Aquatic Physical Habitat and Hydrology in Abandoned Mined Land Studies

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ABSTRACT

Abiotic and non-chemical factors may limit the ability of a stream to respond to improvements in traditional water quality parameters because physical habitat and sediment characteristics may also limit the populations of aquatic animals. A reach of the Upper Animas River in southwestern Colorado is analyzed to show possible limits caused by physical habitat and sediment. Habitat for trout in the Animas River near Howardsville may be limited by high streamflows (because of high velocities) and by winter conditions (by velocities too high for winter habitat needs and low depths). The characteristics of the substrate (bed material) may offset the impacts of high velocities in the spring and the depths and velocities in the winter. The characteristics of the sediment in the river limit the winter habitat. In the river below Howardsville, large rocks provide shelter to trout during winter and spring runoff; fewer velocity shelters are available above Howardsville. Spawning gravels are available in the river below Howardsville but these gravels occur above the water surface of the fall spawning flows, but would be covered by spring spawning flows. Taken as a whole, it is expected the numbers and sizes of the fish would be larger below Howardsville than above if the number and size of velocity shelters is the only factor limiting fish populations. If the location of the spawning gravels is also a limiting factor, then the river spawning fish would be spring spawners, such as cutthroat trout. There are beaver ponds upstream of Howardsville that may provide fall spawning habitat for brook trout. An informal goal for the Upper Animas River is to establish a brown trout fishery. This is not a desirable goal because: (1) brown trout require that 50–70% of the river be pools and that the river must be shaded, however, there are few pools in the subject reach; and (2) brown trout spawn in the fall but the spawning gravels are high in the cross section where they can only be used by spring spawners. The existing Animas River requires a trout that can use the substrate in the main channel as habitat during most of the year. The trout most adapted to a river with few pools and gravel/cobble/rubble substrate is the brook trout. Cutthroat trout could also use the river because spawning gravels are available during spring runoff.

INTRODUCTION

As part of the Abandoned Mined Lands Initiative (AMLI) in the Upper Animas River Basin, Colorado, a reconnaissance study was done to determine if physical habitat may be a limiting factor for populations of aquatic animals. Toxicity is almost certainly the primary limiting factor on the populations of fish and other aquatic animals in the Upper Animas River ecosystem (Besser and others, 1998). However, physical habitat and hydrologic factors may restrict the ability of a recovery program to reach the species and fish biomass goals that may be established for the program. The program may then be considered ineffective because the goals were not reached. Consideration of physical habitat and hydrological limitations, in addition to toxicology, will result in improved fishery goals for recovery of the aquatic ecosystem.

Formal goals of a recovery program have not been established for the Upper Animas. The informal goal, apparently, is to establish a brown trout fishery in the reach of the Animas River downstream of Silverton. At this time, there are two third-order streams in the Upper Animas Basin supporting a fishery, the South Fork of Mineral Creek and the Animas River between Eureka and Silverton. There has been little mining-related impact on the South Fork of Mineral Creek, however, mining and milling

activities have had considerable impact on the Animas River between Eureka and Silverton. Although there have been no formal recovery goals established for the Eureka to Silverton Reach, this paper assumes a reasonable goal would be to improve the trout fishery in the Eureka to Silverton Reach and explore the possibility that physical habitat, along with the characteristics of the streamflow, may influence the fishery. Because of the informal brown trout fishery goal, comments will be made on factors that may limit a brown trout fishery and not limit a fishery for other trout. Physical habitat factors will be described first, then hydrologic factors will be integrated with the physical habitat to show the abiotic considerations that should be included in an AMLI aquatic restoration project. The hydrologic considerations are: (1) the magnitude and variation of the streamflows, and (2) the sediment in the stream bed (substrate).

In this paper, the biotic limitations caused by metals in the water and the impacts that past mining and milling have had on the physical characteristics of the river are ignored. Altering the physical habitat by: (1) changing the sediment load in the river through construction of a modified channel; or (2) causing a change in the riparian vegetation, are also ignored. A comprehensive study should include both of these elements. This paper concentrates on the existing river and its ability to produce habitat for fish. A comprehensive study would also include other aquatic animals, especially aquatic invertebrates. To reiterate, this paper is incomplete because direct toxicity, interrelations among toxicity, physical habitat, and sediment, and the effects of physical habitat modifications have not been considered. Another assumption is that the fishery restoration goal should include natural reproduction. Other alternatives include a 'put-and-take' fishery or a 'put-and-grow' fishery (stock fingerlings and let them grow to a catchable size).

