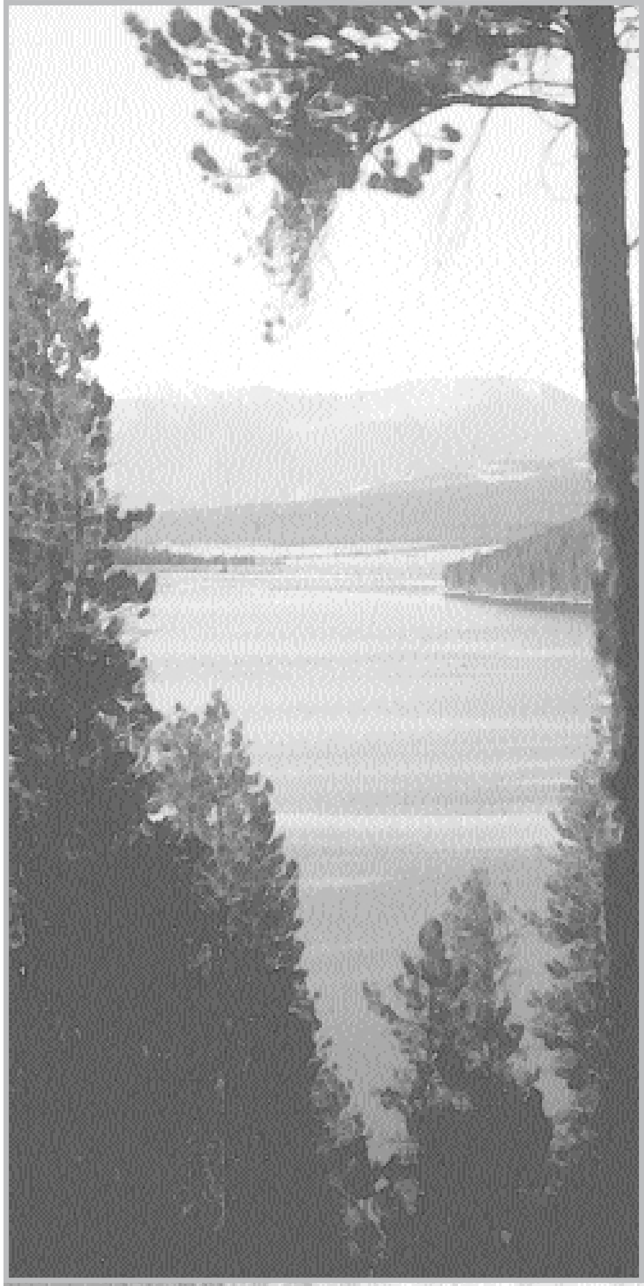
Arkansas River Water Needs Assessment



Section 5.
Natural Resource Assessment

By:

Clay Bridges, Bureau of Land Management
Mark Elkins, Colorado Division of Wildlife
Dave Gilbert, Bureau of Land Management
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July 2000

Preface

Each section of the *Arkansas River Water Needs Assessment* contains information that may be useful for a variety of purposes. However, each section is just a part of the overall *Arkansas River Water Needs Assessment* and the information contained therein should not be taken out of context or considered in isolation. Decisions regarding riverflows and reservoir levels should consider the findings of the assessment as a whole, while also recognizing that such decisions are limited by the necessity to supply water for domestic, agricultural, and other uses in the basin consistent with existing water rights held by water users. A summary of the entire assessment can be found in Section 1 of this report.

Acknowledgments

This assessment could not have been completed without an extensive amount of coordination and cooperation among the participating agencies. The following individuals participated in interagency workgroups throughout the assessment and are recognized for the significant amount of time and resources they invested in conducting various studies and documenting the findings in this report:

> Water Workgroup: Bill Carey (Bureau of Land Management), John Gierard (formerly Bureau of Reclamation, now Western Area Power Administration), Dan Muller (Bureau of Land Management), Roy Smith (Bureau of Land Management), Steve Swanson (Bureau of Land Management), and Steve Witte (Colorado Division of Water Resources).
>
> Biological Workgroup: Clay Bridges (Bureau of Land Management, retired), Mark Elkins (Colorado Division of Wildlife), Dave Gilbert (Bureau of Land Management), Doug Krieger (Colorado Division of Wildlife), Greg Policky (Colorado Division of Wildlife), and Rich Roline (Bureau of Reclamation).
>
> Recreation Workgroup: Mike French (Colorado Division of Parks and Outdoor Recreation), Steve Reese (Colorado Division of Parks and Outdoor Recreation, retired), Mike Sugaski (U.S. Forest Service), and Dave Taliaferro (Bureau of Land Management).
>
> Editorial and Graphics Workgroup: Linda Hill (Bureau of Land Management) and Jennifer Kapus (Bureau of Land Management).

The assessment team was guided throughout the process by a management advisory group, which was established through a formal memorandum of understanding. The members of this group are recognized for being responsive to the study team's needs and providing helpful advice, on numerous occasions, regarding controversial issues that arose during the study: Levi Deike (Bureau of Land Management), Dave Giger (Colorado Division of Parks and Outdoor Recreation), Alice Johns (Bureau of Reclamation), Dan McAuliffe (Colorado Department of Natural Resources), and Donnie Sparks (Bureau of Land Management).

During the assessment process, the services of several individuals were acquired through contracts and an interagency agreement. The timely deliverables, extraordinary assistance, and dedication to the assessment of these individuals under these formal arrangements were extremely appreciated. Kip Bossong (U.S. Geological Survey) compiled and analyzed a large amount of historic data, which significantly aided the streamflow analyses in this report. Bruce DiGennaro (formerly EDAW) provided a wealth of insight and strategy towards completing the recreation user surveys and assessment. Teresa Rice (formerly University of Colorado Natural Resource Law Center) completed an enormous amount of research on water uses and institutions. Both Bruce and Teresa wrote reports that are of such quality they could stand alone as exhaustive treatments of their respective assignments.

Certain individuals who were responsible for initiating preliminary discussions and studies leading to this assessment deserve special thanks for their vision and support. They include: Mac Berta (Bureau of Land Management, retired), Jim Fogg (Bureau of Land Management), Jack Garner (Bureau of Reclamation), Larry MacDonnell (formerly University of Colorado Natural Resource Law Center), Steve Norris (Colorado Division of Wildlife), Don Prichard (Bureau of Land Management), Donnie Sparks (Bureau of Land Management), Steve Vandas (U.S. Geological Survey), and Pete Zwaneveld (Bureau of Land Management).

Several individuals provided the team with helpful insight and reviews of documents. In particular, we acknowledge the following individuals for their commitment to participating in meetings and providing review comments:

Legal and Institutional Analysis Advisory Group: Carl Genova (Southeastern Colorado Water Conservancy District), Denzel Goodwin (Upper Arkansas River Water Conservation District), Alan Hamel (Pueblo Board of Water Works), Steven Kastner (Colorado Division of Water Resources), Phil Saletta (Colorado Springs Utilities), and Tom Simpson (Southeastern Colorado Water Conservancy District).

Biology, Hydrology, and Recreation Peer Reviewers: Mark Butler (U.S. Fish and Wildlife Service), Paul Flack (Colorado Division of Parks and Outdoor Recreation), Bill Hagdorn (Bureau of Land Management), Mike Lewis (U.S. Geological Survey), Rich Niemeyer (National Park Service), Scott Schuler (U.S. Forest Service), and Jay Thompson (Bureau of Land Management).

Advisor on Reservoir Operations: Tom Gibbens (Bureau of Reclamation, retired).

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Section 5. Natural Resource Assessment

Resource Values

The purpose of this section is to describe the aquatic and terrestrial biota found in and associated with the Upper Arkansas River Basin and its associated reservoirs, and to highlight those species and their life stages that are either dependent on flow (river) or water elevation (reservoirs). The resource values are considered by habitat type: the Arkansas River corridor, the coldwater upper reservoir systems (Twin, Turquoise, and Clear Creek), and the warmwater lower reservoir system (Pueblo). The relationship of specific resource values to water is evaluated using data from a number of reports and studies that are listed in the references at the end of this chapter. Some of the relevant information used in this section is general in nature and was obtained from published reports on species life histories, habitat, freshwater ecology, limnology, and hydrology. Other data is specific to actual data collections and studies completed within the Upper Arkansas River Basin by the U.S. Bureau of Land Management (BLM), U.S. Bureau of Reclamation (BOR), U.S. Forest Service (USFS), Colorado Division of Wildlife (CDOW), and Colorado State University (CSU).

Aquatic and terrestrial habitat varies considerably within the study area. Elevations range from almost 10,000 feet above sea level at Turquoise Reservoir to less than 5,000 feet at Pueblo Reservoir. The terrain consists of mountainous topography in the upper basin, canyon reaches along the upper river corridor, and a rolling valley plains ecosystem below Cañon City. Dominant vegetation consists of conifers in the mountains, riparian vegetation such as cottonwoods and willows within the river corridor, and pinon/juniper on the river uplands. The river is characterized by six distinct aquatic habitat types that are defined by river geomorphology. These habitat types are intermixed within the study area.

The complexity of river habitat and landforms provides a rich diversity of wildlife within the basin. Approximately 25 fish species have been identified by the Colorado Division of Wildlife (CDOW) as inhabiting the study area. These include members of the trout, minnow, catfish, bass, and perch families. Terrestrial wildlife species range from amphibians and reptiles, to a variety of mammals and birds. There are a number of species within the study area that are Federally listed as threatened or endangered, including the greenback cutthroat trout, bald eagle, peregrine falcon, and Mexican spotted owl. The only State listed wildlife species occurring in the study area are the southern redbelly dace and possibly the boreal toad.

The resource values evaluated were selected based on their importance to the ecology of the Arkansas River Valley and to users of those resources, and on their perceived dependence on riverflows or reservoir water elevations/fluctuations. The resource values considered were:

Fisheries
~ Lake trout, rainbow trout, and primary/secondary production (Twin, Turquoise, and Clear Creek Reservoirs)
~ Black bass and crappie (Pueblo Reservoir)
~ Brown and rainbow trout (Arkansas River)

Wildlife
~ Waterfowl (all reservoirs)
~ Raptors, including bald eagles, golden eagles, osprey, and peregrine falcons (river and reservoirs)
~ Wading birds and shore birds (river and reservoirs)
~ Bighorn sheep (river and reservoirs)
~ Amphibians and reptiles (river and reservoirs)

Riparian Wetlands
~ Riparian woody species (Arkansas River)
~ Shoreline vegetation (reservoirs)

Fisheries

Coldwater Reservoir Habitat and Biota

Twin Lakes Reservoir and Turquoise Reservoir were constructed and are operated as part of the Fryingpan-Arkansas Project administered by the BOR. Both reservoirs are situated on public lands controlled by the USFS and have recreational amenities including campgrounds, day-use parking and picnic areas, and boat ramps. Twin Lakes Reservoir was formed from two natural mountain lakes on Lake Creek that were enlarged to a single reservoir with two subbasins. The combined reservoir is at an elevation of 9,202 feet and has a surface area of 2,767 acres at capacity. Turquoise Reservoir is a 1,789-surface-acre impoundment located on the Lake Fork of the Arkansas River at an elevation of 9,869 feet. Both reservoirs are considered to be oligotrophic to ultraoligotrophic (low biotic productivity) due to their water source, location within granitic basins, high elevation, and high flushing rates.

Clear Creek Reservoir is located on Clear Creek, north of Buena Vista, Colorado, at an elevation of approximately 8,880 feet. The 439-surface-acre impoundment is operated by the Pueblo Board of Water Works, and is managed as a State Wildlife Area through a lease agreement with the CDOW. This reservoir is not part of the Fryingpan-Arkansas Project, but is an important component of water management within the study area.

Lake Trout

This species is found only in Twin and Turquoise Reservoirs and the populations are supported by natural reproduction and some supplemental stocking. Lake trout are sensitive to reservoir water surface elevations and fluctuations at several stages during their life. Their dependence on water depth is particularly important during spawning, incubation of eggs, and development of young fry, but water fluctuation is also a critical aspect for feeding and for the prey base. This species has been studied extensively in Twin Lakes, but life history attributes are likely similar for lake trout in Turquoise Reservoir (Griest 1976).

Lake trout, or mackinaw trout as they are sometimes called, are highly prized by sport anglers because they are a long-lived fish and can reach substantial sizes. The record lake trout in Colorado is 38.4 pounds. Lake trout older than 25 years are common. Growth rates for lake trout vary due to many factors (e.g., age, strain, location, food, etc.). Carlander (1969) found that the weight of lake trout increases at a rate greater than the cube of the length. He also found that the age of lake trout at first spawn is related to growth rates. Where the growth rate is slow, maturity may not be reached until age 17. With rapid growth rates, males may reach maturity by age 5 and females at age 6. Griest (1977) found lake trout in Twin Lakes to mature over a period of years. In other words, 20.9 percent of age 4 males are mature and 100 percent of males reach maturity by age 7. Comparatively, 8.1 percent of age 4 females are mature and 100 percent of females reach maturity by age 9.

Lake trout select spawning areas in shoreline habitat. Therefore, the success of reproduction and egg incubation is susceptible to water level decreases from October to June. Historically, Fryingpan-Arkansas Project operations during this period are characterized by reservoir drawdown at Twin Lakes and Turquoise Reservoirs. Lake trout are considered lacustrine spawners and spawn during October and November in Twin Lakes (Nolting 1968; Walch 1979). Frequently, this spawn seems to occur with fall turnover. Lake trout broadcast eggs and milt over a spawning bed. The prefer substrate that is cobble, rubble, or boulders with good interstitial spacing, but they have been known to use sand and silt bottoms. Spawning depths in lakes have been reported to range from 5.9 inches to over 180.5 feet (Carlander 1969). Nolting (1968) reported lake trout spawn at 6.6- to 32.8-foot depths and prefer temperatures near 47.3 °F in Twin Lakes. Walch (1979) located spawning lake trout at similar depths, 4.9-39.4 feet, in Twin Lakes. The key to a successful spawn in lakes or reservoirs is that the spawn depths remain below natural or human-caused drawdown levels to prevent exposure of eggs (Bergerson and Maiolie 1981). Successful incubation and hatching of eggs deposited in spawning areas (5- to 35-foot water strata) will be increased by restricting drawdowns from October to March to no more than 10 feet (from October 1 water elevations) at Twin Lakes and Turquoise Reservoirs. Most spawning activity takes place between dusk and 11 p.m. (Carlander 1969). Lake trout do not spawn every year, but may spawn once every 2 or 3 years (Burr 1987). Nolting (1968) reported spawning success in Twin Lakes, primarily on the south shore and in the north Bay. Walch (1979) found spawning lake trout in the eastern two-thirds of the lower lake and found that they did not use the powerplant area. Hatching likely occurs in February or March in Twin Lakes, with fry migrating to deeper water by June (DeRouche 1969).

Between June and October, lake trout are less likely to be directly affected by water fluctuations (however, their food base may be). Lake trout are highly mobile and usually occur wherever water temperatures are favorable. Overall, Walch (1979) determined that, in the summer, lake trout preferred deeper areas of lower Twin Lakes, where the water temperature is cool, and most fish were found within 9.8 feet of the bottom. They were found at depths where temperatures averaged 47.3 50.9 °F in late summer and fall. Few fish moved into water warmer than 53.6 °F, except to forage. Shoreward movements occurred year-round, usually during the day and just prior to sunset in the winter. Most fish exhibiting shoreward movement during the ice-free season were large (over 21.7 inches), while all fish, regardless of size, moved inshore in the winter.

