Research Work Plan

GENETIC PURITY, HABITAT, AND POPULATION CHARACTERISTICS OF YELLOWSTONE CUTTHROAT TROUT, IN THE GREYBULL RIVER DRAINAGE, WYOMING

February 24, 1994

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Justification

Maintenance and restoration of genetically pure populations of native trout is a major goal of the Wyoming Department of Game and Fish (WDGF) fish division and the United States Forest Service (USFS). Since Wyoming is thought to contain some of the few remnant populations of pure Yellowstone cutthroat trout (Oncorhynchus clarki bouveiri) remaining throughout its historic range (Varley and Gresswell 1988), managers have focused on this unique subspecies. A primary goal is to preserve the few genetically unaltered populations in order to maintain the native animal diversity within Wyoming for practical, scientific, and aesthetic values (Varley and Gresswell 1988). Identification of remaining, pure Yellowstone cutthroat trout populations is important; if collectively the remaining populations still retain the majority of the subspecies genetic information, it may be possible to reassemble the original gene pool by preserving these isolated populations (Shiozawa and Williams 1988). Yellowstone cutthroat trout preservation may also prevent complete extirpation, or listing of the subspecies as threatened or endangered under the Endangered Species Act, which could impact uses of watersheds and their sport fisheries in areas identified as critical for Yellowstone cutthroat trout. Preserving the Yellowstone cutthroat trout subspecies in Wyoming will also enable fishery managers to use the subspecies in the future to enhance sport fisheries in the state.

Identification of genetically pure Yellowstone cutthroat trout populations is important so fishery managers know how and where to focus management efforts. The uniqueness of the subspecies could hamper watershed management if Yellowstone cutthroat trout stocks continue to decline. Fisheries managers must consider stock and habitat preservation, thus stocking of other salmonids to establish or enhance a sport fishery cannot be done due to potential competition and hybridization with Yellowstone cutthroat trout. Conversely, if managers knew where genetically pure populations of Yellowstone cutthroat trout existed, management efforts could be intensified in those areas and other fishery management options may be available for areas unimportant to Yellowstone cutthroat trout.

Although generalized Yellowstone cutthroat trout distributions in Wyoming are known, it is unknown where pure, genetically unaltered populations occur. Identification of these locations is critical to future management and preservation of the subspecies in Wyoming, as well as maintaining and enhancing other fisheries within the areas where the subspecies naturally occurs.

The goal of this project is to identify the location of potentially pure Yellowstone cutthroat trout within the Greybull-Wood River drainage, one of the drainages in Wyoming identified by fishery managers with a high potential for containing Yellowstone cutthroat trout. The project will also describe habitat and population characteristics. The information provided by this survey will aid fishery managers in future management decisions within this region.

The investigation of the Greybull River drainage for Yellowstone cutthroat trout is one component of a much larger investigation being coordinated among the Wyoming Department of

Game and Fish, the United States Forest Service, and other state agencies. Future investigations in Wyoming will assess the North and South Forks of the Shoshone River and the Clarks Fork River. Similar investigations are presently occurring in surrounding states as part of a region-wide Yellowstone Cutthroat Trout Management Plan. My project will assist in gathering data for this large effort, coordinated by the USFS, to preserve and manage the Yellowstone cutthroat trout subspecies.

History and Discovery:

The cutthroat trout (Oncorhynchus clarki) was encountered by several early explorers who passed through its widespread native range in western North America. The Coronado expedition from 1540-1542 described a stream near Cicuye that abounded with excellent trout (Hammond 1940). Fathers Escalante and Dominguez, trying to find a shortcut to the Spanish missions in southern California, described Lake of the Timpanogitizes as having an "abundant supply of fish" (Tanner 1936). The Lewis and Clark expedition in 1805 described the fish they had caught near present day Great Falls, Montana, as trout from 40 to 60 cm, with a small dash of red on each side; this was the first reference to the red marks under the lower jaw, a distinguishing cutthroat trout feature (Trotter and Bisson 1988, Trotter 1987). Other 19th Century explorers recorded references to cutthroat trout as they traveled throughout the western United States. Freemont (1845) wrote about the large Pyramid Lake cutthroat trout, Edward Hewitt wrote of catching cutthroat trout from rivers in Yellowstone Park in 1881, and David Thompson made notes of trout catches from the northern Rocky Mountains (White 1950).

Yellowstone Cutthroat Trout Lineage and Distribution :

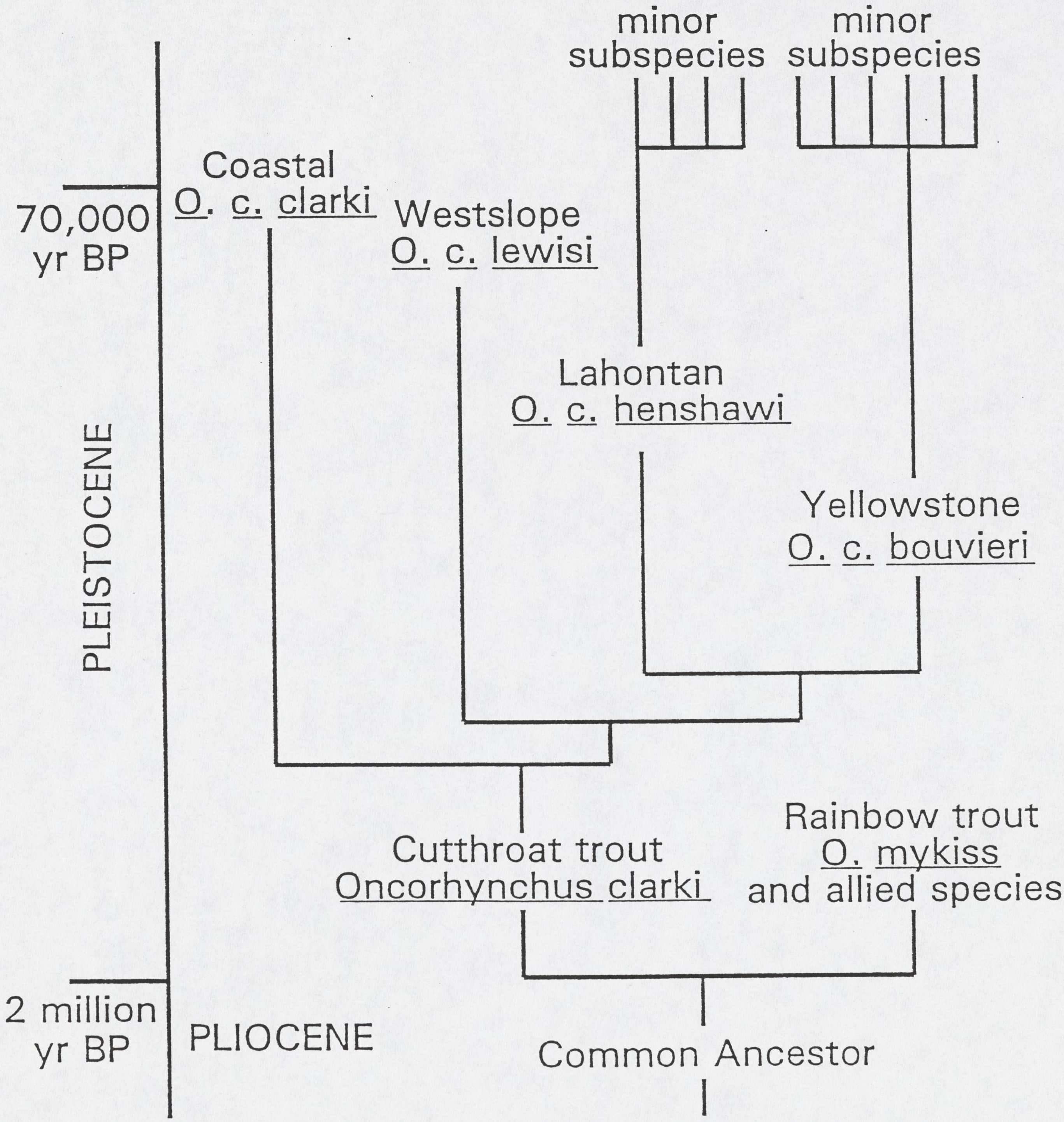
The phylogenetic branching from a common trout ancestor leading to present species and subspecies of North American cutthroat trout and rainbow trout (Oncorhynchus mykiss) probably occurred in the early Pleistocene era (2 million years ago) based on electrophoretic and DNA evidence (Loudenslager and Gall 1980; Wilson et al. 1985; Gyllesten and Wilson 1987; Leary et al. 1987;

