Mountain Whitefish Conservation and Management Plan for the Big Lost River Drainage, Idaho

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Idaho Department of Fish and Game

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EXECUTIVE SUMMARY

Recent declines in the distribution and abundance of mountain whitefish *Prosopium williamsoni* in the Big Lost River drainage have made evident the need for planning and implementing conservation actions to stabilize and increase the existing population. The goal of this management plan for the conservation of mountain whitefish in the Big Lost River drainage in Idaho is to ensure the mountain whitefish population in the Big Lost River drainage persists through natural and anthropogenic events at levels capable of providing a recreational fishery. Specific population objectives include maintaining two metapopulations of at least 5,000 adult mountain whitefish each, one above and one below Mackay Dam.

This document reviews estimates of historic and current distribution and abundance based on fishery surveys and historic accounts. Mountain whitefish have experienced significant declines in distribution and abundance in the Big Lost River basin. Sampling completed in 2002-2005 indicate that mountain whitefish currently occupy about 83 km of stream, or about 24% of historical levels. Adult abundance in 2005 was estimated to be 2,742 fish or about 1.5% of historical levels.

The plan describes the isolated nature of the Big Lost River drainage and how that likely explains the genetic differences between Big Lost River mountain whitefish and other populations of Snake River basin mountain whitefish. Analysis of microsatellite and mitochondrial DNA from mountain whitefish suggests the Big Lost River population is genetically divergent from its parent population in the Upper Snake River.

Potential factors affecting the Big Lost River mountain whitefish population persistence are identified in the plan, including habitat alteration, entrainment, passage barriers, dewatering, altered flow regimes, competition and predation with non-native fish, disease, and exploitation. These factors are briefly discussed as they may relate to the mountain whitefish population in the drainage.

Specific population objectives are identified for the management areas above and below Mackay Dam. The status of each objective is then classified as met or unmet. Management actions believed to be critical to the attainment of population objectives are identified. Finally, monitoring and evaluation efforts necessary to evaluate the effectiveness of management actions are identified.

GOAL

To ensure the mountain whitefish *Prosopium williamsoni* population in the Big Lost River drainage persists through natural and anthropogenic events at levels capable of providing a recreational fishery.

PLAN OBJECTIVES

The purpose of this document is to:

1. summarize available information on mountain whitefish in the Big Lost River drainage,
2. identify and briefly describe the Big Lost River drainage in terms of geography, hydrology, and anthropogenic changes,
3. identify specific population objectives that will ensure persistence of mountain whitefish in the Big Lost River drainage, and
4. identify conservation actions that will ensure long term viability of the population.

Population objectives

The intent of this plan is to establish and maintain a mountain whitefish population in the Big Lost River basin that has a reasonable chance of persisting through processes that could lead to their extinction. Rieman and McIntyre, (1993) described three general processes that can lead to extinction. These include 1) deterministic risks, 2) stochastic risks, and 3) genetic risks. The relative threat of each of these risks to mountain whitefish in the Big Lost River basin is discussed below.

Deterministic risks are associated with habitat change or loss that results in negative population growth. If negative population growth persists for a sufficient amount of time the population simply decreases until it is extinct. The Big Lost River drainage has undoubtedly lost a significant portion of historical aquatic habitat in recent decades. If this trend were to continue mountain whitefish would eventually disappear from the Big Lost River drainage. This risk can be countered by having sufficient habitat to maintain or increase population growth.

Stochastic risks are associated with random processes and include both demographic risks and environmental risks. Demographic risks include random variation in demographic characteristics such as sex ratios. For example, if random chance resulted in all the individuals in a population being female and this pattern persisted long enough the population would experience negative population growth which would eventually become extinct. However, demographic risks are generally considered very minor unless a population is extremely small. For example, this could be a substantial risk in a population of less than 20 adults. Demographic risks are not considered an important threat to mountain whitefish in the Big Lost River at this time. Environmental risks result from random variation in the environment and include both chronic events such as global climate change and acute, catastrophic events such floods and wildfires. This risk can be countered by achieving abundance, distribution, and connectivity patterns that allow populations to persist through these events.

Genetic risks are associated with a loss of genetic diversity. Genetic diversity increases the probability that a population will persist through a stochastic environmental event. Conversely, a loss in genetic diversity decreases the ability of a population to persist through these types of events. The mountain whitefish population in the Big Lost River basin appears to have limited genetic variation. Whiteley et al., (2006) examined 26 mountain whitefish from the lower Big Lost River and 32 mountain whitefish from the upper Big Lost River and found the fish had no microsatellite variation and only moderate allozyme variation. However, it is unclear if this limited genetic diversity is a result of natural factors that have limited or reduced genetic diversity or anthropogenic influences that have eliminated genetic diversity since the arrival of European settlers. Either way, the limited genetic diversity of mountain whitefish in the Big Lost River basin makes them more susceptible to stochastic environmental extinction risks. Although limited genetic diversity can not be improved in the short term this risk can be countered by preventing the loss of any additional genetic diversity.

With these risks in mind, we have developed distribution, abundance, and connectivity objectives that we believe will result in a mountain whitefish population basin that has a reasonable chance of persisting into the future. Since the populations above Mackay Reservoir and below Mackay Reservoir are functionally separate each has been treated as a separate metapopulation with their own objectives.

Distribution is an important consideration in preventing population extinction. The general concept is to maintain a distribution pattern such that all individuals in a population will not encounter the same stochastic environmental event at the same time. Unfortunately, identifying a distribution that will accomplish this is very difficult. In establishing the distribution objectives for this plan we considered stochastic environmental events resulting from both natural and anthropogenic sources that were reasonably likely to occur in the Big Lost River basin. We then described a distribution pattern that we believed would prevent all the individuals in the Big Lost River basin from being exposed to the same stochastic event. Obviously, no distribution pattern will prevent all individuals in the Big Lost River basin from being exposed to regional or global influences such as regional droughts or long term global climate change, but we did account for these influences in establishing distribution objectives.

A great deal of discussion exists in the scientific literature related to the number of individuals necessary to insure the viability of a population. Rieman et al., (1993) suggests that the probability of extinction of local isolated bull trout *Salvelinus confluentus* populations increases sharply at population sizes below 1,000 to 2,000 individuals. Most of the quantitative information pertaining population viability relates to the conservation of genetic diversity. A guideline proposed by Soulé (1987), suggests an effective population size of 500 is needed in a closed population to prevent extinction due to the loss of genetic diversity. Effective population size, however, refers to effectively breeding individuals rather than just adults. Rieman and Allendorf (2001) suggest that for bull trout an annual average of 1,000 spawners is a cautious number to maintain genetic diversity. Nelson and Soulé (1987) suggest a total population of 5,000 individuals is necessary to maintain genetic variation. Based on this work, we believe a population size of 5,000 to be a conservative minimum to insure long-term persistence of each metapopulation.

Connectivity is extremely important in preventing population extinction for at least two reasons. First, connectivity allows fish to complete life history movements such as spawning and juvenile migrations. Second, connectivity allows fish to recolonize areas where they have been eliminated by stochastic environmental events once conditions again become suitable. Our desire in establishing a connectivity objective was to develop sufficient connectivity to allow fish to complete live history movements within occupied stream reaches and allow fish to naturally reestablish in areas where they have been eliminated.

Based on available research, we believe the following distribution and abundance objectives in this plan represent a conservative minimum to insure long-term persistence of the population.

I. Maintain a metapopulation above Mackay Dam with the following characteristics:
   1) A distribution to include:
      - the mainstem Big Lost River between the Chilly Diversion and North Fork Big Lost River AND,
      - at least three of the following tributaries:
         - North Fork Big Lost River
         - East Fork Big Lost River
         - Wildhorse Creek
         - Star Hope Creek
      - Mackay Reservoir, including Parsons and Warm Springs creeks
   2) An abundance of at least 5,000 adult fish (>200 mm) with at least 100 adults in each occupied stream reach.
   3) Natural levels of connectivity sufficient for all age classes to make natural movements in all historically occupied habitat. In that section of the Big Lost River between the Chilly Diversion and Mackay Dam this objective does not apply to stream flows.

II. Maintain a metapopulation below Mackay Dam with the following characteristics:
   1) A distribution to include:
      - Big Lost River between Mackay Dam and the Blaine Diversion
      - At least one of the following stream reaches:
         - Big Lost River between the Blaine and the Moore Diversions
         - Antelope Creek between Marsh Canyon and Iron Bog Creek

2) An abundance of at least 5,000 adult fish (>200 mm) with at least 100 adults in each occupied stream reach.
3) Natural levels of connectivity sufficient for all age classes to make natural movements in the Big Lost River between Mackay Dam and the Moore Diversion and in Antelope Creek between the Big Lost River and Iron Bog Creek. In that section of Antelope Creek between the Big Lost River and Marsh Canyon this objective does not apply to stream flows.