The Upper Animas River is located in Southwestern Colorado where a number of studies are underway to understand the hydrology, toxicology, and physical aquatic habitat of the basin. The studies have an overlapping goal of demonstrating the importance of considering physical habitat factors when linking water quality, toxicity, and fish populations. The hydrology of the basin is described by Milhous (1998a). Background information on the Upper Animas Basin and the aquatic biology of the basin has been given by Besser and others (1998) and by Besser and others (1998). A toxicity study was described by Nimmo and others (1998). The reach of the Animas River between Eureka and Silverton has two characteristics: (1) a relatively low gradient section above Howardsville with beaver ponds and gravel substrate, and (2) a steeper reach downstream of Howardsville with cobble and rubble substrate and no beaver ponds. About midway between Howardsville and Silverton is a short section with rock walls, pools, and some gravel in backwater areas of the size needed by trout for spawning. There are some short sections with undercut banks in the reach above Howardsville. There is little shading of the Animas River between Eureka and Silverton.

PHYSICAL HABITAT FOR TROUT

A relationship between discharge and one representation of physical habitat in rivers was determined for the Animas River near Howardsville using the Physical Habitat Simulation System (Milhous and others, 1989). Specifics of the actual simulation used for the Animas River are given in Milhous (1998b). The function developed and the daily streamflows for a typical water year (1994), are given in Figure 1. The

Figure 1. The 1994 daily streamflows and the relation between habitat and discharge for trout in the Animas River near Howardsville.

annual discharge for 1994 was 97 cfs, which is equal to or exceeded 60% of the years; the maximum daily discharge was 879 cfs which is exceeded 27% of the years. In other words, the maximum discharge was relatively large in 1994, but the total volume was on the low side. The physical habitat function shown in Figure 1 is applicable to adult trout (rainbow, brown, brook, and cutthroat). The function is of reconnaissance quality, meaning there may be a small amount of habitat at the higher flows and as the flows approach zero because pools are not adequately represented in the model.

Comparing the trout habitat function to the streamflow indicates that both high and streamflows may limit trout habitat. The low flows shown in Figure 1 are representative of the flows in the winter. The minimum 7-day winter streamflow was 14.3 cfs in 1994 (exceeded by about 40% of the years) compared to a range for the 61 years of record of 10–21 cfs, with about two-thirds of the years having winter streamflows in the range of 11–17 cfs.

TROUT POPULATIONS AND HABITAT NEEDS

Brook trout are found in the reach of the Animas River upstream of Howardsville. Below Howardsville, brook trout, rainbow trout, and cutthroat trout have been collected (State of Colorado, 1992). The rainbow trout are probably a result of stocking in the early 1990's. The number of trout collected in October 1992 along the reach between Silverton and Eureka is given in Table 1. There were no trout found in the Animas River above Eureka. The trout biomass densities given in Figure 2 are from the same locations as in Table 1. The first three locations (A40a, A45, and A53) are above Howardsville and the last three (A53a, A55a, and A68) are below Howardsville. Residents of Silverton have reported catching trout in the reach near A55a. The biomass of brook trout is reduced at the two locations where other trout species are found, possibly caused by competition with the other trout species. Some of the habitat needs for each of the trout species considered in this paper are summarized in Table 2.

Trout use pools and undercut banks as resting places and as velocity shelters which allow the fish to conserve energy. When the pools are close to fast water, trout can rest in the pools and feed in the fast water. Trout will also use the gravel, cobble, and rubble in the river channel as resting places and velocity shelters (substrate shelters). If the number of pools and undercut banks are limited, the numbers and size of the trout will be limited to those using the channel. The sources used for Table 2 suggest that the size of the fish and the ability of the fish to use the substrate shelters and, therefore, the stream channel, is related to the percent of the substrate in the 100 to 400 mm size range.

The information in this section will be used in the discussion that follows.

HIGH STREAMFLOW LIMITS ON PHYSICAL HABITAT

The velocities in the Animas River are too high for optimal adult trout habitat when the streamflows are high. When the velocities are high, the fish must seek shelters and other ways of reducing their expenditure of energy. In such situations, the fish are considered to be under stress caused by a lack of appropriate physical habitat. An index to habitat stress has been developed and is described in detail by Milhous (1998b). The index is a measure of the stress on the fish that may be caused by higher velocities. As the velocities increase with an increase in streamflows, they will pass a threshold above which the habitat is not desirable but below which the index is zero. The index is analogous to the effects of floods for humans (and other terrestrial animals. Streamflows that are within the bank cause little or no stress on humans (a human habitat index would be zero). As the water over-tops the bank, the index would be greater than zero, but not large (analogous to human stress that might occur and may be of slight concern but usually not a significant concern). As the habitat stress index increases, the impact of the high flows on the fish and invertebrate populations could be significant (the same as the impact of major floods on human populations). A duration

Table 1. Numbers of trout collected in October 1992 in the Animas River between Eureka and Silverton. Data from the State of Colorado (1992).