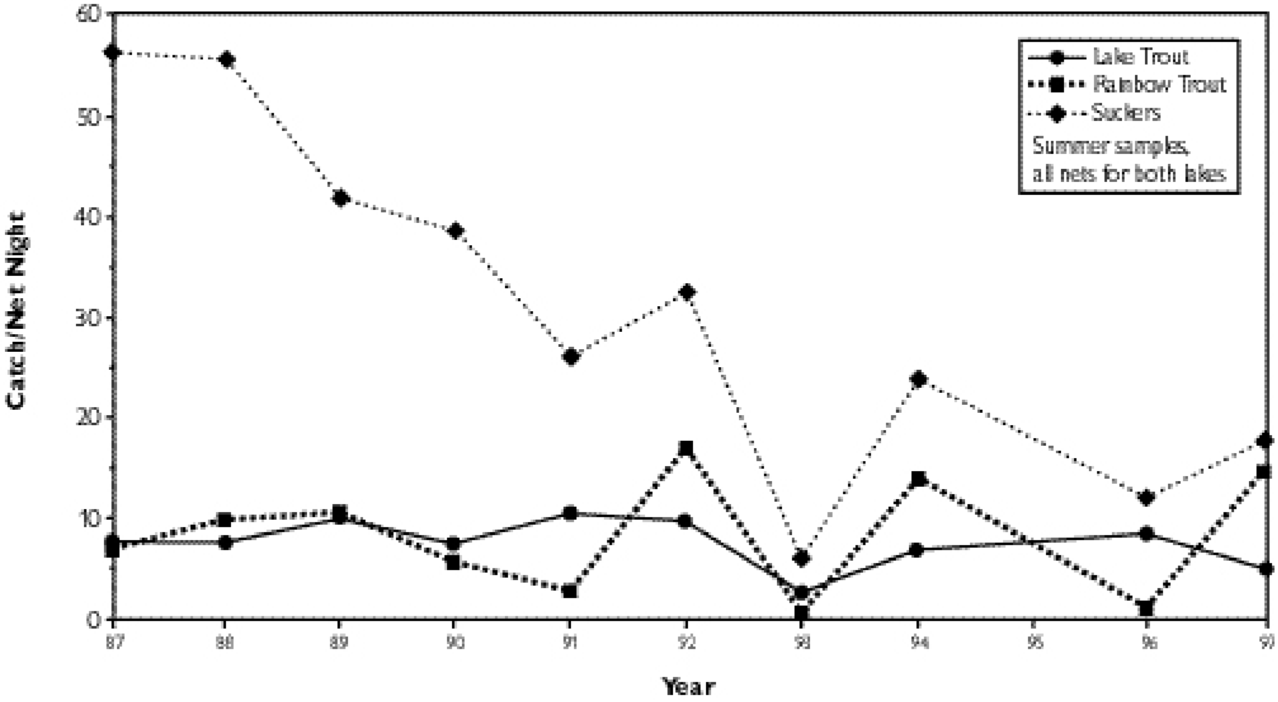
Fish prey for lake trout is limited in both Twin Lakes and Turquoise Reservoirs. This means that primary and secondary productivity is a much more important component for their food base. Literature suggests that lake trout feed on the most abundant food available. As juveniles, they feed primarily on small crustaceans, macroinvertebrates, or small fish, switching to primarily a fish diet as they mature. Griest (1977) reported that lake trout growth rate slowed between ages 5 and 8 at Twin Lakes. This corresponds to a shift in preferred forage. Lake trout less than age 5 utilize zooplankton and macroinvertebrates, and those over age 8 prefer fish for forage. Few lake trout over 16.9 inches (approximately age 6) are present in either Twin Lakes or Turquoise Reservoir. Large forage is not available in sufficient quantity to recruit many lake trout over age 6. This is directly related to the poor productive capacity of these reservoirs, beginning at the lowest trophic levels of the food chain. Water level variability impacts on base production is discussed in more detail below.

A population assessment of lake trout at Twin Lakes indicates that their numbers have declined with water management changes related to operations of the Mt. Elbert pumped storage project. Annual standardized gill net surveys conducted by the CDOW reveal that lake trout numbers have stabilized at low levels, but only with supplemental stocking since 1985 (Figure 5-1). Approximately 20,000, 3.9-inch lake trout were planted annually from 1985 to 1993, with the exception of 1989 and 1991. The number of fingerlings stocked was reduced to 12,000 annually from 1994 to 1996 in response to the lake's decreasing carrying capacity. Hydroacoustic studies conducted by BOR in 1980, 1993, and 1994 also show a decline in the lake trout fishery in Twin Lakes Reservoir after the Mt. Elbert plant began operation (Mueller and Hiebert 1996). Restrictive harvest fishing regulations, regardless of type, have not influenced lake trout size structure, providing further evidence of the impact of environmental/water factors controlling the fish community.

Lake trout numbers have fluctuated considerably at Turquoise Reservoir since 1987 despite steady annual stocking of 16,000, 3- to 5-inch fish, although no fish were planted between 1988 and 1990 (Figure 5-2). There is no lake trout fishery at Clear Creek Reservoir.

FIGURE 5-1

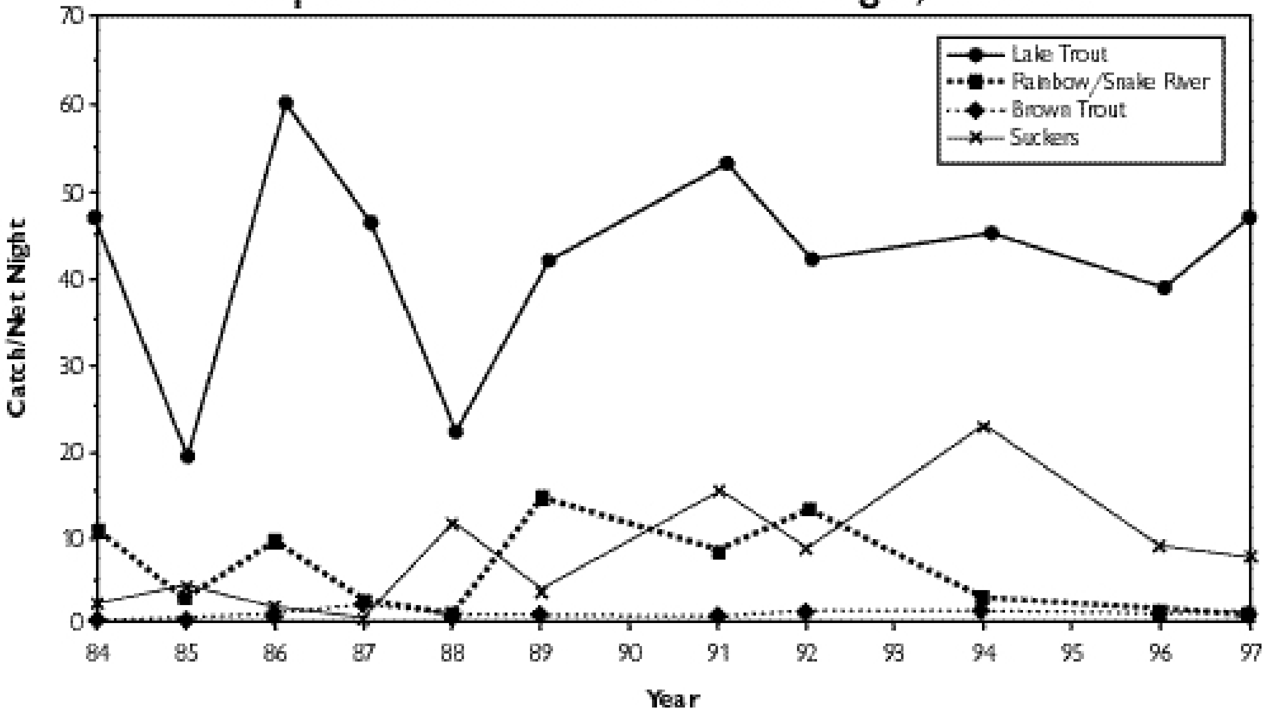
Twin Lakes Reservoirs Catch/Gill Net Night, 1987-1997



Note: For sampling purposes, a number of gill nets are set in the lake on the same night each year. The left axis represents the average number of fish from each species found in each of the gill nets when they are retrieved from the lake.

FIGURE 5-2

Turquoise Reservoir Catch/Gill Net Night, 1984-1997



Note: For sampling purposes, a number of gill nets are set in the lake on the same night each year. The left axis represents the average number of fish from each species found in each of the gill nets when they are retrieved from the lake.

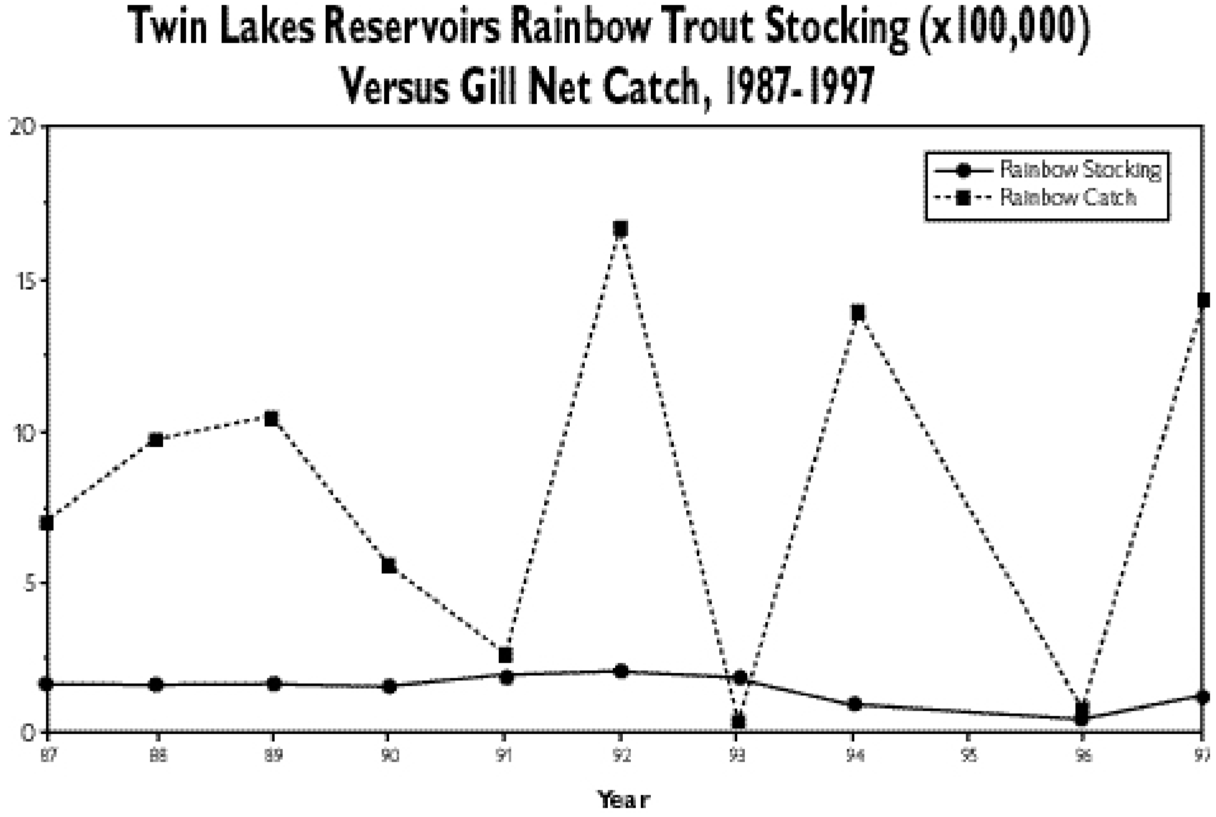
Rainbow Trout

This species is found in all three coldwater reservoirs and is the dominant sport fish. Very little natural reproduction occurs and populations are supported by stocking of catchable (10-inch) and subcatchable (7-inch) fish. These fish are typically stocked regularly during the fishing season from after ice-out (mid- to late May) to September. They are sought by anglers during both the regular fishing season and ice fishing season at Twin Lakes Reservoir and Clear Creek Reservoir.

Rainbow trout feed on zooplankton and invertebrates that are typically associated with the littoral areas of the reservoirs. Water elevation and fluctuation determine the amount of available littoral area and also have some impact on the productivity of those areas for food for rainbow trout. In some instances, the depth of the reservoir outlet is important to the potential loss of fish from the reservoirs.

At Twin Lakes, rainbow trout numbers fluctuated considerably from 1984-1993 based on CDOW gill net surveys (Figure 5-3) in spite of relatively consistent annual stocking of 160,000, 7- to 10 inch fish during this time period. Predation of rainbow trout by lake trout, particularly by older fish, has been documented (Nolting 1968; Griest 1977) and might influence the number of rainbow trout present in any year. Variation in gill net catch of rainbow trout might also be explained by fish escapement from the reservoir (Nesler 1981). Data suggest that fish left the reservoir during high releases and possibly during winter releases when environmental conditions were unfavorable. The low production capacity of the lakes may also contribute to poor overwinter survival. The limited number of fish caught that were larger than the size stocked (longer than 12 inches) is indicative of this condition. Approximately 38,000, 7- to 9-inch rainbow have been stocked annually at Turquoise Reservoir since 1989, but again gill net surveys show considerable variation in catches since that time.

FIGURE 5-3



Note: For sampling purposes, a number of gill nets are set in the lake on the same night each year. The left axis represents the average number of fish from each species found in each of the gill nets when they are retrieved from the lake.

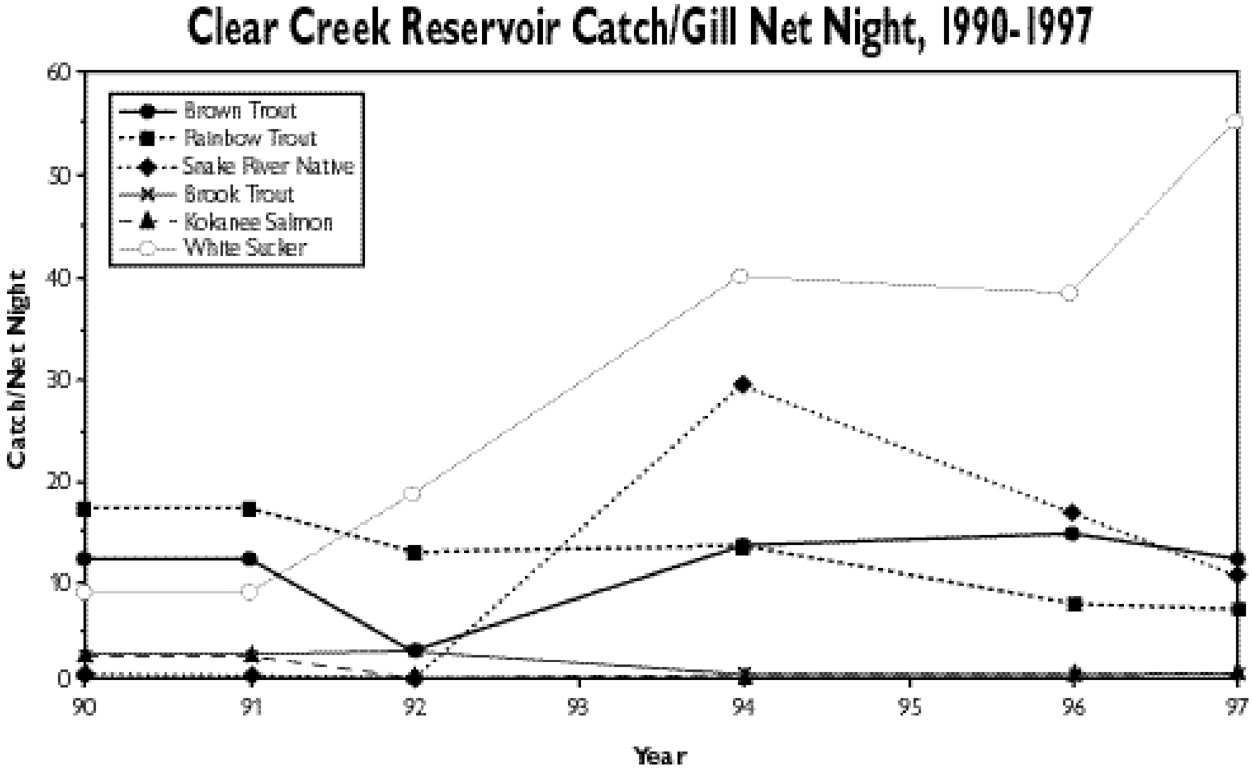
The abundance and size of rainbow trout at Clear Creek, on the other hand, represent a productive fishery with rainbows and a diverse fish community (Figure 5-4). Fish survival and growth is good and trout overwinter well in the reservoir. However, trout are susceptible to flushing out of the reservoir as evidenced by the sampling of reservoir fish downstream in the Arkansas River. Typically trout use the entire water column and can be flushed through the outlet regardless of the surface elevation.

