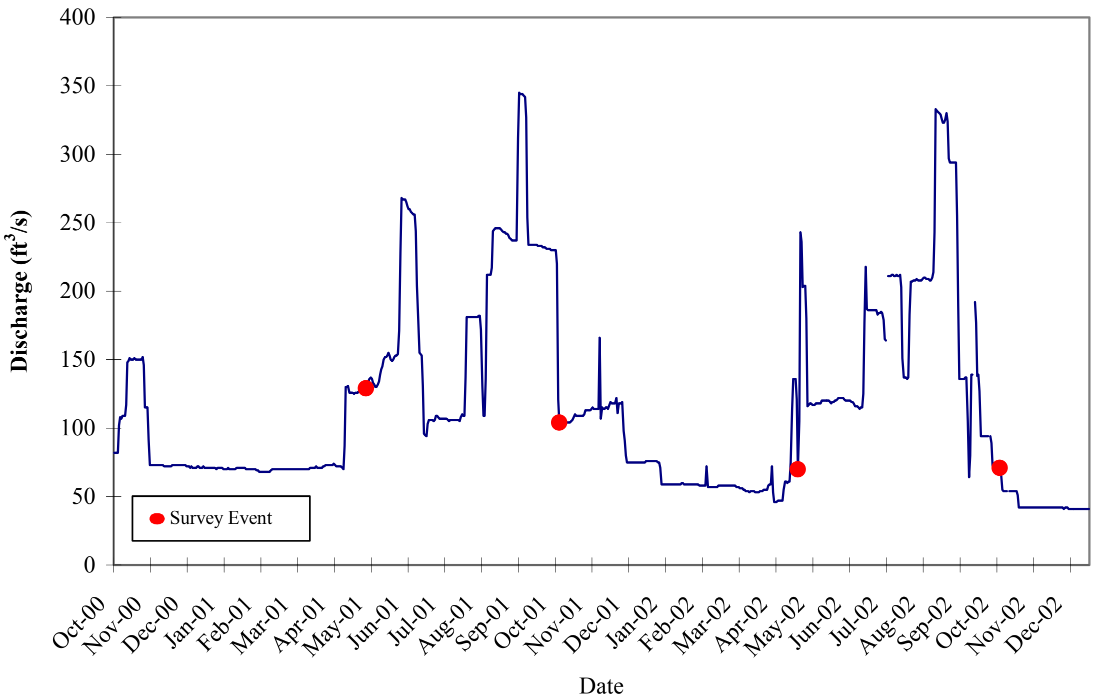
The physical and biological processes that influence the presence and abundance of *M. relicta* in the Fryingpan River are only partially understood. With no quantitative studies to determine the role of *M. relicta* in the food chain, the occurrence and importance of this species in the Fryingpan River must be based on limited knowledge of the species life history, reports from fishermen and speculation. It has been reported by fishermen that the greatest number of shrimp are released from the reservoir into the Fryingpan River during relatively high flows that occur during the winter months. Nehring (1991) described a process in which daily migrations and oxygen requirements of mysid populations resulted in movement within the proximity of the outlet structure of Ruedi Dam primarily during the winter months. It was later hypothesized that the swimming ability of *M. relicta* was sufficient to avoid entrainment during periods of low volume releases from the reservoir (Nehring and Thompson 1994). In contrast, reports from fishermen during December 2002 describe relatively high densities of mysids in the river despite low releases at the end of a record drought year (T. Heng, Taylor Creek Fly Shops, Inc., personal communication). It may be possible that the stage of Ruedi Reservoir also has an important influence on mysid location and consequently entrainment.

The methodology used in the MEC study is specifically designed to quantify benthic macroinvertebrates and does not provide an adequate means of capturing or estimating numbers of *M. relicta*. At this time there has been no research conducted in the Fryingpan River that quantifies the availability of this organism. The quantitative data collected by MEC suggests that relatively high numbers of macroinvertebrates were present throughout the study area, but the highest densities were reported below Ruedi Dam. Although the ratio of density to biomass suggests that most of the organisms below the dam are small in size, the density and biomass estimates at this location are adequate to support an exceptional trout fishery. Several investigations describe the presence of an exceptional fishery during the period before mysids were present (Finnell 1972; Nehring 1980). Yet data from fishery studies (Nehring and Thompson 1994) indicate that the presence of *M. relicta* is important for maintaining the elevated biomass and fish condition that exists in the reach extending for several kilometers below Ruedi Dam.

Flow alterations

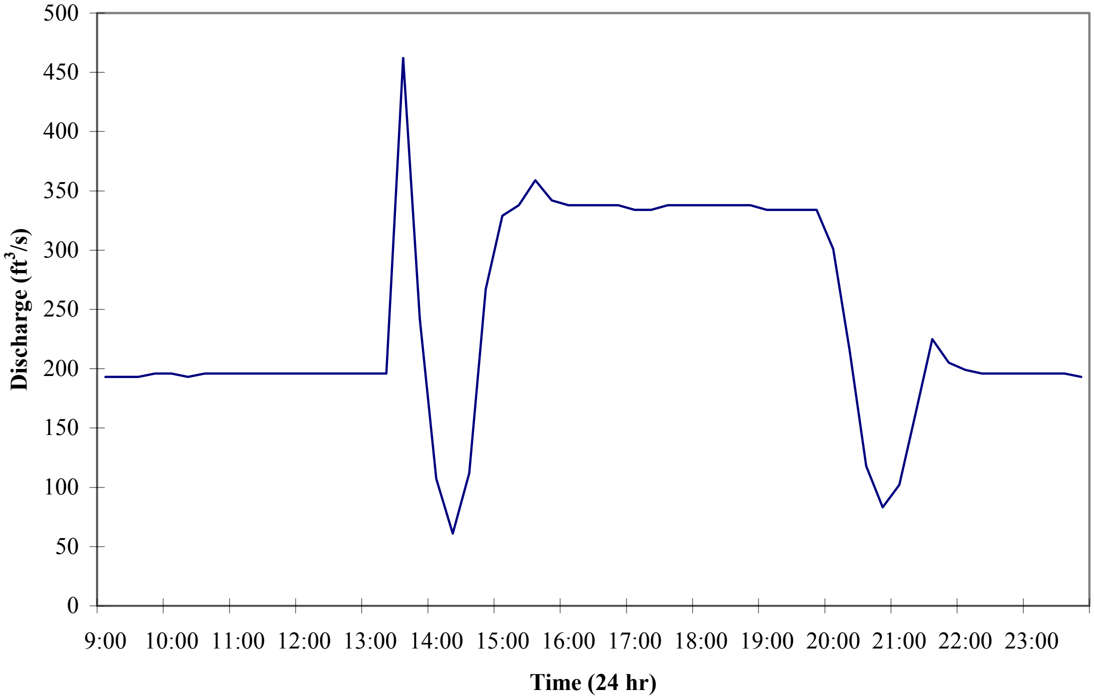
The flow regime is considered to be one of the most important factors that influence aquatic communities (Poff et al. 1997). Much of the community composition in the Fryingpan and Roaring Fork rivers at this time is a product of the current flow regime. Comparing the results of seasonal macroinvertebrate sampling among years can help assess the impact of long-term flow changes related to dam operations. Long-term changes in flow patterns would include those that could be observed or measured on a seasonal or annual basis. A comparison of discharge patterns between years indicates that a similar period of low flows occurred prior to each spring sampling event (Figure 61). The increase in discharge prior to sampling during the spring 2001 may be responsible for the lower densities in samples at FPR-RES at that time. Adequate time for redistribution and colonization of habitats after changes in discharge may not have occurred.

Figure 61. Sampling events and hydrograph for the Fryingpan River at Ruedi Dam (USGS gage 09080400).



Short-term changes in discharge also have the ability to adversely impact macroinvertebrate communities (Moog 1993), but these impacts are often more difficult to measure. A rapid increase in discharge can alter the existing aquatic habitat (due to the change in velocity) and increase the overall habitat by increasing the wetted area. A rapid decrease in discharge results in a rapid loss of wetted area that can leave benthic macroinvertebrates stranded along the shore margins. These rapid flow changes have been observed in the Fryingpan River below Ruedi Reservoir (Figure 62). The species-specific dispersal mechanisms or swimming ability of benthic macroinvertebrates may determine the potential for adaptation under these conditions. Ward and Stanford (1979) suggest that the high densities of benthic macroinvertebrates that commonly occur in tailwaters may be reduced as a consequence of rapid flow fluctuations.

Figure 62. Discharge for Fryingpan River at Ruedi Dam (USGS gage 09080400) on 26 June 2002. Provisional data.



An indirect effect of low flows that may directly affect macroinvertebrate communities is the formation of anchor ice. A negative response has been associated with harsh winter conditions and anchor ice (in macroinvertebrate community assemblages) (Bradt et al. 1999). Anchor ice often has a scouring effect on the substrate surface – an area that constitutes important habitat for many species of benthic macroinvertebrates. The formation of anchor ice is a function of flows and air temperature. As discharge decreases the potential for anchor ice increases. Voelz and Ward (1989) found a progressive downstream increase in the frequency and magnitude of disturbance associated with anchor ice in a regulated Colorado stream. It is likely that the low winter flows in the Fryingpan River increase the potential for anchor ice formation in the middle to lower reaches. The macroinvertebrate portion of this study has been continued into 2003, with special emphasis placed on determining the possible effects of anchor ice. The potential impact and recovery from anchor ice in the Fryingpan River are unknown at this time.

Thermal Regime

The thermal regime in the Fryingpan River below Ruedi Dam is entirely regulated by Ruedi Reservoir. The effect of Ruedi Reservoir upon the Fryingpan River has resulted in a thermal regime that lacks many of the thermal characteristics that typify a natural high mountain river. Annual and diel fluctuation is severely reduced and climatological features become unimportant factors in determining the thermal regime. Water temperatures are warmer in the winter and cooler in the summer as compared to unregulated rivers. Numerous researchers have reported similar findings from other tailwater rivers (e.g. Wright 1967; Lehmkuhl 1972; Ward 1974).

On a typical unregulated or partially regulated river, maximum yearly water temperatures occur during the late summer months. However, below the Ruedi Dam, the maximum yearly temperature occurred during early November. Ward (1974) found that maximum water temperatures in the South Platte River below Cheesman Dam occurred in late fall to early winter as well. He hypothesized that the timing of maximum temperature corresponded with the “turning over” of Cheesman Reservoir. During the summer time, many lakes and reservoirs thermally stratify. When air temperatures begin cooling, surface water temperatures also begin to drop and become denser. As the surface water becomes cooler and denser the stratification is disrupted and the reservoir waters become mixed (turning over). Warmer water is found throughout the vertical profile of the reservoir and becomes available to be released into the river below.

It is unclear what positive or deleterious effects this shift in maximum annual temperature timing may have on the aquatic communities below the dam. An important life history event occurring during this time is brown trout spawning and egg incubation. The increased temperatures during the spawning and incubation period may be beneficial to the survival and hatching success of brown trout eggs.

The amount of influence that the Fryingpan River has on the thermal regime of the Roaring Fork River is directly related to the Fryingpan River discharge in proportion to the Roaring Fork River discharge. Frequently during the late summer and early fall (Figure 5), Ruedi Reservoir releases are increased to augment low flow conditions on the 15-Mile reach of the Colorado River near Grand Junction. Flows in the Roaring Fork River are at baseflow conditions at this time. When these additional releases are made, Fryingpan River input becomes a large proportion of the overall Roaring Fork River discharge and thus has a greater impact on water temperatures. During 2001, this resulted in a cooling of Roaring Fork River water until early October and a warming after.

Spawning

Salmonids deposit their eggs in redds which they dig in the stream gravels. These eggs are then covered with up to several inches of gravel during the spawning process (Burner 1952). Once hatched, the larvae remain in the gravel until the yolk is absorbed and then move up through the gravel at the onset of feeding. This larval life stage is classified as alevin (Balon 1975) or metalarva (Snyder 1983; Martinez 1984).

Because salmonids bury their eggs in stream gravels, incubation success depends on proper intragravel temperature, dissolved oxygen concentration, intragravel water velocity, and substrate particle size (Chapman 1988). Instream water velocity and depth are important because they influence the intragravel conditions but are not directly related to embryo habitat quality.

Complete embryo development requires proper temperatures. The normal incubation period for fall spawning salmonids, such as brown trout, is from early fall until late winter. Fry typically emerge in early spring. Normal temperature regimes for incubation begin at approximately 8^{o}C, decrease to near 0^{o}C during the winter and then increase through hatching and emergence. Fall spawning salmonid embryos can endure low stream temperatures (< 2^{o}C) if they have progressed to the 128 cell stage of development before the temperature drops below 6^{o}C (Combs 1965). Longer than normal periods of extremely low temperatures can cause delayed hatching or mortality. Temperatures above 15^{o}C can also cause mortality (Reiser and Bjornn 1979). The releases from Ruedi Dam have a narrow range of annual fluctuation but are warmer (9.12^{o}C) during early November. This altered temperature regime is conducive to brown trout spawning success, but not spring spawning rainbow trout.

The normal incubation period for spring spawning salmonids, such as rainbow trout, ranges from mid-March through late May. Average daily incubation temperatures begin at approximately 4^{o}C and reach approximately 14^{o}C at emergence. Temperatures outside of this range can be lethal (Reiser and Bjornn 1979). Extremely low water temperatures occuring during spring below Ruedi Dam are likely reducing the survival of rainbow trout eggs. Temperatures in March 2001 were as low as 2.70^{o}C on March 3 and increased very slowly during the following months. Water temperatures do not exceed 10^{o}C until after June 1 annually.

The accumulated temperature units (tu) can be used to determine when embryos hatch and larvae emerge. A degree (^{o}C) above zero for one day equals one temperature unit. Total temperature units required for emergence vary among the different salmonid species but reported tu values range from 550 for rainbow trout to 800 for brown trout (Piper et al. 1982).

Intragravel temperatures influence developmental rates of incubating embryos and larvae. Water temperatures above normal in a particular stream can accelerate the developmental rate of embryos. The developmental rate is important for overall growth and formation of internal and external biological structures. Above normal water temperatures result in accumulating tu's required for emergence earlier than normal, so larvae emerge earlier. Below normal temperatures can delay emergence relative to the optimal tu range for the species or cause mortality. Both the early and delayed emergence can have adverse effects on the fish. In natural conditions the fish emerge at a time of year that is optimal for their survival. Early or delayed emergence could be detrimental to survival. Timoshina (1972) reported that temperatures below 10^{o}C delayed development of embryonic structures and hatching in rainbow trout. During the spring of 2002, temperatures in the Fryinpan River only exceeded 10°C in the lower reach and this condition did not occur until June. It is likely that temperatures in the Fryinpan River rarely, if ever, reach 10°C prior to June 1 in the reach between Ruedi Dam and Taylor Creek.

Dissolved oxygen

Dissolved oxygen levels have a direct effect on the quality of incubation habitat and salmonid survival. Silver et al. (1963) and Shumway et al. (1964) found a direct relationship between dissolved oxygen concentration and the size of salmonid fry at hatching. The fry hatching from eggs incubated at 2.6 mg/l dissolved oxygen were 4 mm shorter than those incubated at 11.2 mg/l (Silver et al. 1963). Silver et al. (1963) stated that the smaller fry probably would not survive under natural conditions, although this was based on the author's judgment and not on empirical data. Both studies report total mortality at dissolved oxygen levels below 2.0 mg/l.

Davis (1975) in a review of dissolved oxygen requirements for several Canadian fish species reports a minimum concentration of 8 mg/l dissolved oxygen for proper incubation and development of salmonid embryos. Reiser and Bjornn (1979) recommend a minimum of 5.0 mg/l for salmonid embryos. Embryos can survive at 5.0 mg/l but are smaller at hatching than embryos incubated at 8.0 mg/l (Silver et al. 1963; Shumway et al. 1964). Several researchers demonstrated that embryo oxygen demand varies with temperature and developmental stage (Hayes et al. 1951; Daykin 1965; Wickett 1975; Zinichev and Zotin 1987). All of the dissolved oxygen levels measured in artificial redds in the Fryinpan River were adequate for egg survival, however, lower oxygen levels were recorded at some sites during periods of low flow.

Substrate Size

Substrate size and composition, especially the amount of fine sediment, has a direct effect on the intragravel velocity and therefore the amount of dissolved oxygen carried to and metabolic wastes carried away from the embryos. Size distribution of substrate was recorded at each site in the Fryingpan River (Figure 63). Substrate size and composition, especially the degree of clogging of interstitial spaces, also is an important factor in determining fry emergence (Shirazi and Seim 1981). Rainbow trout spawn in a variety of substrate sizes from small gravels (2 mm) to larger cobbles (150 mm) but utilize the smaller size more frequently (Reiser and Bjornn 1979; Shirazi and Seim 1981).

Tappel and Bjornn (1983) report that the percent substrate sizes < 9.5 mm and < 0.85 mm give a better representation of percent emergence than a single particle size. In this study, percent emergence was inversely correlated to the 0.85 mm size class and positively correlated with the 9.5 mm size class (Figure 64). Ninety to 93% of the variability in embryo survival was correlated with substrate particle size composition.

Figure 63. Sediment size class distribution of artificial redds and surface material.

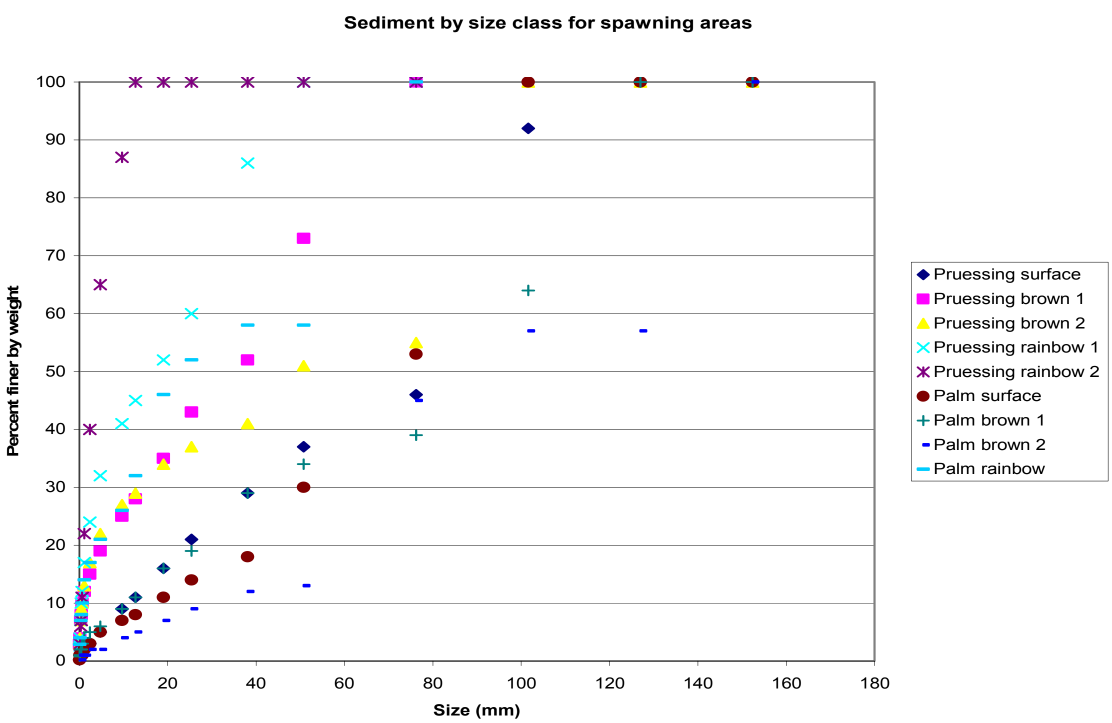
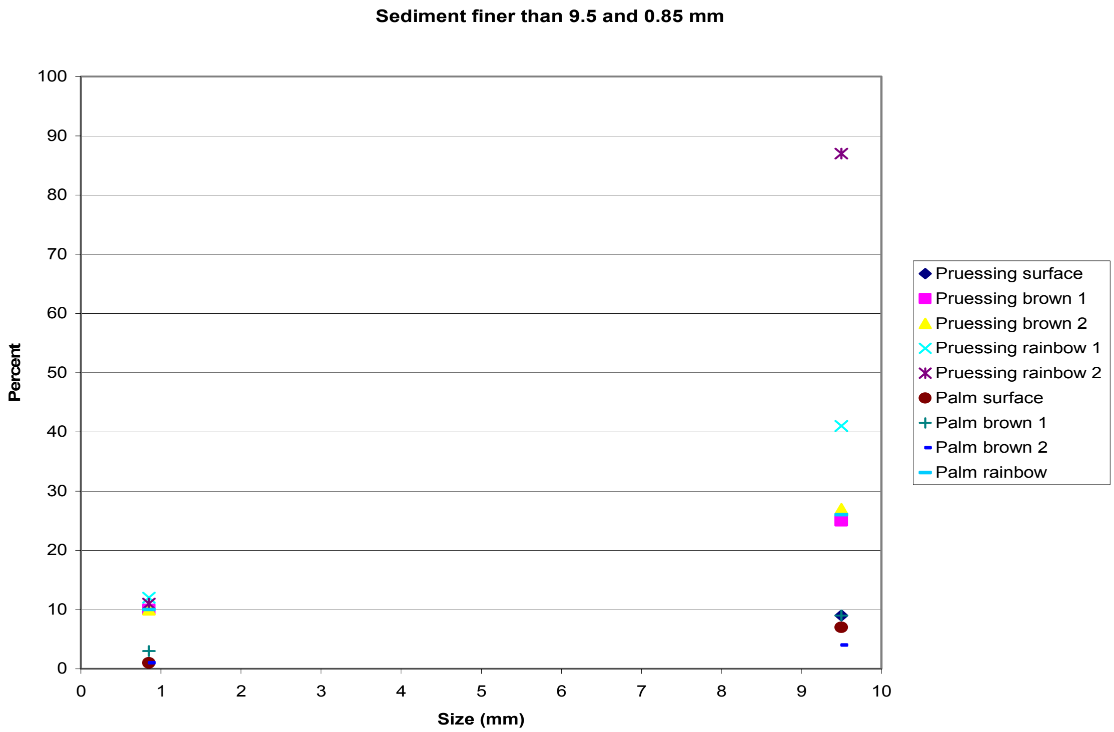


Figure 64. Sediment distribution for 9.5 mm and 0.85 mm size classes.



Witzel and MacCrimmon (1981) report an increase in survival to emergence for rainbow trout with an increase in substrate particle size. The highest survival rates were reported for particles 26.5 mm diameter. Chevalier and Carson (1985) report that fine silts (less than 0.007 mm) have a much greater effect on intragravel flow than fine sand (less than 0.85 mm) particles. For example, a substrate with 3% fine silts has the same intragravel hydraulic characteristics as substrate with 25% fine sand. Koski (1975) reports a negative correlation between percent fines (silt and sand combined) and fry emergence.