DRAINAGE SUMMARY

The Big Lost River is one of several hydrologically isolated stream basins located along the northern rim of the Snake River Plain in south-central Idaho. This group of streams, which includes the Big Lost River, Little Lost River, Birch Creek, Medicine Lodge Creek, and Camas-Beaver Creek drainages, has collectively been termed the Sinks Drainages or Lost Streams. These streams originate in the mountains of southeastern Idaho and flow in a southerly direction where they sink into the Snake River Plain. Although these drainages are located within the Snake River basin the immense lava flows of the Snake River Plain prevent the streams from forming connections with other streams.

The Big Lost River is the largest of the Sinks Drainages covering 5,159 km^2. The Big Lost River originates in the Pioneer, Boulder, Lost River, and White Knob mountain ranges and flows down the Big Lost River Valley and then onto the Snake River Plain where it terminates at the Big Lost River Sinks. Major tributaries include East Fork, Star Hope Creek, Wildhorse Creek, North Fork, Thousand Springs Creek, Warm Springs Creek, Alder Creek, Pass Creek, and Antelope Creek. Elevations range from 1,459 m at the Big Lost River Sinks to 3,859 m at the summit of Borah Peak. The climate of the drainage is generally cool and dry. Precipitation along the valley floor is about 20 cm but increases to over 100 cm at higher elevations. Mean annual precipitation at Mackay, which has a period of record from 1931 to 2005, is 24 cm and temperatures range from -36 to 40˚C. Mean annual precipitation at the Idaho National Laboratory, which has a period of record from 1954 to 2005, is 22 cm and temperatures range from -44 to 41˚C. Vegetation within the basins ranges from sagebrush steppe at lower elevations to coniferous forests at mid elevations to alpine at higher elevations. The drainage is comprised primarily of federal land managed by the Forest Service (USFS; 42%), Bureau of Land Management (BLM; 26%), and Department of Energy (DOE; 15%) with lesser amounts of private (14%) and state (2%) lands. The drainage is within portions of Butte and Custer counties and is sparsely populated with agriculture being the dominant land use on private lands. Primary uses of Federal land include cattle grazing and recreation.

Eleven species of fish in addition to mountain whitefish have been documented in the basin. These are rainbow trout *Oncorhynchus mykiss*, cutthroat trout *O. clarki*, brook trout *S. fontinalis*, golden trout *O. aguabonita*, brown trout *Salmo trutta*, kokanee *O. nerka*, arctic grayling *Thymallus arcticus*, Paiute sculpin *Cottus beldingi*, shorthead sculpin *C. confusus*, speckled dace *Rhinichthys osculus*, and lake trout *S. namaycush* (Gamett 2003; Idaho

Department of Fish and Game (IDFG), unpublished data). Although several of these species are native to surrounding areas recent research indicates that only three species, the mountain whitefish, shorthead sculpin, and Paiute sculpin, are native to the Big Lost River basin (Gamett 2003).

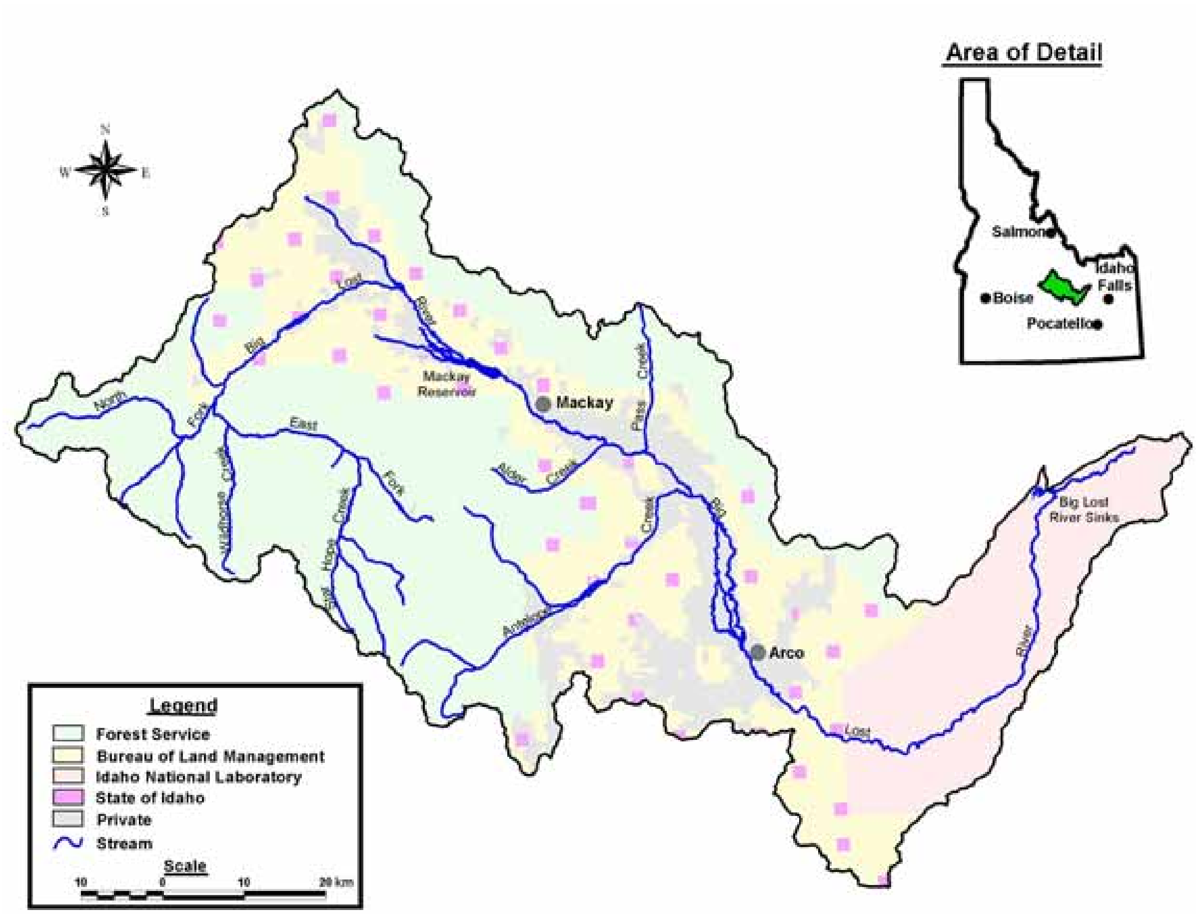

Figure 1. Overview of stream network and land ownership in the Big Lost River drainage, Idaho.

MOUNTAIN WHITEFISH POPULATION

General Species Description

Mountain whitefish are members of the salmonid family (subfamily Coregoninae). In the United States their native range extends from central California and the Lahontan basin in Nevada to the northwester states, including Idaho, Wyoming, and Montana. In Canada they are widespread in British Columbia and western Alberta (Scott and Crossman 1973).

Mountain whitefish are very common throughout larger streams and rivers in their range, and are one of the most abundant game fish in Idaho (Simpson and Wallace 1982). They seem to prefer larger streams to smaller streams (Scott and Crossman 1973), though there is little available information regarding the minimum size stream that constitutes suitable year-round habitat. Though primarily a steam dwelling species, they also occupy lakes and reservoirs, at least on a seasonal basis.

Mountain whitefish are a long-lived species, with some individuals living up to 29 years (Northcote and Ennis 1994). In Idaho, individuals have been documented to be at least 23 years old (Steve Elle, IDFG, personal communication). Maturity is variable, but generally does not occur before age-3 (Scott and Crossman 1973; Northcote and Ennis 1994). Corsi (1989) found that most mountain whitefish in the Big Lost River basin over 250 mm were mature but that all fish less than 200 mm were not mature. Spawning occurs in late fall (typically October and November) when water temperatures reach 40 to 45^{o}F (Simpson and Wallace 1982). Spawning generally occurs at night, with fish broadcasting their eggs and sperm in riffle areas over clean gravel. Eggs incubate throughout the winter months and hatching typically occurs in March and April. Migrations associated with spawning behavior appear to be highly variable across systems, with some populations migrating into tributaries to spawn, while others move very little (Northcote and Ennis 1994). Upon hatching, fry are thought to occupy lateral habitats and low velocity areas. Adult habitat is variable, consisting of shallow riffles, moderate runs, and deep pools during the summer, but primarily deeper pools in the winter (Northcote and Ennis 1994).

Additional information on the biology, management, and habitat utilization of mountain whitefish can be found in Northcote and Ennis (1994), which is the most recent and thorough literature review of the species.

Origin

Mountain whitefish are believed to have been isolated in the Sinks Drainages for a considerable amount of time. Two recent studies have attempted to address range-wide patterns of genetic structure and phylogeography of the species, providing important insight to the origin and significance of the population in the Big Lost River drainage.