Primary and Secondary Production

The production of phytoplankton (primary) and zooplankton or invertebrates (secondary) is considered the base of the food chain in aquatic ecosystems. Generally, the greater the potential for production of these food sources, the greater the standing crop of fish that can be supported. A simple analogy is the production of cattle, where the lushness of the grazing lands determines the number and weight of livestock produced from a given area of land. Because of the physical, chemical, and geomorphological characteristics of the upper basin reservoirs, they are considered oligotrophic and have a low capacity for base fish food production in terms of phytoplankton and zooplankton. One of the primary determinants of the physical and chemical characteristics of the upper basin reservoirs (and therefore the food production capacity as well) is the water regime. Because the productivity of the reservoirs is already at a low baseline level, factors such as water elevations, timing and magnitude of fluctuation, water temperature, and flushing rate play a particularly critical role in the productivity potential at any point in time.

Primary productivity can be approximated by measuring the amount of chlorophyll biomass (contained in phytoplankton) present in a given volume of water. Chlorophyll biomass has been quantified during 1993-1996 in all three reservoirs from a variety of depths and locations (BOR-unpublished report). The values for chlorophyll biomass are similar for the three reservoirs, ranging

FIGURE 5-4


Clear Creek Reservoir Catch/Gill Net Night, 1990-1997

Note: For sampling purposes, a number of gill nets are set in the lake on the same night each year. The left axis represents the average number of fish from each species found in each of the gill nets, when they are retrieved from the lake.

from 0.6-3.5 µg/m^3, and are representative of oligotrophic waters. Secondary productivity is characterized by the species and densities of zooplankton. Larger species, typically represented by cladocerans, are preferred food for planktivorous fish like small rainbow and lake trout. On the other hand, small zooplankters like rotifers can be used as forage, but are not as valuable as a food item.

An indication that primary productivity is affected by water management operations is evident from data at Twin Lakes. Primary productivity, as indicated by chlorophyll biomass, has declined in Twin Lakes with changes in water movement, volume, and fluctuation related to powerplant operation. Chlorophyll biomass for Twin Lakes from 1993-1996 is significantly lower than values determined for the 1977-1985 period, when values ranged from 2.0-7.6 µg/m^3 in the lower basin and from 1.4-6.0 µg/m^3 in the upper basin. In fact, the recent (1993-1996) August value in Twin Lakes was at, or just above, the minimum value measured during the 1977-1985 period. The euphotic zone in Twin Lakes is subjected to daily mixing by operations of the pumped-storage powerplant. Daily operations can cause the water surface elevation to fluctuate up to 9 feet vertically. Hydraulic retention times in the lakes are significantly less than prior to pumped-storage powerplant operations, even with the overall increase in storage in the reservoir of approximately 15-28 percent behind the new Twin Lakes Dam constructed in 1984. The mean annual storage volume of the lakes from 1977-83 was about 99,000 acre-feet. The mean annual storage from 1984-85 was 129,000 acre-feet, and from 1993-96 was 114,500 acre-feet. A greater storage volume and a decreased hydraulic retention time inevitably mean that flushing of the euphotic zone is occurring at a proportionately higher level than just the computed retention time may indicate. Prior to pumped-storage powerplant operations, the average hydraulic residence time was about 1 year. During the postoperational phase of the previous studies at Twin Lakes and the current studies, the average hydraulic residence time is less than 0.5 year. During peak runoff in late spring and early summer, both lake basins approach or go below the 30 day residence time that seems necessary for planktonic biomass accumulation to occur at the water temperatures usually prevailing at that time of year (Campbell and LaBounty 1985). Prior to pumped-storage powerplant operations, phytoplankton generally reached maxima in summer, and typically within the euphotic zone, the strata at the top of the reservoir that is characterized by light penetration levels conducive to plant growth. However, after powerplant operations (1993-1996 study period), strong vertical biomass maxima were not commonly seen. Induced mixing of the euphotic zone due to powerplant operations tends to prevent accumulation of biomass along an underwater density gradient, such as a thermocline, particularly in the lower basin.

Currently at Twin Lakes Reservoir, drawdown precedes spring runoff in late winter and early spring, and then water surface elevations are held at higher levels in the summer and fall months, with maximum storage levels generally coinciding with the summer growing season. Production in the lakes may continue to be adversely affected as long as pumped storage powerplant operations continue to cause the water surface elevation to fluctuate daily. The effect of pumped storage operations on productivity is compounded when these operations coincide with large volumes of water passing back and forth between the lower lake basin and the forebay. The effect is also compounded when the pumped storage operations coincide with maximum releases from Twin Lakes to Lake Creek and the Otero Pipeline. The daily fluctuation in water surface elevation also adversely affects the littoral areas around the lakes, providing little vegetation or other habitat in the fluctuation zone and only intermittent feeding habitat for terrestrial insects to some fish species.

Unstable water column conditions favor diatoms and other quick-growing, small-bodied algal species (Reynolds 1984). At Twin Lakes, diatoms dominated each August phytoplankton assemblage in both lake basins throughout the study period, ranging from 42-99 percent of total phytoplankton density in the lower basin and from 52-100 percent in the upper basin. Chrysophycean species, i.e., *Dinobryon bavaricum* or *D. cylindricium*, never comprised more than 26 percent of total phytoplankton densities in the upper basin or more than 19 percent in the lower basin. These levels represent a significant departure from algal dominance patterns observed in Twin Lakes during previous studies (1977-85) in the upper basin, which continued to be dominated by chrysophycean species in mid- to late summer. The upper basin still exhibits strong thermal stratification in midsummer, but diatom-dominated phytoplankton densities prevail, perhaps indicating unstable conditions in the euphotic zone or some other circumstance favoring diatoms over chrysophycean algae.

At Twin Lakes Reservoir, secondary productivity, particularly forage for small trout, is similarly limited as the phytoplankton on which it is dependent. This is an ecological feature where physical and chemical attributes (including water management) influence the entire biotic food chain in the reservoirs. Zooplankton group dominance indicates a very low percentage of cladocerans and a relatively high percentage of rotifers, which are particulate feeders on detritus or small-bodied phytoplankton cells (LeCren and Lowe-McConnell 1980). Cladocerans never comprised more than 22 percent of total zooplankton densities in either basin. In addition, the typical cladoceran species was the small-bodied *Bosmina longirostris* rather than the larger cladoceran *Daphnia* sp. Low densities of cladocerans have been typical of Twin Lakes zooplankton studies. Zooplankton grazing pressure on phtyoplanktonic algae may be partially responsible for the overall low chlorophyll biomass in the lakes, but the overall zooplankton densities for groups other than rotifers and copepodids (immature copepods) were also low, translating into a limited food resource for planktivorous fish in both lake basins. Of concern is the fact that zooplankton densities were highest in the littoral areas between 0-32 feet during daylight hours, and are therefore subject to impact by water level fluctuations and releases.

Primary production in Turquoise Reservoir, like that in Twin Lakes Reservoir, is relatively low. Nesler (1981) reported a range of chlorophyll from 2.2-3.5 µg/m^3 from June-September 1980. During the study period (summer months of 1994-96), chlorophyll values ranged from 0.8-2.6 µg/m^3 at the sampling site near the dam, and from 1.5-3.5 µg/m^3 at the sampling site in midreservoir. This still places Turquoise Reservoir in the oligotrophic category (Likens 1975). The greatest production observed in the study period was in July and August (midsummer). The distribution of chlorophyll biomass, like that in Twin Lakes, is greatest in the euphotic zone. Although Turquoise Reservoir thermally stratifies in the summer, usually between 23-29.5 feet deep, no chlorophyll biomass vertical maxima were ever noted either using the transmissometer, which measures light passing through a 1.6-foot path, nor in chlorophyll samples collected at the 29.5-foot depth interval. Phytoplankton populations were dominated by diatoms or green algae and were comparable in densities to those observed in Twin Lakes. Zooplankton populations were also similar or slightly greater than those observed in Twin Lakes. During midsummer, there are sometimes abundant cladocerans (*Daphnia* sp.) in the 0-32-foot intervals, making them susceptible to water fluctuation at that time.

Clear Creek Reservoir is shallower and has more littoral habitat than Twin or Turquoise Reservoirs, and it is common for the euphotic zone to encompass the entire vertical depth of the reservoir. Although shallow, the reservoir does thermally stratify in midsummer and water temperatures are warmer throughout the water column than in either Twin Lakes or Turquoise Reservoirs, and consequently, it produces more food. For example, phytoplankton populations are usually dominated by diatoms and green planktonic algae; however, chrysophycean and blue-green algae can sometimes form a significant percentage of the total population, which is evidence of increased productivity. Zooplankton populations were generally numerically more abundant in Clear Creek Reservoir than in Twin Lakes or Turquoise Reservoirs. Cladoceran species such as *Bosmina* sp. and *Daphnia* sp. form a small percentage of total zooplankton densities throughout the year (3-13 percent), but since overall densities are greater, these may provide valuable fish food resources.

Other Coldwater Fishery Considerations

Although white suckers were not identified as a resource value (primarily because of their limited value as a sport fish), they are a good indicator species of ecological integrity. Suckers of all ages are omnivores that feed indiscriminately on forage items found in and on bottom substrates in littoral areas. Chironomid larvae, zooplankton, invertebrates, and other organic debris comprise much of their diet (USDI 1993). The dependence of suckers on primary and secondary productivity as forage means that decreases in this food resource negatively impact their survival and growth. In turn, lake trout have some dependency on suckers for food. Since 1987, the number of white suckers in Twin Lakes has steadily declined, based on gill net surveys. Predation by lake trout alone cannot explain the decline, and changes in water management and the resulting impacts to primary and secondary productivity are likely contributors to the decline.

Warmwater Reservoir Habitat and Biota

Pueblo Reservoir is located on the Arkansas River just west of the city of Pueblo, Colorado. This main lower reservoir basin encompasses 4,611 acres and is generally characterized as steep-sided and rocky, and when filled to capacity, has a water depth in excess of 118 feet. Shallow littoral zones are found in the backs of the coves and in the upper end of this reservoir. Soils along most shorelines are shallow, very rocky, and do not provide a quality plant source medium. However, since initial filling of the reservoir, multiyear drawdowns and wind/wave erosion activities have increased shoreline soils in some areas. This improved plant source medium has allowed herbaceous and woody vegetation to vegetate these sites. These areas provide excellent habitat and are primary spawning and nursery areas for black bass, crappie, and gizzard shad (primary forage fish) when inundated.

Water levels at Pueblo Reservoir influence the amount and quality of the shoreline habitat that is critical for the development of black bass (largemouth and smallmouth bass) and crappie, the resource values of interest for the reservoir. Drawdowns of 15-25 feet are most commonly seen from April to October, but major drawdowns have dropped the water level 49 feet below the conservation pool. Depending on the timing and magnitude of these drawdowns, the production of sport fish and forage fish can be affected.

With the development of the Winter Water Storage Program (WWSP), water levels have been beneficial to the development of an excellent warmwater fishery. This annual cycle begins with maximum storage in late March, gradual drawdown to early summer (mid-June), with an accelerated drawdown due to irrigation demands during summer and fall. By mid-November, the WWSP begins and the reservoir fills throughout the winter. This water management scheme coincides with requirements for warmwater fish species that inhabit the inshore areas of Pueblo Reservoir. The biological needs of these species for spawning, fry development, and feeding are dependent on water depth and temperature, water chemistry, primary and secondary production, shoreline plant growth, and prey base development, all of which are influenced by water levels and water movement.

Pueblo Reservoir is managed as a warm-, cool-, and coldwater fishery. The coldwater fishery consists mainly of rainbow trout maintained by annual stocking, with some large rainbows available as older, overwintered fish. The warm- and coolwater fishery is primarily composed of black bass, crappie, bluegill, walleye, wiper, and channel catfish. These species comprise the bulk of the fishery at Pueblo Reservoir. The walleye, wiper, and channel catfish populations are supported by stocking and are least affected by the severe fluctuation, while bass and crappie are not stocked and are dependent on reservoir conditions that allow successful reproduction and growth.

Black Bass

Black bass is a grouping of four species of bass, of which three species, largemouth, smallmouth, and spotted bass, are common in Pueblo Reservoir. Black bass are found in riverine habitats, but prefer and reach maximum potential in a lake environment. Stuber et al. (1982) identify optimal habitat as being warmwater lakes containing large areas of shallow water (≤19.7 feet) that supports submergent vegetation and deep enough (9.8-49.2 foot mean depth) to provide sufficient overwintering habitat. This typical bass habitat in Pueblo Reservoir occurs in the coves and the upper end of the reservoir and most likely comprises less than 10 percent of the surface acres in the reservoir.

Ideal temperatures for growth of adult black bass range from 75-86 °F with very little growth occurring below 59 or above 97 °F (Carlander 1977). Preferred temperatures for fry growth are 81-86 °F. Little fry growth occurs below 59 or above 89 °F (Strawn 1961). Summer temperatures in Pueblo Reservoir tend to run in the 59-77 °F range, although the shallow water habitat in the coves and upper end of the reservoir will commonly reach temperatures approaching 86 °F. Pueblo Reservoir water temperatures are higher and occur earlier in the growing season in years when drawdowns are more drastic. Growth of bass in Pueblo Reservoir is slower than the national average (mean length of 11.8 inches by 4 to 5 years of age), due to the relatively cooler water temperatures and adverse environmental conditions.

Stuber et al. (1982) identified gravel as preferred spawning substrate, usually associated with vegetation, rocks, and trees. However, bass have been found to successfully spawn on vegetation, roots, sand, and/or mud. Successful spawning and incubation takes place between 55 and 79 °F. Stable water levels are important during spawning activities and severe drawdowns typically result in poor survival. Spawning in Pueblo Reservoir takes place in the shallow littoral zones at depths of 3-16 feet from late April to early June. This is generally a period of gradual water-level reduction.

Adult black bass feed primarily upon fish and crayfish, while juveniles consume insects and small fish, and bass fry feed upon microcrustaceans and small insects. The primary forage in Pueblo Reservoir for the bass is various life stages of gizzard shad, crayfish, yellow perch, and numerous macroinvertebrates. Young bass are restricted to shallow water habitat after hatching in early summer and are dependent on the availability of suitable food items within these shoreline nursery areas. At Pueblo Reservoir, these food items (primarily shad fry) reach maximum densities in shallow waters when water temperatures exceed 65 °F and primary/secondary productivity is high.

Crappie

White crappie and black crappie are both found in Pueblo Reservoir, with white crappie being more abundant. Preferred habitat for crappie is medium- to large-sized lakes and reservoirs with moderately turbid to clear waters. Cover, especially aquatic vegetation, is important for quality growth and reproduction (Sigler and Miller 1963). Preferred daytime habitat is dense vegetation around submerged trees, brush, or other objects in shallow water (Edwards et al. 1982a). In Pueblo Reservoir, crappie tend to prefer the areas of flooded timber and brush in the coves and upper end of the reservoir.

Spawning usually begins when water temperatures reach 55-57 °F. With these environmental cues, males move into littoral areas to establish territories and construct nests. Nests are shallow bowl shaped depressions (<23.6 inches) in beds of vegetation located on soft mud, sand, or gravel substrate (Edwards et al. 1982a). Crappie spawning in Pueblo Reservoir usually occurs in flooded vegetation and brush in the backs of coves and in the upper reaches of the reservoir during the months of May and June. Drastic drawdowns during this time have contributed to poor spawning success for crappie in some years.

Edwards et al. (1982b) state that the abundance and quality of food is a limiting factor for crappie.

Adults feed predominantly on fish and planktonic insects. Fry and juveniles feed on microcrustaceans and planktonic insects. Adults and juveniles usually feed over open water. Crappie in Pueblo Reservoir are primarily dependent on gizzard shad for forage once they reach a juvenile life stage. At a young life stage, crappie are dependent on shallow water and vegetation for protection from predation and cannot venture to deeper waters for feeding. Stable water management at this time of year (May and June) encourages warming of surface waters and allows productivity to reach acceptable levels, which in turn attracts forage and benefits crappie fry survival and growth.