The results of the spawning investigations on the Fryingpan River show that spawning success is most likely determined by the thermal regime. The sediment analysis shows that there is sufficient clean substrate on the surface of the river and in the artificially constructed redds over the course of the spawning period that emergence should be relatively high based on sediment composition. Dissolved oxygen levels were adequate for development and did not become lethal at any time during the incubation period. The thermal regime had the greatest impact on embryo and egg development. The lower water temperatures near the dam are likely lethal to rainbow trout eggs. Water temperatures are high enough in the lower Fryingpan for rainbow trout to spawn and successfully reproduce with fry emerging during June. Lower water temperatures also are likely to extend the developmental period for brown trout. Emergence dates based on temperature units occurs in April and May. This is one to two months after a normal emergence date in an unregulated river.

All of these factors in combination seem to favor brown trout reproduction success over rainbow trout reproduction success in the Fryingpan River. Another factor that may affect success of rainbow trout recruitment is the timing of emergence, which is late May through mid-June, and almost coincides with the peak flows that occur in the river. Nehring and Anderson (1993) could not find a correlation to flow regime and successful recruitment for the Fryingpan River. The other contributing factors, including water temperature regime, may influence the amount of successful emergence that occurs on the river and therefore not be as evident on the Fryingpan River as the other unregulated rivers.

Fish Community

The fish community in the Fryingpan River has been dominated by non-native species since the first stockings of rainbow, brown and brook trout. Competition with and predation by these three species likely caused the extirpation of the wild Colorado River cutthroat trout population from the Fryingpan River. Another native species, the mottled sculpin, is still found in the Fryingpan River. The combined influences of interspecific competition and whirling disease have resulted in drastic declines of non-native brook trout populations. It is unknown whether a self-sustaining population of Colorado River cutthroat trout could be established in the Fryingpan River through management practices.

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CONCLUSIONS

The ecology of the Fryingpan River has been greatly altered since the construction of Ruedi Reservoir. The river downstream of Ruedi Dam is currently characterized by the regulated hypolimnetic releases. Most influences imposed by Ruedi Dam are predictable and dissipate with increasing distance downstream. From a trout fishery perspective, the altered physical processes that are directly related to dam operations have both negative and positive influences on the biological community.

Overall, the trout fishery in the Fryingpan River is of higher quality today as opposed to the pre-Ruedi Dam era. A variety of factors related to dam operation, food resources, and special regulations pertaining to angler harvest have enhanced the trout fishery. The baseflow releases from Ruedi Dam are significantly greater than historic discharges during winter months in the Fryingpan River. Releases are also consistently warmer during winter months. The biological benefit from these processes can be observed in an increase in winter habitat and an expanded growing season for fish and macroinvertebrates that did not exist prior to the construction of Ruedi Reservoir.

The Fryingpan River below Ruedi Reservoir supports an extraordinarily large population of aquatic macroinvertebrates. The relatively stable aquatic conditions that exist below Ruedi Dam are conducive to high densities and biomass of certain temperature tolerant benthic macroinvertebrate species. An interpretation of limited historical data suggests that current benthic macroinvertebrate densities may range from 4 to more than 20 times the densities that occurred prior to impoundment. Longitudinal changes in benthic macroinvertebrate community structure and function based on temperature tolerance and food acquisition can be observed between Ruedi Dam and Carbondale, Colorado; however, elevated macroinvertebrate production was present throughout the study area. The presence of a functioning riparian area may be important in maintaining the large macroinvertebrate populations in the middle to lower Fryingpan River. The high density and biomass reported throughout this investigation provides an excellent food resource that can maintain large trout populations.

The benthic macroinvertebrate food resource in the Fryingpan River below Ruedi Reservoir is additionally augmented by the occurrence of *M. relicta* (Mysis shrimp). Combining the available river-based macroinvertebrate community with an additional food source (*M. relicta*) creates a substantial prey base for the trout fishery. A combination of physical processes (temperature, discharge, stability of discharge, rate of change in discharge, etc.) directly related to the regulated releases from Ruedi Reservoir maintains the unique ecological functions of this system.

Overall, Ruedi Reservoir creates more favorable habitat conditions for trout; however, certain aspects of the operations can have negative impacts on the trout fishery. The altered environment created by Ruedi Reservoir has negative impacts upon the aquatic communities as well. Due to cold water temperatures during the spawning and incubation period, rainbow trout egg survival is extremely low near the dam. Survival increases with distance downstream of the dam but is still limited by water temperature throughout the Fryingpan River below Ruedi Reservoir.

Since 1989, the Fryingpan River flow regime has been further altered beyond the regime in place following construction of Ruedi Dam. Impacts to the aquatic community due to the elevated fall flows are unclear and difficult if not impossible to tease out with the available data. An elevated fall discharge followed by a sudden decrease around early November may reduce brown trout spawning success in the Fryingpan River due to desiccation and disruption of the hydraulic conditions in the redds. The aquatic community evolved in a system with a natural hydrograph consisting of peak flows during the springtime and baseflows from September through April. Disruption of this hydrograph type may significantly alter the aquatic communities, but the extent of the impacts is unknown.

Although much of the natural variation of the system has been removed, instances of extreme daily or hourly fluctuations in reservoir releases do exist. The most critical time period when extreme (daily or hourly) flow fluctuations may have an adverse effect on trout population characteristics would be during the egg deposition and incubation periods of the spawning period. If severe enough, these fluctuations could disrupt the necessary redd hydraulic characteristics or cause redd desiccation. Because juvenile and adult trout are mobile, severe fluctuations probably don't impact these life stages directly. However, impacts may be observed due to changes in the prey base available to trout.

Fluctuating flows can also have negative impacts on the macroinvertebrate communities. Many benthic macroinvertebrates are poor swimmers and may occupy near-shore habitats. The rapid decrease in discharge could potentially result in stranding and ultimately mortality of a large proportion of certain macroinvertebrate species. Most aquatic insect species in Colorado have adapted to high flows and less stable aquatic conditions associated with snowmelt runoff during spring and early summer. A rapid change in discharge during the fall or winter would probably be the most harmful to benthic macroinvertebrate communities.

Minimum flows were appropriated in 1973 by the Colorado Water Conservation Board to protect the aquatic fauna of the Fryingpan River. However, the trout community (population and fish size) and physical processes during this time were substantially different than they are currently. Although these flows were based upon the best science available and reliably represented pre-dam base flow conditions, they may not adequately protect the current aquatic community.

During winter base flows (CWCB minimum flow during winter of 2002-2003) the probability of significant anchor ice formation increases as discharge decreases. Anchor ice can affect the aquatic community by reducing macroinvertebrate biomass, altering the macroinvertebrate community structure, and increasing salmonid egg mortality. Reducing or changing the trout's prey community may reduce individual health, result in decreased physiological condition, and increase mortality. In addition, mortality due to angling pressure may increase due to reduced body condition.

Historically, the system was partially insulated from the effects of anchor ice because of surface ice formation. Surface ice actually protects the system from anchor ice by buffering the interface between cold atmospheric air and the river water. Ruedi Reservoir releases are warmer in the winter and keep a large section of the Fryingpan River free of surface ice but consequently more susceptible to anchor ice.

The Fryingpan River is a major tributary of the Roaring Fork River; however, much of the altered physical processes relating to Ruedi Dam operation are minimized by the time the Fryingpan River reaches its confluence with the Roaring Fork River. Influence of Ruedi Dam is further diluted downstream of this confluence due to the free-flowing characteristics of the Roaring Fork River. The influence of Ruedi Dam operations on the Roaring Fork River is generally considered minimal, imposing a secondary influence to the existing processes; however, this influence increases as flows in the Roaring Fork River decrease and flows in the Fryingpan River increase. The most significant alteration to the Roaring Fork River ecosystem is the input of water that is warmer in the winter and cooler in the summer than Roaring Fork River water upstream of the Fryingpan River confluence.

MEC Study Conclusions

IFIM

- The amount of suitable trout habitat has increased with post-dam conditions as compared to habitat available pre Ruedi Dam construction.
- The CDOW Catch and Release section contains the best combination of active foraging and refuge/resting habitat in the Fryingpan River.

Macroinvertebrate Community

- Hypolimnetic releases and regulated flows in the Fryingpan River are responsible for maintaining extraordinarily high densities and biomass.
- Densities were highest in the Fryingpan River immediately below Ruedi Dam and in the Roaring Fork River near Carbondale.
- Benthic communities display longitudinal changes in structure.

Spawning

- Rainbow trout spawning success is temperature limited on the Fryingpan River.
- Rainbow trout spawning success may be further reduced by whirling disease.

Trout Populations

- Relative abundance of brown trout has significantly increased over the past 20 years.
- Maximum size and overall biomass has increased dramatically since dam construction.
- The portion of the trout community most affected by reservoir construction and operation is located immediately below the dam.

Thermal Regime

- The annual maximum temperature is shifted from late summer to late fall/early winter.
- Released water has reduced diel and annual temperature fluctuation.
- Water released is warmer than normal in the fall and winter and cooler than normal in the late spring and summer.
- The amount of influence the Fryingpan River has on the Roaring Fork River is dependant upon the proportion of Fryingpan River flow as compared to Roaring Fork River flow.

Hydrology

- Since dam construction, baseflows are augmented by reservoir releases and spring peak flows are reduced.
- Since 1989, reservoir releases have been significantly increased during the late summer/fall (August through October).
- In four of the last nine years maximum yearly flow occurred during September.

- Extreme fluctuations in reservoir releases occur fairly frequently on the hourly and daily level.

Management Recommendations

- Reevaluate the effectiveness of CWCB's instream flow appropriation on the current Fryingpan River salmonid community using current research and techniques.
- Maintain winter baseflows near 100 ft^3/s to minimize downstream anchor ice formation.
- Minimize rapid flow fluctuations and maximize ramping time for all substantial flow changes.
- In years with elevated fall discharges, reduce flows to near winter levels prior to brown trout spawning and stabilize flow rates throughout the late fall and winter.

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GLOSSARY

Accumulated Temperature Units: Sum of the number of degrees above freezing during egg incubation**.**

Anchor Ice: Ice crystals that form in super-cooled water and accumulate on substrate at the bottom of a stream.

Benthic: Bottom dwelling. "Benthic insects" refers to insects that are associated with the bottom substrate of a stream throughout most of their lives.

Diel: Involving a 24-hour period, usually the day and adjoining night.

Entrain: To draw in and transport by the flow of a fluid.

EPT Index (EPT): A metric that uses the number of aquatic macroinvertebrate taxa from three insect Orders that are considered relatively intolerant to pollution.

Evenness: A metric that is primarily based on proportion of individuals in each taxa in a quantitative sample.

Family Biotic Index (FBI): A metric that that produces a numerical value that is sensitive to nutrient enrichment.

Hypolimnetic: Pertaining to the bottom layer of a stratified lake or reservoir.

IFIM: Instream Flow Incremental Methodology.

Longitudinal (succession): Gradation in the composition of communities along a gradient (from Stalnaker et al. 1995).

Matrix Supported Structure:

Metric: An equation that has been developed to provide a numerical solution that describes an ecological response to an existing condition.

Mysids: Members of the crustacean Family Mysidae.

PHABSIM: The Physical HABitat SIMulation system; a set of software and methods that allows the computation of a relation between stream flow and physical habitat for various life stages of an aquatic organism or a recreational activity (from Stalnaker et al. 1995).

Pool: Area of a stream characterized by low velocities and deep water. Often associated with a channel obstruction which scours sediment, causes pooling and results in lower velocities.

Riffle: Areas of the stream in which turbulence in the water column is the major identifying characteristic, as a result of relatively high gradients. These units contain moderately deep to shallow, swift flowing water, and are characterized by boulder or cobble substrates (from Winters and Gallagher 1997).

Run (Glide): Portions of streams which have relatively wide uniform bottoms, low to moderate velocity flows, lack of pronounced turbulence, and have substrates usually consisting of either cobble, gravel or sand (from Winters and Gallagher 1997).

Salmonid: A member of the family (Salmonidae) of fishes, which includes trout, salmon, char, grayling, whitefish and cisco.

Shannon-Weaver diversity index (Diversity): A metric that uses the total number of individuals and the proportion of each species obtained in a quantitative sample to provide a numerical solution that is an indication of community balance.

Stage: The elevation or vertical distance of the water surface above a datum or reference (from Stalnaker et al. 1995).

Stochastic: Relating to the variability and randomness of nature

Weighted Usable Area (WUA): The wetted area of a stream weighted by its suitability for use by aquatic organisms or recreational activities. Units: square feet or square meters, usually per specified length of stream (from Stalnaker et al. 1995).

128 cell stage: Number of cells in developing embryo.

APPENDIX A - Photo Documentation of IFIM Site Characteristics at Different Flows

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Figure A1. Site FPR-BP on the Fryingpan River, January 2002, at 59 ft^3/s. Reported discharge is from USGS gaging station 09080400.

Figure A2. Site FPR-BP on the Fryingpan River, June 2001, at 94 ft^3/s. Reported discharge is from USGS gaging station 09080400.

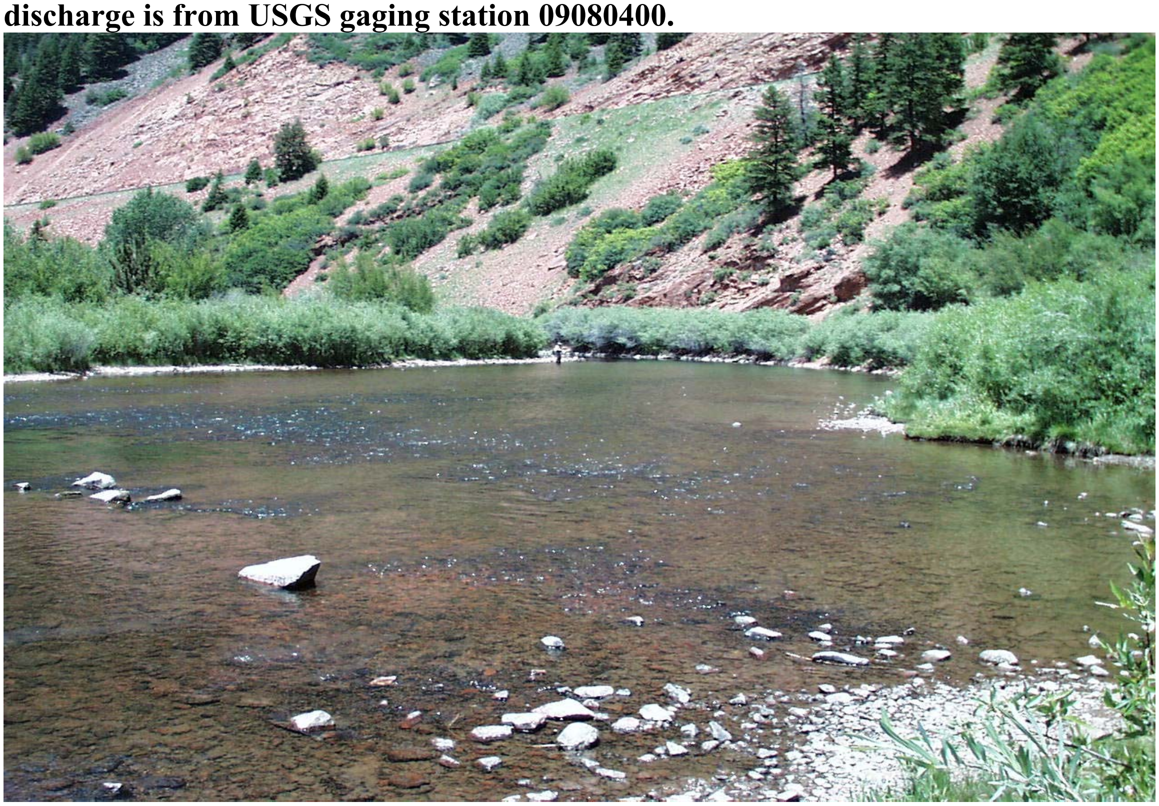

Figure A3. Site FPR-BP on the Fryingpan River, August 2001, at 239 ft^3/s. Reported discharge is from USGS gaging station 09080400.

Figure A4. Site FPR-BP on the Fryingpan River, September 2001, at 342 ft^3/s Reported discharge is from USGS gaging station 09080400.

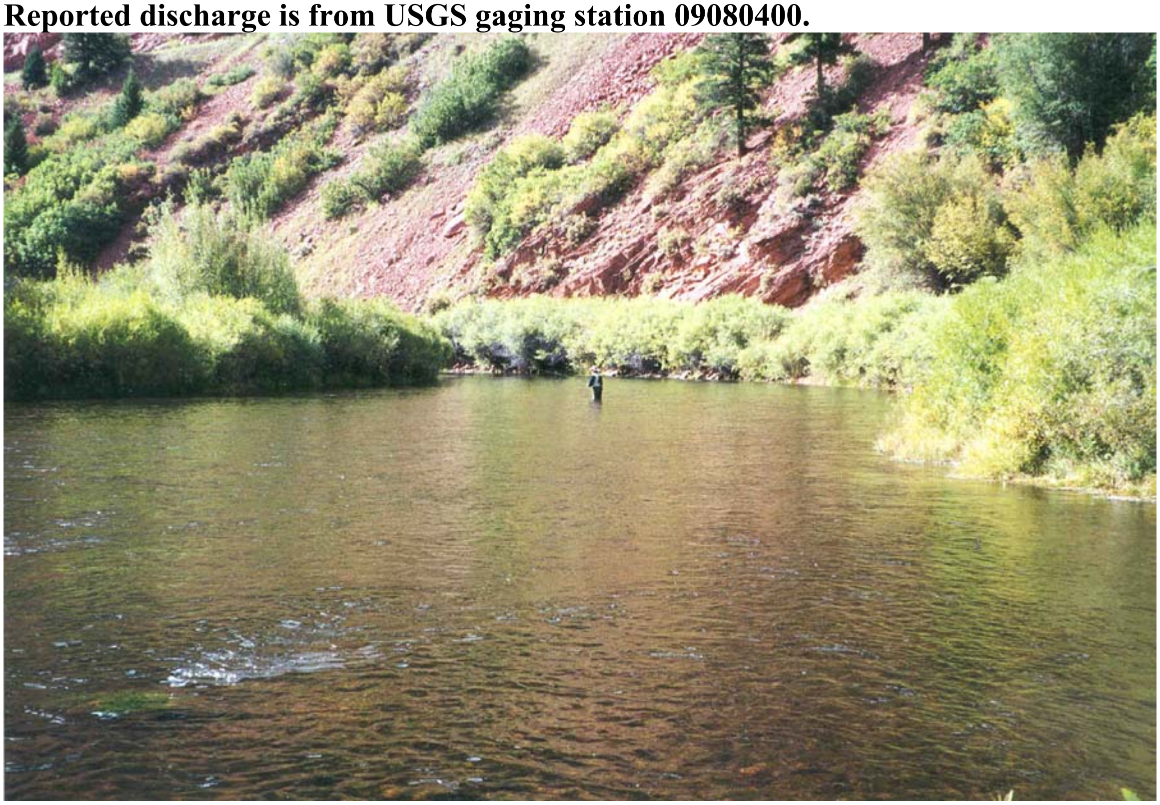

Figure A5. Site FPR-HG on the Fryingpan River, July 2001, at 181 ft^3/s. Reported discharge is from USGS gaging station 09080400.

Figure A6. Site FPR-HG on the Fryingpan River, August 2001, at 239 ft^3/s. Reported discharge is from USGS gaging station 09080400.

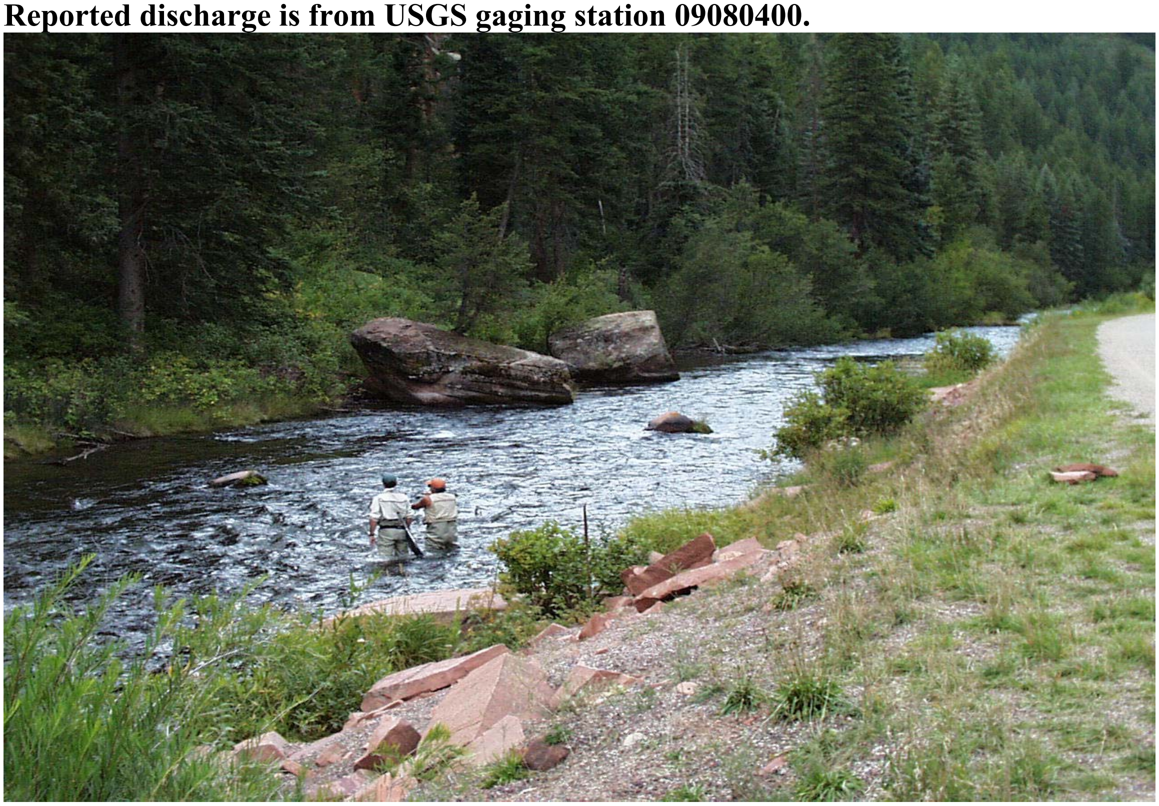

Figure A7. Site FPR-HG on the Fryingpan River, September 2001, at 342 ft^3/s. Reported discharge is from USGS gaging station 09080400.

Figure A8. Site FPR-LG upper on Fryingpan River, August 2001, at 239 ft^3/s. Reported discharge is from USGS gaging station 09080400.