Leary and Allendorf 1988; Figure 1). However, most present day distributions of cutthroat trout resulted from the last glacial period about 40,000-70,000 years ago (Behnke 1988, 1992).

Three lineages of cutthroat trout evolved within the Columbia River Basin (Behnke 1992). One group, the coastal cutthroat trout (Oncorhynchus clarki clarki) dispersed along the Pacific Coast from California to Prince William Sound, Alaska, rarely occurring far inland (Trotter 1987; Behnke 1988, 1992). Two other linages occurred inland, extending across the Continental Divide to southern Saskatchewan and the Missouri and Yellowstone River drainages (Loudenslager and Thorgaard 1979, Trotter 1987; Behnke 1988, 1992).

Despite previous investigations (Miller 1950; Needham and Gard 1959; Behnke 1965, 1972, 1976, 1992; Gold 1977; Leary et al. 1987), inland cutthroat trout systematics remain unclear for several reasons: (1) hybridization, (2) geological events have complicated dispersal understanding, and (3) meristic and morphological characteristics may have as great or greater variability within a region as among regions (Behnke 1976, Loudenslager and Thorgaard 1979). According to Marnell et al. (1987) the westslope cutthroat trout (O. c. lewisi) was native to a vast area from the eastern Cascades (i.e. the Kootenay River in British Columbia) to the upper Missouri River drainage in Montana. It is believed the Yellowstone cutthroat trout traversed the Continental Divide through Pacific Creek of the Snake River drainage at Two Ocean Pass and invaded, through Atlantic Creek, the Yellowstone River system (Evermann 1896, Behnke 1992) in post-glacial times as evidenced by glacial

Figure 1. Cutthroat trout phylogeny.



Phylogeny from Behnke (1992)

geology of the area (Roscoe 1974). Speculation arises that a fourth lineage arose (the Lahontan cutthroat trout, O. c. henshawi) with the Yellowstone cutthroat from a common ancestor and invaded the Lahontan Basin of present day Nevada during the mid-Pleistocene, after which it developed and diversified as conditions changed in the basin (Behnke 1988,1992). However, recent mitochondrial DNA experiments in Utah have tentatively shown that the Lahontan cutthroat trout may not be as closely related to the Yellowstone cutthroat trout as previously thought (Shiozawa and Williams 1988). A Yellowstone cutthroat trout ancestor translocated from the upper Snake River into the Bonneville (Bear River) and Colorado (Green River) basins as recently as 40,000-70,000 years ago and lead to the formation of different subspecies in the Colorado, South Platte, Arkansas, and Rio Grande river drainages during the last glacial period (Behnke 1992).

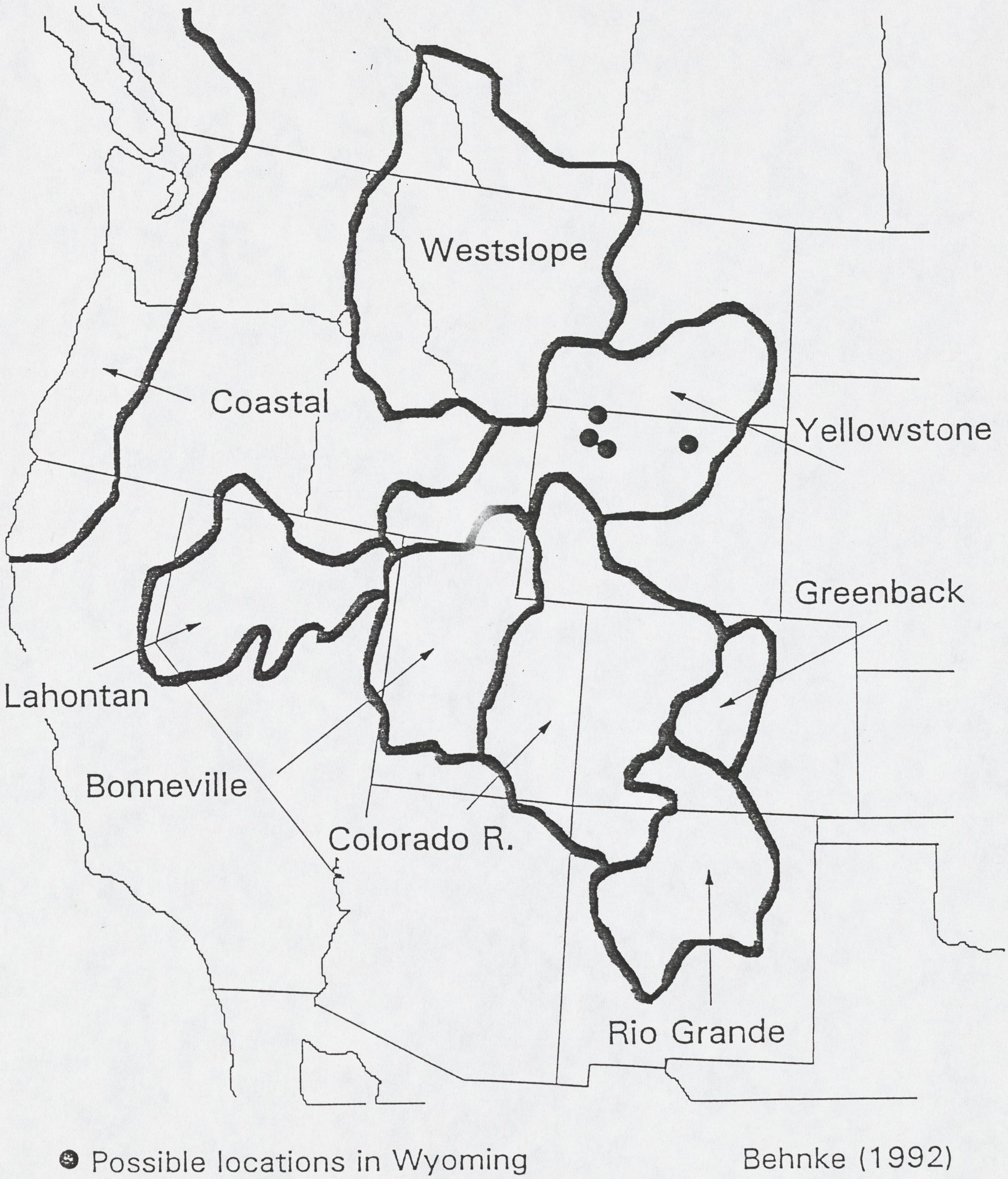
The last glacial activity formed barrier falls on major Columbia River tributaries isolating populations of cutthroat trout, of which present day distributions are remnants. Westslope cutthroat trout were isolated above falls on the Kootenay River, in Montana, on the Clark Fork, Pend Orielle, and Spokane rivers in Washington and Idaho and on the Snake River near Twin Falls, Idaho. Yellowstone cutthroat trout were isolated above the Shoshone Falls on the Snake River 30,000-60,000 years ago (Malde 1965). After the redband trout invaded the Columbia Basin and naturally eliminated the Yellowstone cutthroat below Shoshone Falls; relict populations of Yellowstone cutthroats were left in Crab Creek, Washington, and Waha Lake, Idaho (type locality for subspecies) but both populations are now extinct (Bendire 1882; Jordan and Evermann 1902; Evermann and Nichols 1909; Behnke 1988, 1992).