Whiteley (2005) used microsatellite and allozyme DNA analysis to examine the hierarchical distribution of genetic variation across the range of mountain whitefish. Using microsatellite analysis, he found evidence of five cohesive genetic assemblages across the species range, and suggested this may be a result of isolation occurring in glacial refugium at least 10,000 years ago. Although divergent from other populations, mountain whitefish in the Big Lost River were most closely related to the Upper Snake River populations. Further study showed less genetic differentiation between Yellowstone cutthroat trout in the Yellowstone and upper Snake rivers than mountain whitefish populations over the same area. Contemporary factors such as habitat fragmentation or waterfalls may affect genetic variation at a small scale (Whitely 2005). Given the geographic isolation from other waterbodies, the genetic structuring in the Big Lost River appears to support his supposition. Of the three cohesive genetic assemblages identified with allozyme DNA analysis, the mountain whitefish in the Big Lost River were the most genetically divergent site in the Upper Snake River assemblage.

Campbell and Kozfkay (2006) used mitochondrial DNA (mtDNA) sequencing analyses and found the results to be in complete concordance with previous allozyme and microsatellite investigations that suggest that mountain whitefish across the study area in Idaho, Montana, and Utah are comprised of three distinct genetic assemblages (Whiteley 2005; Whiteley et al. 2006). Divergence estimates between the three genetic assemblages identified were high, ranging from 1.3 to 4.6%. Divergence estimates of this magnitude have been observed in other salmonids subspecies, and even between species. For example, estimates of mtDNA sequence divergence among two subspecies of cutthroat trout (westslope cutthroat trout *O. clarkii lewisi* and Yellowstone cutthroat trout *O. clarkii bouvieri*) ranges from 1.5 to 1.9% (Gyllensten and Wilson 1987; IDFG unpublished data). Sequence divergence between rainbow trout *O. mykiss* and cutthroat trout has been estimated at between 4.0 to 4.5% (Gyllensten and Wilson 1987; Campbell and Kozfkay 2006). Sequencing results also support the theory that the origin of mountain whitefish in the Big Lost River is from the Upper Snake River Basin, with the single haplotype observed in samples from the Big Lost River most closely related to haplotypes found in samples from the Henrys Fork Snake River, Idaho. A molecular clock estimate for mtDNA of 1 to 2% sequence divergence per million years suggests that mountain whitefish could have been isolated in the Big Lost River basin approximately 165,000-330,000 years ago. However, this should only be considered an approximate estimate, and increased sample sizes from the Big Lost River and Upper Snake River basin locations, as well as sequencing multiple mtDNA gene regions, would likely allow a more precise determination of time since divergence.

Whether or not the mountain whitefish population in the Big Lost River drainage constitutes a species or subspecies is beyond the scope of this plan. However, the analysis clearly suggests that, based on the level of genetic divergence, the population is sufficiently unique that it could not simply be replaced or supplemented with mountain whitefish from outside the drainage.

Historical Status

Historical accounts indicate that mountain whitefish were widely distributed and relatively abundant in the Big Lost River basin (Figure 2). Though historical range can never be defined with certainty, fish surveys and anecdotal accounts provide a solid basis from which it can be estimated. From 2004 through 2007, all available accounts of mountain whitefish collections were compiled and mapped (B. Gamett; personal communication). Collections were largely made by fishery biologists, but corroborated accounts by area residents were also included. In total, mountain whitefish were documented in 192 different sampling events throughout the drainage, dating back to the 1894. Historical distribution was then estimated based on documented occurrence and in some instances extended upstream based on stream size. Based on this analysis mountain whitefish historically occupied about 345 km of stream in the basin (Table 1).

Historic adult abundance was estimated using the following process. Corsi (1989) found that mountain whitefish in the upper Big Lost River that were less than 200 mm were never mature but that nearly all fish over 250 mm were mature. Similarly, we evaluated age at maturity and length at maturity for 69 fish in the Big Lost River below the Chilly diversion in 2004 and found that none of the fish less than 200 mm were mature but all fish greater than 300 mm were mature (USFS, unpublished data). Based on these two studies we elected to consider any fish ≥ 200 mm to be an adult. We then estimated the mean number of adults per kilometer that existed prior to the arrival of European settlers. This was done by reviewing adult mountain whitefish abundance estimates collected historically in the Big Lost River drainage and from elsewhere in Idaho. We also took into consideration that mountain whitefish were historically the only salmonid in the Big Lost River and that anthropogenic influences following the arrival of European settlers likely reduced the densities observed in previous estimates. Based on this review, we believe that a conservative *minimum* estimate for the mean number of adults to be 500 fish/km. Historic adult abundance was then estimated by multiplying the kilometers of stream that were historically occupied by 500. Based on a mean density of 500 fish/km, and an historical distribution of 345 stream km, we estimate the total drainage-wide population to have been at least 172,500 adult mountain whitefish (Table 1). We also recognize this number likely fluctuated tremendously with natural variations in precipitation and habitat condition.

Current Status

Mountain whitefish have experienced significant declines in distribution and abundance in the Big Lost River basin. The IDFG and the USFS completed an intensive assessment of mountain whitefish in the Big Lost River basin between 2002 and 2005 (IDFG, unpublished data; USFS, unpublished data). This work indicated that mountain whitefish occupied about 83 km of stream, or about 24% of historical levels (Table 1; Figures 3, 4). Adult abundance in the entire drainage was estimated to be 2,742 fish or about 1.5% of historic levels.

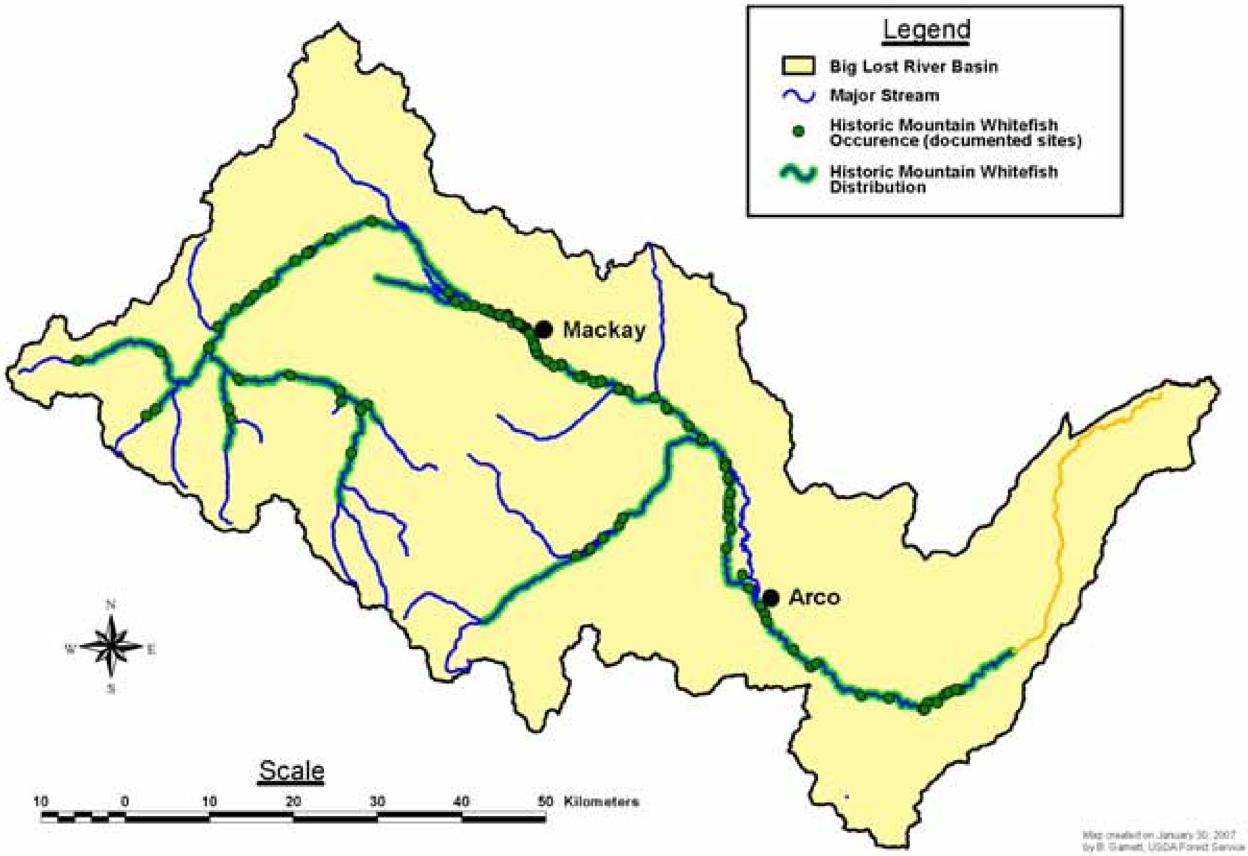

Figure 2. Estimated historical distribution (green shaded line) based on confirmed mountain whitefish collection sites (circles) in the Big Lost River drainage, Idaho.