Site ID	Brook	Rainbow	Cutthroat	Location
	(number of fish/1,000 ft of stream)			
A40a	46.7			above Maggie Gulch
A45	136.7			above P&G tailings
A53	63.6			below P&G tailings
A53a	61.4			below Cunningham Gulch
A55a	21.0[a]	1.0	1.0	above Arrastra Gulch
A68	34.2	36.8		above 14th Street Bridge

[a]The brook trout sample at A55a included fry.

.**Figure 2.** Density of trout measured in October 1992 in the Animas River between Eureka and Silverton. Data from the State of Colorado (1992).

curve for the habitat stress index for the Animas River near Howardsville is given in Figure 3.

Application of the habitat stress index to the Animas River demonstrated that in slightly more than 50% of the years, there was no real habitat stress on the trout populations caused by high streamflows; however, during about 20% of the years, the habitat stress could be important. For the remaining 30% of the years, some habitat stress occurs.

This suggests that there could be variation in the trout population caused by variation in the streamflows alone. This has been demonstrated for the Gunnison River, which is just north of the Animas Basin (Nehring and Miller, 1987). In the Gunnison River, higher streamflows caused a significant loss of young-of-year trout which reduced the population of adult trout in subsequent years.

Trout adjust to higher velocities by using velocity shelters where the velocity is significantly lower than in the surrounding water. Velocity shelters are important for allowing fish to escape habitat stress caused by high streamflows. In many rivers the most important velocity shelters are pools, root wads, and undercut banks on the sides of the stream, and large bed elements such as cobbles and boulders on the stream bed (Raleigh, 1982). There are few pools and undercut banks along the Animas River between Eureka and Silverton. Small pools are found in the vicinity of Arrastra Creek and some undercut banks above Howardsville. Most, but not all, of the velocity shelters in the reach are cobbles and boulders. The size of fish that can be sheltered by boulders and cobbles is related to the size of the armour on the bed surface. In the section on habitat needs (above) the percent of the bed surface with sizes in the range of 100 to 400 mm was the amount of the stream bed that can be used as velocity shelters. The size of material on the bed surface in the range of 100 to 400 mm is given in Table 3.

Table 3 shows there are good velocity shelters within the river channel below Howardsville but not above, also the velocity shelters are large. The fish would be expected to be larger below Howardsville than above. The population and biomass data suggests, but does not prove, that this may be the case.

Table 2. Habitat characteristics and size of three trout species found in the Upper Animas River watershed and for brown trout. Source: Scott and Crossman (1973); Raleigh (1982); Hickman and Raleigh (1982); Raleigh and others (1984).

Trout species	Spawning period	Average length (inches)	% pools	Shading requirements
Cutthroat	spring	12–15	50	
Brook	fall	10–12	50	intermediate
Brown	fall	16	50–70	needed
Rainbow	spring	12–18	40–60	less important

Figure 3. Duration diagram for an annual index to the habitat stress introduced to the trout in the Animas River, Colorado, by high velocities during high flow periods.

There are beaver ponds along the river above Howardsville but none below. The beaver ponds have water flowing through them during high flows, thus providing velocity shelters for the brook trout present above Howardsville.

WINTER STREAMFLOW LIMITS ON HABITAT

The winter streamflows are very low and little physical habitat is available in the Animas River. Any trout in the river would be expected to be under stress caused by the winter conditions. The location of winter habitat is similar to the velocity shelters during spring runoff with two exceptions: (1) the river has essentially no edge (root wads and undercut banks) either because of ice and snow, or the edge of the water is away from the banks, and (2) the substrate (bed material) can be a shelter during the winter. The details of the winter use of the stream bed are described by Meyer and Griffith (1997).

The best winter physical habitat occurs when the streamflows are reasonably stable (Raleigh, 1982). The variation in streamflows during the winter in Animas River is not large because the precipitation is almost all snow during the winter. Between 16 November and 31 March, the median value of the 7-day minimum streamflow is 14 cfs with a median ratio between the 7-day maximum and 7-day minimum streamflow of 1.8. The maximum ratio is 3.9, but two-thirds of the years have a ratio of less than 2.0 (90% less than 2.4). Raleigh (1982) reports the base flow (in this case, winter flows) that are at least 50% of mean annual discharge provide excellent trout habitat, between 25% and 50% fair habitat, and less than 25% poor habitat. The median winter flow in the Animas River at Howardsville is 17% of the median annual discharge.