Fourteen subspecies of cutthroat trout are now recognized as native to western North America (Behnke 1988; Trotter 1987), although Behnke (1979) and Johnson (1987) listed eight major and eight minor subspecies of the cutthroat trout. Cutthroat trout classification is extremely troublesome because distinctive characteristics needed to separate them have not fully developed, or we are unable to find and measure them (Trotter 1987). Behnke (1992) suggests that with the widespread distribution in several major independent drainages, multiple interbasin headwater stream transfers take place, not allowing formation of discretely differentiated populations. Rather population variability within a single drainage may be as great or greater than those of a separate basin.

Evolutionary separation and the degree of genetic divergence of the cutthroat trout subspecies involves unequal periods of time. Relatively large evolutionary divergence separates the four major subspecies (*O. c. clarki*, *lewisi*, *bouvieri* and *henshawi*). Two major subspecies, the coastal and westslope, apparently did not give rise to any other surviving subspecies, whereas four subspecies were derived from the Lahontan lineage and six from the Yellowstone ancestor (Trotter 1987; Behnke 1988,1992; Figure 2).

The Lahontan lineage includes the Humboldt cutthroat trout (unnamed), once native throughout the Humboldt River drainage of eastern Nevada (Behnke 1992), but currently restricted to

Figure 2. Distributions of Oncorhynchus clarki subspecies.



numerous small streams (Coffin 1983, 1988). Alvord cutthroat trout (unnamed), native to Lake Alvord in northwestern Nevada, became extinct upon rainbow trout introduction to the area. Whitehorse cutthroat trout have been isolated from other trout in the Willow and Whitehorse drainages of southeast Oregon for sometime and still persist in Antelope Creek. The final trout that arose from the Lahontan line was the Paiute trout (O. c. seleniris). An unhybridized population exists in east-central California in upper Silver King Creek (Behnke 1992).

The Yellowstone cutthroat trout line is common to all six cutthroat trout native to Wyoming except the westslope cutthroat trout. The greenback cutthroat trout (O. c. stomias) occurred in streams of the South Platte drainage in southeastern Wyoming and was extirpated from the state shortly after European settlement (Baxter and Simon 1970). Their range lies almost entirely within the state of Colorado and disappeared quickly upon introduction of non-native trout. It is now listed as threatened under the Endangered Species act as a few natural populations remain in small headwaters above barrier falls; however, a brood stock has been developed from these populations and successful reintroductions have occurred in streams in Rocky Mountain National Park (Stuber et al. 1988; Behnke 1992).

The Bonneville cutthroat trout, formerly believed extinct (Cope 1955, Platts 1957, Sigler and Miller 1963), is native to the Bonneville Basin of Utah and the Bear River Drainage in southwestern Wyoming (Baxter and Simon 1970; Behnke 1992). They now persist in a few headwater streams.

The Colorado River subspecies is native to the Colorado

River above the Grand Canyon and is found in Wyoming in about forty streams in three widely separated enclaves: (1) western tributaries to the Green River, (2) headwater tributaries to the Blacks Fork, and (3) the North Fork Little Snake River and Big Sandstone Creek drainages (Binns 1977; Clay Speas, USFS, personal communication). Previously, the North Fork Little Snake River and Big Sandstone Creek drainages were considered as separated enclaves (Binns 1977), but they have since been combined. Pure populations still exist in Wyoming; however, Williams et al. (1989) listed the subspecies as a "special concern" and Martinez (1988) noted an alarming increase in hybridization within populations.

The westslope cutthroat trout inhabits the Missouri River drainage in the extreme northwestern corner of Wyoming (Liknes and Graham 1988). The trout has vanished from much of its once vast range, but genetically pure populations can be found in several locations in Montana and Idaho (Behnke 1992).

The finespotted Snake River cutthroat trout apparently is the closest relative to the Yellowstone subspecies as electrophoretic studies have confirmed that the two subspecies are genetically very similar (Loudenslager and Kitchin 1979; Leary et al. 1987; Allendorf and Leary 1988). The Snake River subspecies is unnamed (Baxter and Simon 1970; Trotter 1987) but is considered a unique subspecies. Within Wyoming they occur in the Salt River, Grey's River, and Snake River downstream from Jackson Dam in western Wyoming (Kiefling 1978).

Two other subspecies of trout are thought to have risen from the Yellowstone ancestor, the Rio Grande (_O. c. virginalis_) and the Yellowfin cutthroat trout (O. c. macdonaldi), the former is native to the upper Rio Grande and Pecos Rivers in New Mexico and the latter, now extinct, was known only in Twin Lakes, Colorado (Behnke 1992).

Yellowstone Cutthroat Trout - Present Day Range

No other cutthroat trout subspecies, with the exception of the coastal cutthroat, covered a greater historical range than the Yellowstone cutthroat trout (Varley and Gresswell 1988). However, after the redband trout invaded the middle Columbia River basin during a late glacial period, the once vast range was limited to the Yellowstone River tributaries downstream to the Tongue River, the Snake River above Shoshone Falls and two, now extinct, populations in Waha Lake, Idaho, and Crab Creek, Washington (Varley and Gresswell 1988; Behnke 1992). The subspecies was the most widespread of the cutthroat trout in Wyoming, it occurred in the Wind River-Big Horn River, Clarks Fork, and the upper Snake River in Wyoming (Thurow et al. 1988; Varley and Gresswell 1988; Behnke 1992). Since settlement by Europeans, distribution of genetically pure Yellowstone cutthroat trout has declined dramatically (Varley and Gresswell 1988).