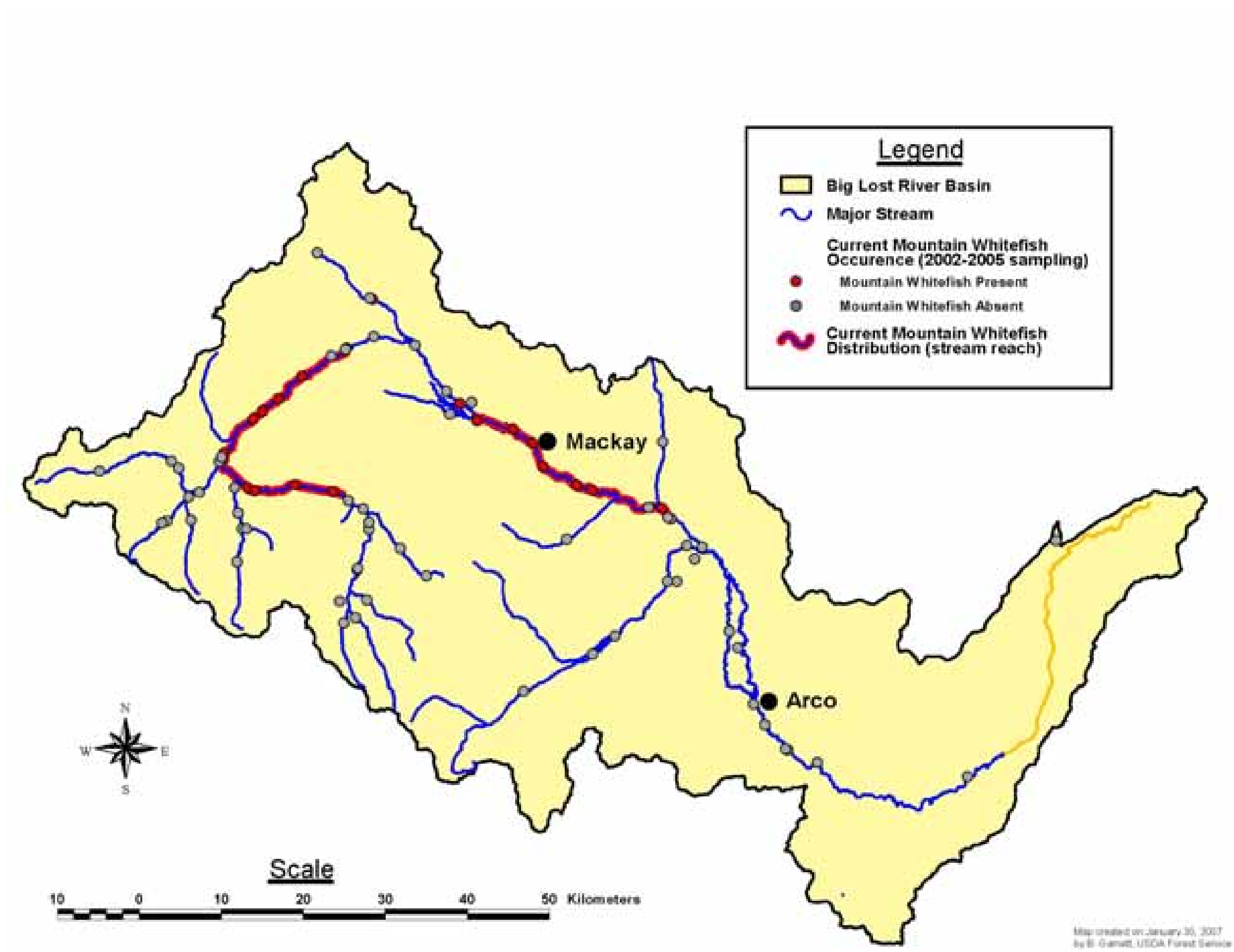

Figure 3. Estimated current distribution of mountain whitefish (red shaded line) based on sampling in 2002-2005 in the Big Lost River drainage, Idaho.

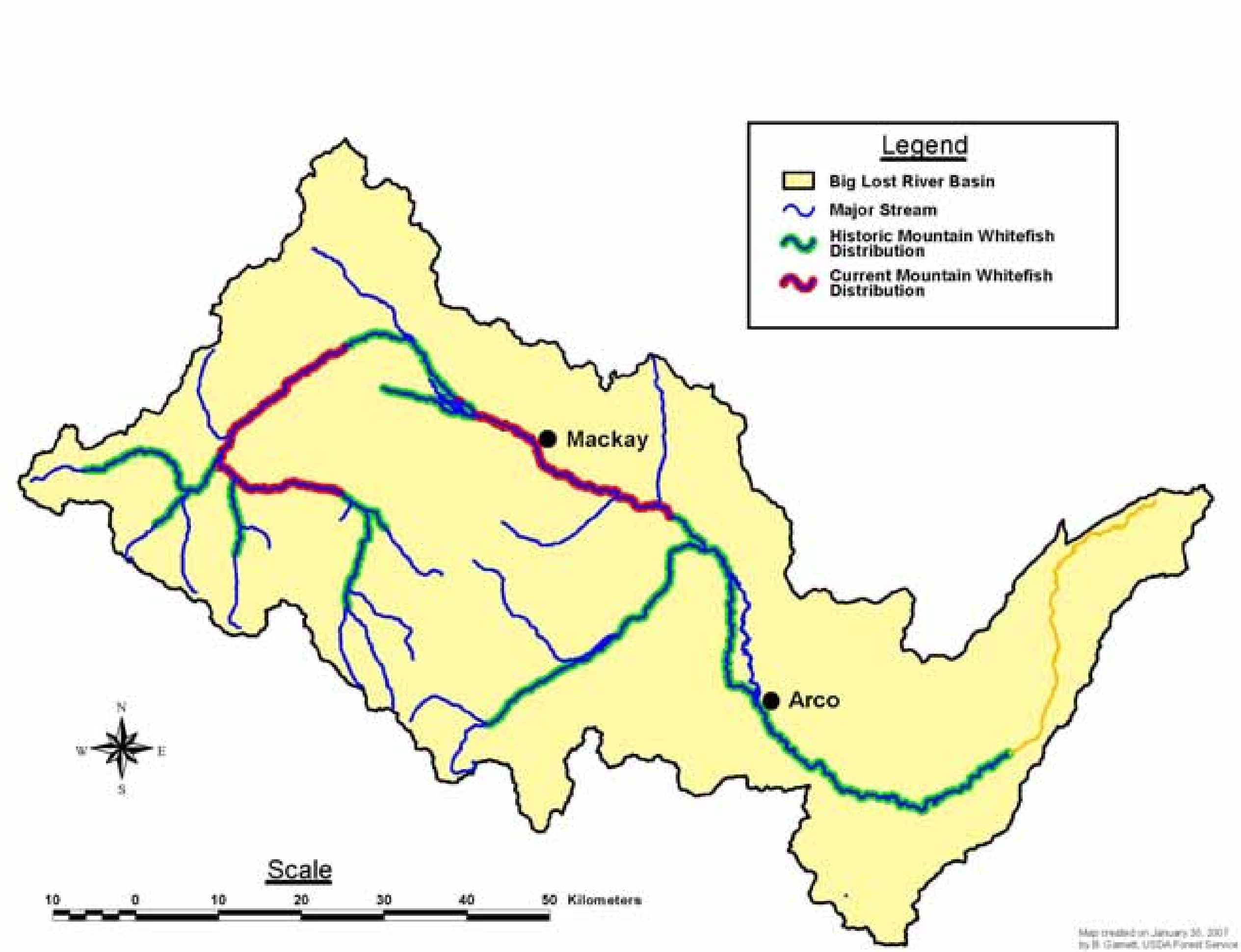

Figure 4. Estimated current (red) and historical (green) distribution of mountain whitefish based on sampling in 2002-2005 in the Big Lost River drainage, Idaho.

Table 1. Summary of historical and current (2002-2005) mountain whitefish distribution and abundance (fish > 200 mm) in the Big Lost River basin. Historical densities were assumed to average 500 fish/km.

	Historical		Current		
Stream or Section	Occupied Length (km)	Abundance	Occupied Length (km)	Mean density (fish/km)	Abundance
<u>Mainstem Big Lost River</u>					
Desert to Arco	40.4	20,202	0	0	0
Arco to Blaine Diversion (includes James Cr.)	55.1	27,555	0	0	0
Blaine Diversion to Mackay Reservoir	32.6	16,319	32.6	19.2	627
Mackay Reservoir to Chilly Diversion	25.1	12,562	0.3	21.4	7
Chilly Diversion to North Fork	24.7	12,363	24.7	61.7	1,526
Antelope Creek	44.3	22,161	0	0	0
<u>East Fork Big Lost River</u>					
North Fork to Star Hope Creek	25.7	12,859	20.9	23.1	483
Star Hope Creek to Corral Creek	4.0	1,981	0	0	0
Mackay Reservoir	4.8	2,390	4.8	?	100[a]
North Fork Big Lost River	30.6	15,300	0	0	0
Star Hope Creek	15.6	7,782	0	0	0
Warm Springs Creek	16.7	8,330	0	0	0
Wildhorse Creek	12.8	6,422	0	0	0
Parsons Creek	6.3	3,132	0	0	0
Summit Creek	6.6	3,296	0	0	0
TOTAL	**345.3**	**172,654**	**83.4**		**2,742**

[a]Minimum estimate based on professional judgment

POTENTIAL LIMITING FACTORS

Although factors affecting and limiting native salmonids have been well documented in the scientific literature, most of the research has been directed at trout and salmon. Little information exists on the response of mountain whitefish populations to anthropogenic effects typically associated with declines of other members of the Salmonidae family. Overharvest (McIntyre and Rieman 1995) along with habitat degradation resulting from water diversion, grazing, mineral extraction, timber harvest and the development of storage reservoirs and hydro-electric dams, have all been associated with impacts to populations of native salmonids in northwestern North America (Thurow et. al., 1997). Additionally, non-native species may displace native salmonids through competition, predation, and hybridization (Fausch 1988).