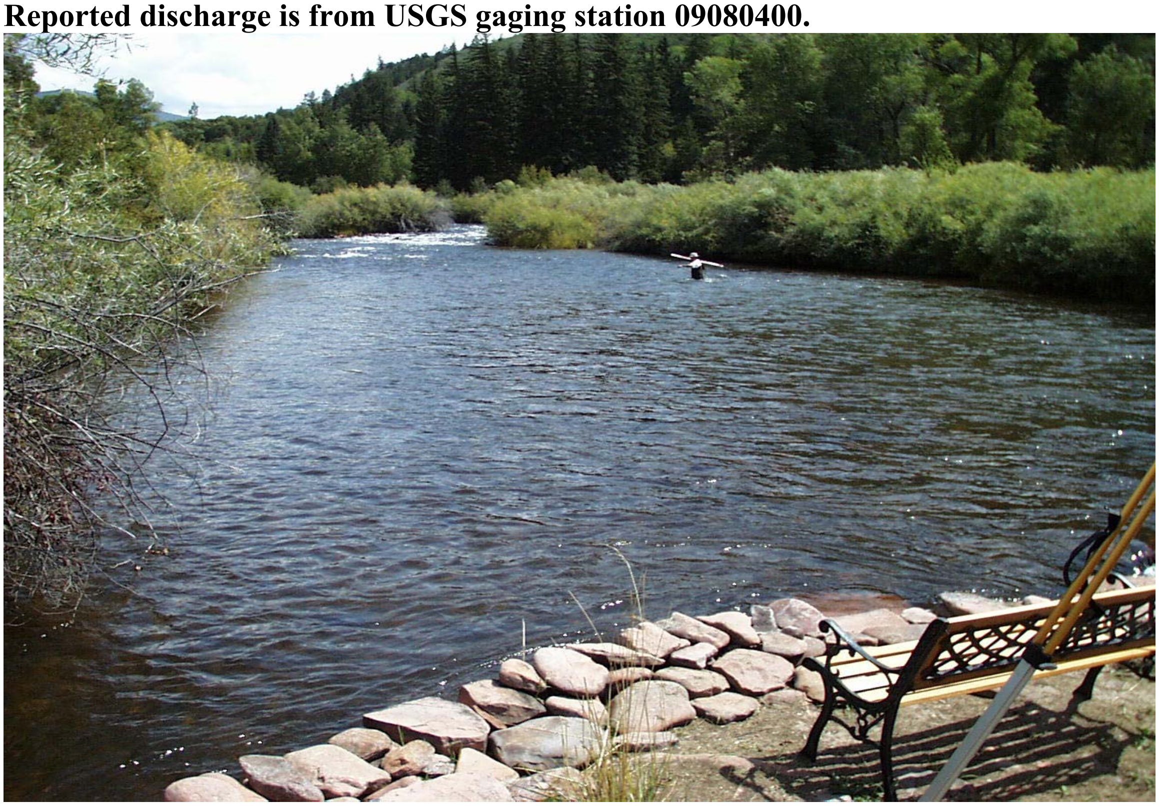

Figure A9. Site FPR-LG upper on Fryingpan River, September 2001, at 342 ft^3/s. Reported discharge is from USGS gaging station 09080400.

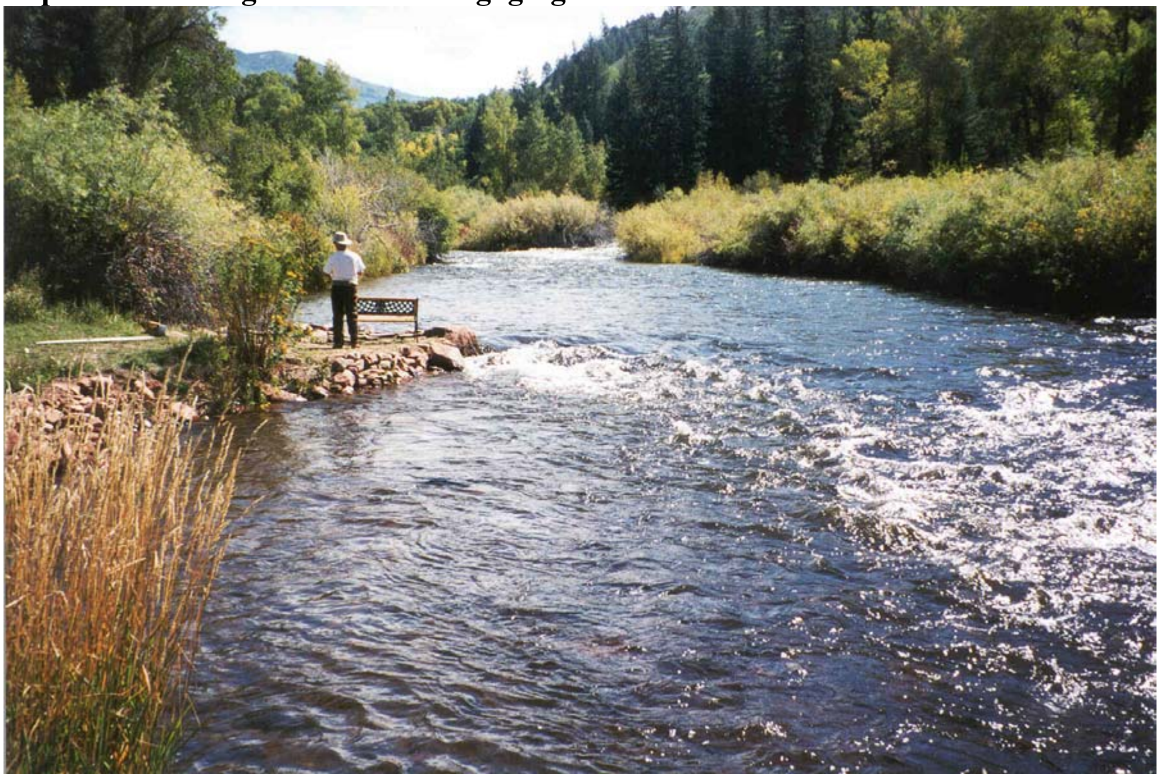

Figure A10. Site FPR-LG lower on Fryingpan River, January 2002, at 59 ft^3/s. Reported discharge is from USGS gaging station 09080400.

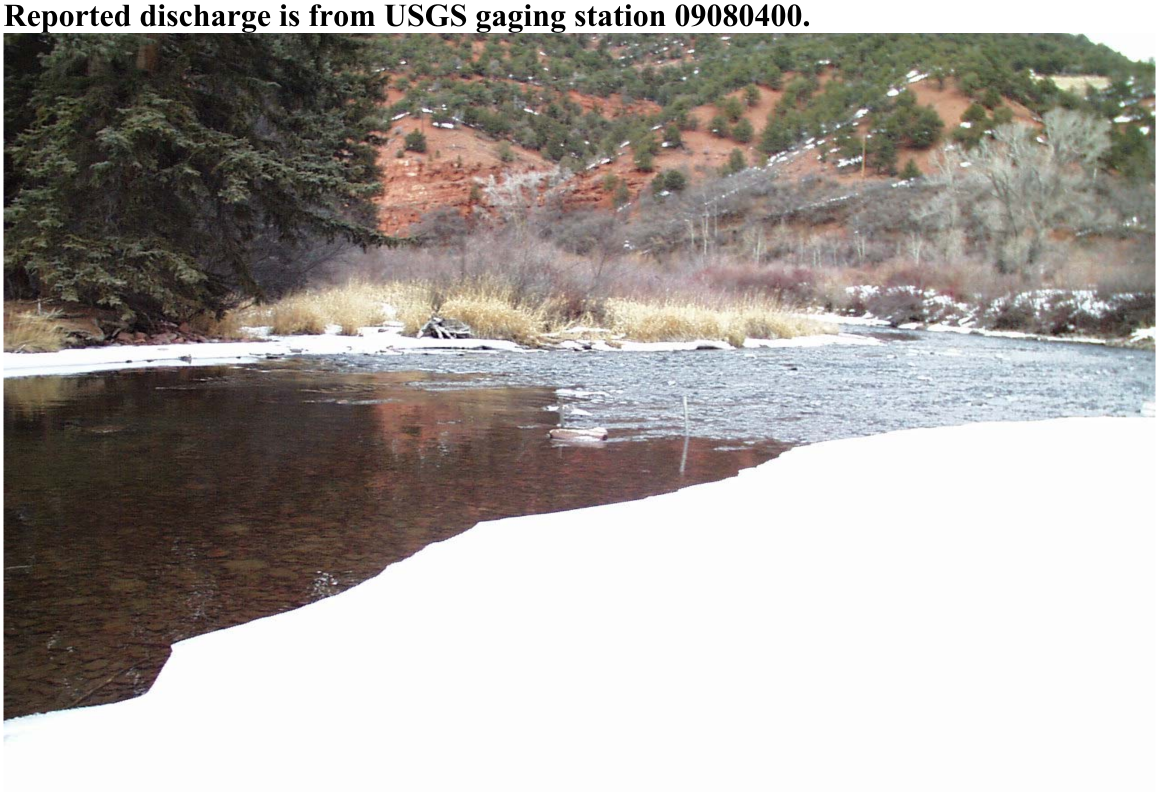

Figure A11. Site FPR-LG lower on Fryingpan River, June 2001, at 94 ft^3/s. Reported discharge is from USGS gaging station 09080400.

Figure A12. Site FPR-LG lower on Fryingpan River, August 2001, at 239 ft^3/s. Reported discharge is from USGS gaging station 09080400.

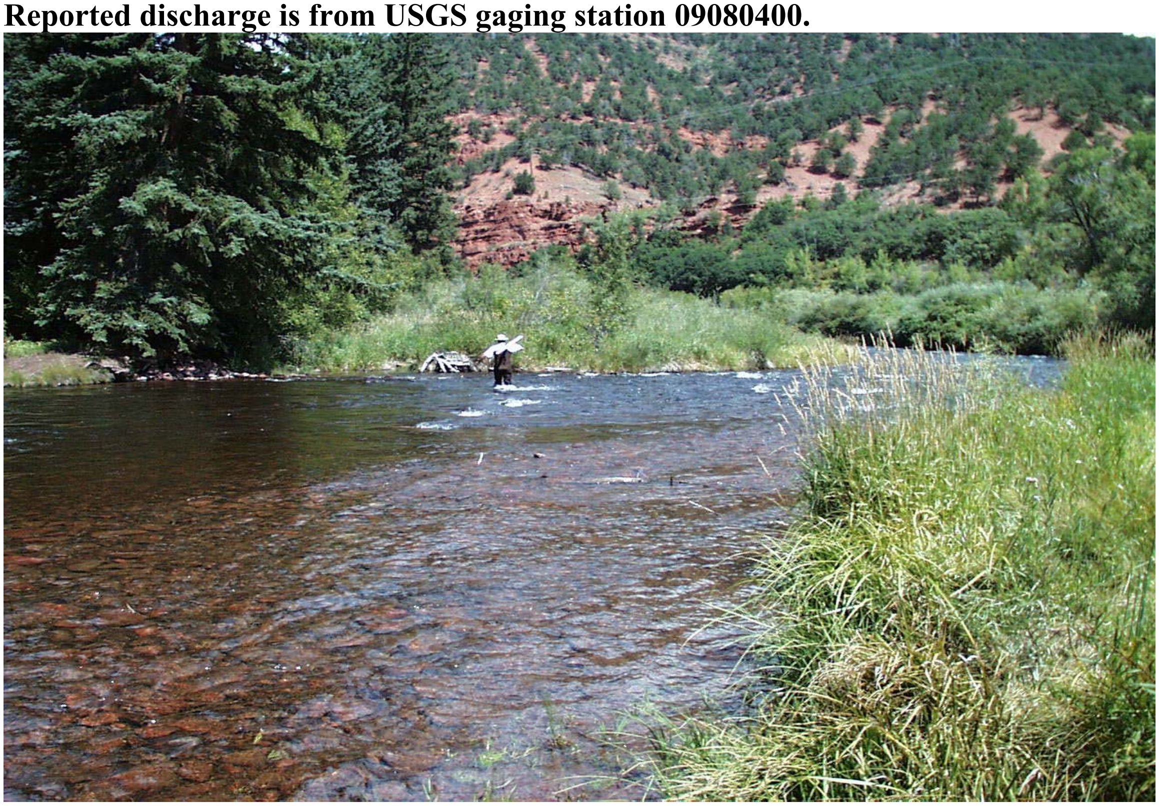

Figure A13. Site FPR-LG lower on Fryingpan River, September 2001, at 342 ft^3/s. Reported discharge is from USGS gaging station 09080400.

Figure A14. Site RFR-TF on the Roaring Fork River, October 2001, at 302 ft^3/s. Reported discharge is from USGS gaging station 09081000.

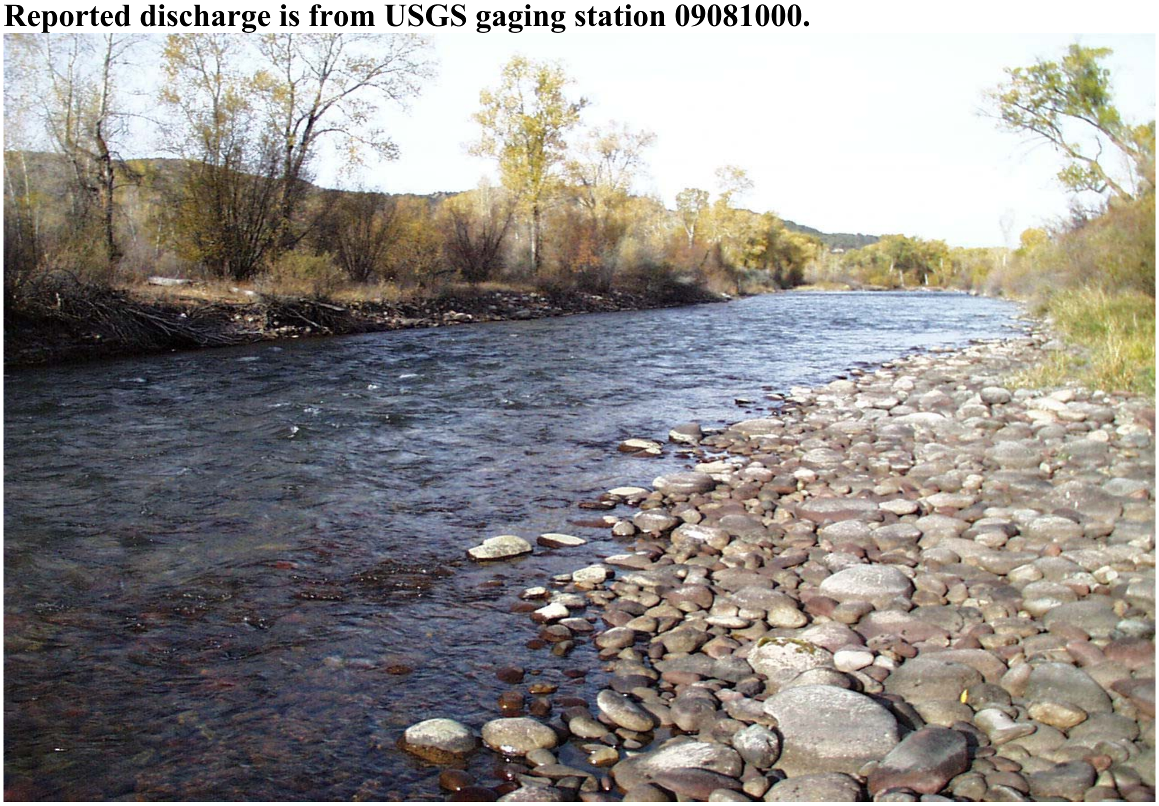

Figure A15. Site RFR-TF on the Roaring Fork River, June 2001, at 876 ft^3/s. Reported discharge is from USGS gaging station 09081000.

APPENDIX B - Invertebrate Data

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Table B1. Macroinvertebrate data collected from the Fryingpan River at site FPR-RES on 1 May 2001.

Fryingpan River										
FPR-RES		Sample			Mean	ni*LOGni	Count	TV		FBI
1 May 2001	1	2	3							
Acentrella insignificans										
Baetis (flavistriga)										
Baetis (tricaudatus)	177	191	626		331.33	835.05	1	4		0.4148
Drunella grandis			2		0.67	-0.12	1	1		0.0002
Drunella coloradensis			5		1.67	0.37	1	1		0.0005
Drunella doddsi	7	6	28		13.67	15.52	1	1		0.0043
Ephemerella sp.	42	71	174		95.67	189.49	1	1		0.0299
Serratella sp.		1			0.33	-0.16	1	1		0.0001
Cinygmula sp.	6	6	9		7.00	5.92	1	4		0.0088
Epeorus longimanus	5	5	4		4.67	3.12	1	4		0.0058
Rhithrogena sp.										
Paraleptophlebia sp.	6	2	3		3.67	2.07	1	2		0.0023
Tricorythodes minutus										
Pteronarcella badia										
Prostoia besametsa			1		0.33	-0.16	1	2		0.0002
Triznaka signata										
Sweltsa sp.										
Claassenia sabulosa										
Hesperoperla pacifica										
Isoperla fulva			1		0.33	-0.16	1	2		0.0002
Isoperla sp. 2										
Brachycentrus americanus		1			0.33	-0.16	1	1		0.0001
Brachycentrus occidentalis										
Culoptila sp.										
Glossosoma sp.		1			0.33	-0.16	1	0		0.0000
Arctopsyche grandis										
Hydropsyche cockerelli										
Hydropsyche sp. (oslari)			1		0.33	-0.16	1	4		0.0004
Lepidostoma sp.	4	1			1.67	0.37	1	4		0.0021
Oecetis sp.										
Rhyacophila brunnea		1	1		0.67	-0.12	1	0		0.0000
Rhyacophila coloradensis										
Neothremma alicia										
Oligophlebodes minuta	14	8	5		9.00	8.59	1	4		0.0113
Orthocladiinae	999	914	2140		1351.00	4229.52	1	6		2.5368
Tanypodinae	1				0.33	-0.16	1	6		0.0006
Tanytarsini	8	5	4		5.67	4.27	1	6		0.0106
Chironomini	17	4	8		9.67	9.52	1	8		0.0242
Diamesinae	713	1273	1615		1200.33	3696.19	1	6		2.2539
Simulium sp.		1			0.33	-0.16	1	6		0.0006
Chelifera sp.										
Clinocera sp.										
Tipula sp.	1		1		0.67	-0.12	1	3		0.0006
Antocha sp.	15	8	5		9.33	9.05	1	3		0.0088
Hexatoma sp.										
Atherix pachypus										
Pericoma sp.										
Optioservus sp.										
Heterlimnius corpulentus	3	2	7		4.00	2.41	1	4		0.0050
Zaitzevia parvula										
Narpus concolor										
Hydracarina sp.	23	6	18		15.67	18.72	1	8		0.0392
Gammarus sp.	1				0.33	-0.16	1	4		0.0004
Planorbidae										
Pisidium sp.	4				1.33	0.17	1	8		0.0033
Dugesia sp.										
Polycelis coronata	122	23	35		60.00	106.69	1	8		0.1502
Oligochaeta	119	40	26		61.67	110.39	1	10		0.1930
Nematoda	8	1	1		3.33	1.74	1	10		0.0104
Totals	2295.0	2571.0	4720.0		3195.33	9247.38	32			
										5.72
Shannon Weaver Diversity						2.03				
Shannon Weaver Evenness						0.406				

Table B2. Macroinvertebrate data collected from the Fryingpan River at site FPR-TC on 1 May 2001.

Fryingpan River										
FPR-TC		Sample			Mean	ni*LOGni	Count	TV		FBI
1 May 2001	1	2	3							
Acentrella insignificans										
Baetis (flavistriga)	5	1	3		3.00	1.43	1	4		0.0075
Baetis (tricaudatus)	189	144	153		162.00	357.94	1	4		0.4060
Drunella grandis	9	1	4		4.67	3.12	1	1		0.0029
Drunella coloradensis										
Drunella doddsi			1		0.33	-0.16	1	1		0.0002
Ephemerella sp.	47	25	33		35.00	54.04	1	1		0.0219
Serratella sp.	27	38	49		38.00	60.03	1	1		0.0238
Cinygmula sp.	290	228	193		237.00	562.82	1	4		0.5940
Epeorus longimanus	53	33	47		44.33	73.01	1	4		0.1111
Rhithrogena sp.										
Paraleptophlebia sp.	167	98	89		118.00	244.48	1	2		0.1479
Tricorythodes minutus										
Pteronarcella badia										
Prostoia besametsa		1			0.33	-0.16	1	2		0.0004
Triznaka signata										
Sweltsa sp.	8	4	6		6.00	4.67	1	1		0.0038
Claassenia sabulosa										
Hesperoperla pacifica										
Isoperla fulva	7	4	5		5.33	3.88	1	2		0.0067
Isoperla sp. 2										
Brachycentrus americanus	55	36	34		41.67	67.49	1	1		0.0261
Brachycentrus occidentalis	2				0.67	-0.12	1	1		0.0004
Culoptila sp.										
Glossosoma sp.	167	13	111		97.00	192.72	1	0		0.0000
Arctopsyche grandis	23	5	10		12.67	13.97	1	4		0.0317
Hydropsyche cockerelli										
Hydropsyche sp. (oslari)										
Lepidostoma sp.	501	105	425		343.67	871.59	1	4		0.8613
Oecetis sp.										
Rhyacophila brunnea		1	1		0.67	-0.12	1	0		0.0000
Rhyacophila coloradensis	2				0.67	-0.12	1	0		0.0000
Neothremma alicia		1			0.33	-0.16	1	4		0.0008
Oligophlebodes minuta	153	37	81		90.33	176.68	1	4		0.2264
Orthocladiinae	255	84	180		173.00	387.18	1	6		0.6504
Tanypodinae	5	2	2		3.00	1.43	1	6		0.0113
Tanytarsini	19	2	4		8.33	7.67	1	6		0.0313
Chironomini										
Diamesinae	3	1			1.33	0.17	1	6		0.0050
Simulium sp.	1				0.33	-0.16	1	6		0.0013
Chelifera sp.	6	5	2		4.33	2.76	1	6		0.0163
Clinocera sp.										
Tipula sp.										
Antocha sp.	19	9	15		14.33	16.57	1	3		0.0269
Hexatoma sp.										
Atherix pachypus	1		1		0.67	-0.12	1	2		0.0008
Pericoma sp.	1	1	1		1.00	0.00	1	10		0.0063
Optioservus sp.		1			0.33	-0.16	1	4		0.0008
Heterlimnius corpulentus	33	31	19		27.67	39.89	1	4		0.0693
Zaitzevia parvula										
Narpus concolor										
Hydracarina sp.	10	5	4		6.33	5.08	1	8		0.0317
Gammarus sp.										
Planorbidae		1			0.33	-0.16	1	8		0.0017
Pisidium sp.	3	29			10.67	10.97	1	8		0.0535
Dugesia sp.										
Polycelis coronata	60	58	3		40.33	64.76	1	8		0.2022
Oligochaeta	57	44	75		58.67	103.75	1	10		0.3676
Nematoda	9	2			3.67	2.07	1	10		0.0230
Totals	2187.0	1050.0	1551.0		1596.00	3328.73	38			
										3.97
Shannon Weaver Diversity						3.71				
Shannon Weaver Evenness						0.707				

Table B3. Macroinvertebrate data collected from the Fryingpan River at site RFR-HB on 1 May 2001.