Reasons for Decline of Yellowstone Cutthroat Trout

Continued dramatic decline of pure populations of Yellowstone cutthroat trout throughout their range has raised concern for their continued preservation and protection, and a need to identify the factors responsible. In the Bighorn National Forest of Wyoming only 66 km of a potential 1609 km (4%)

of suitable stream habitat still support this trout subspecies (Kozel 1988). Hadley (1984) made a systematic evaluation of several Yellowstone cutthroat trout populations in Montana based on meristic features, concluding that only 36% of 138 stream sample had potentially pure populations and 40% of 194 lake samples were believed to contain pure trout. Pure Yellowstone cutthroat trout are believed to occupy 324 km of a historical range of 4217.3 km of streams in Montana, a 92% reduction in original range (Hadley 1984). Genetic analysis of populations determined to be potentially pure (based on meristic features, Hadley 1984) showed that only 24 of 41 (59%) potential pure populations actually were pure (Darling et al. 1992). The Yellowstone cutthroat trout has been classified as a "species of special concern" in Montana because it is found in such a small portion of its original range (Hanzel 1959; Hadley 1984). Recently it received the same designation by the USFS in Region 2 (Ray Zubik, USFS, personal communication).

Hanzel (1959), Behnke (1976) and Varley and Gresswell (1988) noted that most pure remnant populations occur in high-altitude headwaters in remote areas. Behnke (1992) suggested the cutthroat trout enjoy a selective advantage over non-native trout in these areas, probably because they function better in colder waters. Genetically pure populations may also remain in these remote inaccessible headwaters because contact with Europeans and ensuing detrimental factors were minimal until relatively recently (Gresswell and Varley 1988). Several factors have had detrimental effects on cutthroat trout subspecies.

Introduction of exotic salmonids into native ranges of cutthroat trout subspecies, including the Yellowstone, has been the most deleterious effect. Hybridization with the rainbow trout (Hanzel 1959; Behnke 1972; Behnke 1976; Loudenslager and Thorgaard 1979; Busack and Gall 1981; Leary et al. 1984; Campton and Utter 1985; Gyllensten et al. 1985; Allendorf and Leary 1988; Thurow et al. 1988; Shiozawa and Williams 1988; Varley and Gresswell 1988; Wuerthner 1990) has destroyed the genetic integrity of native populations by introgression and practically eliminated pure populations of most of the interior stocks of cutthroat trout. Despite evolutionary diversity, cutthroat trout evolved apart from the redband trout and rainbow trout; thus they lack isolating mechanisms that allow them to coexist together with out hybridizing. All western trout can interbreed freely with cutthroat trout and produce viable hybrids, except for the coastal cutthroat trout which evolved with the anadromous steelhead (Oncorhynchus mykiss) in coastal streams (Behnke 1976, 1992; Allendorf and Leary 1988). According to Hanzel (1959) rainbow trout were introduced into the states west of the Continental Divide in 1891 and have been extensively stocked since that time.

Brown trout (Salmo trutta) and brook trout (Salvelinus fontenalis) were both introduced in the early 1890's and gradually replaced the native cutthroat trout in the lower parts of their native range (Hanzel 1959). Varley and Gresswell (1988) report that introductions of brook trout in Yellowstone National Park almost always result in the disappearance of Yellowstone cutthroat trout. The displacement method is not understood, but Thurow et al. (1988) suggests that differential angling mortality may contribute to the displacement. Cutthroat trout are twice as likely to be caught by anglers as brook trout (MacPhee 1966), and early maturing brook trout (Jensen 1971) can reproductively withstand angling mortality better than the later maturing cutthroat trout. Griffith (1974) showed that brook trout may displace cutthroat trout from optimum velocities and areas of superior invertebrate drift, and force cutthroat trout into areas of higher velocities and lesser amounts of invertebrates. In streams with cutthroat trout and brook trout living sympatrically, the cutthroat trout will usually occupy areas of higher gradient (increased velocities) than the brook trout (Bjornn 1957; Bachmann 1958).

Exploitation rates appear to be the primary factor limiting cutthroat trout in sympatry with the brown trout (Thurow et al. 1988). Thurow (1988) reports that Yellowstone cutthroat trout seem to flourish where quality habitat and low exploitation still exists, even in reaches with brook trout and brown trout.

Of the 13 interior subspecies that are recognized, two are believed extinct (Yellowfin and Alvord cutthroats), 10 have suffered catastrophic declines, and two are holding their own, neither replaced nor hybridized throughout their range (finespotted and whitehorse cutthroat trout; Behnke 1992).

Habitat loss and degradation by humans sources also have influenced the decline of the Yellowstone cutthroat trout. Dams, mining and logging practices, irrigation projects, agricultural practices, and mineral and energy exploration have had an impact on cutthroat trout (Behnke 1976; Allendorf and Leary 1988; Thurow et al. 1988).

The major detrimental effect of dams includes isolating migratory cutthroat trout from tributaries used for spawning and rearing. Miller and Roby (1957) reported migratory cutthroat trout congregating in the after-bay of Palisades Dam attempting to reach upstream spawning areas; a run of large migratory cutthroat trout disappeared shortly after the dam was completed (Thurow et al. 1988). A majority of the reservoirs on the upper Snake River system (Yellowstone cutthroat trout native range) are relatively shallow with little temperature stratification. Silt substrates are present and many nongame species thrive in these impoundments. Attempts to eradicate many nongame species have eliminated thousands of cutthroat trout. Fortunately the migratory nature of the species prevented total extermination (Thurow et al. 1988).

Mining and logging, along with mineral and energy exploration, increased the sediment levels in many streams (Platts and Martin 1978; Thurow 1982; Thurow et al. 1988), which in turn cover and smother suitable spawning gravels (Burns 1972; Murphy et al. 1986). Inadequate design of roads for gaining access to these sites provide the majority of sediment.

Logging and grazing, which warm the water by decreasing vegetative cover, favor the replacement of native trout with more warm-water adapted trout species. Deterioration of stream riparian areas by bank sloughing, erosion, channel instability, and sedimentation result from intensive livestock grazing, especially in arid regions (Thurow 1988; Behnke 1976). Platts and Martin (1978) report that stream reaches displayed unstable banks and silt substrate when altered by livestock in the

Blackfoot River and Willow Creek tributaries. Reaches altered by livestock sustained fewer spawning cutthroat trout and a smaller density of juveniles (Thurow 1982; Corsi 1988). Livestock grazing impacts are widespread across Yellowstone cutthroat range and occur on private as well as government administered lands (Thurow et al. 1988).

Moeller (1981) mentioned that large sediment inputs into the Willow Creek drainage are the result of dry-land wheat farming. Channel dewatering, flow reductions, degraded water quality, and cutthroat trout movement into irrigation ditches are the greatest impacts of water diversion for irrigation. Yellowstone cutthroat trout populations are limited in reaches of the Blackfoot, Henrys Fork, Portneuf, Raft, Teton, and Snake rivers because of low flows (Thurow et al. 1988).

The preceding factors have not only decreased the availability of suitable habitat for the cutthroat trout, but they also favor displacement of native trouts by more tolerant brook trout and brown trout (Behnke 1976,1992). Thus, genetically pure cutthroat populations persist only in isolated headwater streams with relatively undisturbed habitat.