Factors specific to the *Prosopium* genus, however, are not as well-defined. In what is probably the most thorough review in the literature of mountain whitefish biology and habitat, Northcote and Ennis (1994) list impoundments, instream construction (specifically pipelines), sport fisheries, pulpmill effluent, and road construction as environmental factors possibly affecting mountain whitefish habitat in British Columbia. The authors note the lack of information in the literature relative to effects of other forms of habitat alteration and resource development on mountain whitefish.

In a literature and data review of the Big Lost River fishery, Gregory (2005) listed fishing mortality, habitat degradation, water quantity and quality, grazing, whirling disease, and fish stocking as potential causes of declines in the fishery; however, this assessment was oriented toward the trout population and was specific to the drainage above Mackay Reservoir. Based on a general understanding of factors affecting populations of other salmonids in the region, IDFG identified a range of issues that may affect mountain whitefish populations and their habitat in the Big Lost River drainage. Because of the isolation and size of the Big Lost River drainage, the activities that likely constitute a threat are relatively limited and likely fall into one of the following categories: habitat alteration, irrigation, non-native fish interactions, disease, and harvest. It is important to recognize that, as is typically the case with a declining fish or wildlife population, there is likely no single factor responsible, but a combination of factors.

Habitat alteration

Though habitat alteration can be interpreted quite broadly, in this plan we refer to activities directly associated with a degraded stream channel or riparian zone. Though there are increasing cases of streamside development resulting in rip-rapped or otherwise armored banks, in general, habitat alteration in the Big Lost drainage is primarily associated with channelization and grazing.

Channelization

A significant portion of the mainstem Big Lost River has been channelized. In 1965 and 1967, the U.S. Army Corps of Engineers (USACE) conducted an extensive channel clearance project, intended to minimize flood damage in the Big Lost River, primarily between Moore and Mackay. This effort resulted in an immediate and profound decrease in the fish population in the channelized reach (Irizarry 1969). In the lower portion of the upper Big Lost River, a channel straightening project was conducted in the 1930's. This effort resulted in significant downcutting and bank erosion. As a result, a major bank armoring project was undertaken in the 1980's to stabilize the banks; however, these efforts have largely been unsuccessful, and have in many cases, resulted in more extensive downcutting. At an early, but unknown date, a large section of the Big Lost River between Leslie and Darlington was also channelized.

Grazing

Cattle are grazed throughout the Big Lost River drainage, but in the lower river it is generally associated with small pastures and impacts are restricted to small, localized sites.

The more extensive grazing associated with public lands and larger ranch operations occurs mainly in the upper Big Lost River drainage. Though grazing has been associated with degraded habitat in portions of the upper drainage, the chronology of the mountain whitefish population decline and the grazing history do not suggest a strong cause-and-effect relationship. Gregory (2005) discussed the issue at length and points out that grazing practices have generally improved in the past 25 years, not gotten worse. Therefore, the decline in the mountain whitefish population does not seem to have a direct link to grazing-related habitat alteration. Nevertheless, the impacts of grazing to fluvial ecosystems and cold-water biota are well-documented and cannot be discounted, and the recent drought may exacerbate grazing-related impacts.

Irrigation

The agricultural industry in the Big Lost River valley is developed around an extensive irrigation system that uses both surface water flows and groundwater pumping. In this document, we've categorized potential irrigation-related threats into the following groups: entrainment, barriers, dewatering, and flow regime alteration. Some of the impacts to fish populations and fish habitat are well-defined and acknowledged, while others are not well-documented and contentious.

Entrainment

A potential impact associated with irrigation diversion is entrainment of fish from the river channel into ditches and river channels that are subsequently dewatered. None of the major irrigation canals or the numerous smaller ditches transporting water from the Big Lost River and its tributaries are screened to prevent fish entrainment. In a survey funded by the Fish Restoration and Irrigation Mitigation Act, Gregory (2004) identified 54 irrigation diversions in historic mountain whitefish habitat (excluding Antelope Creek) in the Big Lost River basin that were potential sites of fish entrainment. Though the occurrence and extent of entrainment of mountain whitefish or other species is largely unknown, cursory electrofishing surveys in irrigation ditches and fish salvage operations below headgates of dewatered canals have documented the occurrence of entrained fish. Fuller, (1981) documented the entrainment of over 3,000 juvenile mountain whitefish in the 3 in 1 canal near Darlington in 1979. In 2006, the entrainment of over 1,000 juvenile and adult mountain whitefish was documented in the Chilly Canal (USFS, unpublished data). Likewise, large numbers of mountain whitefish have been observed in dewatered sections of the Big Lost River particularly that section of the river below the Chilly Diversion (B. Gamett, personal observation; USFS, unpublished data). However, no quantitative assessment has been conducted to determine whether entrainment affects mountain whitefish or other fish species at the population level.

Barriers

Another less obvious threat associated with irrigation diversions is the potential loss of upstream fish movement. Of the 54 diversions identified by Gregory (2004), six constituted potential year-round fish passage barriers, four were likely seasonal barriers, and three others were possibly barriers depending on discharge and the size of fish migrants. As with altered habitat and unscreened irrigation ditches, mountain whitefish populations seemed to persist for decades despite these apparent barriers. But there may be a compounding effect between stream discharge and the ability of fish to negotiate some of the diversions that still do have water. In other words, diversions that may not have been barriers in the past under a better flow regime may now affect movement.

Dewatering

There has been a significant loss of mountain whitefish habitat in recent years due to dewatering attributable to drought and water withdrawal (and the combined effect of both factors). Historically, the Big Lost River often retained perennial flows and healthy fish populations well below the town of Arco through what is known as the Box Canyon. Drought conditions affected the Sinks drainages from 1987 through 1990. During that period, water storage and natural stream flows did not meet irrigation demand, resulting in extensive development of wells in the area from Mackay south and east to the Idaho National Laboratory (INL) boundary. Ground water development combined with lower natural surface flows has reduced or eliminated most salmonid populations downstream from the Moore Diversion effectively eliminating the 50-plus km of fish habitat from the diversion to the Box Canyon. Since 2001, the river has been dewatered just above the Blaine Diversion four of five years effectively eliminating an additional 16 km of fish habitat.

In the upper Big Lost River, the reach from Chilly Diversion to Mackay Reservoir is routinely dewatered for irrigation and has been degraded by long-term stream alteration activity. However, the historical flow regime through that reach of river is poorly understood, and there may have been periods of naturally dry river channel during some years.

Flow regime alteration

Big Lost River flows are a function of several factors including 1) precipitation, 2) groundwater withdrawal, 3) stream channel condition, 4) irrigation (flood versus sprinkler), and 5) water storage and diversion. Moreover, there are complex, and in many cases poorly understood relationships between these factors that have a significant bearing on stream flows.

The most profound impacts to water management in the Big Lost River resulted from the construction of Mackay Dam, an irrigation storage facility that first stored water in 1918. Since that time the hydrograph below Mackay Dam has been regulated to accommodate irrigation storage and demand. Water is stored from the end of irrigation season (generally the end of October) through the beginning of the following season (generally mid-April to early May). The resultant hydrograph is one with lower winter and spring flows, and higher late-summer and early fall flows (Figure 5). Moller and Van Kirk (2003) found a similarly altered hydrograph impacted reproductive success of Yellowstone cutthroat trout in the South Fork of the Snake River. However, as with other factors, water storage and management associated with Mackay Reservoir and associated alterations to the flow regime are not new to the system, and do not seem to explain the recent decline observed in the mountain whitefish population.

The current drought is the most severe since the 1930's, and without question has had a major impact on surface water flows. Mean annual discharge since 1990 in both the regulated reach (below Mackay Dam; Figure 6) and the unregulated upper river (Howell gauging station; Figure 7) are well below the historic averages. The annual sum of mean monthly discharge of the Big Lost River (gauged above irrigation diversions) since 1990 averages 3,213 cubic feet per second (cfs), compared to 3,958 cfs in the 40 years prior. The 19% decrease in drainage discharge illustrates the impact of the drought on the size of the Big Lost River. The decreased availability of water combined with the high demand has exacerbated the alteration of the flow regime.

Further complicating the issue of stream discharge and the impacts of the drought is increased reliance on groundwater withdrawal. The effect of groundwater pumping on stream discharge is not well understood, and as with the entire Snake River basin, this is a complex issue in the Big Lost River drainage. While it seems evident that pumping has some affect on surface water flows, the degree to which groundwater withdrawal alters stream flows, and the resulting effect on the mountain whitefish population is largely unknown. Furthermore, the groundwater/surface water relationship is confounded by a shift away from flood irrigation toward sprinkler irrigation, which has changed the timing and magnitude of return water to surface flows.