Crappie growth and survival is influenced by water temperatures. Water temperature at Pueblo Reservoir, although largely determined by ambient air temperatures, can also be affected by water elevation (amount of shallow water habitat) and water management (flushing rate). Edwards et al. (1982a) state that adult crappie have been found to exist in summer habitat of temperatures of 63-86 °F with a preferred mean around 75 °F. Optimal growth of juveniles was found between 72 and 77 °F. Little information was available on temperature ranges for fry. Edwards et al. (1982a) found optimal embryo survival between 66 and |67 °F, which is within the range of summer temperatures found at Pueblo Reservoir. Growth of crappie in Pueblo Reservoir is slower than the national average (with the average crappie reaching 9.8 inches in approximately 4 to 6 years) because of the relatively cooler water regime.

Other Warmwater Fishery Considerations

Forage fish important to the survival of black bass and crappie in Pueblo Reservoir are bluegill and gizzard shad. Habitat requirements for bluegill are very similar to the requirements of the black bass. Gizzard shad are a pelagic species for most of the year and feed on plankton. Adult shad in Pueblo Reservoir will reach sizes of 11.8-15.7 inches. Adult shad move into littoral zones when water temperatures approach 68 °F (mid-May to mid-June) and spawn on virtually any flooded substrate including brush, vegetation, wood, rock, and gravel. Newly emerged shad fry provide suitable forage for bass and crappie fry in late spring and early summer. Although young shad in Pueblo Reservoir reach 1.2-3.1 inches by July and August, their small size makes them the major forage species through the growing season.

Arkansas River Habitat and Biota

The Arkansas River is noted for its exceptional brown trout fishery and its developing rainbow trout fishery. Surveys conducted by the CDOW document that brown trout are present throughout the Arkansas River study area. Brown trout numbers average about 2,000 fish/mile throughout much of the river, while rainbow trout average about 100 fish/mile. Brown trout are sustained through natural reproduction, while rainbow trout are supported by stocking of fingerling-sized fish.

For the purpose of this study, these two trout species will be emphasized in the river because of their sportfishing value and the amount of information available. Even though the emphasis of this study is towards managing game species, there are a number of nongame species present in the Arkansas River drainage. For example, white suckers, fathead minnows, and longnose dace are found throughout the study area. Most of the nongame fish species (killifish, dace, shiners, etc.) are found in the lower portions of the Arkansas River and/or Pueblo Reservoir (Woodling 1985). Rare species have not been collected in the studied reservoirs or in the main stem of the Arkansas River. It is assumed that flows that protect and maintain game species should be sufficient to protect nongame species.

To analyze the relationship between Arkansas riverflows and available habitat for brown and rainbow trout, the Instream Flow Incremental Methodology (IFIM) developed by the U.S. Fish and Wildlife Service (Bovee 1982 and Stalnaker et al. 1995) was used. This biological model is used to quantify aquatic habitat as a function of stream discharge by measuring actual stream and hydraulic attributes of depth, velocity, and substrate. The results from IFIM can be found in Appendix C. The amount of habitat for each species for each of their four life stages can then be calculated for different flows using the Physical Habitat Simulation System (PHABSIM). The results from PHABSIM can be found in Appendix D. These techniques have been widely used throughout the United States to evaluate the effects of incremental changes in the streamflow on aquatic life, and have been accepted as an appropriate methodology for resolution of many controversial water related issues (Stalnaker et al. 1995).

For the purpose of this study, habitat in the Arkansas River was characterized within six habitat types, which are interspersed throughout the entire study reach (Figure 5-5):

1. Low gradient, moderate widths, cobble substrate with an unconfined channel: This type of habitat can be found between Leadville and Granite and is represented by the Leadville station.

2. Areas of steep gradient, fast water, medium boulder substrate, and a confined channel: The river between Buena Vista and Granite typifies this habitat type. The Numbers IFIM station is within this section.

3. Deep pools, moderate gradient, narrow widths, and large boulder substrate: Browns Canyon is typical of this habitat type and is characterized by the Browns Canyon station.

4. Low gradient, wide, moderate depth riffles, cobble substrate, and islands: The river between Coaldale and Howard is typical of this habitat type and is characterized by the Independent Whitewater station.

5. Moderate gradient, medium boulder and cobble substrate, moderate widths, and pocket water: The river between Texas Creek and Cotopaxi typifies this habitat type and is represented by the Stockyard Bridge station.

6. Stair-stepped, fast water flowing into deep runs, substrate small to medium boulders, with moderate widths: This type of habitat is found between Parkdale and Texas Creek and is represented by the Floodplain site.

Each IFIM site contains a cluster of dependent transects used to characterize the habitat type.

Although IFIM is a well-recognized and widely accepted model to quantify fish habitat and standing crop, historical field data on brown trout collected at the Wellsville site on the Arkansas River from 1981-1996 was also used to establish the relationship between available habitat and fish growth (Anderson and Krieger 1994; Policky - CDOW unpublished reports). Growth of brown trout collected during electrofishing surveys was evaluated in relation to flow levels and water temperatures that the trout had experienced during their lives. The relationships were statistically analyzed to quantify the strength of the correlations.

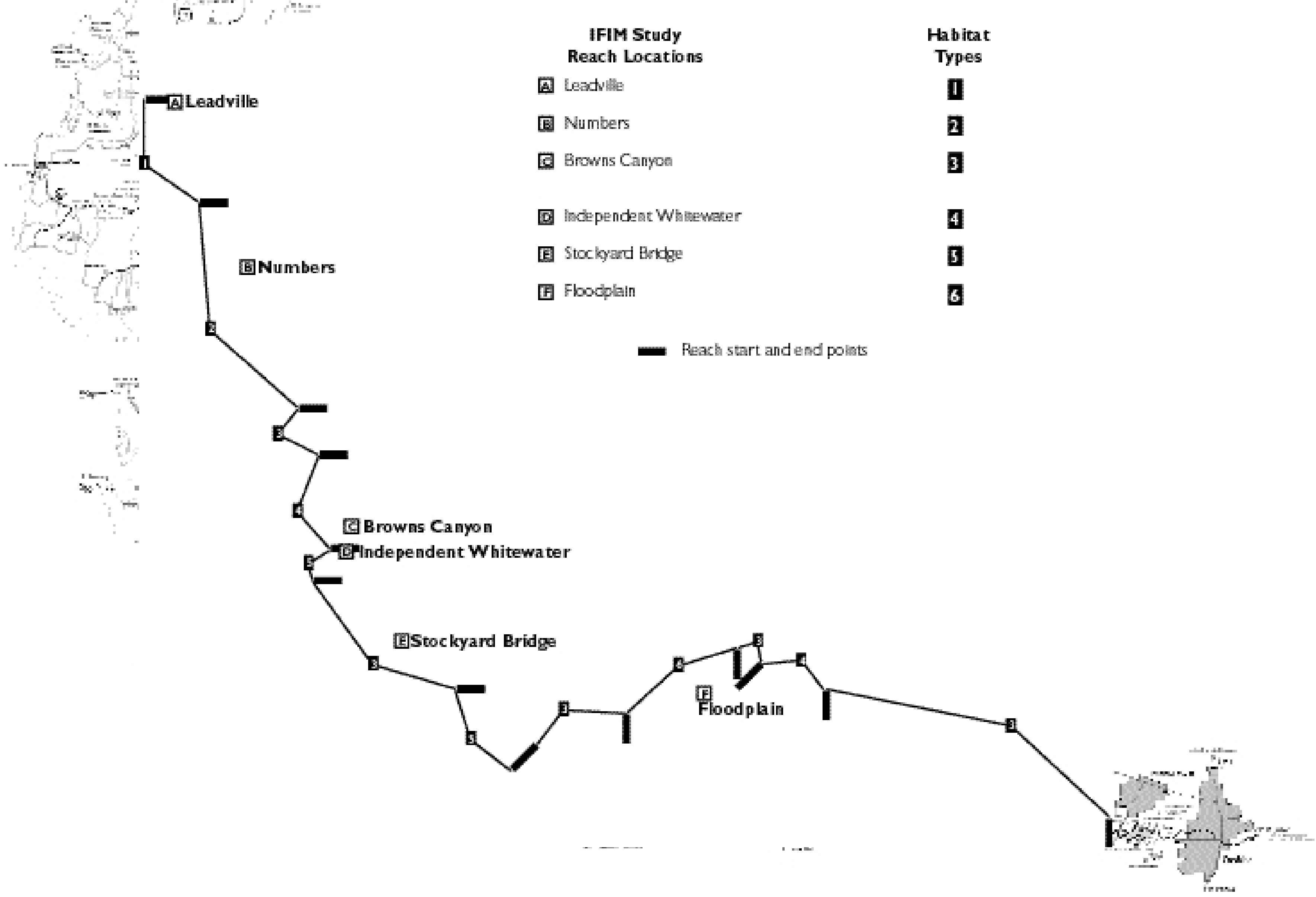
Brown Trout

The quantity and quality of brown trout habitat varies considerably in the Arkansas River depending on water discharge, based on IFIM analysis. Raleigh et al. (1986) identified optimal brown trout habitat as "clear, cool to cold water; a relatively silt-free rocky substrate in riffle-run areas; a 50-70 percent pool to 30-50 percent riffle-run habitat combination with areas of slow, deep water; well vegetated, stable stream banks; abundant instream cover; and relatively stable annual water flow and temperature regimes." Basically, brown trout occupy reaches of low to moderate gradient (<1 percent) in suitable, high-gradient river systems. A base flow $\geq$50 percent of the average annual daily flow is considered excellent for brown trout production (Binns and Eiserman 1979).

Frost and Brown (1967) established that migration to locate suitable spawning sites begins when water temperatures reach 42.8-44.6 °F. Mansell

FIGURE 5-5

Characterization of Habitat in the Study Area



(1966) found that spawning occurs at 44.6-48.2 °F. Spawning sites are generally located at the head of a riffle or at the tail of a pool and have well defined redds. Reiser and Wesche (1977) observed that brown trout prefer gravel 0.4-2.8 inches in diameter for spawning, with the maximum size related to the size of the spawning female. Allen (1951) found the size of redds varied in width from <11.8 to >42.1 inches. Hooper (1973) constituted a range of velocities from 0.5-3.0 ft/s to be suitable for brown trout spawning. Shrivell and Dungey (1983) established that velocity was more important than depth as a selection criterion for spawning, with a mean velocity of 1.3 ft/s the preferred velocity. Waters (1976) observed optimal water depths for brown trout at redd sites to be 9.6-18.0 inches, with a suitable range of 4.8-36.0 inches.

Brown trout spawn in the Arkansas River from mid-October to mid-November. The amount of suitable spawning habitat (depth, velocity, substrate, and water temperature) is dictated by water discharge existing at the time of spawning. Redds were observed in the upper Arkansas River in late October 1992 during an extensive CDOW survey. Redds were most abundant behind boulders or woody debris, in the tail of pools where the stream bottom is rising, or in glides. These areas correspond to appropriate substrate conditions, water velocity, and depth—all necessary for successful spawning. The lower velocities in these areas encourages deposition of appropriate sized gravel. Side channels and ditch diversions are also being utilized by spawning trout. Most redds were found at velocities above 0.5 ft/s. Redds were generally found at depths between 12.0 and 36.0 inches, but some at depths up to 72.0 inches. Areas with the above characteristics and high redd count include the area around State Highway 291 in Salida and just upstream of Badger Creek. For higher gradient, more confined areas, such as Brown's Canyon and Floodplain, redds were often associated with instream cover or were toward the river's edge. Redds were found where gravel was present and depth and velocity were suitable, but were less numerous in these areas. IFIM analysis at the six sampling locations resulted in quantification of available spawning habitat under a range of water discharge.

Tributary streams can be important spawning areas when favorable spawning habitat conditions exist. These sites may be selected if conditions are unsatisfactory in the Arkansas; however, the majority of spawning occurs in the main stem of the Arkansas River. Cottonwood, Chalk, and Texas Creeks are examples of tributary streams where brown trout spawning is known to occur.

Brown trout eggs incubate from mid-October through March in the Arkansas River. During this period, flows have to be high enough to meet the needs of developing embryos (prevent winter freezing), but not so high that they allow destructive movement of the substrate.

Brown trout hatch and emerge in the Arkansas River from April 1 to May 15. Flows and resulting fry habitat from April through June (snowmelt runoff period) influences fry survival, recruitment success, and resulting year class strength on the Arkansas River (Nehring and Anderson 1986). Nehring and Anderson (1993) reported similar results for 12 other Colorado streams.

Like any salmonid, dispersal of fry takes place immediately after emergence. Mills (1971) found that brown trout fry were aggressive and territorial, and that they distributed themselves to suitable habitat within a week. Wesche (1980) found that both fry and juvenile brown trout prefer shallower depths and velocities <0.5 ft/s, while adults prefer depths ≥5.9 inches and a focal point velocity of <0.5 ft/s for resting and feeding. Shuler (1992) and Shuler et al. (1994) reported depths ranging from 2.0-3.0 feet and velocities from 0.9-1.3 ft/s as being optimum for adult brown trout, while juvenile brown trout have optimum depths ranging from 0.9-1.7 feet and velocities from 0.3-0.7 ft/s. Shuler's study was conducted on the Rio Grande River, Colorado, which has a gradient, channel width, elevation, and brown trout population similar to the Arkansas River. Fry habitat for brown trout was one of the life stages quantified by IFIM and PHABSIM analysis.

Cover, which is essential to adult and juvenile brown trout for survival and growth, is dependent on flow. Quantification of habitat for these two life stages within the Arkansas River was part of the output of the IFIM modeling. In general, cover important to brown trout includes such items as instream and streambank vegetation, undercut banks, woody debris, substrate, pool depth, and surface turbulence. Raleigh et al. (1986), based on numerous studies throughout the U.S., found that a cover area of ≥35 percent of the total stream area provides adequate cover for adults, while ≥15 percent of the total stream area is adequate for fry and juveniles. During winter months, substrate particle size of 3.9-15.7 inches provides excellent cover for fry and small juveniles (Everest 1969). Typically adults tend to move into deeper, slower moving water during the winter.

Many researchers have reported on the foraging strategy of brown trout and flow-related impacts on feeding efficiency. They are bottom-oriented (Shrivell and Dungey 1983), visual feeders (Bachman 1984; Ringler 1979; Bannon and Ringler 1986) that use a sit and wait foraging strategy (Ringler 1979). Brown trout are categorized as size-selective feeders, preferring larger prey (Ringler 1979). Generally they feed on terrestrial and aquatic insects until they exceed 10.0 inches in length and then they switch to fish and crustaceans (Hannukula 1969). Winters (1988) suggested the absence of forage fish or large invertebrates may be limiting the size potential of brown trout on the Arkansas River. He found that collector-gatherers dominated the benthos community, while shredding invertebrates were almost nonexistent. Trout fry in the Arkansas River feed predominantly on drifting aquatic and terrestrial macroinvertebrates, while older fish feed predominantly on *Brachycentrus occidentalis* larvae, and all age classes of trout feed on adult chironomids and ephemeropterans when available. Winters (1988) also noted that mean monthly densities of benthic macroinvertebrates were lowest during runoff and highest during autumn. Mean biomass values were also lowest during snowmelt runoff, but were highest in the spring (prerunoff) when large mature nymphs were abundant. Accordingly, brown trout body condition was lowest following snowmelt runoff and was highest before runoff in the spring. Winters' study demonstrates the importance of pre- and postrunoff periods on macroinvertebrate populations and the resulting brown trout foraging efficiency and growth.

Fausch (1984) suggest salmonids select feeding positions on the basis of water velocity characteristics and their food supply in order to maximize net energy gain, and therefore, growth is predictably related to flow. Greater depths and increased velocities not only increase the metabolic cost associated with foraging, but also create conditions that reduce the capture of drifting insects.