Propagation of Yellowstone Cutthroat Trout

Yellowstone cutthroat trout were first propagated at the Bozeman (Montana) National Fish Hatchery in 1898 from Henry's Lake stock; however, they were mixed with westslope cutthroat trout and distributed as "black-spotted trout" (Behnke 1992). In 1899 the first egg collections were taken from the West Thumb area of Yellowstone Lake under the supervision of the Spearfish

(South Dakota) National Fish Hatchery (Varley 1979; Behnke 1992). An immense operation grew from this initial egg collection operation which included a permanent hatchery at Lake Village. From 1899 to 1957, more than 818 million Yellowstone cutthroat trout eggs were collected (For example, 43,500,000 eggs in 1940) and from 1905-1957 it was the dominant subspecies propagated. The result of this operation was fry and eggs shipped worldwide, to many western state and federal agencies, and to private organizations. The large scale propagation and resulting wide-spread distribution led to the name Yellowstone cutthroat trout being established for virtually all interior cutthroat trout stocks (Varley 1979; Behnke 1988). Intense angler harvest, coupled with the spawning operations, resulted in near collapses of natural spawning migrations from Yellowstone Lake. In Clear Creek annual counts of spawners dropped from 16,000 to 3,353 in 9 years (Benson and Bulkey 1963). A major problem with propagating the Yellowstone Lake stock throughout the western United States results from its evolutionary programming. For thousands of years the Yellowstone Lake cutthroat trout evolved with only one other fish (longnose dace Rhynichthis cataracte) in a stable oligotrophic environment; thus, when it is introduced to an area, it is poorly adapted to coexist with other fish species in unstable environments (Behnke 1992). Present-day Yellowstone cutthroat trout hatchery stocks in Montana (McBride strain), Wyoming (McBride strain and a new LaHardy Rapids strain) and Idaho (Henry's Lake strain) are used to reestablish Yellowstone cutthroat trout (Varley and Gresswell 1988; Dotson 1985; McMullen and Dotson 1988; Thurow et al. 1988).

<u>**Life History of the Yellowstone Cutthroat Trout**</u>

Most information about life history and ecology of Yellowstone cutthroat trout is based on the population in Yellowstone Lake (Cope 1956, 1957a, 1957b; Bulkley 1961). However, different habitats and environmental conditions in which cutthroat trout exist lead to wide variability in life histories and ecological traits among populations (Behnke 1976); thus, the following will be a general synopsis of the life history of Yellowstone cutthroat trout.

Migration and Spawning - Yellowstone cutthroat trout spawn in fluvial environments (Cope 1957a; Varley and Gresswell 1988). Four migratory spawning patterns are exhibited by Yellowstone cutthroat trout: (1) fluvial populations disperse within their home range for spawning; (2) fluvial-adfluvial populations migrate to smaller tributary streams from larger rivers; (3) lacustrine-adfluvial populations ascend tributaries from lakes to spawn; and (4) allacustrine cutthroat trout migrate downstream from a lake outlet to spawn (Thurow et al. 1988; Varley and Gresswell 1988; Darling et al. 1992). Spawning can occur from late April through August depending on altitude, latitude, water temperature, and run-off conditions. As altitude increases migration peaks occur later in the year. Peak migration occurred at Trout Lake (elevation 2,121 m) around May 20, while in Sylvan Lake (elevation 2,565 m) the peak was in late July (Varley and Gresswell 1988; Behnke 1976). Spawning migrations begin when water temperature is about 10 C and flows subside from spring peaks (Ball and Cope 1961; Varley and Gresswell 1988). Spawning occurs in perennial groundwater or snowfed streams where suitable substrate (rocks 12-85 mm diameter; Cope 1957b), water temperatures (5.5-15.5 C; Varley and Gresswell 1988), and stream gradients (commonly less than 3%; Cope 1957a, 1957b; Behnke 1976; Varley and Gresswell 1988) occur. Males generally migrate earlier and stay longer (6-25 days; Ball and Cope 1961), but females tend to outnumber males in spawning areas (Thurow 1982; Moore and Schill 1984). Age, weight, and condition of both sexes decreases as spawning runs progress (Ball and Cope 1961; Varley and Gresswell 1988). Yellowstone cutthroat trout become sexually mature at age 2 to 6 (Behnke 1976; Thurow et al. 1988; Darling et al. 1992); however, in tributaries to Yellowstone Lake they were principally age 4 to 7 in spawning streams (Irving 1955; Benson 1960; Bulkley 1961; Jones et al. 1985). Mature fish are typically larger than 200 mm total length in the Snake River drainage (average 300-500 mm; Irving 1955; Thurow 1982; Moore and Schill 1984; Corsi 1988); however, Johnson (1963) collected spawners of 150 mm. Ball and Cope (1961) reported repeat spawner densities as low as 1% (exploited population), but Jones et al. (1982) indicated 26% of spawners had spawned previously in a Yellowstone Lake tributary. Females are more likely to repeat spawn (Thurow 1982) which more frequently occurs in alternate rather than consecutive years (Ball and Cope 1961; Varley and Gresswell 1988). Post-spawn mortality can be quite high; 48.1% was reported by Ball and Cope (1961) for five streams, while Jones et al. (1985) found that mortality averaged 12.9% over five years in Clear Creek. In Arnica Creek untagged trout had 25 to 44% mortality from 1950-53 (Ball and Cope 1961).

Fecundity of a typical female (394 mm TL) will be 1300-1500 eggs (Moore and Schill 1984; Jones et al. 1985). Behnke (1976) suggests a general figure of 1000 eggs per 450 grams of body weight, with wide individual variation. Once deposited in the gravel, the eggs typically hatch in 25-30 days (310 C degree days), normally suffering 12-42% mortality from inadequate water flows (Benson 1960; Ball and Cope 1961).

Young of Year - Fry typically emerge from gravels in early to mid-summer, 2 weeks after hatching (Behnke 1976; Varley and Gresswell 1988) and congregate in shallow, slow-moving stream habitats. In some tributary systems, fry from migratory parents may begin upstream or downstream movements shortly after emergence (Irving 1955; Benson 1960; Ball and Cope 1961; Moore and Schill 1984). Fry often rear for 1-3 years in tributaries prior to emigrating to larger waters (Thurow et al. 1988). Averett and MacPhee (1971) reported that 7% spent 1 year, 67% spent 2 years, and 26% spent 3 years in their natal stream. Johnson (1963) found no evidence of extensive fry movement in the Flathead River drainage. Length of growing season dictates size and fry may range from 25 to 75 mm by fall. Chapman and Bjornn (1969) suggested that size at emigration is probably a function of quality and amounts of overwintering habitat. Downstream migrations of juveniles that have overwintered in the natal stream occur from June to September. Mortality studies show a 36% survival rate from the time the juvenile leaves the stream until they return as spawners (Benson 1960).

Age and Growth - Fry reaching 41-44 mm in length usually have distinguishable scale platlets (Laakso and Cope 1956). Late-emerging fry may not reach lengths at which scale formation is initiated during their first year because growth rate declines to negligible levels in October (Brown and Bailey 1952). Growth is varied among populations of Yellowstone cutthroat trout because of environmental factors. Accelerated growth, clearly shown on scales, may occur when a juvenile migrates to a lake environment; however, growth may decrease during gonadal development (Averett and MacPhee 1971). Elevation also affects annual growth rate of trout. Hazzard (1932) found growth of brook trout was slower in cold headwater streams than in warmer, lowland streams. In the West Gallatin River, arising in Yellowstone Park, comparisons of growth rates, elevation, and water temperatures indicated that higher elevations, with lower water temperatures, had smaller annual length increments (Purkett 1951). Maximum life spans of most native western trout may reach 11-12 years in areas of low annual metabolic energy expenditures due to cold water temperatures, a short growing season, or sparse food supplies; however, 6-7 years is normal for cutthroat trout (Behnke 1992). Total length at age for Yellowstone cutthroat trout populations in the Snake River drainage are summarized in Table 1 (from Thurow et al. 1988; Appendix E).