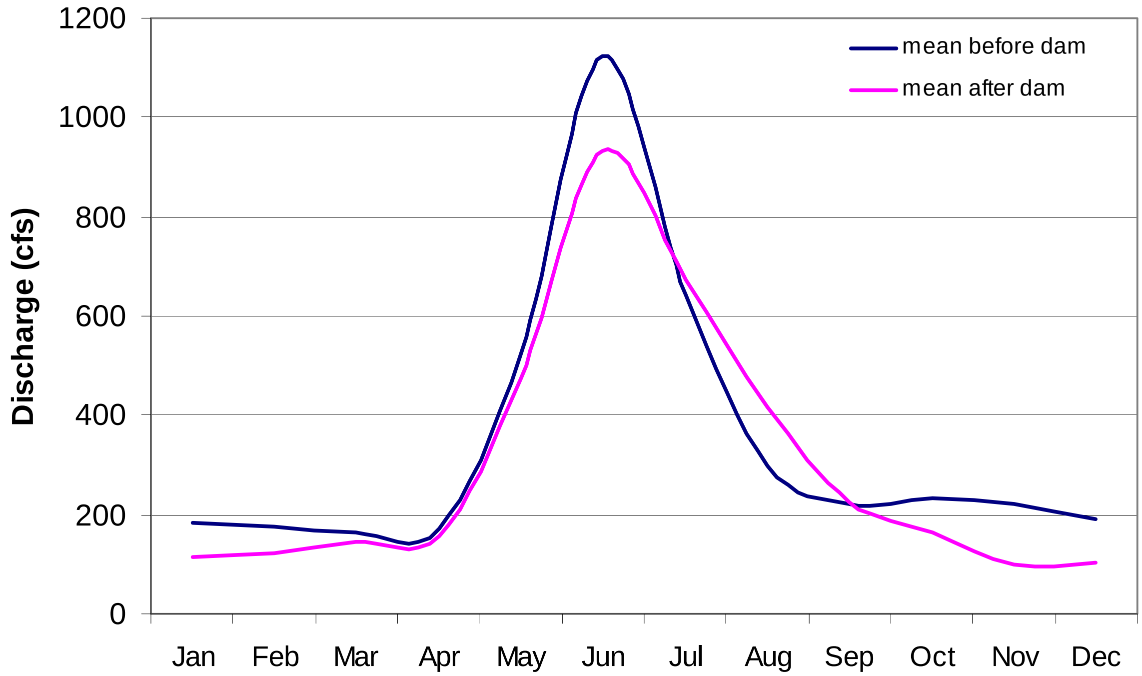

Figure 5. Mean annual hydrograph of Big Lost River, Idaho for years of record before and after construction of Mackay Dam as measured at the gauging station below Mackay Dam.

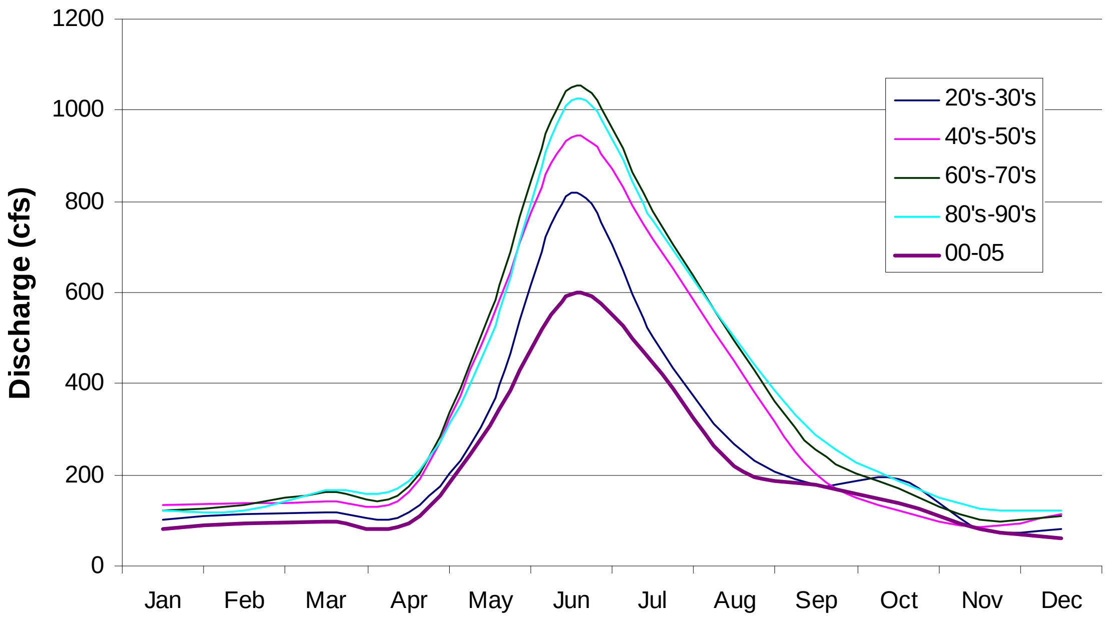

Figure 6. Mean monthly discharge by 20-year periods at the gauging station below Mackay Dam on the Big Lost River, Idaho.

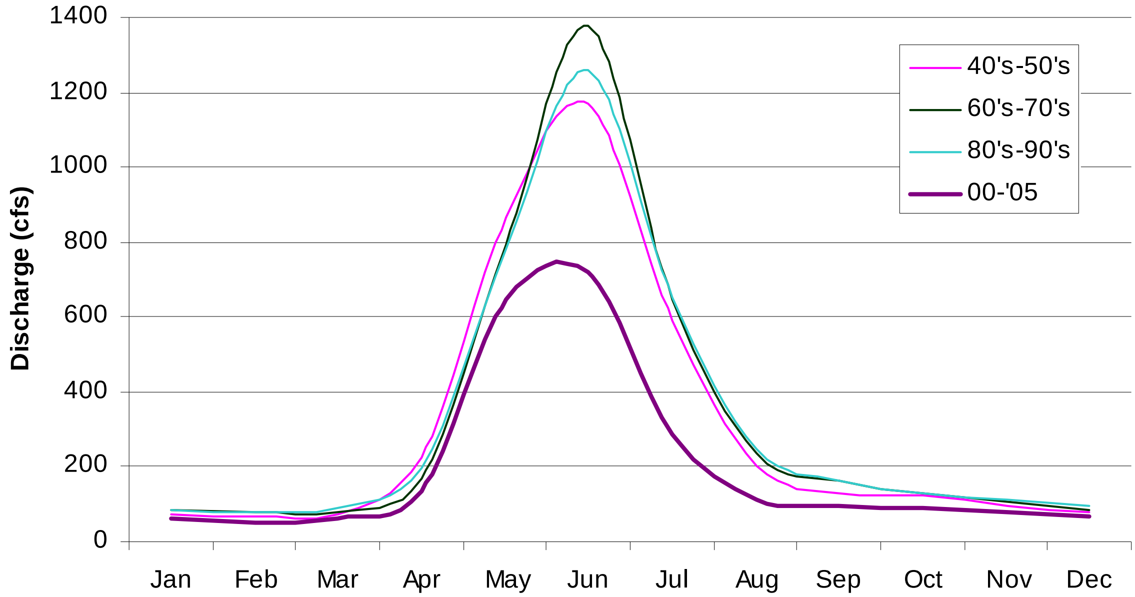

Figure 7. Mean monthly discharge by 20-year periods above Mackay Reservoir at the Howell Ranch gauging station on the Big Lost River, Idaho.

Non-native fish interactions

Competition

Though a perception exists with many anglers (and at least historically has existed with many biologists) that whitefish compete with trout for habitat or food resources, remarkably little research has addressed the question. What has been printed is largely inconclusive. In a study that assessed habitat utilization and feeding habits between trout and mountain whitefish in the Big Lost Drainage, Fuller (1981) concluded that there were few differences in invertebrate consumption between mountain whitefish and brook or rainbow trout. He noted, however, that the dietary overlap did not necessarily confirm competition because mountain whitefish consumed invertebrates from the substrate, where they were far more abundant than in the drift, where trout primarily fed.

Other studies have demonstrated a similar pattern. In a feeding ecology study of mountain whitefish in the upper Snake River in Wyoming, Pontius (1972) found that flies (dipterans) and cased caddis flies (trichoptera) were the most important food item for mountain whitefish. Although trout also fed on dipterans, their stomachs contained a much higher abundance of mayfly (ephemeroptera) and trichoptera adults and larvae and terrestrial adults, indicating they fed on drifting insects and on the surface. However, the amount of gravel in their stomachs, led the author to believe mountain whitefish fed primarily on bottom dwelling insects, but also on drifting insects. In another ecology study of the same system, Kiefling (1978) reported that mountain whitefish and cutthroat trout exhibit resource partitioning with respect to food type. However, he believed there was potential for competition for specific food items (Chironomidae) between mountain whitefish and small trout. In a feeding ecology study of the Kootenai River DosSantos (1985) stated that, based on quantitative results and underwater observations, mountain whitefish and rainbow trout did not actively compete for resources. In a summary of his findings, he stated that "….whitefish appear to be more selective feeders than rainbow trout, keying in on chironomids from both the benthos and drift. Rainbow trout appear to be an opportunistic water column and surface feeder, selecting insects in relation to their seasonal abundance."