Roaring Fork River										
RFR-HB		Sample			Mean	ni*LOGni	Count	TV		FBI
1 May 2001	1	2	3							
Acentrella insignificans	5	2	2		3.00	1.43	1	4		0.0096
Baetis (flavistriga)	62	55	119		78.67	149.14	1	4		0.2527
Baetis (tricaudatus)	54	68	102		74.67	139.86	1	4		0.2398
Drunella grandis	8	9	9		8.67	8.13	1	1		0.0070
Drunella coloradensis										
Drunella doddsi										
Ephemerella sp.	32	88	112		77.33	146.03	1	1		0.0621
Serratella sp.										
Cinygmula sp.	4	2	10		5.33	3.88	1	4		0.0171
Epeorus longimanus	28	302	398		242.67	578.76	1	4		0.7794
Rhithrogena sp.	5		1		2.00	0.60	1	4		0.0064
Paraleptophlebia sp.	19	43	69		43.67	71.62	1	2		0.0701
Tricorythodes minutus										
Pteronarcella badia			1		0.33	-0.16	1	0		0.0000
Prostoia besametsa										
Triznaka signata	33	2	7		14.00	16.05	1	1		0.0112
Sweltsa sp.										
Claassenia sabulosa		4	8		4.00	2.41	1	1		0.0032
Hesperoperla pacifica										
Isoperla fulva	1	1			0.67	-0.12	1	2		0.0011
Isoperla sp. 2		1	1		0.67	-0.12	1	2		0.0011
Brachycentrus americanus			1		0.33	-0.16	1	1		0.0003
Brachycentrus occidentalis										
Culoptila sp.		3			1.00	0.00	1	0		0.0000
Glossosoma sp.	83	77	205		121.67	253.70	1	0		0.0000
Arctopsyche grandis		1	4		1.67	0.37	1	4		0.0054
Hydropsyche cockerelli	1	10	27		12.67	13.97	1	4		0.0407
Hydropsyche sp. (oslari)										
Lepidostoma sp.	226	430	584		413.33	1081.40	1	4		1.3276
Oecetis sp.										
Rhyacophila brunnea										
Rhyacophila coloradensis										
Neothremma alicia										
Oligophlebodes minuta										
Orthocladiinae	98	61	81		80.00	152.25	1	6		0.3854
Tanypodinae		8	12		6.67	5.49	1	6		0.0321
Tanytarsini	18	14	31		21.00	27.77	1	6		0.1012
Chironomini	1	8	2		3.67	2.07	1	8		0.0236
Diamesinae	10		1		3.67	2.07	1	6		0.0177
Simulium sp.		1			0.33	-0.16	1	6		0.0016
Chelifera sp.										
Clinocera sp.	1				0.33	-0.16	1	6		0.0016
Tipula sp.										
Antocha sp.		2	1		1.00	0.00	1	3		0.0024
Hexatoma sp.										
Atherix pachypus	2	1			1.00	0.00	1	2		0.0016
Pericoma sp.										
Optioservus sp.	2	7	7		5.33	3.88	1	4		0.0171
Heterlimnius corpulentus										
Zaitzevia parvula	1	1	1		1.00	0.00	1	4		0.0032
Narpus concolor	1				0.33	-0.16	1	4		0.0011
Hydracarina sp.	1	1	3		1.67	0.37	1	8		0.0107
Gammarus sp.										
Planorbidae										
Pisidium sp.										
Dugesia sp.										
Polycelis coronata		4	2		2.00	0.60	1	8		0.0128
Oligochaeta	2	19	12		11.00	11.46	1	10		0.0883
Nematoda										
Totals	698.0	1225.0	1813.0		1245.33	2672.26	35			
										3.54
Shannon Weaver Diversity						3.15				
Shannon Weaver Evenness						0.615				

Table B4. Macroinvertebrate data collected from the Fryingpan River at site RFR-C on 1 May 2001.

Roaring Fork River										
RFR-C		Sample			Mean	ni*LOGni	Count	TV		FBI
1 May 2001	1	2	3							
Acentrella insignificans		4	4		2.67	1.14	1	4		0.0045
Baetis (flavistriga)	7	43	31		27.00	38.65	1	4		0.0460
Baetis (tricaudatus)	37	128	139		101.33	203.25	1	4		0.1728
Drunella grandis	11	4	21		12.00	12.95	1	1		0.0051
Drunella coloradensis										
Drunella doddsi										
Ephemerella sp.	22	60	9		30.33	44.95	1	1		0.0129
Serratella sp.										
Cinygmula sp.										
Epeorus longimanus	6	6	14		8.67	8.13	1	4		0.0148
Rhithrogena sp.										
Paraleptophlebia sp.	2	23	32		19.00	24.30	1	2		0.0162
Tricorythodes minutus	1	2	1		1.33	0.17	1	4		0.0023
Pteronarcella badia	1				0.33	-0.16	1	0		0.0000
Prostoia besametsa										
Triznaka signata										
Sweltsa sp.	1				0.33	-0.16	1	1		0.0001
Claassenia sabulosa	2		2		1.33	0.17	1	1		0.0006
Hesperoperla pacifica										
Isoperla fulva										
Isoperla sp. 2										
Brachycentrus americanus			1		0.33	-0.16	1	1		0.0001
Brachycentrus occidentalis										
Culoptila sp.	2	2	3		2.33	0.86	1	0		0.0000
Glossosoma sp.		2	11		4.33	2.76	1	0		0.0000
Arctopsyche grandis			2		0.67	-0.12	1	4		0.0011
Hydropsyche cockerelli			14		4.67	3.12	1	4		0.0080
Hydropsyche sp. (oslari)	3	1	27		10.33	10.48	1	4		0.0176
Lepidostoma sp.	9	24	13		15.33	18.18	1	4		0.0261
Oecetis sp.		1			0.33	-0.16	1	4		0.0006
Rhyacophila brunnea										
Rhyacophila coloradensis										
Neothremma alicia										
Oligophlebodes minuta										
Orthocladiinae	1056	1465	2117		1546.00	4930.52	1	6		3.9534
Tanypodinae	18	21	7		15.33	18.18	1	6		0.0392
Tanytarsini	22	25	3		16.67	20.36	1	6		0.0426
Chironomini	36	34	6		25.33	35.56	1	8		0.0864
Diamesinae	36	48	19		34.33	52.73	1	6		0.0878
Simulium sp.										
Chelifera sp.	2	2	1		1.67	0.37	1	6		0.0043
Clinocera sp.		1			0.33	-0.16	1	6		0.0009
Tipula sp.										
Antocha sp.	6	14	62		27.33	39.27	1	3		0.0349
Hexatoma sp.			1		0.33	-0.16	1	3		0.0004
Atherix pachypus	13	30	42		28.33	41.15	1	2		0.0242
Pericoma sp.										
Optioservus sp.	144	264	209		205.67	475.74	1	4		0.3506
Heterlimnius corpulentus										
Zaitzevia parvula	9	15	14		12.67	13.97	1	4		0.0216
Narpus concolor										
Hydracarina sp.	1		1		0.67	-0.12	1	8		0.0023
Gammarus sp.										
Planorbidae										
Pisidium sp.										
Dugesia sp.			1		0.33	-0.16	1	8		0.0011
Polycelis coronata	2	9	5		5.33	3.88	1	8		0.0182
Oligochaeta	78	210	251		179.67	405.05	1	10		0.7657
Nematoda		7	4		3.67	2.07	1	10		0.0156
Totals	1527.0	2445.0	3067.0		2346.33	6406.59	36			
										5.78
Shannon Weaver Diversity						2.13				
Shannon Weaver Evenness						0.411				

Table B5. Macroinvertebrate data collected from the Fryingpan River at site FPR-RES on 11 October 2001.

Fryingpan River										
FPR-RES		Sample			Mean	ni*LOGni	Count	TV		FBI
11 October 2001	1	2	3							
Acentrella insignificans	2	7	2		3.67	2.07	1	4		0.0102
Baetis (flavistriga)										
Baetis (tricaudatus)	345	432	186		321.00	804.59	1	4		0.8950
Drunella grandis			1		0.33	-0.16	1	1		0.0002
Drunella coloradensis		1			0.33	-0.16	1	1		0.0002
Drunella doddsi	8	11	3		7.33	6.35	1	1		0.0051
Ephemerella sp.	9	15	5		9.67	9.52	1	1		0.0067
Cinygmula sp.										
Epeorus longimanus										
Rhithrogena sp.	2	5	1		2.67	1.14	1	4		0.0074
Paraleptophlebia sp.	4	6	2		4.00	2.41	1	2		0.0056
Tricorythodes minutus										
Caenis sp.										
Pteronarcella badia										
Capnia sp.										
Zapada sp.	2	1			1.00	0.00	1	2		0.0014
Paraperla frontalis										
Sweltsa sp.			1		0.33	-0.16	1	1		0.0002
Triznaka signata										
Claassenia sabulosa										
Hesperoperla pacifica										
Skwala americana										
Isoperla fulva										
Isoperla sp. 2										
Brachycentrus americanus	1				0.33	-0.16	1	1		0.0002
Brachycentrus occidentalis		1			0.33	-0.16	1	1		0.0002
Culoptila sp.										
Glossosoma sp.	24	13	8		15.00	17.64	1	0		0.0000
Arctopsyche grandis	1				0.33	-0.16	1	4		0.0009
Hydropsyche cockerelli										
Hydropsyche occidentalis										
Hydropsyche sp. (oslari)										
Hydroptila sp.	1	1			0.67	-0.12	1	1		0.0005
Lepidostoma sp.	2				0.67	-0.12	1	4		0.0019
Ceraclea sp.										
Oecetis sp.										
Rhyacophila brunnea										
Rhyacophila coloradensis		2			0.67	-0.12	1	0		0.0000
Neothremma alicia		1			0.33	-0.16	1	4		0.0009
Oligophlebodes minuta			1		0.33	-0.16	1	4		0.0009
Orthocladiinae	735	616	803		718.00	2050.70	1	6		3.0028
Tanypodinae										
Tanytarsini		5			1.67	0.37	1	6		0.0070
Chironomini										
Diamesinae	8	5	15		9.33	9.05	1	6		0.0390
Simulium sp.	8	17			8.33	7.67	1	6		0.0349
Protanyderus margarita										
Chelifera sp.										
Clinocera sp.										
Hemerodromia sp.										
Antocha sp.	40	33	10		27.67	39.89	1	3		0.0579
Dicranota sp.										
Hexatoma sp.										
Atherix pachypus										
Pericoma sp.										
Optioservus sp.	2	3			1.67	0.37	1	4		0.0046
Heterlimnius corpulentus	19	59	20		32.67	49.46	1	4		0.0911
Zaitzevia parvula										
Narpus concolor										
Hydracarina sp.	5	7	3		5.00	3.49	1	8		0.0279
Gammarus sp.	1				0.33	-0.16	1	4		0.0009
Physa sp.										
Pisidium sp.		3			1.00	0.00	1	8		0.0056
Dugesia sp.	1				0.33	-0.16	1	8		0.0019
Polycelis coronata	22	312	6		113.33	232.83	1	8		0.6320
Oligochaeta	95	242	83		140.00	300.46	1	10		0.9758
Nematoda	2	10	7		6.33	5.08	1	10		0.0441
Totals	1339.0	1808.0	1157.0		1434.67	3541.15	33			
										5.86
Shannon Weaver Diversity						2.29				
Shannon Weaver Evenness						0.453				

Table B6. Macroinvertebrate data collected from the Fryingpan River at site FPR-TC on 11 October 2001.

Fryingpan River										
FPR-TC		Sample			Mean	ni*LOGni	Count	TV		FBI
11 October 2001	1	2	3							
Acentrella insignificans	8	3	4		5.00	3.49	1	4		0.0223
Baetis (flavistriga)										
Baetis (tricaudatus)	109	141	203		151.00	329.03	1	4		0.6736
Drunella grandis	6	4	5		5.00	3.49	1	1		0.0056
Drunella coloradensis										
Drunella doddsi		1	2		1.00	0.00	1	1		0.0011
Ephemerella sp.	4	9	12		8.33	7.67	1	1		0.0093
Cinygmula sp.	39	40	63		47.33	79.29	1	4		0.2112
Epeorus longimanus		4	2		2.00	0.60	1	4		0.0089
Rhithrogena sp.										
Paraleptophlebia sp.	62	42	81		61.67	110.39	1	2		0.1375
Tricorythodes minutus										
Caenis sp.			1		0.33	-0.16	1	7		0.0026
Pteronarcella badia										
Capnia sp.			2		0.67	-0.12	1	0		0.0000
Zapada sp.			2		0.67	-0.12	1	2		0.0015
Paraperla frontalis										
Sweltsa sp.										
Triznaka signata										
Claassenia sabulosa										
Hesperoperla pacifica	5	5	2		4.00	2.41	1	1		0.0045
Skwala americana										
Isoperla fulva	5	1	1		2.33	0.86	1	2		0.0052
Isoperla sp. 2	1		1		0.67	-0.12	1	2		0.0015
Brachycentrus americanus	9		2		3.67	2.07	1	1		0.0041
Brachycentrus occidentalis		1			0.33	-0.16	1	1		0.0004
Culoptila sp.										
Glossosoma sp.	1	7	3		3.67	2.07	1	0		0.0000
Arctopsyche grandis	7	9	12		9.33	9.05	1	4		0.0416
Hydropsyche cockerelli	5	3	8		5.33	3.88	1	4		0.0238
Hydropsyche occidentalis										
Hydropsyche sp. (oslari)										
Hydroptila sp.										
Lepidostoma sp.	126	67	79		90.67	177.48	1	4		0.4045
Ceraclea sp.										
Oecetis sp.										
Rhyacophila brunnea	1	1			0.67	-0.12	1	0		0.0000
Rhyacophila coloradensis	2	2	3		2.33	0.86	1	0		0.0000
Neothremma alicia										
Oligophlebodes minuta	130	142	79		117.00	241.98	1	4		0.5219
Orthocladiinae	120	132	111		121.00	252.02	1	6		0.8097
Tanypodinae	1		2		1.00	0.00	1	6		0.0067
Tanytarsini	1	3	7		3.67	2.07	1	6		0.0245
Chironomini										
Diamesinae	4				1.33	0.17	1	6		0.0089
Simulium sp.	2		32		11.33	11.95	1	6		0.0758
Protanyderus margarita										
Chelifera sp.		1	2		1.00	0.00	1	6		0.0067
Clinocera sp.										
Hemerodromia sp.										
Antocha sp.	55	53	43		50.33	85.66	1	3		0.1684
Dicranota sp.	1		2		1.00	0.00	1	3		0.0033
Hexatoma sp.										
Atherix pachypus		1	1		0.67	-0.12	1	2		0.0015
Pericoma sp.	1	2	1		1.33	0.17	1	10		0.0149
Optioservus sp.	1	2	1		1.33	0.17	1	4		0.0059
Heterlimnius corpulentus	49	51	72		57.33	100.82	1	4		0.2558
Zaitzevia parvula										
Narpus concolor										
Hydracarina sp.	1		1		0.67	-0.12	1	8		0.0059
Gammarus sp.	1				0.33	-0.16	1	4		0.0015
Physa sp.										
Pisidium sp.	1	1	1		1.00	0.00	1	8		0.0089
Dugesia sp.										
Polycelis coronata	40	18	24		27.33	39.27	1	8		0.2439
Oligochaeta	169	64	11		81.33	155.37	1	10		0.9071
Nematoda	13	2	20		11.67	12.45	1	10		0.1301
Totals	980.0	812.0	898.0		896.67	1633.53	41			
										4.76
Shannon Weaver Diversity						3.76				
Shannon Weaver Evenness						0.701				

Table B7. Macroinvertebrate data collected from the Fryingpan River at site RFR-711 on 11 October 2001.

Roaring Fork River										
RFR-711		Sample			Mean	ni*LOGni	Count	TV		FBI
11 October 2001	1	2	3							
Acentrella insignificans	1				0.33	-0.16	1	4		0.0010
Baetis (flavistriga)	6	11	12		9.67	9.52	1	4		0.0276
Baetis (tricaudatus)	201	519	204		308.00	766.47	1	4		0.8785
Drunella grandis	37	18	42		32.33	48.81	1	1		0.0231
Drunella coloradensis										
Drunella doddsi		2	3		1.67	0.37	1	1		0.0012
Ephemerella sp.	197	181	180		186.00	422.13	1	1		0.1326
Cinygmula sp.	2	1	1		1.33	0.17	1	4		0.0038
Epeorus longimanus	11	8			6.33	5.08	1	4		0.0181
Rhithrogena sp.	100	83	56		79.67	151.47	1	4		0.2272
Paraleptophlebia sp.	42	26	30		32.67	49.46	1	2		0.0466
Tricorythodes minutus										
Caenis sp.										
Pteronarcella badia		1			0.33	-0.16	1	0		0.0000
Capnia sp.			1		0.33	-0.16	1	0		0.0000
Zapada sp.										
Paraperla frontalis			1		0.33	-0.16	1	1		0.0002
Sweltsa sp.	1				0.33	-0.16	1	1		0.0002
Triznaka signata	10	1	7		6.00	4.67	1	1		0.0043
Claassenia sabulosa	3		1		1.33	0.17	1	1		0.0010
Hesperoperla pacifica										
Skwala americana	1		1		0.67	-0.12	1	2		0.0010
Isoperla fulva			2		0.67	-0.12	1	2		0.0010
Isoperla sp. 2	1				0.33	-0.16	1	2		0.0005
Brachycentrus americanus	4	3	1		2.67	1.14	1	1		0.0019
Brachycentrus occidentalis	1	4	2		2.33	0.86	1	1		0.0017
Culoptila sp.	8	12	4		8.00	7.22	1	0		0.0000
Glossosoma sp.	662	104	196		320.67	803.61	1	0		0.0000
Arctopsyche grandis	2	13	8		7.67	6.78	1	4		0.0219
Hydropsyche cockerelli	16	66	34		38.67	61.38	1	4		0.1103
Hydropsyche occidentalis										
Hydropsyche sp. (oslari)	24	46	27		32.33	48.81	1	4		0.0922
Hydroptila sp.										
Lepidostoma sp.	210	31	98		113.00	232.00	1	4		0.3223
Ceraclea sp.										
Oecetis sp.										
Rhyacophila brunnea										
Rhyacophila coloradensis	3	8	4		5.00	3.49	1	0		0.0000
Neothremma alicia										
Oligophlebodes minuta		1			0.33	-0.16	1	4		0.0010
Orthocladiinae	29	119	31		59.67	105.95	1	6		0.2553
Tanypodinae	8	10	8		8.67	8.13	1	6		0.0371
Tanytarsini	4		1		1.67	0.37	1	6		0.0071
Chironomini	1	37	11		16.33	19.81	1	8		0.0932
Diamesinae	1				0.33	-0.16	1	6		0.0014
Simulium sp.	2	17	2		7.00	5.92	1	6		0.0300
Protanyderus margarita										
Chelifera sp.	1	1	4		2.00	0.60	1	6		0.0086
Clinocera sp.	1				0.33	-0.16	1	6		0.0014
Hemerodromia sp.										
Antocha sp.	24	14	26		21.33	28.35	1	3		0.0456
Dicranota sp.										
Hexatoma sp.	1	2	3		2.00	0.60	1	3		0.0043
Atherix pachypus	29	48	25		34.00	52.07	1	2		0.0485
Pericoma sp.										
Optioservus sp.	7	28	38		24.33	33.73	1	4		0.0694
Heterlimnius corpulentus										
Zaitzevia parvula			1		0.33	-0.16	1	4		0.0010
Narpus concolor										
Hydracarina sp.	1	5	4		3.33	1.74	1	8		0.0190
Gammarus sp.										
Physa sp.										
Pisidium sp.										
Dugesia sp.										
Polycelis coronata	8				2.67	1.14	1	8		0.0152
Oligochaeta	9	7	7		7.67	6.78	1	10		0.0547
Nematoda	4	19	12		11.67	12.45	1	10		0.0832
Totals	1673.0	1446.0	1088.0		1402.33	2899.43	46			
										2.69
Shannon Weaver Diversity						3.59				
Shannon Weaver Evenness						0.649				

Table B8. Macroinvertebrate data collected from the Fryingpan River at site RFR-HB on 11 October 2001.

Roaring Fork River										
RFR-HB		Sample			Mean	ni*LOGni	Count	TV		FBI
11 October 2001	1	2	3							
Acentrella insignificans										
Baetis (flavistriga)	2	3	3		2.67	1.14	1	4		0.0064
Baetis (tricaudatus)	200	111	210		173.67	388.96	1	4		0.4156
Drunella grandis	24	23	16		21.00	27.77	1	1		0.0126
Drunella coloradensis										
Drunella doddsi	1				0.33	-0.16	1	1		0.0002
Ephemerella sp.	93	95	78		88.67	172.70	1	1		0.0530
Cinygmula sp.										
Epeorus longimanus	5	1	3		3.00	1.43	1	4		0.0072
Rhithrogena sp.	12	11	4		9.00	8.59	1	4		0.0215
Paraleptophlebia sp.	27	86	19		44.00	72.31	1	2		0.0526
Tricorythodes minutus										
Caenis sp.										
Pteronarcella badia										
Capnia sp.										
Zapada sp.										
Paraperla frontalis										
Sweltsa sp.	1	1			0.67	-0.12	1	1		0.0004
Triznaka signata	4	10	7		7.00	5.92	1	1		0.0042
Claassenia sabulosa	9	28	27		21.33	28.35	1	1		0.0128
Hesperoperla pacifica										
Skwala americana										
Isoperla fulva	1	2			1.00	0.00	1	2		0.0012
Isoperla sp. 2		1			0.33	-0.16	1	2		0.0004
Brachycentrus americanus	1				0.33	-0.16	1	1		0.0002
Brachycentrus occidentalis	7	2	3		4.00	2.41	1	1		0.0024
Culoptila sp.	10	9	6		8.33	7.67	1	0		0.0000
Glossosoma sp.	953	1125	752		943.33	2806.10	1	0		0.0000
Arctopsyche grandis	3	4	8		5.00	3.49	1	4		0.0120
Hydropsyche cockerelli	29	26	30		28.33	41.15	1	4		0.0678
Hydropsyche occidentalis										
Hydropsyche sp. (oslari)	40	29	31		33.33	50.76	1	4		0.0798
Hydroptila sp.										
Lepidostoma sp.	159	150	155		154.67	338.63	1	4		0.3701
Ceraclea sp.										
Oecetis sp.			1		0.33	-0.16	1	4		0.0008
Rhyacophila brunnea										
Rhyacophila coloradensis	1	1			0.67	-0.12	1	0		0.0000
Neothremma alicia										
Oligophlebodes minuta	1				0.33	-0.16	1	4		0.0008
Orthocladiinae	29	27	48		34.67	53.38	1	6		0.1244
Tanypodinae	1	9	7		5.67	4.27	1	6		0.0203
Tanytarsini		1	1		0.67	-0.12	1	6		0.0024
Chironomini	8	7	4		6.33	5.08	1	8		0.0303
Diamesinae										
Simulium sp.	1	2			1.00	0.00	1	6		0.0036
Protanyderus margarita			3		1.00	0.00	1	6		0.0036
Chelifera sp.			1		0.33	-0.16	1	6		0.0012
Clinocera sp.	1		1		0.67	-0.12	1	6		0.0024
Hemerodromia sp.										
Antocha sp.	12	2	10		8.00	7.22	1	3		0.0144
Dicranota sp.										
Hexatoma sp.		2	1		1.00	0.00	1	3		0.0018
Atherix pachypus	2	3	1		2.00	0.60	1	2		0.0024
Pericoma sp.										
Optioservus sp.	21	39	18		26.00	36.79	1	4		0.0622
Heterlimnius corpulentus										
Zaitzevia parvula		5			1.67	0.37	1	4		0.0040
Narpus concolor	3	16	14		11.00	11.46	1	4		0.0263
Hydracarina sp.	1	12	13		8.67	8.13	1	8		0.0415
Gammarus sp.										
Physa sp.	6	3			3.00	1.43	1	8		0.0144
Pisidium sp.	1				0.33	-0.16	1	8		0.0016
Dugesia sp.										
Polycelis coronata										
Oligochaeta	4	1	1		2.00	0.60	1	10		0.0120
Nematoda	2	11	6		6.33	5.08	1	10		0.0379
Totals	1675.0	1858.0	1482.0		1671.67	4090.21	43			
										1.53
Shannon Weaver Diversity						2.58				
Shannon Weaver Evenness						0.475				

Table B9. Macroinvertebrate data collected from the Fryingpan River at site RFR-C on 11 October 2001.