Rainbow Trout

The quantity and quality of rainbow trout habitat varies considerably in the Arkansas River depending on water discharge, as determined by IFIM and PHABSIM analysis. Generally, optimal rainbow trout riverine habitat is characterized by clear, cold water; a silt-free rocky substrate in riffle-run areas; an approximately 1:1 pool-to-riffle ratio, with areas of slow, deep water; well vegetated streambanks; abundant instream cover; and relatively stable waterflow, temperature regimes, and streambanks (Raleigh et al. 1984).

Rainbow trout females normally select a redd site in gravel substrate at the head of a riffle or the downstream edge of a pool (Orcutt et al. 1968). Raleigh et al. (1984) found optimal spawning gravel conditions to include ≤5 percent fines; ≥30 percent fines are assumed to result in low survival of embryos and emerging sac fry. Optimal spawning substrate size averages 0.6-2.4 inches for rainbows ≤20 inches long and 0.6-3.9 inches for spawners ≥20 inches long (Orcutt et al. 1968). Raleigh et al. (1984) state that optimal water velocity above rainbow trout redds is between 1.0-2.3 ft/s. Velocities <0.3 ft/s or greater than 3.0 ft/s are unsuitable.

Rainbow trout spawn in the Arkansas River from March to early April. They generally select spawning sites with similar substrate, depth, and velocity characteristics to brown trout (see Brown Trout section above). Typically, they tend to select sites closer to the edge of the river because of higher midchannel velocities during spawning.

Rainbow trout eggs incubate from March to late May in the Arkansas River. Incubation time varies inversely with temperature. Eggs usually hatch within 28-40 days after they were deposited (Cope 1957).

Rainbow trout hatch by the end of May and emerge from the gravel in June in the Arkansas River. This emergence period corresponds to high flows and limited fry habitat, which was supported by IFIM modeling outputs. Fry require shallower water and lower velocities than at other stages of the trout life cycle (Horner and Bjornn 1976). They utilize velocities <1 ft/s, but velocities <0.3 ft/s are preferred (Griffith 1972). Rainbow trout fry overwinter in shallow areas of low velocity, with rubble being the principal cover (Bustard and Narver 1975). Optimal size substrate ranges from 3.9-15.7 inches in diameter (Hartman 1965). Due to limited fry production, rainbow trout populations are supported by fingerling stocking of wild stock from the Colorado River. IFIM analysis at the six sampling locations resulted in quantification of available spawning habitat under a range of water discharge.

Cover is an essential component in rainbow trout streams, and to a large extent determines the stream's carrying capacity. It can be found in two forms: 1) bank cover (vegetation) and 2) instream cover (substrate, turbulence, etc.). Wesche (1980) reports that areas of obscured stream bottom with water ≥5.9 inches deep and velocities of ≤0.5 ft/s will provide important cover. A cover area of ≥25 percent of the total stream area provides adequate cover for adult trout (Raleigh et al. 1984). Adult and juvenile rainbow trout are opportunistic feeders. Their diet consists mainly of aquatic insects (Allen 1969), but foods such as zooplankton (McAfee 1966), terrestrial insects, and fish are locally or seasonally important (Carlander 1969). The relative importance of aquatic and terrestrial insects to resident stream rainbow trout varies greatly among different environments, seasonally and daily, and with the age of the trout (Bission 1978). Rainbow trout feeding efficiency is affected by water discharge (like brown trout) in the Arkansas River with pre- and postrunoff periods being the most critical times.

As for brown trout, flow regime influences the amount of quality rainbow trout habitat. A base flow of ≥50 percent of the average annual daily flow is considered excellent for maintaining quality habitat, 25-50 percent is considered fair, and <25 percent is considered poor (Binns and Eiserman 1979).

Wildlife

Wildlife values associated with the Arkansas River corridor riparian and wetland habitats, floodplains, and reservoirs are diverse and important in maintaining the ecological stability of this part of Colorado. Species range from amphibians and reptiles to a variety of mammals and birds.

Riparian and wetland areas have been well-documented as the most productive and attractive of all wildlife habitats (USDA 1979). Riparian communities have an importance to fish, wildlife, and recreation which is greatly disproportionate to the acreage of these areas (Brown et al. 1977). Although less than 1 percent of the landscape is riparian vegetation, greater than 80 percent of breeding bird species occur in this vegetation type in the central Rocky Mountains (Knopf 1988). Riparian areas often provide the key resources that support biological diversity both in the riparian area and nearby uplands (USDA 1990).

Riparian and wetland areas (see also Riparian Habitats discussion) are critical for water-dependent terrestrial wildlife species and provide important corridors for movement of wildlife (Bacon 1990). The linear nature of riparian ecosystems provides distinct corridors important as migration and dispersal routes and as forested connectors between habitats for wildlife such as birds, bats, deer, elk, and small mammals (Brinson et al. 1981).

Periodic flooding is one of the most significant phenomena affecting use of riparian ecosystems by fish and wildlife (Brinson et al. 1981). Runoff has been consistently correlated with the kind and amount of vegetation (Miller et al. 1989). Short-term floods (several days) often have little detrimental effect on wildlife; deer mice, tree squirrels, and box turtles apparently take refuge in unflooded sites or trees (Brinson et al. 1981). In contrast, severe flooding (several weeks) temporarily eliminates and may limit resident small mammal populations in a floodplain (Brinson et al. 1981).

Floodflows are not always considered detrimental to wildlife and their habitats; they are needed to improve and maintain the quality of various wildlife species' habitats. While floods cause some destruction of nests and other loss to wildlife and may at times temporally destroy wildlife habitat, the possibility of more serious and irreversible damage to the riparian ecosystem, and thus to wildlife, lies in floodflow reduction and reduced instream flows (Bayha 1983).

Species addressed in this document are those potentially at risk for significant direct or indirect impacts from variations in flow levels of the Arkansas River and water fluctuations in the associated reservoirs described. Some species potentially are subject to human disturbance and the amount and timing of human disturbance is related to flow levels. Disturbance usually involves interactions with humans; however, automobile strikes, vegetation trampling, and other direct effects increase with increased human use.

There are numerous ways in which wildlife express disturbance. These expressions vary seasonally and by species. For waterfowl and many other birds, for instance, spring disturbance may cause abandonment of nest sites prior to, or after initiation of, incubation. Disturbance can flush young of the year, causing them to expend metabolic resources to flee. Ground nests may also be trampled. Mammals such as bighorn sheep are vulnerable to disturbance. Mammals stressed by disturbance can be weakened, and animals of any age are subject to increasing mortality if weakened. The scenarios for potential wildlife harm are difficult to predict without intense, local, species-by-species study.

Unless otherwise noted and referenced, all information in this wildlife discussion has been taken from the Colorado Division of Wildlife's "1983 Colorado Species Data Base - Quick Test Program."

Waterfowl

Canada geese were evaluated because they winter and nest along the Arkansas corridor. This species is most commonly found associated with large reservoirs, meadows, and "small grain" fields. Limited use is made of the river itself. The greatest direct impacts are from hunting and predation on the geese, as well as on their eggs, by predators such as foxes. Indirect impacts result from water fluctuation damage to nests and impacts on food sources.

Canada geese feed on the surface of the water, on aquatic vegetation, and on terrestrial grasses, forbs, grains, stems, leaves, fruits, flowers, and insects. The quality of winter forage has a significant effect on spring reproductive success.

Important periods for geese along the Arkansas River include the breeding and molting period of March through July. Peak nesting occurs around the first of April. Most nests are located within 30 feet of open water, but some may be found up to 300 feet from water. An incubation period of 25-30 days is typical. Paired adults normally reach sexual maturity after 3 years and return to the area where they were fledged. It is important that water levels are not raised quickly during April.

Wood ducks are specialized breeders within the corridor. They nest in cavities from April to July; their preferred nesting habitat is large cottonwood trees. Nests are usually located 30 feet or higher in large trees. Incubation takes 30 days. Hens return to the same breeding area year after year. Periodic high floodflows are needed to maintain nesting habitat, i.e., tree regeneration, as availability of suitable nest sites can be a limiting factor.

The common merganser feeds at various depths below the surface. Food consists of fish, invertebrates, crayfish, and other aquatic life. Mergansers are also primarily tree cavity nesters. Nests are used year after year and may be located up to 200 yards from water. Aquatic, wetland, and cottonwood/willow riparian areas are important habitats for these birds and impacts to these ecosystems would impact merganser populations. The amount, velocity, and quality of water that affects prey species and the ability of mergansers to forage would affect their use of the river and reservoirs.

Raptors

The goshawk is addressed in this document because of its "special concern" status in Colorado. This species is generally considered a bird of the coniferous forests but is actually a habitat generalist and will hunt along rivers and streams, preying on a wide range of 50 or more birds and mammals (Graham et al. 1993).

Goshawk nest from April to July and exhibit a high nest site tenacity (Graham et al. 1993). Nests are located in trees. Limiting factors are prey abundance and availability of suitable nest sites (Graham et al. 1993). Water levels in the Arkansas River are expected to have a minimal impact on goshawk populations unless drastic changes are made.

There is one known bald eagle nest site in the Arkansas River drainage (offsite main stem). There is also considerable winter use along the river and on several of the associated lakes and reservoirs. Bald eagles feed primarily on fish and waterfowl in the aquatic, riparian, and wetland habitats. Trees more than 30 feet from the shoreline are seldom used by eagles on the lookout for fish (Bayha 1983).

Dense cottonwood-willow sites are extremely important to wintering bald eagles for resting, and perching, and roosting (Bayha 1983). Wintering eagles normally arrive in Colorado in late October, and most birds leave by mid-April.

Limiting factors for wintering bald eagles in Colorado include availability of fish, wounded or sick waterfowl, and illegal killing. Bald eagles are highly intolerant of human disturbance within about 800 feet of their roost tree. A buffer of dense riparian vegetative cover extending a 250-foot or more radius around a roost tree helps reduce the negative effects of nearby human activity (Bayha 1983).

Golden eagles are found in many habitats throughout south-central Colorado, but some of the most important habitats are in the riparian and wetland areas. These areas are used for nesting, migration, wintering, and hunting zones. The primary prey species are squirrels, rabbits, and hares with some waterfowl taken in winter, especially on frozen lakes and reservoir. Breeding takes place from March to July; nests are located on cliffs and in large trees.

Important factors that limit the region's golden eagle populations include nest desertion resulting from human harassment, scarcity of prey, and illegal killing of birds. Water-related factors that affect riparian habitats, wetland habitats, or prey species habitats would impact use of the area by golden eagles.

Osprey are closely associated with water and fish. Osprey migrate as far as South America, then return to North America to nest and fledge their young. Breeding takes place between April and July. These birds roost and nest in large coniferous and cottonwood trees, often with their nests overhanging water.

Several factors that adversely affect osprey populations include limited nest sites, low fish numbers, pesticides, and illegal shootings. Any changes in flows that would impact tall conifers and cottonwood trees could affect nesting sites. Abormal water quality or quantity changes could affect the osprey's food sources.

Another predatory bird that breeds in the Arkansas River area from April to July is the peregrine falcon. This bird is listed as "endangered" by the Federal Government. Several "hack sites" have been constructed in the vicinity of the Arkansas River in an effort to establish viable populations within their historic range. This hacking effort has been successful and currently there are nesting birds along the river corridor.

Peregrine falcons feed primarily on birds and find the most rewarding hunting areas in riparian and wetland habitats. Waterbirds, passerines, and other small- to medium-sized birds are preferred. Nest sites are located on small ledges on the sides of steep cliffs. Impacts to riparian and wetland vegetation, as well as water conditions that would affect prey species, would have an affect on peregrine falcon use within this area.

The spotted owl that inhabits the Arkansas River watershed is the southern or Mexican subspecies. This subspecies has been declared a "threatened species" by the Federal Government. This species is not directly tied to the Arkansas River but does use the watershed and canyons of the river's side drainages. Mexican spotted owls feed on rodents, squirrels, reptiles, amphibians, insects, small birds, and spiders. Nest sites are located in canyons, often near the base of steep canyon walls. All known Colorado nest sites have been located on rock ledges or in small crevices.

Shorebirds

Great blue heron use along the Arkansas River corridor is high, but usage locations are dispersed for much of the year. Rookeries (nest colonies) are located on Pueblo Reservoir and near Salida in groves of large cottonwood trees. These areas are considered crucial to maintaining viable populations in this area.

Colonies require a minimum one-half-mile buffer zone that is free of disruptive human activity during the nesting period of mid-March to late July (Bayha 1983). These birds feed on a variety of insects and small fish in the shallow waters and associated mud flats. Frogs, lizards, snakes, and small mammals are also sometimes taken.

Herons are most likely to be affected by changes in flows that destroy large cottonwood trees, reduce habitat of prey species, and reduce the extent of shallow areas for foraging.

American avocets use mud flats and shallow water habitats along the Arkansas River and associated reservoirs. These birds feed on seeds, fruits, and other aquatic vegetation parts, as well as on a variety of insects. Avocets nest on mud flats, sand bars, gravel, and in marshes. Nests are bare ground scrapes and usually contain four eggs, which are incubated over a 24-day period from April through July.

Any action that would seasonally flood nesting habitats, especially after the avocets have begun nesting, or that would disrupt feeding would adversely affect these birds.

Killdeer are closely associated with the Arkansas River's wetland and shoreline habitats for most of their life cycle; some birds inhabit the area yearlong, while others migrate. Killdeer use sand bars and mud flats for feeding and nesting. These birds feed primarily on invertebrates. Killdeer breeding habitat is usually bare sandy ground. Breeding takes place from April to July.

Any activities that limit potential nest sites, destroy existing nests, or adversely affect prey populations would impact killdeer populations.

Spotted sandpipers use wetlands, water surfaces, and riparian areas during the spring, summer, and fall before they migrate south for the winter.

These birds feed on a variety of insects, snails, mollusks, spiders, and other invertebrates.

Spotted sandpipers breed in June and July in many different habitats: on bare soil, sand, rubble, marshes, grass, and woody sites. The birds reach sexual maturity in 2 years. A female mates with two or more males and the males care for the brood.

Activities that make prey and their habitats unavailable to spotted sandpipers and those actions that destroy or make nest sites unsuitable should be avoided.

Dipper

The American dipper is a species with a wide distribution across western North America, but its habitat preferences are flowing rivers and streams. The dipper is totally dependent upon clean riverine ecosystems. Nests are located on logs, bridges, midstream rocks, and streamside gravel beds. The birds breed from late February into July, with most birds bringing off two clutches per year.

The dependence of the dipper on quality water that has predictable flows, especially during nesting season, makes water management crucial for this species' survival along the Arkansas River and many of its tributaries.

Mammals

Bighorn sheep are yearlong residents of the drainage, though they sometimes move seasonally within the overall area. Sheep are primarily grazers, but do utilize shrubs at some times of the year. Bighorns require freestanding water and come to the Arkansas River daily during most of the year to drink and feed on succulent vegetation associated with the riparian zone.

Bighorns breed from November through December and lambs are born in May or June. Lambing grounds are usually the roughest and steepest areas of the bighorn's ranges. Home ranges extend from .25 mile to 2 miles (occasionally more), depending on availability of food, water, living space, and the level of disturbance. Predators, disease, human disturbance, and low quality/quantity of food and water adversely impact this species.

Actions that increase human disturbance, change water quality (or significantly change water quantity), or impact riparian vegetation will affect bighorn sheep.

Amphibians and Reptiles

In contrast to the bighorn sheep, amphibians like the Woodhouse's toad receive little attention or recognition from the general public; they are, however, an integral and important part of the properly functioning riparian ecosystem and are now being recognized as valuable indicators of environmental quality (Brinson et al. 1981). The Woodhouse's toad occupies riparian and wetland habitats along the Arkansas River up to about 7,900 feet. This toad species breeds in the aquatic habitats and spends the rest of its life in a riparian or wetland area. Woodhouse's toads eat a variety of insects, spiders, and centipedes. They breed in May and June and tadpoles hatch within a few days.

Because of their dependence upon aquatic, riparian, and wetland habitats, all actions that affect these habitats will affect Woodhouse's toads. Water temperature and water quality are important habitat elements to manage, as are flows that impact breeding.