Though trout are not native to the Big Lost River drainage, they were introduced well over 100 years ago. The abundance of mountain whitefish as recently as twenty years ago, and the absence of any evidence of competition in the studies suggest competition is not likely related to the recent decline in the mountain whitefish population.

Predation

The literature contains virtually no information on the impacts of predation on mountain whitefish populations. Cutthroat trout predation on mountain whitefish has been observed (B. Gamett, personal observation) and it is also likely that rainbow trout predation on mountain whitefish occurs. However, based on the feeding ecology studies in the upper Snake River and the Kootenai River, there is little evidence that cutthroat or rainbow trout feed extensively on juvenile mountain whitefish. The likely limited extent of predation by cutthroat and rainbow trout, and an absence of more piscivorous fish in the drainage suggest that predation likely has no population level impact on mountain whitefish. Furthermore, the recent nature of the decline in the mountain whitefish population does not suggest a relationship to predation from other fish.

Undoubtedly some degree of avian and mammalian predation on mountain whitefish. This may include otters, osprey, and blue heron. Anecdotal evidence suggests that otters are more abundant than they were in recent decades, possibly resulting in an increase in mammalian predation. However, otters have always been a component of the Big Lost River ecosystem. Though increased predation in recent years may have a compounding effect, it does not account for the drainage-wide decline in the population.

Disease

The most salient disease known to affect wild salmonid populations in western streams is whirling disease. *Myxobolus cerebralis*, the causative agent of whirling disease, has been thoroughly documented in the Big Lost River system. Though the origin and date of first introduction to the Big Lost River is unknown, it was first documented in the drainage in 1987 (Elle 1998). Based on lesion severity of sentinel rainbow trout, the Big Lost River was one of very few systems in Idaho where the disease was suspected of significantly affecting trout populations (Elle 1997).

The susceptibility of mountain whitefish to the disease is questionable. MacConnell et al. (2000) demonstrated that juvenile mountain whitefish could be infected by *M. cerebralis* when exposed to triactinomyxons (TAMs), however, they were unable to evaluate survival due to high mortality of control fish and they used an extremely high TAM level for the exposure. In a susceptibility chart compiled for various salmonids, mountain whitefish are categorized as “less susceptible” than rainbow trout, but “susceptible”, with the further explanation that “clinical disease common at high parasite doses, but greater resistance to disease at low doses.” They also note there are conflicting reports and insufficient data pertaining to the species.

A fish health inspection done in 2004 by IDFG failed to show infection of *M. cerebralis* or any other pathogen in a sample of 48 juvenile mountain whitefish from near the Chilly Diversion (IDFG, unpublished data). Though the possibility that whirling disease or another disease may be affecting the mountain whitefish population cannot be discounted, there is little evidence that is the case in Idaho. There are no documented accounts of a mountain whitefish population suffering from a disease-related decline, but the affects of whirling disease on mountain whitefish populations are currently being evaluated in Montana.

Exploitation

As suggested by the statewide general whitefish limits (25 per day) whitefish are generally an underexploited species, highly resilient to angling pressure. There are no documented cases in Idaho where mountain whitefish populations are believed to have declined as a result of excessive harvest. While they are often the most abundant game species in western rivers, with few exceptions they are often overlooked and discounted by anglers (Northcote and Ennis 1994). Despite liberal daily limits in Idaho (outside of the Big Lost drainage), Meyer et al. (2007) found that total annual survival rates for mountain whitefish in rivers throughout the state averaged 76% and ranged from 59 to 87%. Such high rates of survival are not uncommon for completely unexploited fish populations.

In the Big Lost River drainage, mountain whitefish have contributed minimally to the recreational fishery in recent years. Based on past creel surveys and anecdotal observations, the target fishery for mountain whitefish has been very limited. Angler checks and observations in recent years indicate the target mountain whitefish fishery was virtually non-existent by 2000, again suggesting the population decline is unrelated to exploitation. Nevertheless, to ensure angling mortality does not affect the ability of the population to recover, IDFG implemented catch-and-release regulations for mountain whitefish in the entire drainage beginning January 1, 2006.

MANAGEMENT ACTIONS

The objectives for distribution, abundance, and connectivity are currently unmet in both the upper and lower river populations (Table 2). Actions believed to be critical to the restoration of population objectives are identified in Table 3. In addition to actions identified in Table 3, any other unidentified activity likely to result in a decrease in existing flows, quality of habitat or connectivity will be prevented where authority allows, and discouraged when outside the authority of the relevant parties. We recognize there may be additional actions that could protect and restore mountain whitefish populations in the Big Lost River basin. Increasing stream flows in currently dewatered reaches of river would undoubtedly result in a greater distribution and abundance of the population, and we will pursue such opportunities where they can be done in a collaborative manner. However, we do not believe such actions are necessary to achieve the objectives outlined in this plan. The purpose of this plan is not eliminate all human impacts on mountain whitefish and restore mountain whitefish numbers to historic levels. Rather the purpose of the plan is to establish a pattern of distribution, abundance, and connectivity that will ensure mountain whitefish in the Big Lost River drainage will persists through natural and anthropogenic events with a sufficient surplus capable of providing angling opportunity.

POPULATION MONITORING AND ASSESSMENT

Research and assessment efforts in recent years have greatly increased our understanding of the life-history, ecology, and habitat relationships of mountain whitefish in the Big Lost River drainage. Since the population surveys were completed in 2003, biologists with IDFG, USFS, and Trout Unlimited have initiated a range of research efforts to better understand factors affecting the mountain whitefish population. A movement study using radio telemetry in 2004 and 2005 has indicated general movement patterns, spawning migrations, and locations. The use of artificial substrate mats has definitively documented the occurrence of spawning and helped define spawning locations (IDFG, unpublished data). Biologists have worked with the Big Lost Irrigation District to assess general levels of entrainment through the use of trap nets and electrofishing throughout the irrigation season and by collecting and quantifying fish stranded in canals as dewatering occurs. Finally, a laboratory experiment has helped define the ability of juvenile mountain whitefish to successfully jump vertical barriers, which is relevant to the design of passage facilities over existing barriers.

Nevertheless, additional assessments are still necessary to further understand the effects of various anthropogenic and natural changes to the drainage. Table 4 identifies critical assessment and research efforts in evaluating and prioritizing management actions. We anticipate that as new research questions develop, as yet unforeseen assessments and projects will be added to the list.

Table 2. Status of management objectives by management area.

Management Area	Objective	Status of Objective	Discussion
Above Mackay Dam	Distribution: Establish and maintain mountain whitefish in 1) the Big Lost River between the Chilly Diversion and North Fork Big Lost River and 2) at least three of the following tributaries: a) North For Big Lost River, b) East Fork Big Lost River, c) Wildhorse Creek, or d) Star Hope Creek.	Not Met	Initial sampling completed in 2003- 2005 indicated that mountain whitefish were present in the Big Lost River between the Chilly Diversion and North Fork, and the East Fork. However, mountain whitefish were not detected in North Fork of the Big Lost River, Wildhorse Creek or Star Hope Creek. After this sampling work mountain whitefish were released into the North Fork from salvage efforts. Follow up sampling indicated that small numbers of fish were again present in the North Fork. In order to achieve this objective, mountain whitefish need to remain established in the North Fork Big Lost River and be reestablished in either Wildhorse Creek or Star Hope Creek.
	Abundance: Establish and maintain at least 5,000 adult fish (>200 mm) with at least 100 adults in each occupied stream reach	Not Met	Sampling completed in 2003 - 2005 indicates that the adult abundance in this management area is approximately 2,000 fish. The adult abundance is about 1,700 fish in the Big Lost River between the Chilly Diversion and North Fork, and about 300 in the East Fork. In order to achieve this objective, overall adult abundance needs to increase by about 3,000 with at least 100 adults occurring in at least two of the following streams: Wildhorse Creek, Star Hope Creek, or the North Fork.
	Connectivity: Establish and maintain natural levels of connectivity sufficient for all age classes to make natural movements in all historically occupied habitat. In that section of the Big Lost River between the Chilly Diversion and Mackay Dam this objective does not apply to stream flows.	Not Met	Irrigation diversions create partial and/or seasonal barriers in three locations. This includes the 6X, Chilly, and Nielsen diversions. In order to meet this objective fish passage would need to be restored at these diversions.
Below Mackay Dam	Distribution: Establish and maintain mountain whitefish in 1) the Big Lost River between the Mackay Dam and Blaine Diversion and 2) at least one of the following stream reaches: a) Big Lost River between Blaine Diversion and Moore Diversion or b) Antelope Creek between Marsh Canyon and Iron Bog Creek.	Not Met	Sampling completed in 2002 indicates that mountain whitefish are present in the Big Lost River between Mackay Dam and the Blaine Diversion. Although mountain whitefish do seasonally occur in the Big Lost River between the Blaine Diversion and the Moore Diversion dewatering in recent years has prevented the fish from occupying this reach on a perennial basis. Mountain whitefish were not detected in Antelope Creek in sampling completed in 1987 (Corsi and Elle 1989) or in sampling completed in 2004. To meet this objective, mountain whitefish would need to be restored below the Blaine Diversion or in Antelope Creek.
	Abundance: Establish and maintain at least 5,000 adult fish (>200 mm) with at least 100 adults in each occupied stream reach	Not Met	Sampling completed in 2002 indicates that the adult abundance in this management area is approximately 600 fish. All of these fish occur in the Big Lost River between the Mackay Dam and the Blaine Diversion. In order to achieve this objective, overall adult abundance needs to increase by about 4,400 with at least 100 mountain whitefish occurring in either the Big Lost River between the Blaine and Moore diversions or in Antelope Creek between Marsh Canyon and Iron Bog Creek.
	Connectivity: Establish and maintain natural levels of connectivity sufficient for all age classes to make natural movements between Mackay Dam and the Moore Diversion and in Antelope Creek between the Big Lost River and Iron Bog Creek. In that section of Antelope Creek between the Big Lost River and Marsh Canyon this objective does not apply to stream flows.	Not Met	Irrigation diversions create complete, partial, and/or seasonal barriers in five locations on the Big Lost River between the Mackay Dam and the Moore Diversion. This includes the Swauger, Darlington, Burnett, Blaine, and Lower Burnett diversions. The status of connectivity in Antelope Creek is unknown.