Roaring Fork River										
RFR-C		Sample			Mean	ni*LOGni	Count	TV		FBI
11 October 2001	1	2	3							
Acentrella insignificans			3		1.00	0.00	1	4		0.0017
Baetis (flavistriga)	3	7	5		5.00	3.49	1	4		0.0086
Baetis (tricaudatus)	177	483	508		389.33	1008.50	1	4		0.6731
Drunella grandis	16	46	42		34.67	53.38	1	1		0.0150
Drunella coloradensis										
Drunella doddsi										
Ephemerella sp.	128	263	384		258.33	623.15	1	1		0.1117
Cinygmula sp.										
Epeorus longimanus		1	3		1.33	0.17	1	4		0.0023
Rhithrogena sp.										
Paraleptophlebia sp.	7	18	31		18.67	23.73	1	2		0.0161
Tricorythodes minutus		1	1		0.67	-0.12	1	4		0.0012
Caenis sp.										
Pteronarcella badia										
Capnia sp.										
Zapada sp.										
Paraperla frontalis										
Sweltsa sp.										
Triznaka signata										
Claassenia sabulosa	1	4	7		4.00	2.41	1	1		0.0017
Hesperoperla pacifica										
Skwala americana										
Isoperla fulva		1	1		0.67	-0.12	1	2		0.0006
Isoperla sp. 2	2		3		1.67	0.37	1	2		0.0014
Brachycentrus americanus	1	7	7		5.00	3.49	1	1		0.0022
Brachycentrus occidentalis	20	26	50		32.00	48.16	1	1		0.0138
Culoptila sp.	8	5	72		28.33	41.15	1	0		0.0000
Glossosoma sp.	9	6	13		9.33	9.05	1	0		0.0000
Arctopsyche grandis	2	7	4		4.33	2.76	1	4		0.0075
Hydropsyche cockerelli	5	44	32		27.00	38.65	1	4		0.0467
Hydropsyche occidentalis		1			0.33	-0.16	1	4		0.0006
Hydropsyche sp. (oslari)	21	138	77		78.67	149.14	1	4		0.1360
Hydroptila sp.										
Lepidostoma sp.	8	1	24		11.00	11.46	1	4		0.0190
Ceraclea sp.		1			0.33	-0.16	1	4		0.0006
Oecetis sp.										
Rhyacophila brunnea										
Rhyacophila coloradensis		3			1.00	0.00	1	0		0.0000
Neothremma alicia										
Oligophlebodes minuta										
Orthocladiinae	501	603	482		528.67	1439.66	1	6		1.3710
Tanypodinae	17	18	9		14.67	17.11	1	6		0.0380
Tanytarsini										
Chironomini	20	25	57		34.00	52.07	1	8		0.1176
Diamesinae										
Simulium sp.			1		0.33	-0.16	1	6		0.0009
Protanyderus margarita		1			0.33	-0.16	1	6		0.0009
Chelifera sp.	1	2	2		1.67	0.37	1	6		0.0043
Clinocera sp.	5	5	4		4.67	3.12	1	6		0.0121
Hemerodromia sp.		1	1		0.67	-0.12	1	6		0.0017
Antocha sp.	37	81	51		56.33	98.63	1	3		0.0730
Dicranota sp.										
Hexatoma sp.										
Atherix pachypus	63	165	105		111.00	227.03	1	2		0.0960
Pericoma sp.										
Optioservus sp.	182	473	578		411.00	1074.29	1	4		0.7106
Heterlimnius corpulentus										
Zaitzevia parvula	3	16	14		11.00	11.46	1	4		0.0190
Narpus concolor		2			0.67	-0.12	1	4		0.0012
Hydracarina sp.	3	3			2.00	0.60	1	8		0.0069
Gammarus sp.										
Physa sp.	2	1			1.00	0.00	1	8		0.0035
Pisidium sp.										
Dugesia sp.	3	5	12		6.67	5.49	1	8		0.0231
Polycelis coronata		1			0.33	-0.16	1	8		0.0012
Oligochaeta	381	118	126		208.33	483.07	1	10		0.9004
Nematoda	7	6	10		7.67	6.78	1	10		0.0331
Totals	1633.0	2589.0	2719.0		2313.67	5437.47	41			
										4.47
Shannon Weaver Diversity						3.37				
Shannon Weaver Evenness						0.629				

Table B10. Macroinvertebrate data collected from the Fryingpan River at site FPR-RES on 30 April 2002.

Fryingpan River										
FPR-RES		Sample			Mean	ni*LOGni	Count	TV		FBI
30 April 2002	1	2	3							
Acentrella insignificans	1	1			0.67	-0.12	1	4		0.0005
Baetis (flavistriga)										
Baetis (tricaudatus)	1041	654	2105		1266.67	3930.04	1	4		0.9255
Drunella grandis	4	1	6		3.67	2.07	1	1		0.0007
Drunella coloradensis		2			0.67	-0.12	1	1		0.0001
Drunella doddsi	3	3	7		4.33	2.76	1	1		0.0008
Ephemerella sp.	65	33	73		57.00	100.08	1	1		0.0104
Serratella sp.			1		0.33	-0.16	1	1		0.0001
Cinygmula sp.	16	11	17		14.67	17.11	1	4		0.0107
Epeorus longimanus	3	2	7		4.00	2.41	1	4		0.0029
Rhithrogena sp.										
Paraleptophlebia sp.	2	7	1		3.33	1.74	1	2		0.0012
Tricorythodes minutus										
Pteronarcella badia										
Prostoia besametsa	1		1		0.67	-0.12	1	2		0.0002
Triznaka signata		1			0.33	-0.16	1	1		0.0001
Sweltsa sp.										
Claassenia sabulosa										
Hesperoperla pacifica										
Isoperla fulva										
Isoperla sp. 2	1				0.33	-0.16	1	2		0.0001
Skwala americana										
Brachycentrus americanus			1		0.33	-0.16	1	1		0.0001
Brachycentrus occidentalis										
Culoptila sp.										
Glossosoma sp.	3	2	9		4.67	3.12	1	0		0.0000
Arctopsyche grandis										
Hydropsyche cockerelli										
Hydropsyche occidentalis										
Hydropsyche sp. *(oslari)*										
Hydroptila sp.	1				0.33	-0.16	1	1		0.0001
Lepidostoma sp.	2				0.67	-0.12	1	4		0.0005
Ceraclea sp.										
Oecetis sp.										
Rhyacophila brunnea	1	2	4		2.33	0.86	1	0		0.0000
Rhyacophila coloradensis			1		0.33	-0.16	1	0		0.0000
Neothremma alicia										
Oligophlebodes minuta		1	2		1.00	0.00	1	4		0.0007
Orthocladiinae	1962	1398	2291		1883.67	6169.02	1	6		2.0645
Tanypodinae			1		0.33	-0.16	1	6		0.0004
Tanytarsini	4	14	6		8.00	7.22	1	6		0.0088
Chironomini		1	3		1.33	0.17	1	8		0.0019
Diamesinae	738	1087	936		920.33	2727.82	1	6		1.0087
Simulium sp.		6	6		4.00	2.41	1	6		0.0044
Protanyderus margarita										
Bibiocephala grandis										
Chelifera sp.										
Clinocera sp.										
Hemerodromia sp.										
Tipula sp.										
Antocha sp.		6	8		4.67	3.12	1	3		0.0026
Dicranota sp.										
Hexatoma sp.										
Atherix pachypus										
Pericoma sp.										
Optioservus sp.										
Heterlimnius corpulentus	5	16	1		7.33	6.35	1	4		0.0054
Zaitzevia parvula										
Narpus concolor										
Hydracarina sp.	36	10	20		22.00	29.53	1	8		0.0322
Gammarus sp.										
Physa sp.										
Planorbidae										
Pisidium sp.	1	5			2.00	0.60	1	8		0.0029
Dugesia sp.										
Polycelis coronata	1066	737	836		879.67	2590.02	1	8		1.2855
Oligochaeta	220	391	504		371.67	955.24	1	10		0.6789
Nematoda	1	4	4		3.00	1.43	1	10		0.0055
Totals	5177.0	4395.0	6851.0		5474.33	16551.53	33			
										6.06
Shannon Weaver Diversity						2.37				
Shannon Weaver Evenness						0.471				

Table B11. Macroinvertebrate data collected from the Fryingpan River at site FPR-TC on 30 April 2002.

Fryingpan River										
FPR-TC		Sample			Mean	ni*LOGni	Count	TV		FBI
30 April 2002	1	2	3							
Acentrella insignificans										
Baetis (flavistriga)	6	3	7		5.33	3.88	1	4		0.0114
Baetis (tricaudatus)	408	191	112		237.00	562.82	1	4		0.5084
Drunella grandis	1		4		1.67	0.37	1	1		0.0009
Drunella coloradensis										
Drunella doddsi										
Ephemerella sp.	14	8	11		11.00	11.46	1	1		0.0059
Serratella sp.	39	14	5		19.33	24.87	1	1		0.0104
Cinygmula sp.	136	51	160		115.67	238.64	1	4		0.2481
Epeorus longimanus	48	56	63		55.67	97.17	1	4		0.1194
Rhithrogena sp.										
Paraleptophlebia sp.	67	82	140		96.33	191.10	1	2		0.1033
Tricorythodes minutus										
Pteronarcella badia										
Prostoia besametsa										
Triznaka signata			1		0.33	-0.16	1	1		0.0002
Sweltsa sp.										
Claassenia sabulosa		1			0.33	-0.16	1	1		0.0002
Hesperoperla pacifica	4	6	5		5.00	3.49	1	1		0.0027
Isoperla fulva	2		2		1.33	0.17	1	2		0.0014
Isoperla sp. 2										
Skwala americana		1			0.33	-0.16	1	2		0.0004
Brachycentrus americanus	25	18	27		23.33	31.92	1	1		0.0125
Brachycentrus occidentalis										
Culoptila sp.										
Glossosoma sp.	1	13	1		5.00	3.49	1	0		0.0000
Arctopsyche grandis	13	12	9		11.33	11.95	1	4		0.0243
Hydropsyche cockerelli	3		1		1.33	0.17	1	4		0.0029
Hydropsyche occidentalis										
Hydropsyche sp. *(oslari)*										
Hydroptila sp.										
Lepidostoma sp.	452	248	264		321.33	805.57	1	4		0.6893
Ceraclea sp.										
Oecetis sp.										
Rhyacophila brunnea	2	2	6		3.33	1.74	1	0		0.0000
Rhyacophila coloradensis	1		1		0.67	-0.12	1	0		0.0000
Neothremma alicia		2			0.67	-0.12	1	4		0.0014
Oligophlebodes minuta	210	88	108		135.33	288.45	1	4		0.2903
Orthocladiinae	336	371	432		379.67	979.31	1	6		1.2217
Tanypodinae	7	9	22		12.67	13.97	1	6		0.0408
Tanytarsini	63	90	85		79.33	150.69	1	6		0.2553
Chironomini	5	1	1		2.33	0.86	1	8		0.0100
Diamesinae	23	34	14		23.67	32.52	1	6		0.0762
Simulium sp.										
Protanyderus margarita										
Bibiocephala grandis										
Chelifera sp.	2	3	1		2.00	0.60	1	6		0.0064
Clinocera sp.			1		0.33	-0.16	1	6		0.0011
Hemerodromia sp.										
Tipula sp.										
Antocha sp.	10	21	31		20.67	27.18	1	3		0.0332
Dicranota sp.	2	1			1.00	0.00	1	3		0.0016
Hexatoma sp.	1				0.33	-0.16	1	3		0.0005
Atherix pachypus	2				0.67	-0.12	1	2		0.0007
Pericoma sp.	1	3	3		2.33	0.86	1	10		0.0125
Optioservus sp.	3		7		3.33	1.74	1	4		0.0072
Heterlimnius corpulentus	41	15	68		41.33	66.81	1	4		0.0887
Zaitzevia parvula		1	1		0.67	-0.12	1	4		0.0014
Narpus concolor										
Hydracarina sp.	3	5	1		3.00	1.43	1	8		0.0129
Gammarus sp.										
Physa sp.										
Planorbidae										
Pisidium sp.	28	34	40		34.00	52.07	1	8		0.1459
Dugesia sp.										
Polycelis coronata	238	185	108		177.00	397.89	1	8		0.7594
Oligochaeta	62		24		28.67	41.78	1	10		0.1537
Nematoda										
Totals	2259.0	1569.0	1766.0		1864.67	4043.71	41			
										4.86
Shannon Weaver Diversity						3.66				
Shannon Weaver Evenness						0.683				

Table B12. Macroinvertebrate data collected from the Fryingpan River at site RFR-711 on 30 April 2002.

Roaring Fork River										
RFR - 711		Sample			Mean	ni*LOGni	Count	TV		FBI
30 April 2002	1	2	3							
Acentrella insignificans										
Baetis (flavistriga)	13	30	12		18.33	23.16	1	4		0.0650
Baetis (tricaudatus)	89	75	87		83.67	160.85	1	4		0.2965
Drunella grandis	10	30	14		18.00	22.59	1	1		0.0159
Drunella coloradensis										
Drunella doddsi										
Ephemerella sp.	72	96	113		93.67	184.67	1	1		0.0830
Serratella sp.	1	4	1		2.00	0.60	1	1		0.0018
Cinygmula sp.		3			1.00	0.00	1	4		0.0035
Epeorus longimanus	37	61	45		47.67	79.99	1	4		0.1689
Rhithrogena sp.		1	2		1.00	0.00	1	4		0.0035
Paraleptophlebia sp.	6	23	22		17.00	20.92	1	2		0.0301
Tricorythodes minutus										
Pteronarcella badia										
Prostoia besametsa										
Triznaka signata			2		0.67	-0.12	1	1		0.0006
Sweltsa sp.	2	2	2		2.00	0.60	1	1		0.0018
Claassenia sabulosa	1	2	1		1.33	0.17	1	1		0.0012
Hesperoperla pacifica										
Isoperla fulva										
Isoperla sp. 2										
Skwala americana										
Brachycentrus americanus	11	12	8		10.33	10.48	1	1		0.0092
Brachycentrus occidentalis	1				0.33	-0.16	1	1		0.0003
Culoptila sp.	1	6	32		13.00	14.48	1	0		0.0000
Glossosoma sp.	118	116	119		117.67	243.65	1	0		0.0000
Arctopsyche grandis	8	4	5		5.67	4.27	1	4		0.0201
Hydropsyche cockerelli	34	39	20		31.00	46.23	1	4		0.1099
Hydropsyche occidentalis										
Hydropsyche sp. *(oslari)*	10	9	12		10.33	10.48	1	4		0.0366
Hydroptila sp.										
Lepidostoma sp.	39	454	315		269.33	654.56	1	4		0.9545
Ceraclea sp.										
Oecetis sp.										
Rhyacophila brunnea										
Rhyacophila coloradensis	4	1	5		3.33	1.74	1	0		0.0000
Neothremma alicia										
Oligophlebodes minuta	2	2	2		2.00	0.60	1	4		0.0071
Orthocladiinae	147	207	163		172.33	385.40	1	6		0.9161
Tanypodinae	14	41	28		27.67	39.89	1	6		0.1471
Tanytarsini	7	123	82		70.67	130.68	1	6		0.3757
Chironomini	3	5	1		3.00	1.43	1	8		0.0213
Diamesinae	4		5		3.00	1.43	1	6		0.0159
Simulium sp.	5	3	1		3.00	1.43	1	6		0.0159
Protanyderus margarita										
Bibiocephala grandis	3		4		2.33	0.86	1	0		0.0000
Chelifera sp.	2	1	4		2.33	0.86	1	6		0.0124
Clinocera sp.	2				0.67	-0.12	1	6		0.0035
Hemerodromia sp.		2	1		1.00	0.00	1	6		0.0053
Tipula sp.										
Antocha sp.	26	32	19		25.67	36.17	1	3		0.0682
Dicranota sp.										
Hexatoma sp.	1	1	3		1.67	0.37	1	3		0.0044
Atherix pachypus	20	26	22		22.67	30.72	1	2		0.0402
Pericoma sp.										
Optioservus sp.	12	21	22		18.33	23.16	1	4		0.0650
Heterlimnius corpulentus	1				0.33	-0.16	1	4		0.0012
Zaitzevia parvula										
Narpus concolor		1			0.33	-0.16	1	4		0.0012
Hydracarina sp.		1	2		1.00	0.00	1	8		0.0071
Gammarus sp.										
Physa sp.										
Planorbidae			2		0.67	-0.12	1	8		0.0047
Pisidium sp.										
Dugesia sp.										
Polycelis coronata	4	12	6		7.33	6.35	1	8		0.0520
Oligochaeta	14	30			14.67	17.11	1	10		0.1299
Nematoda	1		1		0.67	-0.12	1	10		0.0059
Totals	725.0	1476.0	1185.0		1128.67	2154.97	43			
										3.70
Shannon Weaver Diversity						3.80				
Shannon Weaver Evenness						0.700				

Table B13. Macroinvertebrate data collected from the Fryingpan River at site RFR-HB on 30 April 2002.

Roaring Fork River										
RFR-HB		Sample			Mean	ni*LOGni	Count	TV		FBI
30 April 2002	1	2	3							
Acentrella insignificans	1				0.33	-0.16	1	4		0.0010
Baetis (flavistriga)	39	90	35		54.67	95.00	1	4		0.1688
Baetis (tricaudatus)	185	496	304		328.33	826.19	1	4		1.0139
Drunella grandis	9	14	15		12.67	13.97	1	1		0.0098
Drunella coloradensis										
Drunella doddsi	1				0.33	-0.16	1	1		0.0003
Ephemerella sp.	34	164	67		88.33	171.91	1	1		0.0682
Serratella sp.										
Cinygmula sp.	1	1	1		1.00	0.00	1	4		0.0031
Epeorus longimanus	42	79	63		61.33	109.65	1	4		0.1894
Rhithrogena sp.	6	3	3		4.00	2.41	1	4		0.0124
Paraleptophlebia sp.	39	122	26		62.33	111.87	1	2		0.0962
Tricorythodes minutus										
Pteronarcella badia										
Prostoia besametsa										
Triznaka signata	1	10	7		6.00	4.67	1	1		0.0046
Sweltsa sp.			1		0.33	-0.16	1	1		0.0003
Claassenia sabulosa	10	4	2		5.33	3.88	1	1		0.0041
Hesperoperla pacifica		1			0.33	-0.16	1	1		0.0003
Isoperla fulva		1	2		1.00	0.00	1	2		0.0015
Isoperla sp. 2			1		0.33	-0.16	1	2		0.0005
Skwala americana										
Brachycentrus americanus		8	5		4.33	2.76	1	1		0.0033
Brachycentrus occidentalis										
Culoptila sp.	2		3		1.67	0.37	1	0		0.0000
Glossosoma sp.	41	390	189		206.67	478.49	1	0		0.0000
Arctopsyche grandis	3	9	13		8.33	7.67	1	4		0.0257
Hydropsyche cockerelli	4	36	36		25.33	35.56	1	4		0.0782
Hydropsyche occidentalis										
Hydropsyche sp. *(oslari)*	4	35	18		19.00	24.30	1	4		0.0587
Hydroptila sp.										
Lepidostoma sp.	144	162	115		140.33	301.32	1	4		0.4334
Ceraclea sp.			1		0.33	-0.16	1	4		0.0010
Oecetis sp.										
Rhyacophila brunnea										
Rhyacophila coloradensis		2	2		1.33	0.17	1	0		0.0000
Neothremma alicia										
Oligophlebodes minuta										
Orthocladiinae	41	353	166		186.67	423.93	1	6		0.8646
Tanypodinae	14	18	12		14.67	17.11	1	6		0.0679
Tanytarsini	3	47	10		20.00	26.02	1	6		0.0926
Chironomini	3	14	3		6.67	5.49	1	8		0.0412
Diamesinae		1			0.33	-0.16	1	6		0.0015
Simulium sp.		3	1		1.33	0.17	1	6		0.0062
Protanyderus margarita	1				0.33	-0.16	1	6		0.0015
Bibiocephala grandis	1		1		0.67	-0.12	1	0		0.0000
Chelifera sp.	1		1		0.67	-0.12	1	6		0.0031
Clinocera sp.		2			0.67	-0.12	1	6		0.0031
Hemerodromia sp.										
Tipula sp.										
Antocha sp.	3	12	9		8.00	7.22	1	3		0.0185
Dicranota sp.										
Hexatoma sp.			1		0.33	-0.16	1	3		0.0008
Atherix pachypus	9	1	4		4.67	3.12	1	2		0.0072
Pericoma sp.										
Optioservus sp.	13	6	6		8.33	7.67	1	4		0.0257
Heterlimnius corpulentus										
Zaitzevia parvula		1			0.33	-0.16	1	4		0.0010
Narpus concolor			1		0.33	-0.16	1	4		0.0010
Hydracarina sp.	1	2	2		1.67	0.37	1	8		0.0103
Gammarus sp.										
Physa sp.										
Planorbidae										
Pisidium sp.										
Dugesia sp.										
Polycelis coronata	7	3			3.33	1.74	1	8		0.0206
Oligochaeta	3		4		2.33	0.86	1	10		0.0180
Nematoda										
Totals	666.0	2090.0	1130.0		1295.33	2681.77	44			
										3.36
Shannon Weaver Diversity						3.46				
Shannon Weaver Evenness						0.634				

Table B14. Macroinvertebrate data collected from the Fryingpan River at site RFR-C on 30 April 2002.