Painted turtles are found in lacustrine, littoral, palustrine, and riverine aquatic habitats and adjacent riparian and wetland areas of the Arkansas River drainage (most often found in ponds near rivers and streams). They feed on snails, mollusks, insects, worms, carrion, and vegetation. Feeding occurs in waters with temperatures of 59 °F or warmer. Painted turtles are active from March through November and overwinter in muddy bottoms of ponds that have mud up to 18 inches deep.

These turtles breed in water that is less than 2 feet deep after reaching sexual maturity at about 3 years of age. Painted turtles breed from March to mid-June and may use waters that have temperatures of 50-82 °F. They build nests that can be up to 200 feet from water. Management practices that protect and sustain aquatic habitats, primarily a water table to maintain lowland standing water, will be beneficial to painted turtles.

Riparian Habitats

Riparian and wetland resources receive significant attention from land management agencies (USDI 1991, USDA 1992) and the public because of their limited relative abundance, functions associated with improving water quality and quantity, importance to wildlife, and numerous other critical functions that collectively lead to healthier watersheds. These important features, coupled with the potential for management to alter and disrupt riparian function, dictate careful evaluation prior to undertaking management actions that may affect riparian habitat.

Riparian and wetland resources in the region addressed by this water needs assessment have been greatly modified. A century of road, railway, and dam construction, irrigation, conversion of land to agriculture, urban development, and other modifications have transformed riparian resources. Riparian and wetland resources have been altered as a result of:

1. Vegetation Manipulation - land use activities such as recreational vehicle use, grazing, and introduction/invasion of exotic vegetation.

2. Watershed Alteration - land use activities such as road construction, logging, and grazing affect infiltration, runoff, sediment supply, and water quality.

3. Direct Modification - channelization of streams, draining or filling of wetlands, and conversion to other uses.

4. Hydrologic Alteration - water diversions, water importations, and dam construction.

The Arkansas River's riparian and wetland areas have been altered by all the modifications listed above. Understanding these changes is essential when evaluating recommended flow management scenarios. It is important to realize that all future modifications will be acting upon a system that has already been greatly modified.

Because this study deals with potential modification of the existing hydrologic regime, it is crucial to link hydrology to the ecology of the riverine environment. Changes to riparian areas and wetlands will affect other resources that depend upon properly functioning riparian and wetland areas.

Description of Riparian and Wetland Resources

The extent of riparian and wetland resources within the study area is determined to a large degree by natural geomorphology. Much of the Arkansas River is bounded by rock, narrow, and confined due to its landform. Many reaches that were confined naturally are now even more confined as a result of highway and railroad construction. The rocky, narrow canyon topography, coupled with high spring flows, limits soil development and plant establishment. In less confined reaches, meander bars and streamside floodplains have a limited band of riparian vegetation. For example, downstream of Cañon City, and for a short reach between Leadville and Granite, the river features a well-developed floodplain with substantial acres of riparian vegetation.

The majority of the riparian and wetland vegetation along the Arkansas River is composed of grasses, sedges, rushes, willows (several species), alders, birch, and cottonwood. There are limited amounts of emergent or submergent shoreline vegetation. The combination of cool temperatures, lack of nutrients, and high flows limits aquatic macrophytes. Kittel et al. (1996) provide an excellent description of community-based riparian and wetland resources in the Arkansas River Basin.

Based on the channel classification system of Rosgen and Silvey (1996), most of the Arkansas River is classified as either a “B” or “F” channel type. There are small areas that are classified as “C” channel types. The predominant channel types (B and F) are not well-suited for the development of extensive riparian and wetland vegetation. From a geologic standpoint the river is incised in pre- Cambrian rock, except for downstream of Cañon City and the reach between Leadville and Granite. Below Cañon City, and just below Leadville, the river flows through sedimentary/alluvial outwash materials that allow floodplain development.

General River Hydrology, Riparian and Wetland Resources

Because of the constricted nature of the channel, the annual flow regime greatly affects riparian and wetland resources. Flows at bankfull and higher increase depth much faster than width compared to unconfined river systems. Bankfull flow (1.5-year high-flow frequency) and higher, less frequent peak flows scour the channel of fine sediment deposits and vegetation. Discharges at bankfull flow (i.e., the riparian vegetation line in many reaches) are 2,000-2,200, 2,300, 2,500, and 3,000 cfs for the Numbers, Browns Canyon at Hecla Junction, Wellsville, and Floodplain cross sections, respectively. There is a large separation between bankfull stage and lower base flows, which leaves a large expanse of rock between base flow levels and the riparian and wetland vegetation line. Late summer water surface elevations, for example, are substantially below the riparian and wetland vegetation line for much of the study area. The growing season water table, however, is linked to established riparian and wetland communities.

Reservoir Riparian and Wetland Resources

Reservoir operations largely dictate the composition of the reservoir riparian and wetland communities. Operation procedures differ substantially from reservoir to reservoir. The upper reservoirs, Turquoise, Twin Lakes, and Clear Creek, tend to be near full pool early in the growing season. This operation schedule supports a narrow band of wetland vegetation along the reservoir shoreline, except where bedrock is the dominant substrate. Wetland vegetation is also found at inlet areas in response to the delta effect and sediment deposits. Shoreline areas at the mouths of tributaries, and areas with substantial hillside toe-slope moisture, also support wetland communities. The upper reservoirs are usually full and spilling through runoff. Drawdown begins in late summer. Drawdown occurs prior to plant dormancy; however, the water needs of plants are reduced late in the growing season, when drawdown leads to lowering of the water table. The wetland vegetation communities at these high elevation reservoirs have evolved to survive the water management timetable.

Operation procedures for Pueblo Reservoir are very different. Timing of annual full pool is variable, depending on snowpack, and is rarely at maximum. During dry periods, existing wetland vegetation dies because of separation from the water table. When the dry period ends, filling to a higher level inundates recently established low lake level shoreline vegetation. Unlike the upper reservoirs, drawdown at Pueblo Reservoir coincides with the growing season, so even in relatively stable years, the water table separates from the vegetation before plants become dormant. Even though there is substantial wetland vegetation at Pueblo Reservoir, the community is not stable. The reservoir supports substantial riparian vegetation around the inlet due to a large delta effect. Standing dead cottonwood trees in the shallow inlet area, which are important for bird populations, are remnants of trees living prior to reservoir construction. These trees are not regenerating and will topple over time. Younger trees are establishing at the upper inlet margin.

Hydrologic Concepts Related to Riparian and Wetland Resources

Numerous site-specific variables determine the composition of a riparian or wetland community

(Nilsson 1982). The geomorphic setting, soils, land use, climate, discharge, and a host of other factors are important. The timing, duration, and magnitude of discharge are of major importance to the riparian community. Risser and Harris (1989) discuss riparian studies and point to the difficulties, inconsistencies, and inherent problems related to transferability of results from one location to another. The unique setting of each riparian area makes transferability of results unreliable. Risser and Harris (1989) note, however, that common ecological principles apply almost everywhere. Without intensive local study, it is difficult to predict how flow modification in the Arkansas River will affect riparian community composition. However, established ecological principles and existing studies can be used to predict how the riparian community will respond to different flow regimes.

There has been considerable research on the effects of flow reduction on riparian and wetland resources (Szaro and DeBano 1985; Smith et al. 1991; Kondolf et al. 1987). The results of these studies document the effects of diverted water or reduced flow on riparian communities. Other studies discuss altered hydrograph scenarios, common in this region of the country, whereby peak flows are reduced and annual low flow is raised (Risser and Harris 1989; Petts et al. 1995). Response to reduced peak flows and higher annual flows below reservoirs is well-documented, typically resulting in encroachment of riparian vegetation.

Research on flow reduction shows that reduction in annual or growing season discharge affects foliage basal area, foliage density, water table, and width of the riparian area (Reily and Johnson 1982; Stromberg and Patten 1990, 1991). Other variables that change in response to alteration of the hydrograph are sediment characteristics (e.g., sediment size), water temperature, and inundation/saturation regimes. Each of these variables directly influences riparian vegetation. Winter flow changes alter icing patterns, which change (by physical actions) riparian and wetland disturbance patterns. Reduction of peak flows causes riparian and wetland vegetation encroachment into the channel, thereby reducing stream width (Risser and Harris 1989, Petts et al. 1995). Many of the past investigations document effects when flows are reduced during partial or extreme dewatering situations; fluctuating flow scenarios are less studied.

There have been few studies of riparian and wetland response to increased late summer flow. Stabler (1985) reports increased summer flows resulted in beneficial effects to riparian vegetation when grazing practices were modified and flows increased. Similar beneficial effects related to beaver dams and increased flows have also been documented (Wilen et al. 1975). In these increased flow studies, stream size has been relatively small, certainly much smaller than that of the Arkansas River.

Inference to the Arkansas River

Studies show that reduced flow, particularly during the growing season, has a negative effect on riparian and wetland vegetation. Conversely, a likely assumption is that extended high flows during the growing season would benefit plant basal area, foliage density, and other factors, which collectively determine a riparian area's extent and functioning condition. However, it is difficult to transfer results of actions from one riparian area to another. Soil moisture, bank erosion rates, and water table levels are just some of the variables to consider when flows are modified. Flow manipulations will likely cause an evolution to a new riparian community, with a different width and composition. An action perceived to enhance vegetation could erode streambanks and ultimately limit the vegetation extent.

The Arkansas River is rocky and subject to high scouring flows. Since most of the study area does not have well-developed floodplains, riparian community composition and extent are governed by channel geomorphology and high flows. Extended high base flows in the upper Arkansas River will likely further erode sediment deposition areas, and may **slightly** raise the water table in areas that are not solid rock.

Channel profiles for the sampling sites in this study yielded "grassline" elevations that match flows of 2,000 cfs and higher for upstream reaches, and 3,000 cfs for the floodplain reach. Although there is a clear separation between bankfull vegetation and late summer flows, elevated summer flows do have the potential to inundate plant roots in some areas.

Flow Effects on Riparian Vegetation

The upper Arkansas River has relatively little riparian or wetland vegetation as a result of its channel type and geomorphology. The scarcity of riparian and wetland vegetation in the Arkansas River basin increases the importance of properly maintaining or enhancing existing riparian and wetland areas. Riparian vegetation is controlled by high flow events and the elevation of riparian vegetation is generally separated from lower base flows. Riparian and wetland communities have adapted to the historic hydrograph, which incorporates natural flow variability. Fluctuations in late summer flows within this natural variability are unlikely to cause obvious changes to the riparian or wetland communities, unless they are consistently higher or lower than average. Extended high flows will serve to erode banks and widen the channel in areas with depositional features. In areas that are largely rock or confined, increased flow will raise water surface elevations slightly, but water levels will still remain below the streambank grassline. In other less confined reaches, riparian areas will widen in response to the increased flows. However, these gains will likely be offset by loss of riparian vegetation in areas where banks have eroded.

Reservoir operations play a key role in determining the structure of adjacent riparian and wetland communities. Different reservoir operating plans result in different vegetation communities. Significant changes in reservoir operations will alter the corresponding vegetation community. Composition of future reservoir riparian communities are tied to water levels and timing of drawdown.

Analysis of Water Preferences

Fisheries

Coldwater Reservoirs

Twin, Turquoise, Clear Creek, and Pueblo Reservoirs have been studied extensively by the Bureau of Reclamation Research Section, the Division of Wildlife, and graduate students from Colorado State University. Numerous studies are cited in the Resource Values - Fisheries discussion that provide a basis to examine fish populations, and the base production on which they are dependent, in relation to water levels. Using this information, some conclusions have been formulated that present water level requirements for maintaining aquatic biota.

To provide optimal habitat for lake trout, rainbow trout, and primary/secondary productivity, which supports the food chain, an ideal water level management plan for the upper coldwater reservoirs would be to maintain full reservoirs (top of the conservation pool) year-round and stabilize water levels, particularly from July to October, with no daily fluctuation.

Water operations that entail significant changes in water elevations or flushing rates do not present conditions that allow establishment of a sustained fishery. For example, current operation of Twin Lakes during the summer induces mixing of the euphotic zone (top 30 feet of water), particularly in the lower lake, on a daily basis. This daily mixing disrupts physical and chemical conditions that limit plankton reproduction, prevents vegetation from establishing in the littoral areas around the lake, and thus decreases primary and secondary food production. Thermocline development occurs at the lower level of this euphotic zone and is an important feature for holding warmed water near the surface during the summer months. Disruption of this water stratum by drawdown or by increasing flushing rates directly limits biotic food production and fish feeding. It follows that the greater the disruption (in vertical feet drawdown or volume of flushing), the greater the decrease in overall biotic production and fishery potential. Lake and rainbow trout are dependent upon primary and secondary producers for a food base, and decreases in this food base will negatively impact the survival and growth rates of trout. Where these conditions continue, the establishment, development, and management of reservoir trout fisheries will be limited. If water evacuation is necessary, particularly during the critical summer period (July to October), incremental invasion of the littoral zone within the top 30 feet will result in proportionally greater impacts to sustaining aquatic life.

If water releases are necessary during the fall and winter, restricting drawdowns from October to March to no more than 10 feet (from October 1 water elevations) at Twin Lakes and Turquoise Reservoirs will increase the successful incubation and hatching of lake trout eggs deposited in spawning areas.

Shoreline habitat for fry and juvenile lake trout at Twin and Turquoise Reservoirs increases with higher water levels in the spring. Stabilizing or increasing water levels from March to June allows these littoral areas to provide food and cover for fry and juveniles until they are ready to move to deeper water.

Of the three reservoirs, Clear Creek is the most productive due to its shallow basin and warmer water. Clear Creek Reservoir also does not experience the continuous water level fluctuations seen at Turquoise Reservoir, and more notably at Twin Lakes, and this benefits productivity as well. As a result, Clear Creek Reservoir shows better year-round trout survival and growth. Nonetheless, with incremental drawdown from full pool, the loss of production within the euphotic zone (basically the entire water column) and the physical loss of rainbow trout due to emigration increases. This loss is likely to increase as the water surface elevation drops due to the proximity of the outlet to the warmer and more nutrient-laden surface waters. Flushing rates also will increase with proportionally greater drawdown and less reservoir volume.

Warmwater Reservoir

Pueblo Reservoir, located in the lower reaches of the Arkansas River study area, provides habitat for several warmwater species of fish that may be affected either positively or negatively by water fluctuation. Two groups of these species (black bass and crappie) were selected as resource values for assessment because of their dependency on water level and fluctuation. Based on information summarized in the Resource Values discussion, the following water management plan optimizes fishery values in Pueblo Reservoir:

1. Fill the reservoir to the top of the conservation pool (4880 feet) from November through March.
2. Maintain a full reservoir pool from March to July 15.
3. Draw down approximately 10-20 percent of surface acreage of the reservoir from July 15 to August 15.
4. Maintain stable water levels from August 15 to November 1.

This water level fluctuation plan holds a variety of benefits to the fishery in Pueblo Reservoir. Filling the reservoir in the late fall and winter allows for the inundation of vegetation and the shoreline, which will provide food, cover, and spawning areas in the spring. The stable water level during the spring and early summer allows for good spawning habitat, high plankton levels to feed fry, and cover for adults, juveniles, and fry during this period. A drawdown in mid-July to mid-August exposes the shoreline for recolonization of vegetation and concentrates forage species for maximum utilization by sport species for growth.

The fluctuation plan presented for Pueblo Reservoir is a fairly standard warmwater fluctuation plan for reservoirs across the United States. Hall and Van Den Avyle (1986) stated that because plants support bacteria, zooplankton, benthos, and fish, effects of water level changes on primary production can greatly influence responses at higher trophic levels. Additions to the plan could include seeding of exposed shoreline with ryegrass or wheat to enhance vegetation growth. Groen and Schroeder (1978) showed an increase in walleye, white crappie, white bass, and gizzard shad as a result of this type of water level management plan.

Conversely, a water level management plan that includes rising water levels in late summer and downward fluctuations in spring and early summer has been shown to have adverse effects on sport fish populations. The dewatering of spawning areas can result in abandonment of nests by adult crappie, which can result in increased predation of eggs. Spring drawdowns can dewater black bass redds and eggs and result in weakened or failed year class survival. High water levels in late summer could reduce foraging efficiency and growth of sport fish, as well as preventing establishment of habitat conditions necessary for optimum spawning activities during the following spring spawning season.