Voids in the substrate are used by wintering trout as resting locations to avoid expending energy. The specific weight and porosity for a sample collected upstream of Howardsville was determined and compared to the samples from two other rivers in Table 4. Fines (sediment less than 3 mm) are considered to be undesirable in the bed material used as trout habitat. The percent of fines in the bed material is also given in Table 4. The data show the Animas River has less voids than the other two unregulated rivers, but the percent of fines is similar to Soda Butte Creek. The habitat value of the substrate in the Animas

Table 3. The percent of velocity shelters and the maximum size of the surface layer at four locations in the Animas River between Eureka and Silverton. The percent shelters is the difference between the percent of the surface less than 400 mm and more than 100 mm. D/S is downstream of Howardsville and U/S is upstream.

Location	% shelters	Median size of shelters (mm)	Maximum size (mm)
U/S 1	34	123	145
U/S 2	0	---	95
D/S 1	60	142	220
D/S 2	78	171	430

River is probably lower than in the other rivers because the mixture of low porosity and a relatively high percentage of fines means the bed material is firmer than the other two rivers. (In relative terms, Oak Creek is loose, the Animas River is firm, and Soda Butte Creek is intermediate.) The relatively firm substrate and high percentage of fines indicate that the bed material in this reach of the Animas River is probably poor winter trout habitat.

During winter, the streamflows are lower than in the fall. The informal target species is brown trout, which spawn in the fall (October) and the fry leave the redds just before spring runoff. An analysis of the change in width between October and the minimum width during the winter showed that, if the redds were uniformly distributed in the cross section, between 71 and 94% of the redds created in October would survive the winter. The problem is that spawning gravels are not uniformly distributed in the cross section. In fact, no bars or spawning gravels have been found in the subject reach of the Animas River that would be available in October. Spawning gravels have been found near the junction of the Animas River with Arrastra Creek, but these were located above the elevation of the October flows. This means that reproductive success of brown trout would not be likely in the reach between Silverton and Eureka. The spawning gravels are in a location where they could be used by spring spawners, such as rainbow and cutthroat trout. Brook trout are also fall spawners but they probably use the small pockets of gravel that can be found among the beaver ponds.

DISCUSSION

The fish biomass is larger above Howardsville probably because of the existence of beaver ponds and some undercut banks. The data suggest, somewhat unclearly, that the fish are smaller above Howardsville than below, possibly because of the size of the velocity shelters.

The question posed at the beginning of this paper was the desirability of attempting to design a recovery program that had a goal of establishing a brown trout fishery. The goal of establishing a brown trout fishery as part of the aquatic ecosystem restoration effort recovery is rejected for the two reasons given below.

1. Brown trout require that 50–70% of the river are pools and the river must be shaded. There are few pools and the river has little shade.
2. Brown trout spawn in the fall but the spawning gravels are high in the cross section where they can be used by spring spawners but would be unavailable for fall spawners. There probably are some spawning gravels near the beaver ponds, but the environment near the beaver ponds is probably not usable by brown trout (small size of substrate and few to no pools).

The present Animas River requires a trout that can use the substrate in the main channel as habitat during most of the year. The trout most adapted to a river with few pools and gravel/cobble/rubble substrate is brook trout (Raleigh, 1982). Cutthroat trout could also use the river because spawning gravels are available during spring runoff.

Table 4. Specific weight and gravity, porosity, and percent less than 3 mm of the bed material of three unregulated rivers.

Stream	Specific weight (lb/ft3)	Specific gravity	Porosity	% ≤3 mm
Oak Creek, Oregon	105	2.85	0.41	13
Soda Butte Creek, WY-MT				
Upstream	108	2.65	0.35	16
Downstream	104		0.37	23
Animas River, Colorado				
above Howardsville	135	2.80	0.22	20

The objective of this paper was to demonstrate that physical habitat must be considered in the formulation of fishery goals for AMLI and other aquatic restoration efforts. Physical habitat considerations alone could limit or eliminate some species of aquatic animals as is probably the case for the brown trout in the Animas River. The velocity shelters are mostly associated with the gravel/cobble/rubble substrate which means smaller trout, such as brook and cutthroat, should be selected as the target species for habitat restoration.

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