Roaring Fork River										
RFR-C		Sample			Mean	ni*LOGni	Count	TV		FBI
30 April 2002	1	2	3							
Acentrella insignificans										
Baetis (flavistriga)	5	15	6		8.67	8.13	1	4		0.0088
Baetis (tricaudatus)	232	791	714		579.00	1599.59	1	4		0.5900
Drunella grandis	4	32	9		15.00	17.64	1	1		0.0038
Drunella coloradensis										
Drunella doddsi										
Ephemerella sp.	70	56	64		63.33	114.10	1	1		0.0161
Serratella sp.										
Cinygmula sp.										
Epeorus longimanus	1	6	4		3.67	2.07	1	4		0.0037
Rhithrogena sp.										
Paraleptophlebia sp.	14	23	12		16.33	19.81	1	2		0.0083
Tricorythodes minutus	7	3	4		4.67	3.12	1	4		0.0048
Pteronarcella badia										
Prostoia besametsa										
Triznaka signata										
Sweltsa sp.										
Claassenia sabulosa		7			2.33	0.86	1	1		0.0006
Hesperoperla pacifica										
Isoperla fulva										
Isoperla sp. 2		1	1		0.67	-0.12	1	2		0.0003
Skwala americana										
Brachycentrus americanus	1	9	4		4.67	3.12	1	1		0.0012
Brachycentrus occidentalis										
Culoptila sp.	35	23	48		35.33	54.70	1	0		0.0000
Glossosoma sp.		4	1		1.67	0.37	1	0		0.0000
Arctopsyche grandis		9	2		3.67	2.07	1	4		0.0037
Hydropsyche cockerelli		64	20		28.00	40.52	1	4		0.0285
Hydropsyche occidentalis			1		0.33	-0.16	1	4		0.0003
Hydropsyche sp. *(oslari)*	9	223	42		91.33	179.07	1	4		0.0931
Hydroptila sp.										
Lepidostoma sp.	9	7	3		6.33	5.08	1	4		0.0065
Ceraclea sp.										
Oecetis sp.	1				0.33	-0.16	1	4		0.0003
Rhyacophila brunnea										
Rhyacophila coloradensis		2	2		1.33	0.17	1	0		0.0000
Neothremma alicia										
Oligophlebodes minuta										
Orthocladiinae	1827	1912	2003		1914.00	6281.64	1	6		2.9256
Tanypodinae	28	46	37		37.00	58.02	1	6		0.0566
Tanytarsini	9	1	1		3.67	2.07	1	6		0.0056
Chironomini	28	15	28		23.67	32.52	1	8		0.0482
Diamesinae	7	3	2		4.00	2.41	1	6		0.0061
Simulium sp.		3			1.00	0.00	1	6		0.0015
Protanyderus margarita										
Bibiocephala grandis										
Chelifera sp.		1	3		1.33	0.17	1	6		0.0020
Clinocera sp.	1				0.33	-0.16	1	6		0.0005
Hemerodromia sp.										
Tipula sp.										
Antocha sp.	105	177	137		139.67	299.60	1	3		0.1067
Dicranota sp.										
Hexatoma sp.										
Atherix pachypus	108	143	104		118.33	245.32	1	2		0.0603
Pericoma sp.										
Optioservus sp.	325	416	351		364.00	932.24	1	4		0.3709
Heterlimnius corpulentus			2		0.67	-0.12	1	4		0.0007
Zaitzevia parvula	9	29	22		20.00	26.02	1	4		0.0204
Narpus concolor	2		1		1.00	0.00	1	4		0.0010
Hydracarina sp.	15	6	2		7.67	6.78	1	8		0.0156
Gammarus sp.										
Physa sp.	1	1			0.67	-0.12	1	4		0.0007
Planorbidae										
Pisidium sp.										
Dugesia sp.	7	9	5		7.00	5.92	1	8		0.0143
Polycelis coronata										
Oligochaeta	377	437	367		393.67	1021.62	1	10		1.0029
Nematoda	6	23	34		21.00	27.77	1	10		0.0535
Totals	3243.0	4497.0	4036.0		3925.33	10991.68	38			
										5.46
Shannon Weaver Diversity						2.64				
Shannon Weaver Evenness						0.502				

APPENDIX C - Habitat Mapping Data

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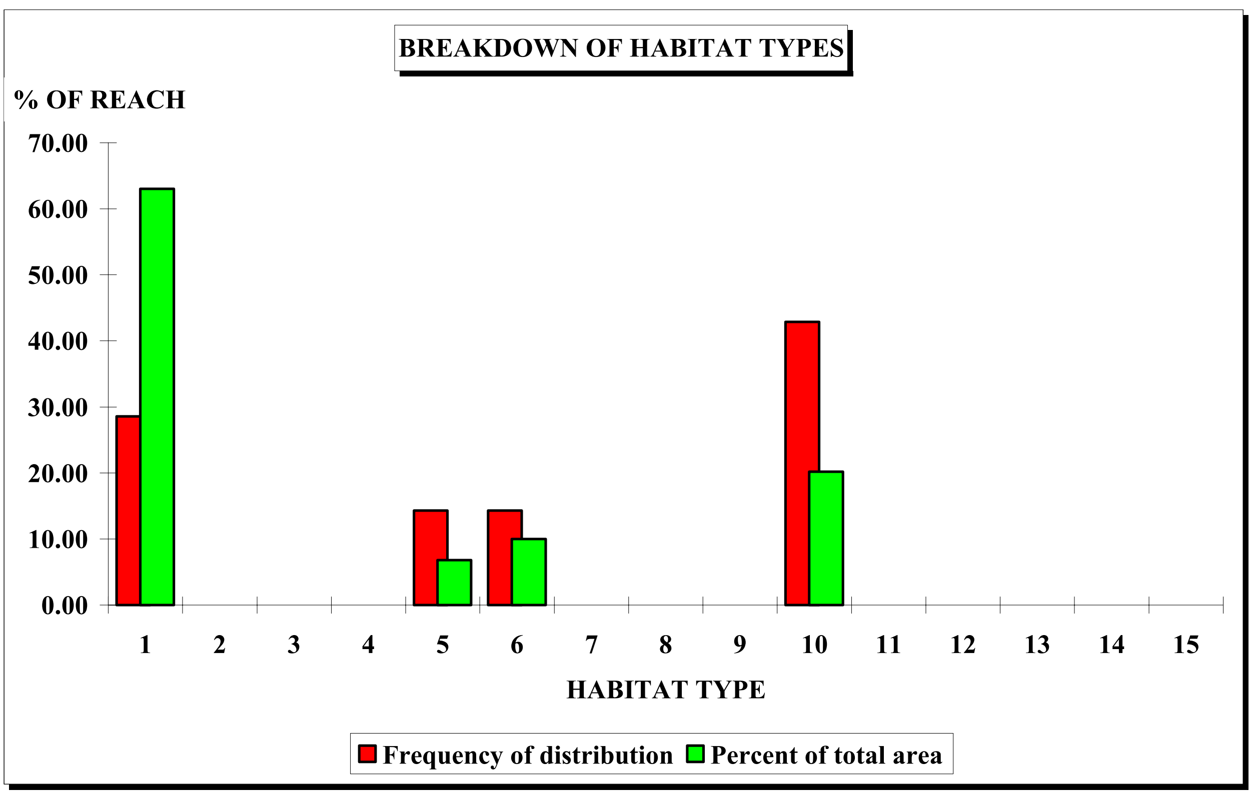
Table C1. Habitat mapping at site FPR-BP on the Fryingpan River.

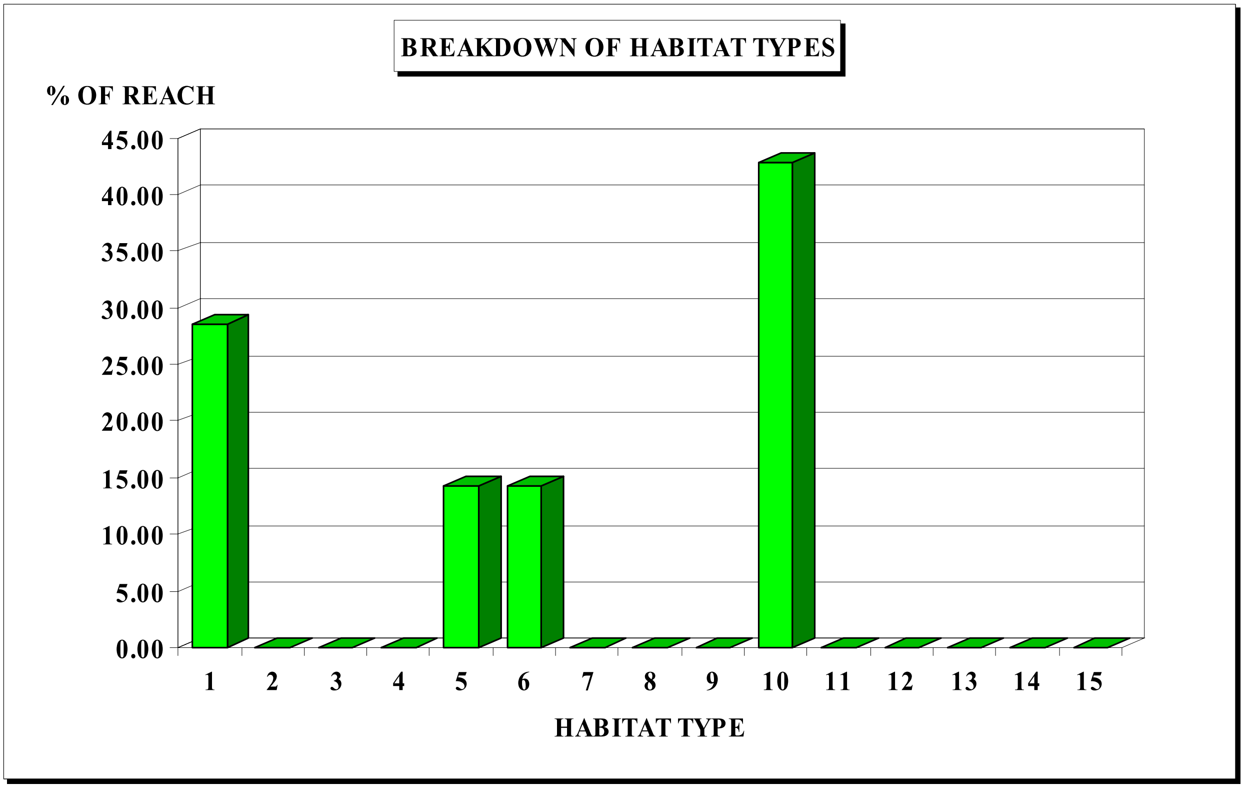
Fryingpan - FPR-BP

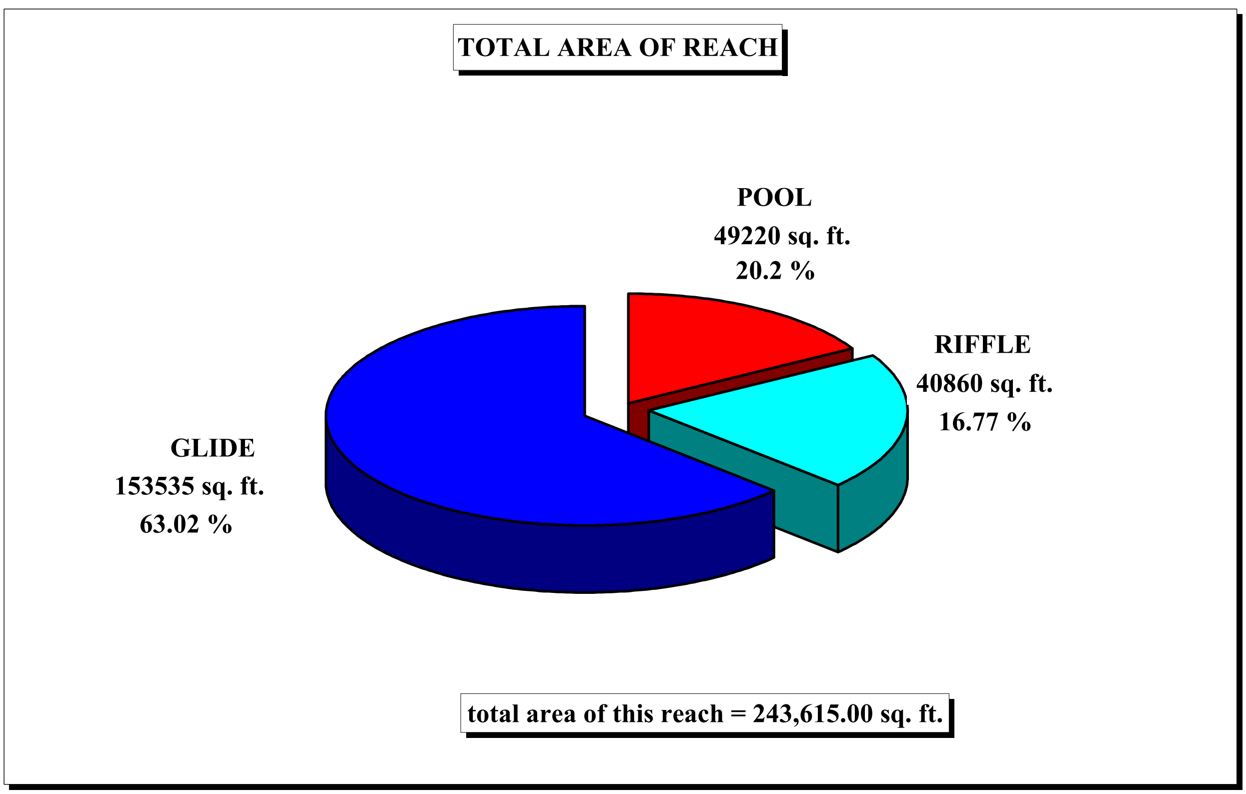
	POOL	RIFFLE	GLIDE	REACH TOTAL		POOL	RIFFLE	GLIDE	REACH TOTAL
TOTAL LENGTH OF HABITAT (ft.)	498	700	989	2187	TOTAL AREA OF HABITAT (sq. ft.)	40860	49220	153535	243615
AVERAGE WIDTH OF HABITAT (ft.)	90.00	66.67	116.00	90.89	% OF TOTAL NUM. OF HABITATS	28.57	42.86	28.57	100.00
AVERAGE RESIDUAL DEPTH (ft.)	0.00	0.00	0.00	0.00	HABITAT TYPE	16.77	20.20	63.02	100.00
					AS A % OF TOTAL AREA				
AVERAGE DEPTH (ft.)	0.00	0.00	0.00	0.00					
					% OF TOTAL COVERS 2 - 5	0.00	0.00	0.00	0.00
TOTAL COVER TYPE 2 (sq. ft.)	0.00	0.00	0.00	0.00	TO TOTAL HABITAT				
AVE. TYPE 2 COVER PER UNIT	0.00	0.00	0.00	0.00					
					% OF CVR 2 TO TOTAL AREA	0.00	0.00	0.00	0.00
TOTAL COVER TYPE 3 (sq. ft.)	0.00	0.00	0.00	0.00	% OF CVR 3 TO TOTAL AREA	0.00	0.00	0.00	0.00
AVE. TYPE 3 COVER PER UNIT	0.00	0.00	0.00	0.00					
TOTAL COVER TYPE 4 (sq. ft.)	0.00	0.00	0.00	0.00	% OF CVR 4 TO TOTAL AREA	0.00	0.00	0.00	0.00
AVE. TYPE 4 COVER PER UNIT	0.00	0.00	0.00	0.00					
TOTAL COVER TYPE 5 (sq. ft.)	0.00	0.00	0.00	0.00	% OF CVR 5 TO TOTAL AREA	0.00	0.00	0.00	0.00
AVE. TYPE 5 COVER PER UNIT	0.00	0.00	0.00	0.00					
					% BANK ROCK CONTENT				
% BANK STABILITY TYPE 1					TYPE 2				
LEFT BANK	50.00	66.67	100.00	71.43	LEFT BANK	50.00	33.33	0.00	28.57
RIGHT BANK	50.00	33.33	100.00	57.14	RIGHT BANK	100.00	66.67	0.00	57.14
% BANK STABILITY TYPE 2					TYPE 3				
LEFT BANK	0.00	0.00	0.00	0.00	LEFT BANK	0.00	0.00	0.00	0.00
RIGHT BANK	0.00	0.00	0.00	0.00	RIGHT BANK	0.00	0.00	0.00	0.00
% BANK STABILITY TYPE 3					TYPE 4				
LEFT BANK	50.00	33.33	0.00	28.57	LEFT BANK	0.00	66.67	0.00	28.57
RIGHT BANK	50.00	66.67	0.00	42.86	RIGHT BANK	0.00	33.33	100.00	42.86
% BANK STABILITY TYPE 4					TYPE 5				
LEFT BANK	0.00	0.00	0.00	0.00	LEFT BANK	0.00	0.00	0.00	0.00
RIGHT BANK	0.00	0.00	0.00	0.00	RIGHT BANK	0.00	0.00	0.00	0.00
					TYPE 6				
					LEFT BANK	50.00	0.00	100.00	42.86
					RIGHT BANK	0.00	0.00	0.00	0.00
TOTAL OF ERODING BANKS (ft.)	0.00	0.00	0.00	0.00					
					TYPE 7				
					LEFT BANK	0.00	0.00	0.00	0.00
					RIGHT BANK	0.00	0.00	0.00	0.00
TOTAL LRG. ORGANIC DEBRIS	0.00	0.00	0.00	0	TYPE 8				
					LEFT BANK	0.00	0.00	0.00	0.00
					RIGHT BANK	0.00	0.00	0.00	0.00
AVERAGE OF SUBSTRATA TYPE FOR HABITAT ON THIS REACH									
PLANT DEBRIS	0.00	0.00	0.00	0.00	SAND\SILT	0.00	0.00	5.00	1.67
GRAVEL	5.00	3.33	15.00	7.78	RUBBLE	40.00	43.33	60.00	47.78
BOULDER	55.00	53.33	20.00	42.78	BEDROCK	0.00	0.00	0.00	0.00

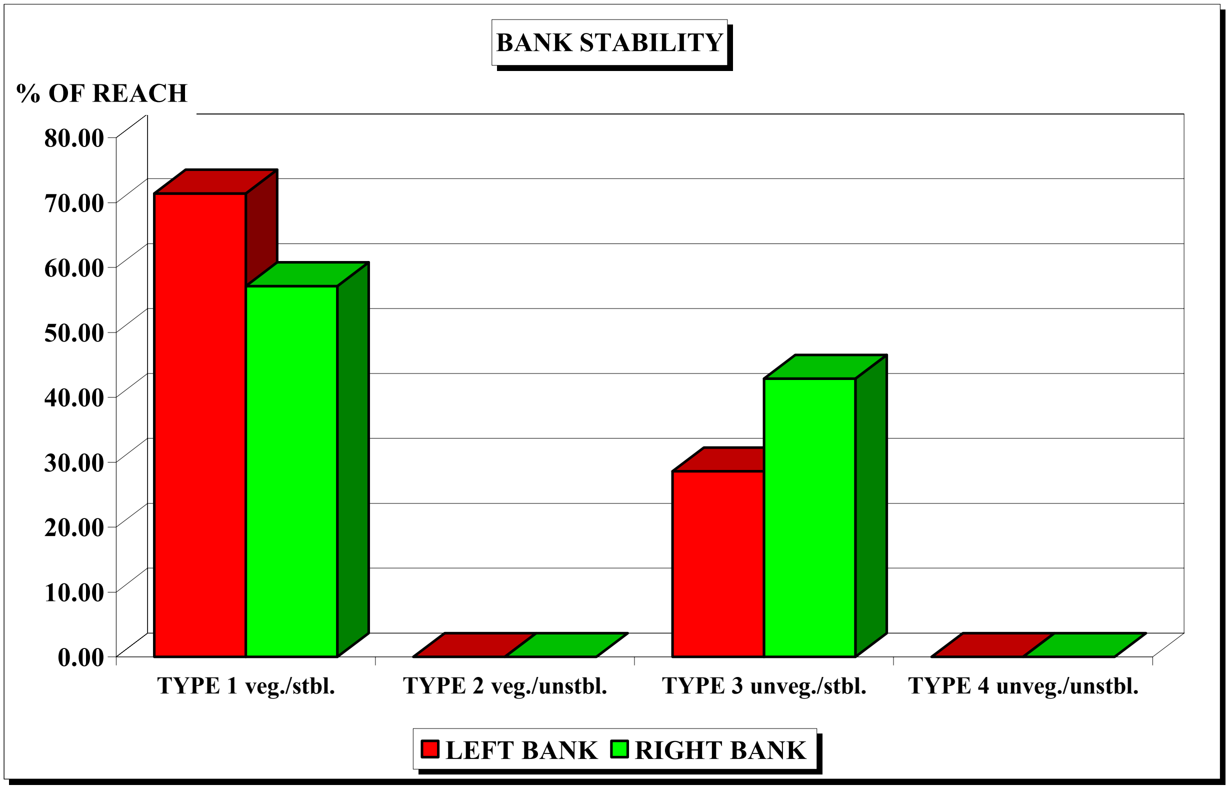
Table C1 (continued). Habitat mapping site FPR-BP on the Fryingpan River.

HABITAT TYPE ANALYSIS									
				TOTAL					TOTAL
NUMBER OF TYPE 2 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 9 HABITAT	0.00	0.00	0	0.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 3 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 10 HABITAT	0.00	3.00	0	3.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	100.00	0	42.86
NUMBER OF TYPE 4 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 11 HABITAT	0.00	0.00	0	0.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 5 HABITAT	1.00	0.00	0.00	1.00	NUMBER OF TYPE 12 HABITAT	0.00	0.00	0	0.00
% OF HABITAT	40.38	0.00	0.00	14.29	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 6 HABITAT	1.00	0.00	0.00	1.00	NUMBER OF TYPE 13 HABITAT	0.00	0.00	0	0.00
% OF HABITAT	59.62	0.00	0.00	14.29	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 7 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 14 HABITAT	0.00	0.00	0	0.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 8 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 15 HABITAT	0.00	0.00	0	0.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	0.00	0	0.00
TOTAL NUMBER OF HABITAT	2.00	3.00	2.00	7.00	NUMBER OF GLIDES	0.00	0.00	2	2.00
TOTAL % OF HABITAT	100.00	100.00	100.00	100.00		0.00	0.00	100.00	28.57




BREAKDOWN OF HABITAT TYPES
% OF REACH
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
HABITAT TYPE


TOTAL AREA OF REACH
POOL
49220 sq. ft.
20.2 %
RIFFLE
40860 sq. ft.
16.77 %
GLIDE
153535 sq. ft.
63.02 %
total area of this reach = 243,615.00 sq. ft.