Arkansas River

Each life stage of a fish (spawning, fry, fingerling, adult) has specific habitat requirements that can be defined by three values: depth, velocity, and substrate. By physically measuring these three attributes and using IFIM to analyze the data and essentially "map" a cross-section of a stream, the amount of habitat suitable for various life stages of trout can be predicted.

The discharge of a stream, of course, alters all three of these attributes. As discharge changes, so does the water depth, water velocity, and possibly the type of substrate inundated. Therefore, the defined habitat for trout also changes with flow. The amount of habitat for each trout species and each life stage can be quantified for any stream discharge using PHABSIM and compared with habitat suitability curves for each species. These two model components link the physical habitat to the biological habitat requirements of the fish, and result in a model output that quanitifies fish habitat in units called "weighted usable area" (WUA).

Habitat modeling was accomplished during the fall of 1996 using PHABSIM (Milhous et al. 1989) for each of the six study reaches. Water surface elevations and velocities were simulated for flows ranging from 350-2000 cfs. The habitat suitability information used for the Arkansas River was originally developed from the South Platte River. The spawning and fry data were developed in 1987 (Nehring and Anderson 1993). The juvenile and adult data utilize substrate codes instead of cover codes because habitat utilization was not verified on the Arkansas River. Also, velocities and depths were adjusted for juveniles and adults to reflect habitat verification studies on the South Platte River in 1988 (Nehring personal communication 1997; Shuler 1992; Shuler and Nehring 1994; Shuler et al. 1994). These curves have been widely applied in Colorado and transferability has been proven to be reliable (Nehring personal communication 1997; Thomas and Bovee 1993). Table 5-1 is an example of output from this modeling process.

The data in Table 5-1 shows that habitat is optimized for adult brown trout at the Floodplain site at 350 cfs, when 49 percent of the total habitat is available. When flows increase to 900 cfs, almost half of the available adult habitat at the Floodplain site is lost (reduced to 29 percent).

Table 5-2 lists the optimum flows for brown trout and rainbow trout life stages of spawning, fry, juvenile, and adult for the six IFIM sites. Modeled data was then reviewed relative to the percent of habitat present with varying discharge to determine flows where habitat is limited for a life stage. These instances are marked with the symbol ¿ in Table 5-2. For example, the optimum flow for brown trout spawning at the Floodplain site

TABLE 5-1

Weighted Usable Area (WUA) for Adult Brown Trout at the Floodplain Site

Discharge (cfs)	WUA (square feet) by Cross Section				Total WUA	% WUA	WUA/1,000 ft River Length
	2	3	4	5			
350	7,350	4,344	1,241	4,496	17,431	49	27,890
450	6,845	4,143	1,143	5,040	17,171	46	27,474
540	6,302	3,682	1,095	5,056	16,135	41	25,816
630	5,788	3,410	1,057	4,625	14,880	37	23,808
730	5,279	3,103	987	4,158	13,527	34	22,352
900	4,665	2,580	795	4,158	12,198	29	19,517
1,200	3,573	2,025	585	3,553	9,736	21	15,558
1,630	2,634	1,586	611	3,375	8,206	17	13,130
1,850	2,362	1,406	623	3,092	7,483	15	11,973
2,000	2,156	1,316	628	3,149	7,249	15	11,598

TABLE 5-2

Arkansas River Optimum Water Discharge for Fisheries

IFIM Station/ Species	Trout Life Stage/Discharge (cfs)			
	Spawning	Fry	Juvenile	Adult
Floodplain:				
brown trout	1850g	540g	350	350
rainbow trout	1850g	540g	350	450
estimated flow	377	377	377	377
Stockyard Bridge:				
brown trout	300	356	356	500
rainbow trout	356	300	300	600
gaged flow	300	300	300	300
Independent Whitewater:				
brown trout	250	400g	250	327
rainbow trout	250	400g	250	400
estimated flow	246	246	246	246
Browns Canyon:				
brown trout	250	250	250	357
rainbow trout	250	250	250	357
estimated flow	246	246	246	246
Numbers:				
brown trout	210	500g	210	350
rainbow trout	210	500g	210	500
estimated flow	131	131	131	131
Leadville:				
brown trout	100	500g	100	100
rainbow trout	100	300g	70	100
estimated flow	28	28	28	28

g denotes flows where limited habitat is available for a life stage

Note: “Estimated flow” means the estimated flow at that site when the gaged flow at Stockyard is 300 cfs. This relationship between flows at various sites is described in the Hydrologic Analysis section of this report.

is 1,850 cfs, but only 0.14 percent of the total habitat is spawning habitat. Accordingly, Arkansas River flows should not be managed to gain this small amount of spawning habitat at Floodplain while sacrificing habitat for other life stages and species in the rest of the river.

Modeling a river with a variety of habitat types typically results in major conflicts between key species and their life stages. This was not the case for the Arkansas River. Optimum flows for both brown trout and rainbow trout at various life stages were similar (Table 5-2). Optimum flows also matched well within the entire study area. For example, habitat at the other IFIM stations is near optimum when gauged flows at the Stockyard Bridge site are 300 cfs (Table 5-2).

Managing the Arkansas River fisheries requires more than identifying optimum flows. It requires balancing flows for key species and their life stages during certain times of the year while accounting for natural flows like runoff. When comparing the modeled data (relative to percent of habitat present) with optimum discharge, a secondary inflection point, where habitat significantly drops, was observed in most cases. For example, in Table 5-1, a significant decline in percent WUA occurs from 450-540 cfs (5 percent). From this, a range of optimum flows was established from 350-450 cfs for brown trout adults at the Floodplain site, which is also illustrated in the habitat versus discharge relationship figures in Appendix C. This exercise was accomplished for all life stages of both brown trout and rainbow trout at all IFIM sites. When optimum flow ranges at the Stockyard site are extrapolated to the other sites, the resulting discharges consistently protect all life stages and species at that site (Table 5-2). From this, the following ideal range of flows was established for the Arkansas River, measured at the Wellsville gauge. Brown trout are the focus of this water needs analysis because they are more prevalent than rainbow trout and they are self-sustained. Rainbow trout habitat will also be optimized as follows, except for fry during runoff, a period where little flow management exists (see the Resource Values discussion).

Period: October 15-November 15
Flows: 250-450 cfs (optimum)

This is the spawning period for brown trout. All efforts should be directed at maintaining steady flows within the range indicated. Best survival will occur if spawning, incubation, hatching, and fry emergence flows are similar.

Period: November 16-March 31
Flows: 250-450 cfs (optimum)

This is the egg incubation period. At least 60 percent of the spawning flow should be maintained to prevent egg desiccation from dewatering of spawning redds.

Period: April 1-May 15
Flows: 250-450 cfs (optimum)

This is the egg hatching and fry emergence period, and is the most critical period concerning fry survival. All efforts should be directed at maintaining steady flows within the range indicated. Fry are especially vulnerable to flows above this range due to their inability to withstand high velocities.

Period: May 16-May 31
Flows: 250-450 cfs (optimum)

This is the period of fry development and their continued protection from flows above this range is important for survival and growth prior to runoff.

Period: June 1-July 15
Flows: 250-450 cfs (optimum)

This is the runoff period where little flow control exists. The fishery could tolerate additional flows above runoff for a short period. This is preferred rather than releasing extra water earlier (April 1-June 1).

Period: July 16-October 14

This is the most critical period concerning trout growth. It is preferred that flows return naturally to base flow or 250 cfs, whichever is greater.

Managing the Arkansas River for brown trout and rainbow trout also requires following some general guidelines:

1. Dramatic fluctuation should be avoided as much as possible (limit the daily change to 25 percent).

2. Every effort should be made to avoid violating the April 1-May 15 flow period recommendation.

3. The following priority ranking should be considered in case of unexpected high snowpack and possible violation of the April 1-May 15 flow recommendation:

    a. Increase flows November 16-March 31 up to 500 cfs.
    b. Increase flows May 16-May 31 up to 500 cfs.
    c. Increase flows June 1-July 15 up to the channel maintenance flow.

4. The following priority ranking should be considered in case of unexpected low snowpack:

    a. Decrease flows June 1-July 15 to the channel maintenance flow.
    b. Decrease flows May 16-May 31 to base flow or the 60 percent rule, whichever is greater.
    c. Decrease flows November 16-March 31 to base flow or the 60 percent rule, whichever is greater.

Fish habitat has an optimum value at a certain velocity and depth, the most important habitat variables on the Arkansas River. As velocity and depth values move further from the optimum, it becomes less likely that a trout will occupy that location in the river. Currently, high flows frequently produce unfavorable habitat conditions in the Arkansas River. As flow increases above 400 cfs at Wellsville, depth and velocity increase disproportionately compared to width. Velocity accounts for large drops in suitable habitat, particularly for small fish. This phenomenon is even more pronounced in more confined river reaches. High velocity is generally recognized as the most critical variable in microhabitat selection by lotic trout (Jenkins 1969; Bachman 1984; Fausch 1984; Shrivell and Dungey 1983). Fausch (1984) and Bachman (1984) point out that brown trout occupy positions in a stream that maximize net energy gain during foraging. The potential profitability of a specific position should be predictably related to growth of a fish (Fausch 1984), and therefore, profitability is also a function of flow. Many authors have suggested the carrying capacity of a stream may be determined by available habitat and number of foraging sites (Chapman 1966; Hunt 1969; Bachman 1984).

Although IFIM is a well-recognized and acceptable model, historical field data on brown trout collected at the Wellsville site on the Arkansas River from 1981-1996 was also used to establish the relationship between available habitat and fish growth (Anderson and Krieger 1994; Policky - CDOW unpublished reports). Growth of brown trout collected during electrofishing surveys was evaluated in relation to flow levels and water temperatures that the trout had experienced during their lives. A strong correlation between brown trout growth and discharge, particularly in August (Anderson and Krieger 1994), was discovered. R-squared values of age 1 and age 2 brown trout growth versus the number of days discharge was <700 cfs in August and September were 0.76 and 0.55, respectively. It is important to stress that 700 cfs does not represent favorable habitat, but simply illustrates the relationship between brown trout growth and discharge. Indeed, trout habitat is optimized at a much lower discharge level, as stated above. Trout growth is a good indicator of the health of an aquatic ecosystem because it integrates all the biotic and abiotic variables impacting organisms and reflects secondary effects of chronic stress (Geode and Barton 1990).

Greater depths and increased velocities not only increase the metabolic cost associated with foraging, but also create conditions that reduce the capture of drifting insects. These conditions, combined with warm water temperatures and poor prey availability (Winters 1988), make August a critical month for trout growth. Higher releases from Twin Lakes in August and September will not decrease water temperature for any appreciable distance downstream. Figures 5-6 and 5-7 demonstrate the poor relationship between flow and water temperature. And, as stated previously, augmented flows at this time cause decreased growth of young fish. The only way to maximize trout growth at this time is to keep flows within the optimum range after runoff.

There is a negative correlation between water temperature and discharge in March and April. However, Figures 5-8 and 5-9 show that this correlation is poor, particularly in March. Anderson and Krieger (1994) felt releases during this period in 1989 and 1993 accounted for some of the variability in growth of age 1 and 2 brown trout captured the following spring. They theorized egg development and subsequent hatching could be delayed by cold water releases in March and April. Subsequently, prerunoff growth could be affected and smaller fish would be less able to withstand the rigors of runoff.

Wildlife

The flows of the Arkansas River affect various wildlife species in a variety of ways including: food availability and variety, quality and quantity of escape cover, habitat for breeding and rearing young, alteration of migration and movement routes, and creation of barriers and hazards resulting in drowning and other forms of accidental death.

Wildlife species living along the river corridor have survived and adapted to fluctuations in water levels. Although a few individuals may die as a result of rising water levels, populations are not normally directly impacted to a significant degree. Vegetation habitat components, however, may and have historically been altered as a result of changes in the water flow regimes of the Arkansas River. These changes in vegetation are then reflected in changes in the associated wildlife populations' use of the riverside habitats and the movements of individuals and groups of animals through and along these riparian zones. Because of this interrelationship between riparian vegetation and wildlife use, flows that protect aquatic, riparian, and wetland habitats will be adequate in fostering suitable wildlife use along the Arkansas River.

Additionally, flows that result in greater human use in the Arkansas corridor and associated reservoirs should be considered in the evaluation of future flow management. Wildlife/human interactions have varying degrees of direct and indirect effects on wildlife populations.

Riparian Habitats

Riverine Riparian Resources

The optimal hydrograph for riparian and wetland resources that exist through most of the study area would be one which closely mimics the natural hydrograph (see the Hydrologic Analysis section of this report). Given the storage and water rights constraints, exact natural flows are unobtainable; however, the natural pattern of flows should be obtainable. High spring flows are needed to move and deposit sediment. Low flows during a large portion of the growing season are needed to allow vegetation to colonize new banks. Riparian vegetation catches sediments at high flow and maintains healthy banks.

Variation in high and low flows is also important. Consistently high growing season flows will result in a wider channel in locations where vegetated banks line the stream (resulting in shallower water). These effects will be less noticeable where the channel is confined and rocky.

Reservoir Wetlands

The optimal water level for reservoir riparian and wetland resource management is difficult to