Habitat - Many environmental factors interact temporally and spatially to affect trout production in streams. Little quantitative information exists on Yellowstone cutthroat trout; however, studies done on other salmonids indicate parameters which are likely to influence Yellowstone cutthroat trout (Darling et al. 1992). Binns and Eisermann (1979) found that nine environmental variables explained over 90% of the variation in standing crops of fluvial trout including cutthroat trout:

late summer streamflows, yearly flow variation, velocity, cover, stream width, eroding stream banks, substrate, nitrate-nitrogen concentration, and maximum water temperature. Although now considered a "headwater" species, the native habitat was once more diverse than the present range. It ranged in elevation from 275 to 2590 m with stream flows of 0.06 to 321 m^3/s. Yellowstone cutthroat trout are adapted to cold water, as well as low flows, and have been found to overwinter in trickles of water for 8 months with extreme cold and ice conditions (Varley and Gresswell 1988).

Management of Yellowstone Cutthroat Trout

Yellowstone cutthroat trout management practices include habitat management, special regulations, stocking, and increased efforts to maintain genetic integrity.

Habitat management comprises protection, enhancement, and improvement of aquatic environments. Efforts have focused on barriers to fish passage, screening irrigation diversions, managing riparian areas, and regulating non-point source pollution (Varley and Gresswell 1988; Thurow et al. 1988). Irrigation screens have reduced the loss of migratory cutthroat trout and have improved recruitment in several drainages (Thurow et al. 1988). Maintaining adequate water flows due to irrigation losses looms as a major problem and many states are attempting to establish fish sustenance as a legally defined "beneficial" use of water (Varley and Gresswell 1988). Riparian-habitat destruction remains a prevalent problem in the upper Snake River

Basin. Undercut stream banks, a significant trout habitat parameter, depend on extensive streamside vegetation (Wesche 1973), which can be altered by livestock. Riparian habitats can be substantially improved by altering livestock grazing strategies (Platts and Rinne 1985) with enclosures and grazing systems or termination of grazing practices (Thurow et al. 1988). Trout abundance can be increased with stream-improvement devices; however, they often require a considerable amount of time, money, and equipment to install. As each stream has its own set of problems, stream improvement and management is complicated and remains a job for a professional biologist familiar with trout ecology (Behnke 1976). Successful habitat management improves living conditions, increases survival and reproduction, provides shelter, and enhances gravels for spawning. Habitat improvement practices such as creating artificial redds and overhangs, cleaning up streams, and stabilizing stream banks are often limited by accessibility, time, and money throughout the Yellowstone cutthroat range and, therefore, are practiced sporadically.

Regulations are designed to: (1) increase recruitment, (2) protect spawners, and (3) increase the numbers of large trout. Typically, regulations include length and bag limits, seasonal closures, and gear restrictions used either singly or in combination (Thurow et al. 1988; Varley and Gresswell 1988). Examples include a slot limit imposed in 1984 on the South Fork of the Snake River which resulted in increases in both density and mean length of fish (Thurow et al. 1988). The Yellowstone cutthroat trout has responded positively to catch-and-release regulations. Special regulations have gained favor with managers and anglers, unlike many habitat management attempts (Varley and Gresswell 1988). Behnke (1976) makes the point that overfishing has never been the sole reason for a trout becoming rare or endangered; thus, regulations will help, but they are not the solution for managing Yellowstone cutthroat trout.

The most controversial management tool, because of its potential impacts on existing populations, is stocking. Stocking includes two commonly used methods, maintenance stocking of waters containing trout and "put-and-take fisheries" where trout are stocked and expected to be harvested in a short period of time. Often used for these purposes, hatchery stocks of cutthroat trout or other trout species present a serious problem due to a loss in genetic variation (Allendorf and Leary 1988). The artificial and controlled environment of hatcheries exert inadvertent selection pressures on stocks which become increasingly adapted to the artificial environment and less to the natural environment. Incubation temperatures, food and feeding, and lack of exercise all exert selective pressures on trout, affecting the phenotype and generally decreasing the stock fitness for survival after stocking (Hynes et al. 1981). Hatchery populations often originate from a small number of individuals (Allendorf and Leary 1981); thus, the gene pool is restricted, compounding the above affects. These "less fit" hatchery fish affect wild populations through competition (Reimers 1957; Vincent 1972) or interbreeding to alter their genetic structure (Reisenbichler and McIntyre 1977). Utter (1981) reported detrimental effects of introduced salmonids on the native stocks. Released hatchery-raised fry usually have an inferior performance when compared to wild relatives (Moav et al. 1978). Reisenbichler and McIntyre (1977) found decreased survival of hatchery steelhead eggs and juveniles planted in the wild.

The genetic structure of hatchery stocks can by improved by: (1) founding the population on a large number of fish, (2) taking eggs from more than one spawning migration or timing (Allendorf and Leary 1988), (3) testing for genetic variation and reintroducing wild gametes (McMullin and Dotson 1988), (4) modifying hatchery practices to reduce artificial selection procedures, or (5) not "grading out" slow growing individuals (Reisenbichler and McIntyre 1977).

Identifying genetically unaltered Yellowstone cutthroat trout populations has become a priority among management agencies in recent years (Varley and Gresswell 1988). Emphasis has been placed on detection of hybridization with other trout species, namely rainbow trout or other cutthroat trout subspecies (Loudenslager and Gall 1980, 1981; Wishard et al. 1980; Leary et al. 1987). All genetically unaltered populations should theoretically be protected, but generally management policy requires positive identification prior to initiation of any action reducing deleterious human impacts (Varley and Gresswell 1988). Probably because a sound biological basis for any regulation protecting the subspecies is needed to counter public reaction. Maintaining genetic integrity of a population is a complicated process.

Genetic make-up, analysis, and management of Yellowstone cutthroat trout

Preservation of remaining native trout populations is the goal and responsibility of state and federal agencies, as well as Native American management agencies (Leary et al. 1989; Darling et al. 1992). The initial step in implementing a restoration or preservation program requires identification of existing native, pure populations (Leary et al. 1989). In the past, morphological comparisons were used to identify where hybridization was occurring, assuming that the hybrid offspring would be morphologically intermediate to the parental taxa and have increased morphological variance (Leary et al. 1985; Marnell et al. 1987; Allendorf and Leary 1988). Recent studies have shown that these assumptions are not always valid and morphological comparisons can provide potentially misleading genetic information (Busack and Gall 1981; Leary et al. 1983, 1984, 1985). Marnell et al. (1987) found close agreement between electrophoretic and meristic results with Yellowstone and westslope cutthroat trout, two subspecies with relatively larger evolutionary separation. However, Loudenslager and Gall (1980) and Loudenslager and Kitchen (1979) were unable to find any consistent differences between more closely related subspecies (O. c. utah, O. c. bouvieri, and finespotted Snake River cutthroat trout), presumably because of a shorter evolutionary separation of these three taxa (Marnell et al. 1987). Another limiting factor was shown by Behnke (1992) when he warned that meristic counts and morphological descriptions are often specific to only localized populations and not all populations of O. c.

bouvieri due to regional differences in these characteristics. Finally, small genetic contributions may not be morphologically detectable (Allendorf and Leary 1988). Thus, morphometric analysis, as used in the past, probably does not adequately assess genetic make-up stocks.