BANK STABILITY
% OF REACH
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
TYPE 1 veg./stbl.
TYPE 2 veg./unstbl.
TYPE 3 unveg./stbl.
TYPE 4 unveg./unstbl.
LEFT BANK
RIGHT BANK

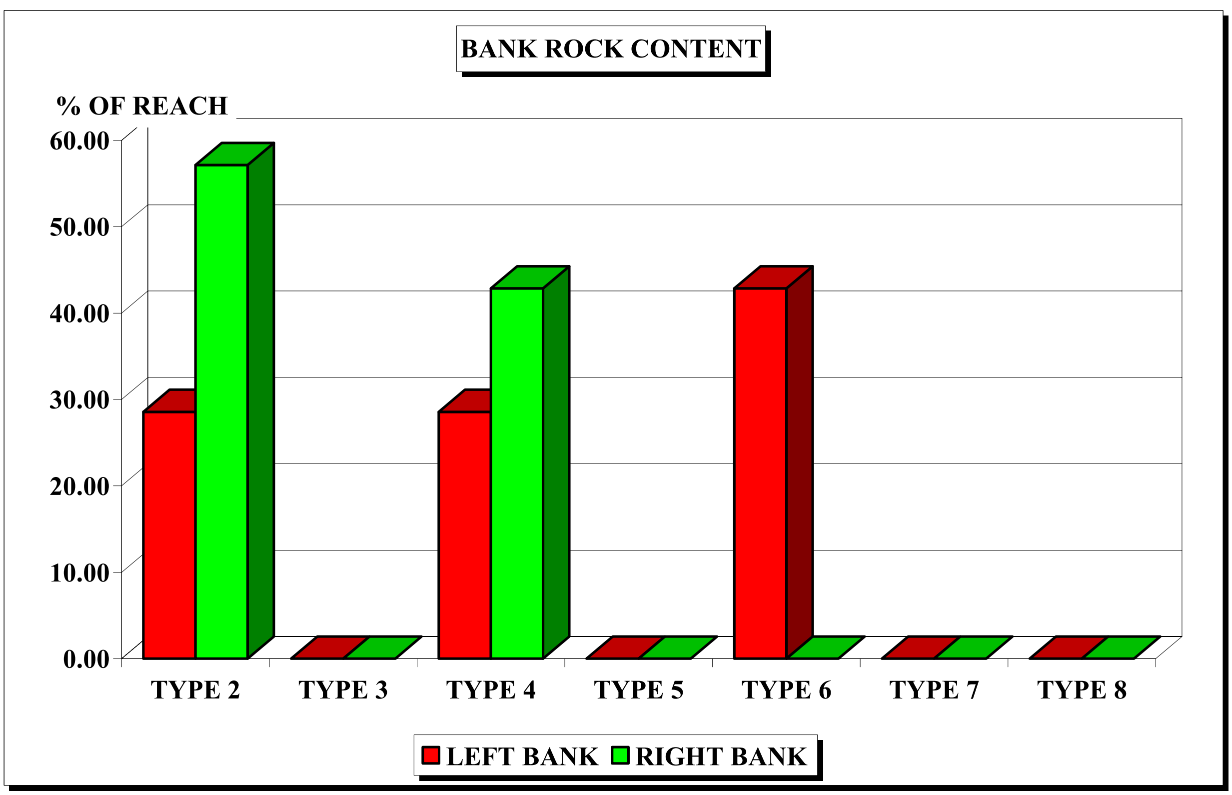

BANK ROCK CONTENT
% OF REACH
60.00
50.00
40.00
30.00
20.00
10.00
0.00
TYPE 2
TYPE 3
TYPE 4
TYPE 5
TYPE 6
TYPE 7
TYPE 8
LEFT BANK
RIGHT BANK

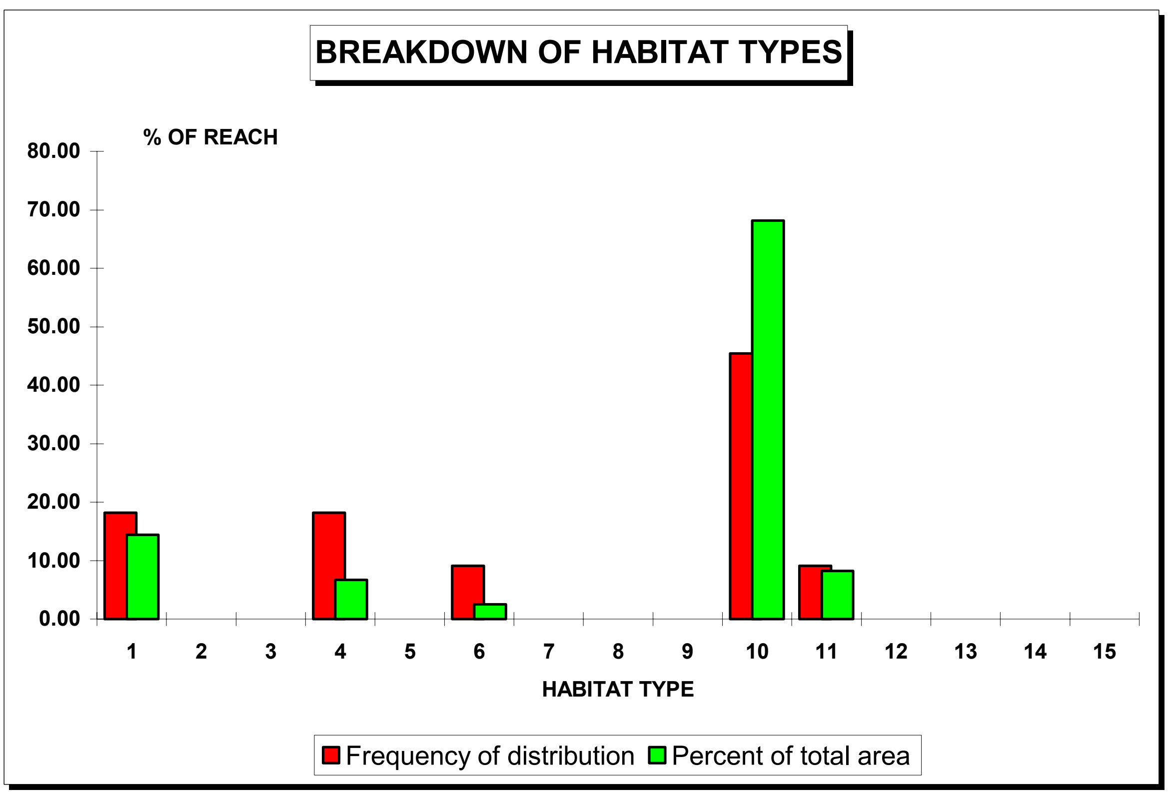
Table C2. Habitat mapping site FPR-HG on the Fryingpan River.

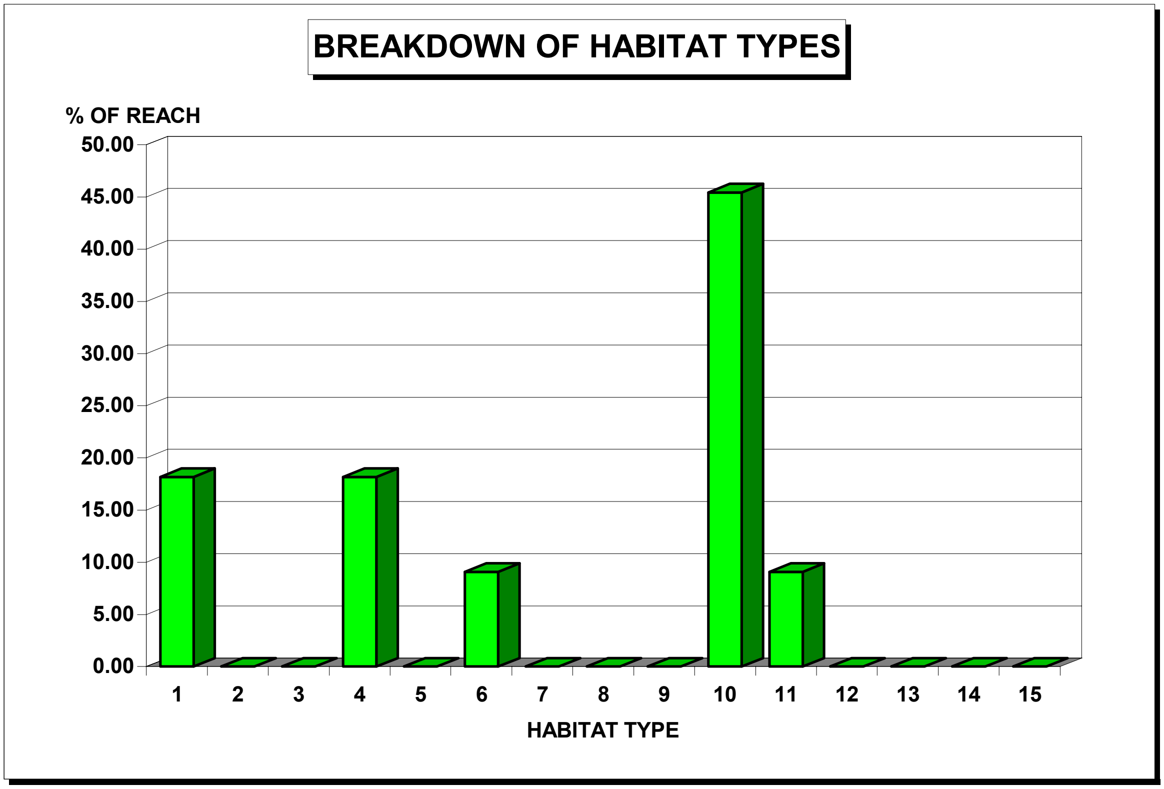
Fryingpan - FPR-HG

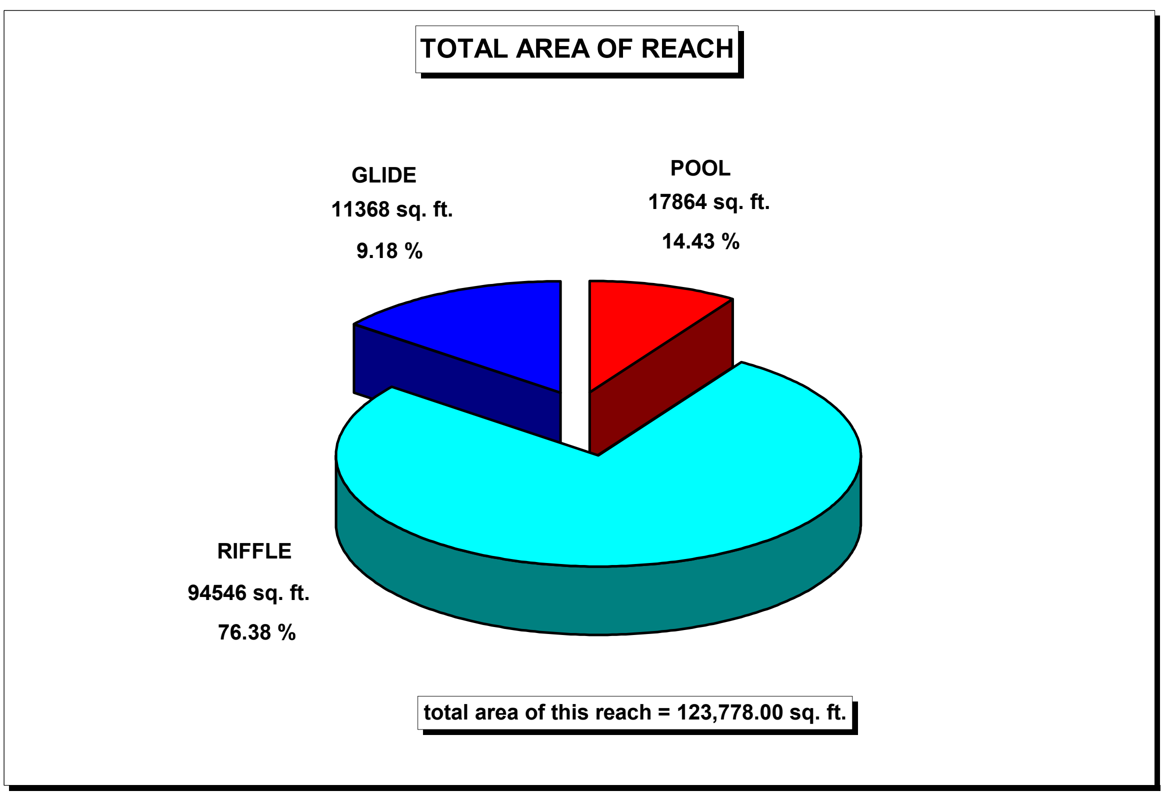
	POOL	RIFFLE	GLIDE	REACH TOTAL		POOL	RIFFLE	GLIDE	REACH TOTAL
TOTAL LENGTH OF HABITAT (	284.00	1961.00	308.00	2553.00	TOTAL AREA OF HABITAT (s	11368.00	94546.00	17864.00	123778.00
AVERAGE WIDTH OF HABITAT	39.67	48.17	54.00	47.28	% OF TOTAL NUM. OF HABIT.	27.27	54.55	18.18	100.00
AVERAGE RESIDUAL DEPTH	0.00	0.00	0.00	0.00	HABITAT TYPE	9.18	76.38	14.43	100.00
					AS A % OF TOTAL AREA				
AVERAGE DEPTH (ft.)	0.00	0.00	0.00	0.00					
					% OF TOTAL COVERS 2 - 5	0.00	0.00	0.00	0.00
TOTAL COVER TYPE 2 (sq. ft.)	0.00	0.00	0.00	0.00	TO TOTAL HABITAT				
AVE. TYPE 2 COVER PER UN	0.00	0.00	0.00	0.00					
					% OF CVR 2 TO TOTAL AREA	0.00	0.00	0.00	0.00
TOTAL COVER TYPE 3 (sq. ft.)	0.00	0.00	0.00	0.00	% OF CVR 3 TO TOTAL AREA	0.00	0.00	0.00	0.00
AVE. TYPE 3 COVER PER UN	0.00	0.00	0.00	0.00					
TOTAL COVER TYPE 4 (sq. ft.)	0.00	0.00	0.00	0.00	% OF CVR 4 TO TOTAL AREA	0.00	0.00	0.00	0.00
AVE. TYPE 4 COVER PER UN	0.00	0.00	0.00	0.00					
TOTAL COVER TYPE 5 (sq. ft.	0.00	0.00	0.00	0.00	% OF CVR 5 TO TOTAL AREA	0.00	0.00	0.00	0.00
AVE. TYPE 5 COVER PER UN	0.00	0.00	0.00	0.00					
					% BANK ROCK CONTENT				
% BANK STABILITY TYPE 1					TYPE 2				
LEFT BANK	33.33	66.67	50.00	54.55	LEFT BANK	66.67	50.00	50.00	54.55
RIGHT BANK	33.33	50.00	100.00	54.55	RIGHT BANK	66.67	50.00	0.00	45.45
% BANK STABILITY TYPE 2					TYPE 3				
LEFT BANK	0.00	0.00	0.00	0.00	LEFT BANK	0.00	0.00	0.00	0.00
RIGHT BANK	0.00	0.00	0.00	0.00	RIGHT BANK	0.00	0.00	0.00	0.00
% BANK STABILITY TYPE 3					TYPE 4				
LEFT BANK	66.67	33.33	50.00	45.45	LEFT BANK	0.00	33.33	0.00	18.18
RIGHT BANK	66.67	50.00	0.00	45.45	RIGHT BANK	0.00	50.00	100.00	45.45
% BANK STABILITY TYPE 4					TYPE 5				
LEFT BANK	0.00	0.00	0.00	0.00	LEFT BANK	0.00	0.00	0.00	0.00
RIGHT BANK	0.00	0.00	0.00	0.00	RIGHT BANK	0.00	0.00	0.00	0.00
					TYPE 6				
					LEFT BANK	33.33	16.67	50.00	27.27
					RIGHT BANK	33.33	0.00	0.00	9.09
TOTAL OF ERODING BANKS (	0.00	0.00	0.00	0.00					
					TYPE 7				
					LEFT BANK	0.00	0.00	0.00	0.00
					RIGHT BANK	0.00	0.00	0.00	0.00
TOTAL LRG. ORGANIC DEBRIS	0.00	0.00	0.00	0	TYPE 8				
					LEFT BANK	0.00	0.00	0.00	0.00
					RIGHT BANK	0.00	0.00	0.00	0.00
AVERAGE OF SUBSTRATA TYPE FOR HABITAT ON THIS REACH									
PLANT DEBRIS	0.00	0.00	0.00	0.00	SAND\SILT	3.33	0.00	0.00	1.11
GRAVEL	0.00	0.00	0.00	0.00	RUBBLE	43.33	40.00	55.00	46.11
BOULDER	53.33	60.00	45.00	52.78	BEDROCK	0.00	0.00	0.00	0.00

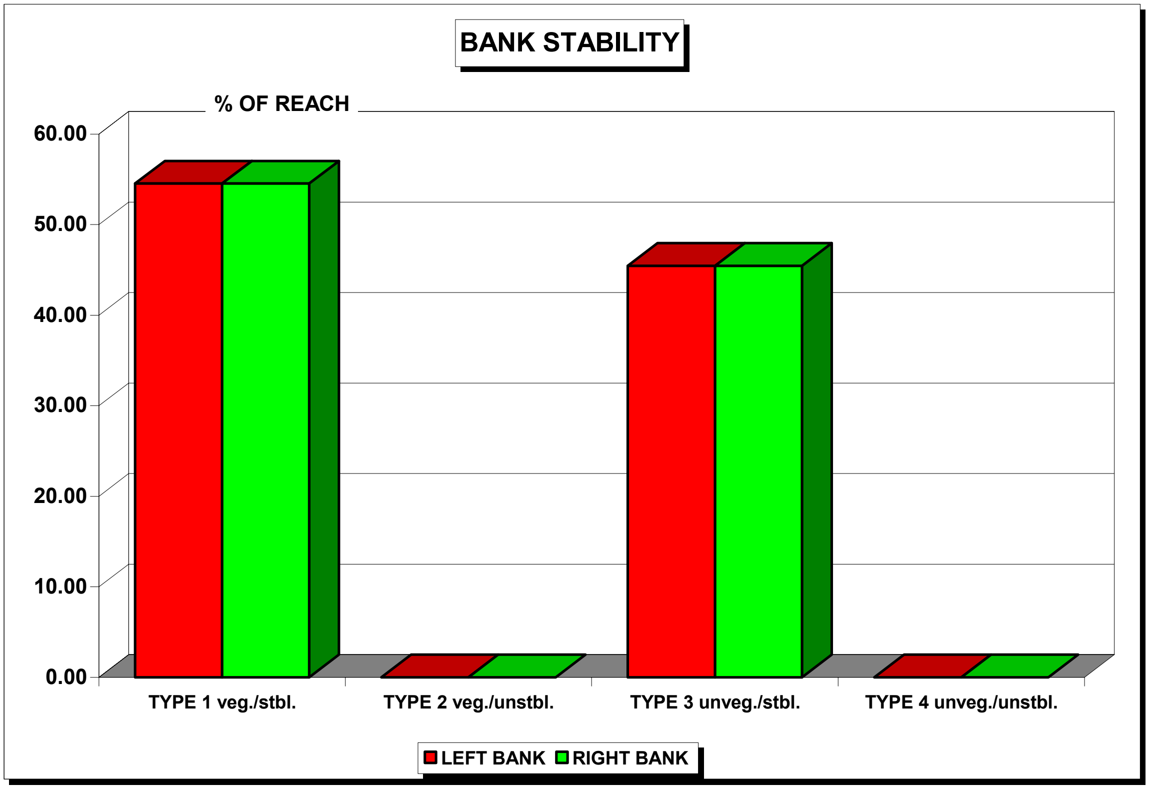
Table C2 (continued). Habitat mapping site FPR-HG on the Fryingpan River.

HABITAT TYPE ANALYSIS									
				TOTAL					TOTAL
NUMBER OF TYPE 2 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 9 HABITAT	0.00	0.00	0	0.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 3 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 10 HABITAT	0.00	5.00	0	5.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	89.26	0	45.45
NUMBER OF TYPE 4 HABITAT	2.00	0.00	0.00	2.00	NUMBER OF TYPE 11 HABITAT	0.00	1.00	0	1.00
% OF HABITAT	72.66	0.00	0.00	18.18	% OF HABITAT	0.00	10.74	0	9.09
NUMBER OF TYPE 5 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 12 HABITAT	0.00	0.00	0	0.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 6 HABITAT	1.00	0.00	0.00	1.00	NUMBER OF TYPE 13 HABITAT	0.00	0.00	0	0.00
% OF HABITAT	27.34	0.00	0.00	9.09	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 7 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 14 HABITAT	0.00	0.00	0	0.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 8 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 15 HABITAT	0.00	0.00	0	0.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	0.00	0	0.00
TOTAL NUMBER OF HABITAT	3.00	6.00	2.00	11.00	NUMBER OF GLIDES	0.00	0.00	2	2.00
TOTAL % OF HABITAT	100.00	100.00	100.00	100.00		0.00	0.00	100.00	18.18




BREAKDOWN OF HABITAT TYPES
% OF REACH
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
HABITAT TYPE


TOTAL AREA OF REACH
GLIDE
11368 sq. ft.
9.18 %
POOL
17864 sq. ft.
14.43 %
RIFFLE
94546 sq. ft.
76.38 %
total area of this reach = 123,778.00 sq. ft.