FIGURE 5-6

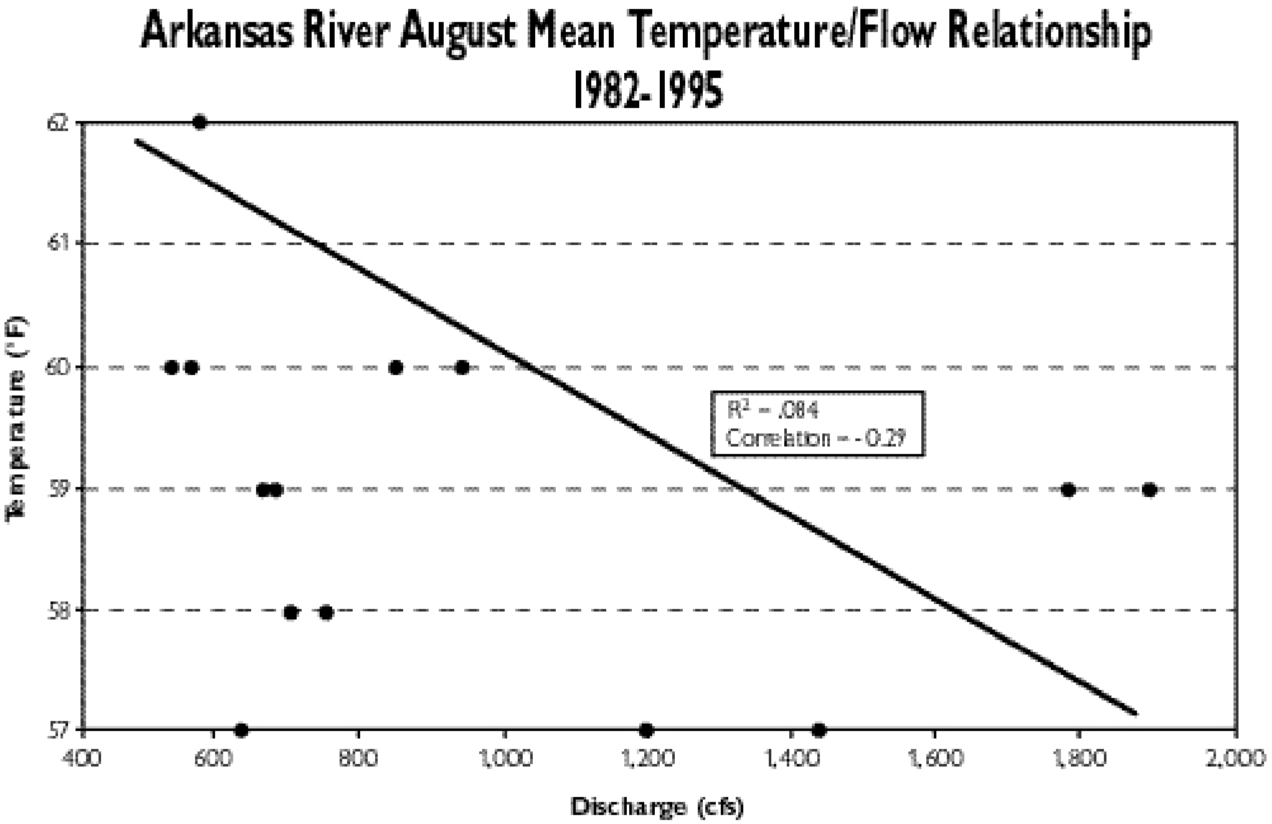


FIGURE 5-7

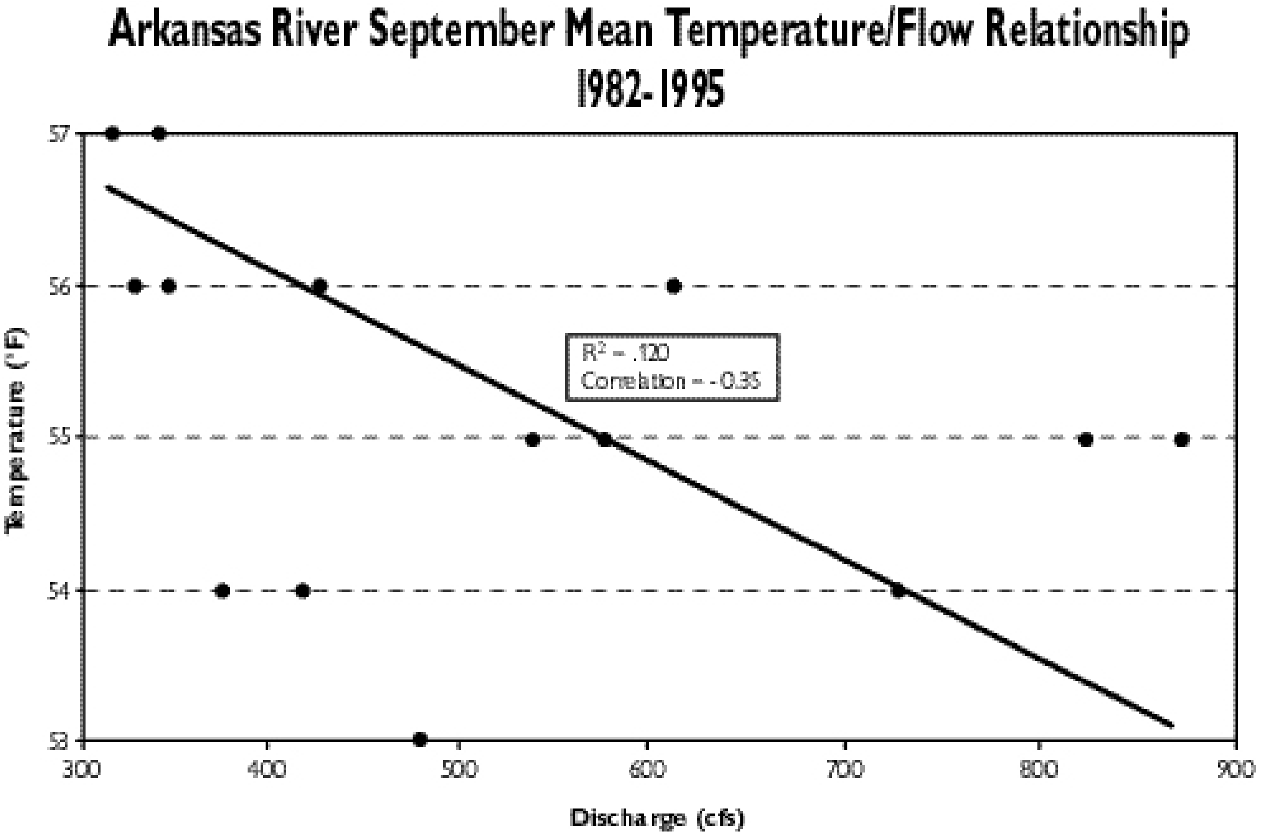


FIGURE 5-8

Arkansas River March Mean Temperature/Flow Relationship 1982-1995

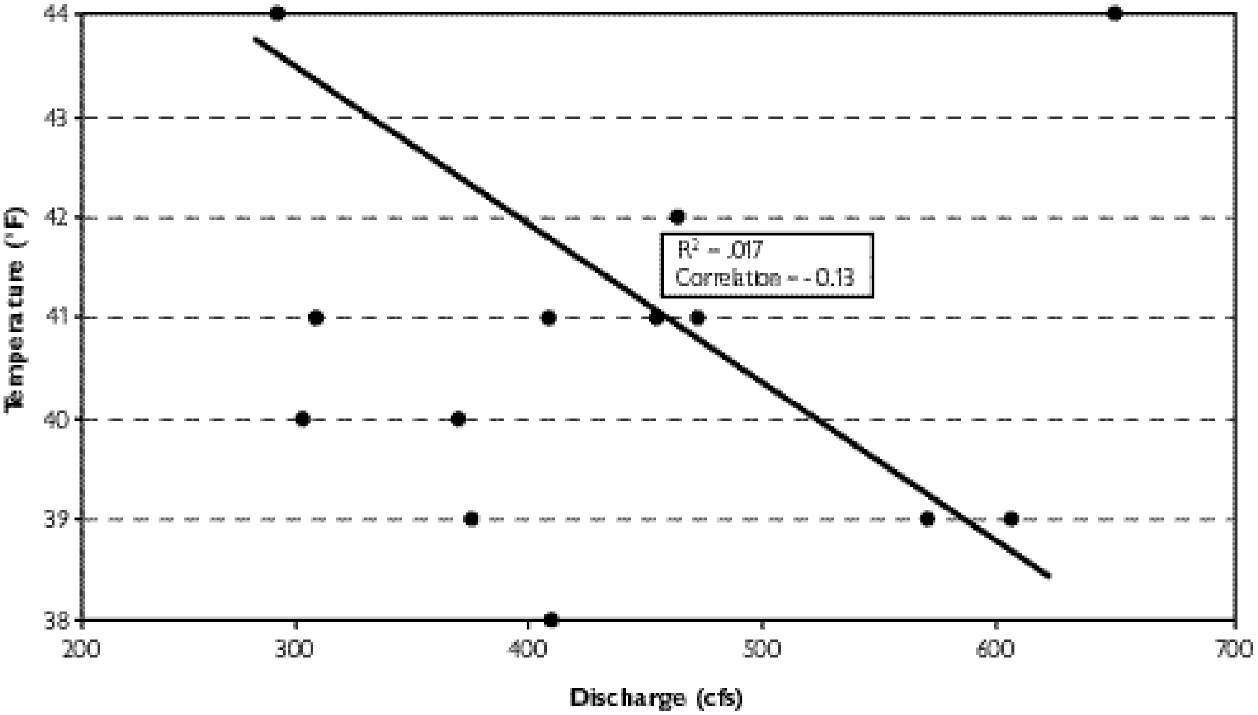
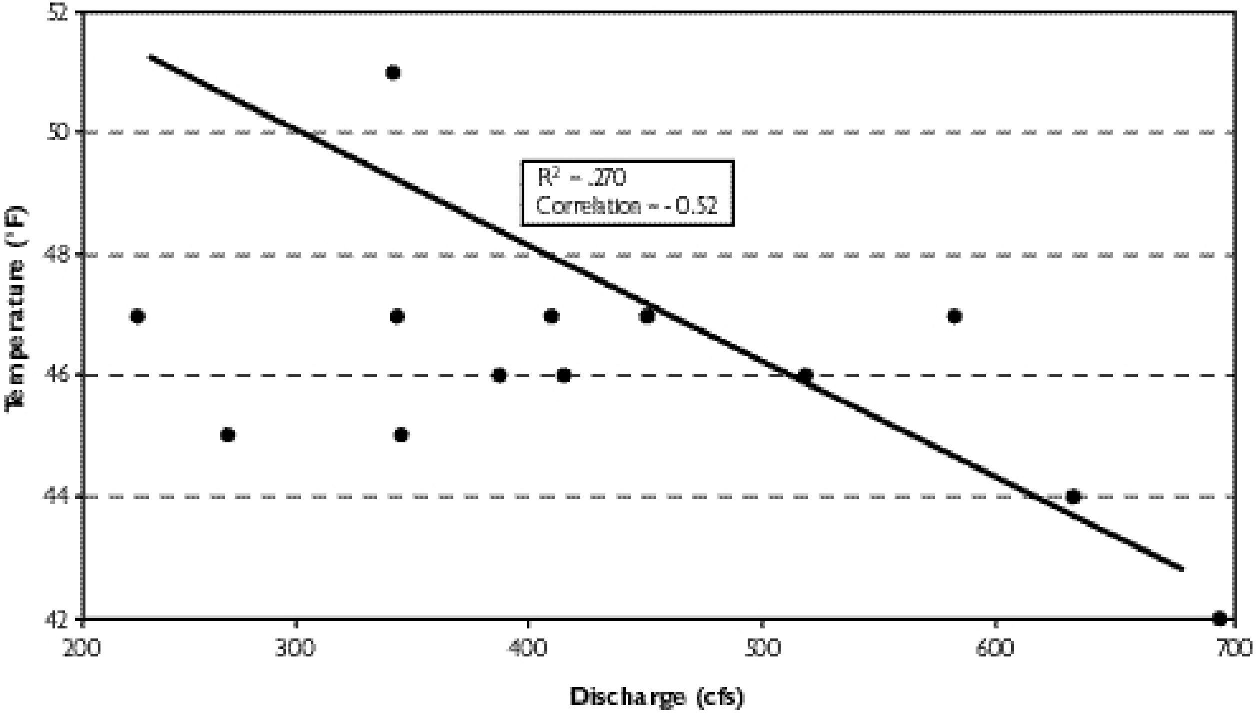


FIGURE 5-9

Arkansas River April Mean Temperature/Flow Relationship 1982-1995



recommend. Reservoirs are constructed for other purposes and operate to meet water demands that counter optimal riparian/wetland management. An operation plan where full pools are obtained as closely as possible to the beginning of the growing season is beneficial. A near stable full pool with a very slight drawdown through the growing season would also be optimal to maintain maximum riparian and wetland resource values (this does not speak to all wildlife species). Drawdown after dormancy has less impact on riparian vegetation. Because late drawdown can conflict with water delivery for agriculture needs, it may not be a workable option. The greatest benefits for reservoir wetlands can be achieved by working toward stabilizing reservoir levels at full pool for as much of the year as possible; coordinating the operation of upper basin and lower reservoirs so that optimal water levels occur at critical periods during the growing season; and modifying drawdown practices to meet both human and riparian/wetland needs.

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Glossary

Bankfull Flow - The maximum stream flow without overflowing in the bank which effectively maintains the channel while discharging sediment, forming bars and bends to generally retain characteristic channels.

Benthos Community - Bottom dwelling organisms including plants, invertebrates, and vertebrate animals that inhabit the benthic zone of a water body.

Biomass - The amount of living matter in a given area or volume of habitat at a given time.

Channel Types - They are defined by evolutionary variables and sequences which result in different width/depth ratios, slope and adjustments over time. They may be wide and shallow, narrow and deep or both.

Channelization - The mechanical alteration of a stream usually by deepening and straightening an existing stream channel to facilitate the movement of water.

Chironomids - Large family of very small, non-biting mosquito-like insects; often found in large swarms, usually in the evening.

Chlorophyll - Green photosynthetic coloring matter of plants made chiefly of esters.

Chrysophycean - A type of segmentation, brightly colored, often living in burrows on mud bottoms created by seasonal shift of phytoplankton.

Cladocerans - An order of crustaceans including water fleas; a part of zooplankton densities.

Confined - The river channel is limited in its lateral movement by valley walls or relic terraces.

Coniferous - Any of an order of evergreen trees or shrubs.

Copepods - Any large subclass of minute fresh-water and marine crustaceans.

Diatom - Microscopic algae with a silaceous skeleton that occurs as plankton or attaches to substrate.

Emergent - Reference here is to a plant rooted in shallow water and having most of the vegetative growth above water.

Endangered and Threatened - Plant or animal life whose innate ability to survive is susceptible to extinction. The endangered are those species that are practically extinct while threatened species are disappearing from our environment at a more rapid, alarming rate than their biological cycle would dictate and are becoming extinct. In both cases the problem is exacerbated because the species habitat is nearly destroyed, drastically modified or has disappeared altogether.

Ephemeropterans - Soft bodied order of insects which includes the mayfly.

Euphotic Zone - Lighted region in a body of water that extends vertically from the surface to the depth at which light is insufficient to enable photosynthesis to exceed respiration of phytoplankton.

Geomorphology - Study of the origin of landforms, the processes that form them, and their material composition.

Gill Net - A flat net suspended vertically in the water. It is a mesh that allows the head of a fish to pass through, but the fish is entangled as it seeks to withdraw.

Glides - A calm stretch of shallow water flowing smoothly.

Hydraulic Retention - Holding back the flow of water - may be caused by a mechanical device or a restrictive occurrence in nature.

IFIM - Abbreviation for instream flow incremental methodology. A method for relating changes in the physical characteristics of a stream to changes in flows.

Inundation - To cover with water or flood.

Lacustrine - Pertaining to lakes, reservoirs, wetlands, or any standing water body with a total surface area exceeding 20 acres.

Limnology - The study of the functional relationships and productivity of freshwater biotic communities as they are affected by the dynamics of physical, chemical, and biotic environmental parameters.

Littoral - Shallow shore area (less than 20 ft. deep) of a water body where light can usually penetrate to the bottom and that is often occupied by rooted macrophytes.

Mackinaw - A large trout usually found in deep cold lakes-a member of the Salmonidae Family.

Macroinvertebrates - Invertebrate animals (without backbone) large enough to be seen without magnification.

Metabolic Cost - The sum of the chemical changes in living cells in a particular environment.

Oligotrophic - Water body characterized by low dissolved nutrients and organic matter, dissolved oxygen near saturation, and chlorophyll levels typically at less than 4 mg/m3 during the growing season.

Palustrine - Nontidal wetland that is dominated by trees, shrubs, persistent emergents, mosses, or lichens.

Phytoplankton - Unattached microscopic plants of plankton, subject to movement by wave or current action.

Planktivorous - Mostly small fish who feed principally on the minute and plant life in an aquatic habitat.

Planktonic - The floating or weakly swimming microscopic animal and plant life in an aquatic habitat.

Raptors - Predatory birds that prey upon other animals.

Recruitment - To secure the services of; to get new members; to restore or increase the health, vigor or intensity.

Redd - Nest excavated in the substrate by fish for spawning where fertilized eggs are deposited and develop until the eggs hatch and larvae emerge from the substrate.

Riffle - A small wave or succession of small waves; an unevenness or disturbance of the surface of a body of water.

Riverine - Relating to, formed by or resembling a river.

Rookeries - The nests, breeding grounds or haunt of gregarious birds or mammals; can also be home for a colony of rooks.

Rotifers - Any of various minute, multicellular aquatic organisms having at the anterior end a wheel-like ring of cilia.

Salmonid - Any of elongated soft-finned fish that have the last vertebrae upturned - Family Salmonidae.

Secondary Producer - The flow of energy through the ecosystem produces various levels of nutrients for feeding (larvae, plankton, etc.) and green plants (photosynthesis). The trophic level is next in the food chain-the secondary producer, a part of the nutrient cycle in the food chain of the ecosystem.

Thermocline - A layer of thermally stratified body of water that separates an upper, warmer, lighter oxygen rich zone from a lower, colder, heavier oxygen poor zone.

Trophic Level - One of several successive levels of nourishment in a food chain, i.e. plant producers constitute the first and lowest trophic level; carnivores the last and highest trophic level.

Turnover - When the thermal stratification found in lakes during the summer ends as water temperatures equalize throughout the water column due to wind action and less solar energy input.

Zooplankton - Microscopic animals of plankton suspended in water of an aquatic habitat - depends on currents and water movement due to limited capability for locomotion.