Three current methodologies are used to assess actual genetic make-up: (1)karyotype analysis, (2) gel electrophoresis, and (3) DNA analysis. Karyotyping may help clarify the origin and relationship among western trout taxa (Miller 1972; Gold 1977). Loudenslager and Thorgaard (1979) found that Yellowstone cutthroat trout have a modal chromosome number (2n) of 64. When compared with the other cutthroat trout subspecies this chromosome number differentiates the Yellowstone from the coastal and westslope subspecies, but shows close relationship to the Alvord and Lahontan cutthroat trout (Table 2; Appendix E). Thus, karyotyping can be a diagnostic tool to differentiate subspecies if pure populations are present, however, if hybrids are present this method becomes less valid. RB 58-60

Electrophoretic analysis of proteins is a powerful and reliable method of determining genetic status of a population (Leary et al. 1989). Tiselius first used electrophoresis in 1937 to distinguish multiple serum protein fractions migrating, under electric influence, through a solution (Avise 1974). Proteins migrate through an electric field at differing rates depending on net charge, size, and shape of the molecule. Polypeptides which migrate different distances through solution (gel) differ by at least one amino acid in composition; thus, the colinearity of the amino acid and DNA base sequences and the electrophoretic mobility of the protein provide indirect DNA (genetic) information. The most valuable systemic information provided by electrophoresis includes data on allelic frequencies at genetic loci in different populations (Avise 1974). Genetic status of a population can be determined when complete, or nearly complete, allele (form of gene) frequency differences exist between taxa at several loci (gene location on chromosome; Leary et al. 1989). Because of this, Ayala and Powell (1972) term the loci where differences exist as diagnostic loci. These loci are important in detecting intertaxa breeding (Leary et al. 1987). At any given locus, organisms may be genetically identical (homozygous or heterozygous for same alleles), 50% the same, or completely different (homozygous or heterozygous for different alleles; Avise 1974). Thus, allelic frequencies within or between populations may be calculated and statistically compared to determine extent of purity or hybridization. Genetically pure individuals possess alleles at all diagnostic loci characteristic of that taxon; however, first generation hybrids will be heterozygous for alleles at all diagnostic loci characteristic of the both parental taxa. Hybrid swarms (back-crossing) result in individuals homozygous at some diagnostic loci and heterozygous at others (Martin et al. 1985; Leary et al. 1989).

Several diagnostic loci exist to differentiate the Yellowstone cutthroat trout from both westslope cutthroat trout and rainbow trout. Liver, eye, or muscle tissue containing 42 commonly assayed nuclear loci are used in gel electrophoresis. Twelve allozyme loci distinguish westslope and Yellowstone cutthroat trout, whereas 8 of the 42 differentiate both cutthroat trout subspecies and the rainbow trout (Table 3; Appendix E). Leary et al. (1987) found no diagnostic loci among Colorado River, finespotted, greenback, and Yellowstone cutthroat trout, eliminating the ability to detect interbreeding among these subspecies.

Nomenclature for gene loci and allele variants encoding the enzymes often surveyed follow Allendorf and Utters' (1979) system. A capitalized abbreviation represents each protein and loci are numbered based on the amount of anodal mobility. Alleles are designated according to their relative mobility in relation to the mobility of the rainbow trout common allele with an assigned mobility of 100. Methods of data comparison include the number of polymorphic loci, average heterozygosity, genetic variation, and Nei's (1972) method.

The third type of genetic analysis is mitochondrial DNA (mtDNA) testing. Use of DNA is a relatively new technique (Kozel et al. 1992); however, mtDNA has been used extensively in Utah to differentiate trout populations (Shiozawa and Williams 1988; Shiozawa et al. 1993a; Shiozawa et al. 1993b). Apparently it can be very accurate in identifying taxa to the subspecies and population levels when used correctly. Williams and Shiozawa (1989) examined DNA from 13 subspecies of cutthroat trout and were able to discriminate between all subspecies. Unlike electrophoresis, a fin provides enough tissue for analysis and the fish does not have to be sacrificed (Williams and Shiozawa 1989). Shiozawa and Williams (1988), using mtDNA procedures, appear to have found results differing from the original proposed cutthroat trout phylogenetic classification (Behnke 1992).

However, these results are tentative and based on a small sample of a much larger, on-going research project.

Mitochondrial DNA analysis is highly technical and requires a well-equipped laboratory. Once DNA is extracted from the cell it is digested with restriction endonucleases, amplified using the polymerase chain reaction, and then: (1) probed with a rainbow trout gene to determine fragment size patterns, (2) analyzed with the southern blotting technique, or (3) examined for differences in primer amplification patterns (Shiozawa and Williams 1988). Mitochondrial DNA diversity in non-hybridized, native trout populations is generally very low (usually none), while populations introgressed with non-native trout often have multiple, divergent mtDNA haplotypes (set of alleles from closely linked loci and usually inherited as a unit; Shiozawa et al. 1993a).

Several problems arise with the use of mtDNA for genetic separation. Maternal inheritance of mtDNA causes diagnostic problems as hybrids will contain only maternal mtDNA; not material from both parental taxa (Avise et al. 1984; Gyllensten et al. 1985). Furthermore, if only males from a taxa participate in hybrid matings their mtDNA will be absent in analysis. A taxas' mtDNA is also more likely to be lost from a hybrid swarm than is nuclear DNA because the effective population size is smaller. Finally, it costs $2200 per 30 fish sample (Kozel et al. 1992; Dennis Shiozawa, Brigham Young University, personal communication). None-the-less, as DNA analysis techniques continue to improve, this method of genetic determination may provide some long awaited answers about cutthroat trout phylogeny.

Shiozawa (personal communication) concluded that when differentiating higher levels of hybridization (i.e. Yellowstone cutthroat trout with rainbow trout or westslope cutthroat trout) allozyme analysis was adequate and faster; however, hybrids of closely related subspecies may require DNA analysis. Leary et al. (1987) also concluded that electrophoretic analysis provided a reliable means to identify genetically pure populations of trout.

Behnke (1976) suggests the most likely locations to find pure populations of native trout are remote headwater areas isolated by barrier falls. Once an area has been surveyed and genetically identified as pure, restoration and preservation programs can be implemented. Darling et al. (1992) identified six management considerations in the preservation of Yellowstone cutthroat trout: (1) within historic range identify and protect existing populations and habitat, (2) enhance habitat and existing populations, (3) restore populations, (4) manage current populations outside historic range, (5) support research to identify genetic problems and habitat requirements, and (6) implement a Yellowstone cutthroat trout information and education program.

Agencies are currently implementing programs to identify pure populations. Several studies have identified the genetic purity in varying western areas. Leary et al (1989) found that 30-40% of Yellowstone cutthroat trout populations appear hybridized in the Yellowstone River drainage, Montana. Sage and Leary (1990) found 10 of 22 populations in the Gallatin River drainage were hybridized. An electrophoretic sample of 25 fish is recommended for a reliable estimate of genetic purity (Leary et al. 1989); however, where populations may be extremely low, fewer fish may be used (Darling et al. 1992). The University of Montana, Missoula, fish genetics laboratory can detect 1% hybridization with rainbow trout or westslope cutthroat trout with 95% confidence limits with a 15 fish sample, while obtaining the same results with 99% confidence limits with a 25 fish sample (Robb Leary, University of Montana, Missoula, personal communication).