BANK STABILITY
% OF REACH
60.00
50.00
40.00
30.00
20.00
10.00
0.00
TYPE 1 veg./stbl.
TYPE 2 veg./unstbl.
TYPE 3 unveg./stbl.
TYPE 4 unveg./unstbl.
LEFT BANK
RIGHT BANK

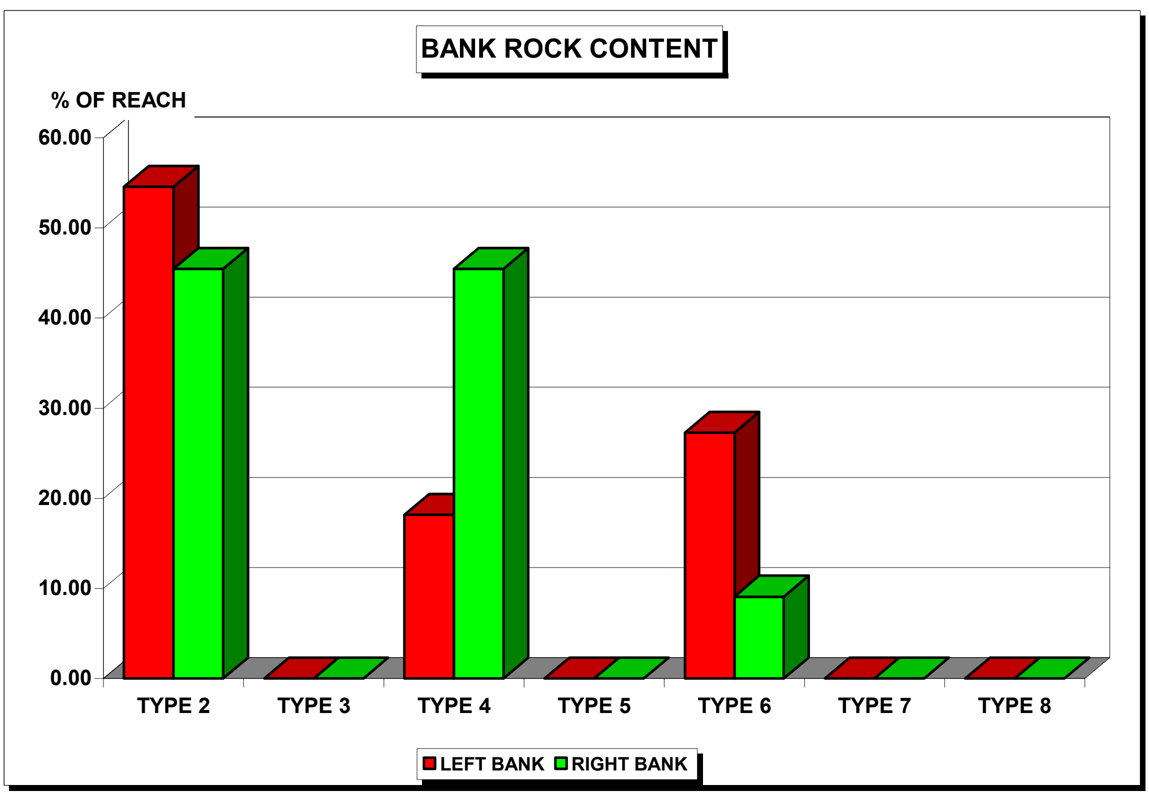

BANK ROCK CONTENT
% OF REACH
60.00
50.00
40.00
30.00
20.00
10.00
0.00
TYPE 2
TYPE 3
TYPE 4
TYPE 5
TYPE 6
TYPE 7
TYPE 8
LEFT BANK
RIGHT BANK

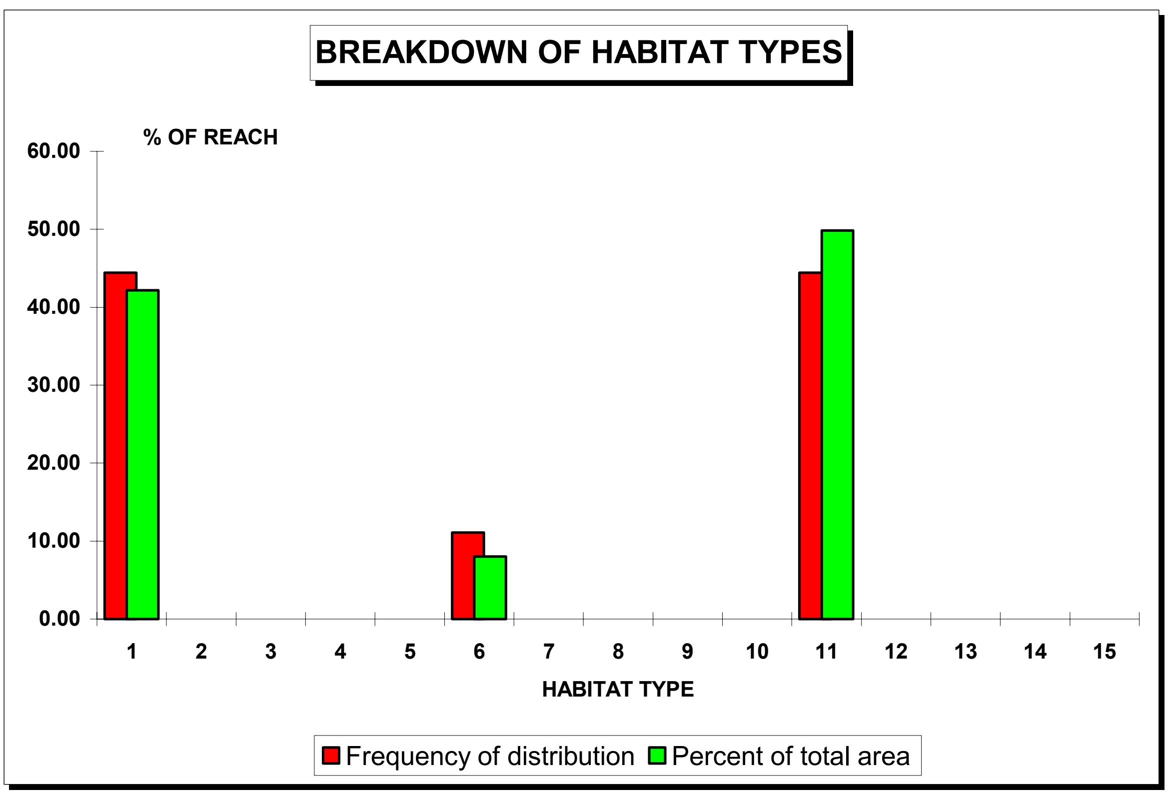
Table C3. Habitat mapping site FPR-LG on the Fryingpan River.

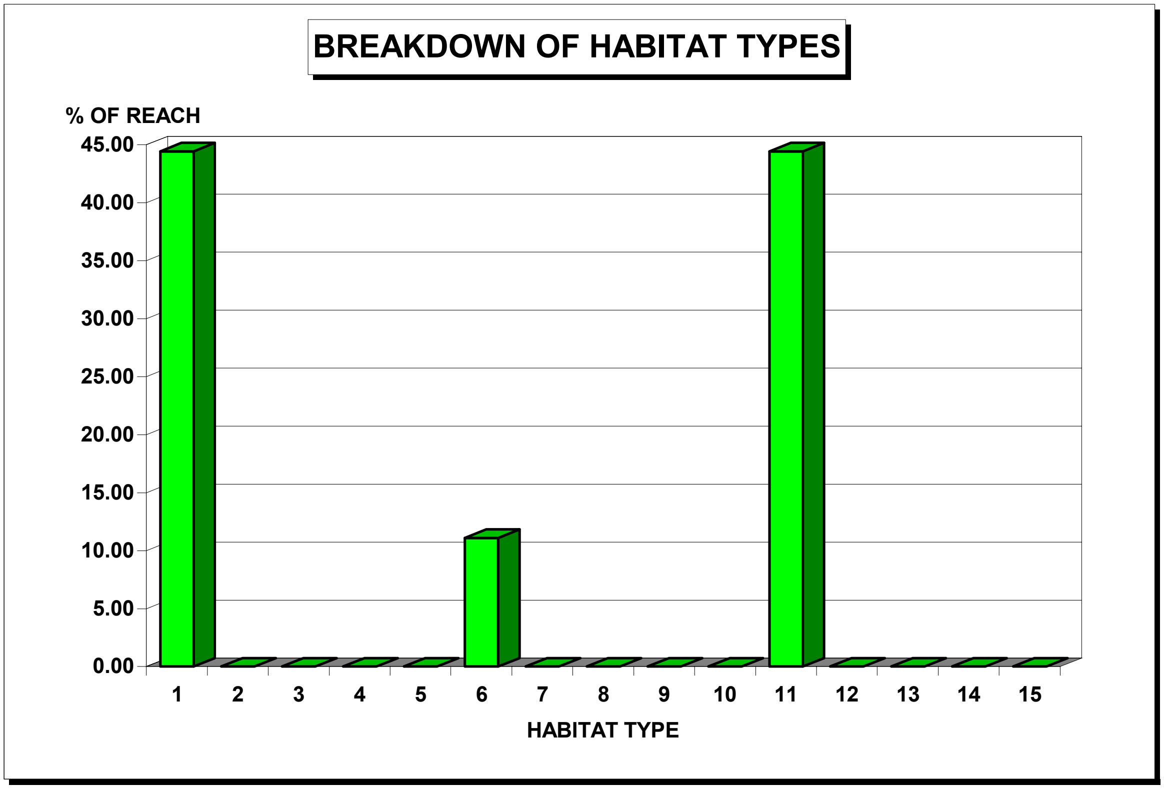
Fryingpan - FPR-LG

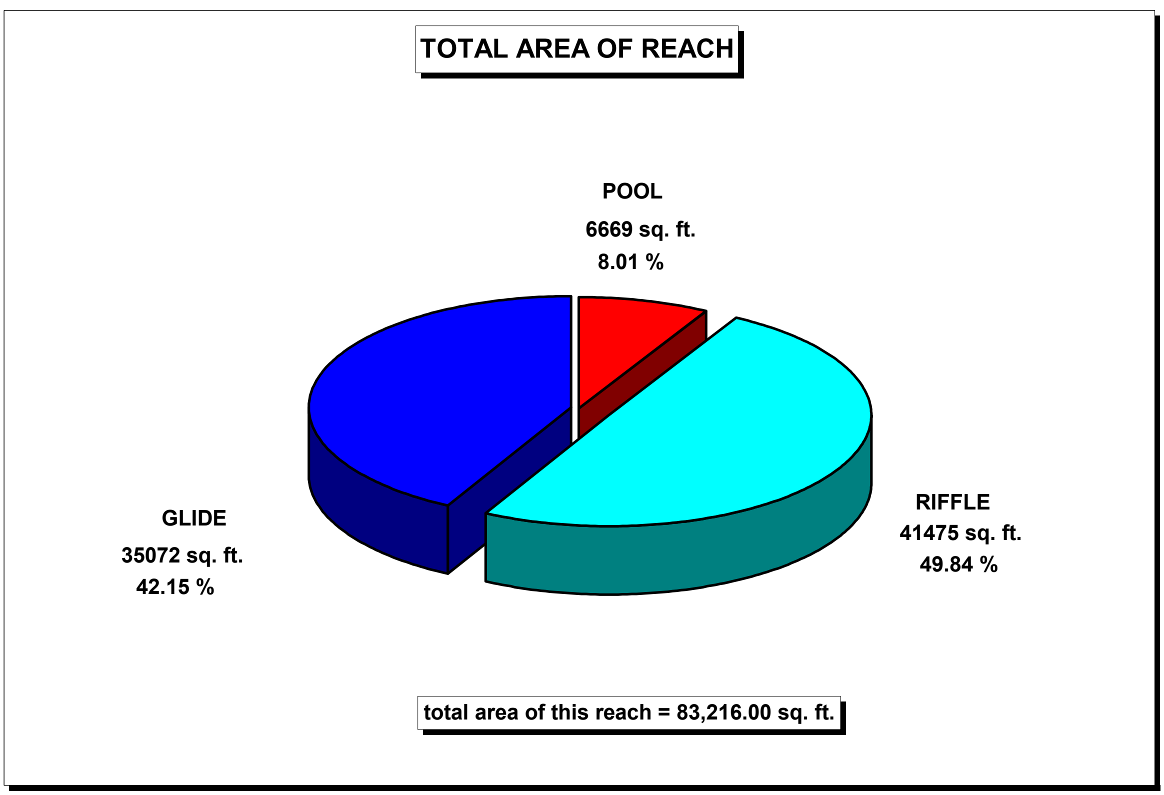
	POOL	RIFFLE	GLIDE	REACH TOTAL		POOL	RIFFLE	GLIDE	REACH TOTAL
TOTAL LENGTH OF HABITAT (	117.00	894.00	716.00	1727.00	TOTAL AREA OF HABITAT (s	6669.00	41475.00	35072.00	83216.00
AVERAGE WIDTH OF HABITAT	57.00	46.25	50.00	51.08	% OF TOTAL NUM. OF HABIT	11.11	44.44	44.44	100.00
AVERAGE RESIDUAL DEPTH	0.00	0.00	0.00	0.00	HABITAT TYPE	8.01	49.84	42.15	100.00
					AS A % OF TOTAL AREA				
AVERAGE DEPTH (ft.)	0.00	0.00	0.00	0.00					
					% OF TOTAL COVERS 2 - 5	0.00	0.00	0.00	0.00
TOTAL COVER TYPE 2 (sq. ft.)	0.00	0.00	0.00	0.00	TO TOTAL HABITAT				
AVE. TYPE 2 COVER PER UN	0.00	0.00	0.00	0.00					
					% OF CVR 2 TO TOTAL AREA	0.00	0.00	0.00	0.00
TOTAL COVER TYPE 3 (sq. ft.)	0.00	0.00	0.00	0.00	% OF CVR 3 TO TOTAL AREA	0.00	0.00	0.00	0.00
AVE. TYPE 3 COVER PER UN	0.00	0.00	0.00	0.00					
TOTAL COVER TYPE 4 (sq. ft.)	0.00	0.00	0.00	0.00	% OF CVR 4 TO TOTAL AREA	0.00	0.00	0.00	0.00
AVE. TYPE 4 COVER PER UN	0.00	0.00	0.00	0.00					
TOTAL COVER TYPE 5 (sq. ft.	0.00	0.00	0.00	0.00	% OF CVR 5 TO TOTAL AREA	0.00	0.00	0.00	0.00
AVE. TYPE 5 COVER PER UN	0.00	0.00	0.00	0.00					
					% BANK ROCK CONTENT				
% BANK STABILITY TYPE 1					TYPE 2				
LEFT BANK	100.00	75.00	100.00	88.89	LEFT BANK	0.00	0.00	0.00	0.00
RIGHT BANK	100.00	100.00	75.00	88.89	RIGHT BANK	0.00	0.00	0.00	0.00
% BANK STABILITY TYPE 2					TYPE 3				
LEFT BANK	0.00	0.00	0.00	0.00	LEFT BANK	0.00	0.00	0.00	0.00
RIGHT BANK	0.00	0.00	0.00	0.00	RIGHT BANK	0.00	0.00	0.00	0.00
% BANK STABILITY TYPE 3					TYPE 4				
LEFT BANK	0.00	25.00	0.00	11.11	LEFT BANK	0.00	0.00	0.00	0.00
RIGHT BANK	0.00	0.00	25.00	11.11	RIGHT BANK	0.00	50.00	0.00	22.22
% BANK STABILITY TYPE 4					TYPE 5				
LEFT BANK	0.00	0.00	0.00	0.00	LEFT BANK	0.00	0.00	0.00	0.00
RIGHT BANK	0.00	0.00	0.00	0.00	RIGHT BANK	0.00	0.00	0.00	0.00
					TYPE 6				
					LEFT BANK	100.00	50.00	50.00	55.56
					RIGHT BANK	0.00	50.00	75.00	55.56
TOTAL OF ERODING BANKS (	0.00	0.00	0.00	0.00					
					TYPE 7				
					LEFT BANK	0.00	0.00	0.00	0.00
					RIGHT BANK	0.00	0.00	0.00	0.00
TOTAL LRG. ORGANIC DEBRI	0.00	0.00	0.00	0	TYPE 8				
					LEFT BANK	0.00	50.00	50.00	44.44
					RIGHT BANK	100.00	0.00	25.00	22.22
AVERAGE OF SUBSTRATA TYPE FOR HABITAT ON THIS REACH									
PLANT DEBRIS	0.00	0.00	0.00	0.00	SAND\SILT	10.00	0.00	0.00	3.33
GRAVEL	30.00	2.50	12.50	15.00	RUBBLE	50.00	62.50	70.00	60.83
BOULDER	10.00	35.00	17.50	20.83	BEDROCK	0.00	0.00	0.00	0.00

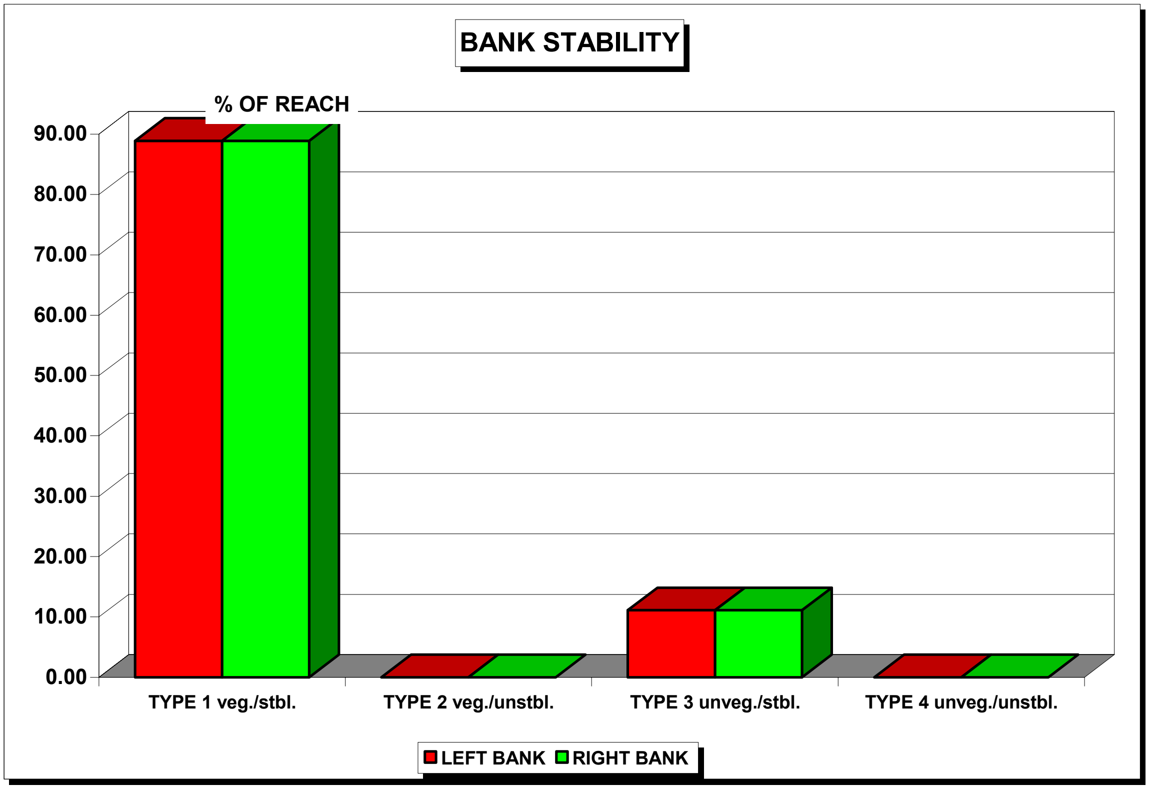
Table C3 (continued). Habitat mapping site FPR-LG on the Fryingpan River.

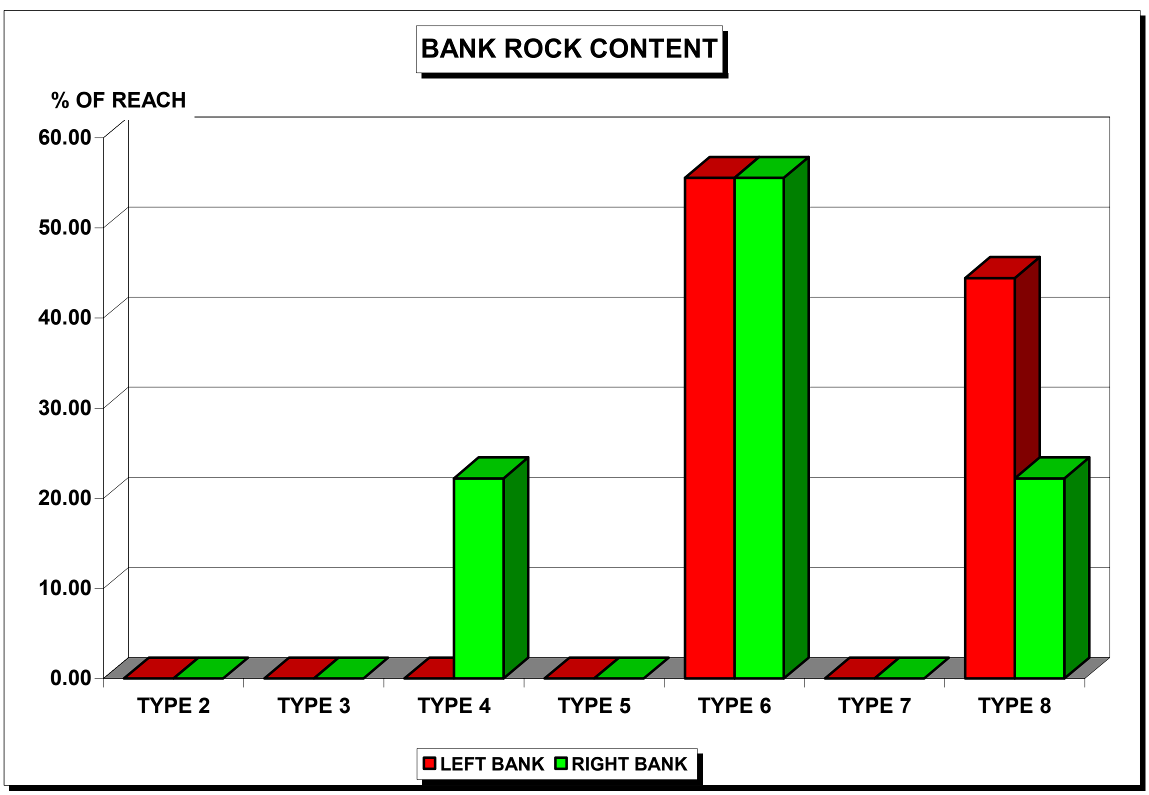
HABITAT TYPE ANALYSIS									
				TOTAL					TOTAL
NUMBER OF TYPE 2 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 9 HABITAT	0.00	0.00	0	0.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 3 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 10 HABITA	0.00	0.00	0	0.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 4 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 11 HABITA	0.00	4.00	0	4.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	100.00	0	44.44
NUMBER OF TYPE 5 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 12 HABITA	0.00	0.00	0	0.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 6 HABITAT	1.00	0.00	0.00	1.00	NUMBER OF TYPE 13 HABITA	0.00	0.00	0	0.00
% OF HABITAT	100.00	0.00	0.00	11.11	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 7 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 14 HABITA	0.00	0.00	0	0.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	0.00	0	0.00
NUMBER OF TYPE 8 HABITAT	0.00	0.00	0.00	0.00	NUMBER OF TYPE 15 HABITA	0.00	0.00	0	0.00
% OF HABITAT	0.00	0.00	0.00	0.00	% OF HABITAT	0.00	0.00	0	0.00
TOTAL NUMBER OF HABITAT	1.00	4.00	4.00	9.00	NUMBER OF GLIDES	0.00	0.00	4	4.00
TOTAL % OF HABITAT	100.00	100.00	100.00	100.00		0.00	0.00	100.00	44.44




BREAKDOWN OF HABITAT TYPES
% OF REACH
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
HABITAT TYPE


TOTAL AREA OF REACH
POOL
6669 sq. ft.
8.01 %
GLIDE
35072 sq. ft.
42.15 %
RIFFLE
41475 sq. ft.
49.84 %
total area of this reach = 83,216.00 sq. ft.


BANK STABILITY
% OF REACH
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
TYPE 1 veg./stbl.
TYPE 2 veg./unstbl.
TYPE 3 unveg./stbl.
TYPE 4 unveg./unstbl.
LEFT BANK
RIGHT BANK


BANK ROCK CONTENT
% OF REACH
60.00
50.00
40.00
30.00
20.00
10.00
0.00
TYPE 2
TYPE 3
TYPE 4
TYPE 5
TYPE 6
TYPE 7
TYPE 8
LEFT BANK
RIGHT BANK

Miller Ecological Consultants, Inc.
1113 Stoney Hill Drive, Suite A
Fort Collins, Colorado 80525
970-224-4505