Table 3. Potential reasons for not meeting management objectives by management area and management actions needed to achieve management objectives.

Management Area	Potential Reasons for Not Meeting Objectives	Management Actions
Above Mackay Dam	1. Reduced flows from drought/diversion	1. Work with IDWR to support diversion monitoring and enforcement of water rights 2. Work to prevent any additional reduction in stream flows 3. Seek opportunities to increase surface water flow where it can be done in a collaborative manner
	2. Habitat alteration	1. Evaluate East Fork Big Lost River, North Fork Big Lost River, Wildhorse Creek, and Star Hope Creek to determine why populations have declined in these areas. If necessary, develop and implement measures to correct problems sufficient to achieve the distribution and abundance objectives. 2. Evaluate ability of Wildhorse Creek and Star Hope Creek to support mountain whitefish. If potential exists, reintroduce mountain whitefish into these streams. 3. Continue efforts to reintroduce mountain whitefish into North Fork Big Lost River. 4. Evaluate fish habitat in the Big Lost River between the Chilly Diversion and North Fork Big Lost River to determine whether anthropogenic influences have reduced the ability of this stream to support mountain whitefish. If necessary, identify and implement actions that will reduce these impacts. 5. Monitor stream alteration and work with IDWR and USACE to prevent illegal stream alteration and discourage channelization and bank rip-rapping. 6. As appropriate, protect private lands through easements, exchanges, cost sharing, etc. 7. Support implementation of the Salmon-Challis National Forest grazing strategy on all national forest lands where there is a potential for livestock grazing to impact historic mountain whitefish habitat.
	3. Entrainment in irrigation canals	1. Evaluate fish entrainment at diversions. If necessary, develop and implement measures to minimize entrainment
	4. Entrainment in Big Lost River between Chilly Diversion and Mackay Reservoir when reach is dewatered	1. Evaluate the impact of entrainment in the Big Lost River below the Chilly Diversion on mountain whitefish distribution and abundance in the management area. If necessary, develop and implement measures to correct problems. In the interim, annually salvage mountain whitefish in the Big Lost River from the Chilly Diversion downstream 2 km when the stream is dewatered and transport fish to suitable waters. Continue this work until the evaluation is completed and any required measures are implemented or until distribution and abundance objectives are met in the management area.
	5. Competition and predation from non-native species	1. Evaluate effect of competition and predation from non-native species on mountain whitefish. If necessary, develop and implement measures to correct problems.
	6. Interference with life history movements by the Chilly, 6X, and Nielsen diversions.	1. Provide a level of fish passage sufficient for all age classes to make natural movements around these diversions.
	7. Fishing	1. Maintain no harvest rule until distribution and abundance objectives are met. Evaluate feasibility of harvest once these objectives are met. 2. Evaluate effect of fishing (e.g. - illegal harvest, hooking mortality, etc.). If necessary, develop and implement measures to correct problems (e.g. - angler education, enforcement, revision of regulations).

	8. Disease	1. Evaluate potential effects of whirling disease on mountain whitefish populations.
Below Mackay Dam	1. Reduction in annual or seasonal flows	1. Work with IDWR to support diversion monitoring and enforcement of water rights 2. Work to prevent any additional reduction in stream flows 3. Seek opportunities to increase surface water flow where it can be done in a collaborative manner 4. Evaluate whether winter flows affect juvenile survival and limit recruitment. Work with water managers to augment winter flows if flow-related survival is believed to prevent population objectives.
	2. Habitat alteration	1. Improve or provide year-round flows in the Big Lost River between the Blaine Diversion and the Moore Diversion. 2. Evaluate fish habitat in Antelope Creek to determine how anthropogenic influences have reduced the ability of this stream to support mountain whitefish. If necessary, identify and implement actions that will reduce these impacts. 3. Evaluate fish habitat in the Big Lost River between Mackay Dam and the Moore Diversion to determine how anthropogenic influences have reduced the ability of this stream to support mountain whitefish. If necessary, identify and implement actions that will reduce these impacts. 4. Monitor stream alteration and work with IDWR and USACE to prevent illegal stream alteration and discourage channelization and bank rip-rapping. 5. As appropriate, protect private lands through easements, exchanges, cost sharing, etc. 6. Support implementation of the Salmon-Challis National Forest grazing strategy on all national forest lands where there is a potential for livestock grazing to impact historic mountain whitefish habitat. 7. Evaluate ability of Antelope Creek to currently support mountain whitefish. If potential exists, reintroduce mountain whitefish into the stream.
	3. Entrainment in irrigation canals	1. Evaluate fish entrainment at diversions. If necessary, develop and implement measures to correct problems
	4. Entrainment in Big Lost River below Blaine Diversion when reach is dewatered	1. Evaluate the impact of entrainment in the Big Lost River below the Blaine Diversion on mountain whitefish distribution and abundance in the management area. If necessary, develop and implement measures to correct problems. In the interim, annually salvage mountain whitefish in the Big Lost River from the Blaine Diversion to Highway 93 when the stream is dewatered and transport fish to suitable waters. Continue this work until the evaluation is completed and any required measures are implemented or until distribution and abundance objectives are met in the management area.
	5. Competition and predation from non-native species	1. Evaluate effect of competition and predation from non-native species on mountain whitefish. If necessary, develop and implement measures to correct problems.
	6. Interference with life history movements by Swauger, Darlington, Burnett, Blaine, and Lower Burnett diversions	1. Provide a level of fish passage sufficient for all age classes to make natural movements around these diversions.
	7. Fishing	1. Maintain no harvest rule until distribution and abundance objectives are met. Evaluate feasibility of harvest once these objectives are met. 2. Evaluate effect of fishing (e.g. - illegal harvest, hooking mortality, etc.). If necessary, develop and implement measures to correct problems (e.g. - angler education, enforcement, revision of regulations).
	8. Disease	1. Evaluate potential effects of whirling disease on mountain whitefish populations.

Table 4. Assessment and research projects necessary to prioritize and evaluate effectiveness of existing and future mountain whitefish management actions.

Assessment or Research Project	Timing and Frequency	Objective
Juvenile snorkeling survey	Annually during mid-winter	To develop a timely, efficient, and non-injurious juvenile recruitment index that will help assess the relationship between environmental factors and reproduction
Adult population monitoring	5-year intervals	To determine response of mountain whitefish population to environmental conditions and management actions identified in this plan
Mackay Reservoir mountain whitefish population assessment	Summer/fall 2007	To determine if Mackay Reservoir holds a significant component of the population above Mackay Dam and to determine the level of migration between the reservoir and the upper river.
Radio telemetry	2005, 2006	To identify seasonal movements, migration timing, effects of barriers on passage and entrainment
Spawning substrate mat surveys	2005, 2006	To identify spawning areas and timing and confirm the occurrence of spawning
Canal entrainment surveys	2006-2008	To identify relative levels of entrainment in major canals and to salvage stranded mountain whitefish and move to sites identified for reintroduction.
Jumping Study	2004-2007	To determine the ability of juvenile whitefish to pass over vertical barriers for use in designing and implementing fish passage projects
Swimming Assessment	2007-2008	To determine swimming ability of mountain whitefish for use in designing and implementing fish passage projects

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