Protection of the subspecies could be accomplished in several ways, most of which have already been discussed. Prohibiting stocking of any hybridizing or competing salmonid species would preserve populations and their genetic integrity. Appropriate harvest regulations may help as well as establishing or maintaining physical barriers to prevent upstream migration of contaminating species (Behnke 1976; Darling et al. 1992).

Enhancement of existing populations is a second priority in managing the Yellowstone cutthroat trout. Eradication of hybridizing salmonid and competing, non-native species in streams or lakes, as well as the surrounding watershed, by electrofishing, poison, or angling may benefit the subspecies. A habitat enhancement objective to manage habitat at 90% or more of the inherent potential (based on criteria set by land and fishery managers) would benefit Yellowstone cutthroat trout populations (Behnke 1976; Darling et al. 1992). Habitat management would place emphasis on conservation in drainages predominately inhabited by native trout, while allowing other uses on drainages with hybrids (Leary 1989). Artificial propagation to supplement existing populations or introduce new populations may also help enhance a population; however, potential problems include: reduced genetic variation, fitness, and survival when compared to a wild population. Use of a donor source would limit these problems. An adequate donor source involves transplanting, with caution, trout from a remnant, pure, wild population of Yellowstone cutthroat trout into areas previously void of fish to extend the current distribution of Yellowstone cutthroat trout (Behnke 1976). Precautions must be taken to: (1) assure genetic purity of the donor source, (2) select donor populations from areas of similar habitat and climatic evolution to enhance survival, and (3) assure the donor stream contains a large enough population to support the removal of a minimum of 50 fish (Darling et al. 1992).

Population restoration and expansion is a third focus of Yellowstone cutthroat trout management. Hadley (1984) estimated only 8% of original stream habitat in the Yellowstone drainage of Montana still supported pure cutthroat trout. Again reintroduction of fish to a barren environment or areas previously treated to remove competing species would expand the range if proper methods are used in selection of brood or donor stock.

Age and Growth Analysis

Basic approaches to aging fish include: (1) direct observation of fish held in confinement or marked and recaptured, (2) a statistical approach based on length-frequency distributions, and (3) anatomical approach based on fish bony structures (Jearld 1983). The latter approach is by far the most widespread method among fishery biologists. Scales, otoliths, spines, and fin rays are the bony structures often used in age determination.

Scales are used to assess fish age; however, several things need to be considered when using salmonid scales to age fish. Scales should be removed from the fish in the area they first appear; both Jearld (1983) and Knudsen and Davis (1985) suggest collecting scales from the area above the lateral line below insertion of the dorsal fin; the area where scales first appear and contain the most complete record of growth (Larscheid 1990). Always sampling scales from the same area has several advantages: the biologist remains consistent, the scales are larger and easier to work, aging difficulties are minimized (Laakso and Cope 1956), and variabilities in scale measurement are reduced (Cooper 1970). Several researchers have found young-of-year cutthroat trout, because of late spawn timing, did not grow to an adequate length for scale (41-44 mm; Brown and Bailey 1952) or annulus formation (Robertson 1947; Alvord 1954; Laasko and Cope 1956; Bulkley 1961; Averett and MacPhee 1971). The first annulus (recognized by circuli "crossing over;" Jearld 1983) in late-hatching populations is not laid down on the scale until the second growing season; thus, analytical problems arise when assessing age. False annuli also present a problem; Hatch (1959) found that 65% of brook trout formed false annuli with apparent regularity in Adirondack lakes, indicating older fish than actually were present. A third difficulty arises with scale regeneration. A regenerated scale does not contain the characteristic circuli pattern present on original scales (Larscheid 1990). Cooper (1970) found regeneration rates as high as 80% for cutthroat trout larger than 140 mm in Chef Creek, while Moring et al. (1981) found 39% of coastal cutthroat trout had more than 90% scale regeneration. Finally, in trout older than 3 years, scales become difficult to interpret as annuli are in close proximity to each other and erosion and reabsorption obliterate scale characteristics in many scales (Alvord 1954).

Otoliths are aged similarly to scales; however, rather than counting where the circuli cross-over, otoliths have opaque bands during periods of slow growth (Jearld 1983). Otoliths are generally considered to be a better indicator of age in salmonids; however, little research substantiates this claim. Otoliths are often used to age coastal cutthroat trout, but their age assessment has never been validated (Armstrong 1971). Scale analysts with the Oregon Department of Fisheries and Wildlife concluded, upon comparison of known age-2 cutthroat trout otoliths and scales, that otoliths gave as good or better age accuracies as scales (Moring et al. 1981). However, Hubert et al. (1987) found otoliths had lowest percent agreement between two readers than either scales or pectoral fin rays in fish from Yellowstone Lake. These data disagree with recent literature indicating scales may be less desirable for aging slow-growing populations. More work is needed to validate use of otoliths for aging salmonids. Much research on warmwater fishes in southern fisheries indicates that otoliths are a more valid aging tool, while in northern waters scales and otoliths are similar

(Kruse et al. in press). Otoliths tend to yield higher age (and probably more accurate) estimates than scales for older fish (Hubert et al. 1987; Kozel and Hubert 1987), probably because of the problems associated with reading scales of older fish. The sacrifice of fish necessary to obtain otoliths is a drawback, as well as preparation time and breakage problems while in storage (Moring et al. 1981). Thus, otoliths and fin rays may provide more accurate assessments of fish age.

Fin rays can be useful for age determination of salmonids (Mills and Beamish 1980; Shirvell 1981). Age and growth interpretations with fin rays can be affected by growth rates and preparation of the rays (Moring et al. 1981). There is evidence that the first annulus of fin rays is often not identified when aging (Moring et al. 1981; Hubert et al. 1987). Mills and Beamish (1980) found no consistent bias between aging methods and suggested that fin rays gave more reliable results than scales. They found better agreement between readers with fin rays than scales as did Hubert et al. (1987).

Estimates of length at age of Yellowstone cutthroat trout were presented earlier. In the past back calculations of length were determined from mean scale measurements with the aid of nomographs constructed from the body-scale relationship (Bulkley 1961). Many researchers constructed body-scale relationships for the particular body of water (Bjornn 1957; Platts 1958; Cooper 1970). Present day growth analysis (length at age) can be computed using computer software and a digitizer or scanner, Disbcal and OPRS are two examples.

Although questions remain about the validity of aging with otoliths, they appear to be the best way to age cutthroat trout. Evidence suggests that otoliths are as good as, and probably better than, scales for aging trout. Since fish in this study will be sacrificed for genetic and meristic analysis, collecting otoliths will not require removing additional fish.

Morphometric and Meristic Analysis

Morphometric analysis and meristic counts have long been used to differentiate between salmonid species and subspecies. Researchers have often been at odds as to whether observed differences were due to environmental or genetic influences (Barlow 1961). It is now known that both environment and genetics can influence the morphometry of a species; however, if environmental influences persist over a period of time the organism will adapt genetically to the influence. Barlow (1961) suggested that the level of heterozygosity is important in determining morphological variability and acts to stabilize development. The more homozygous a population is, the greater chance of abnormal development or phenotypic deviations. Several studies have substantiated this argument. Leary et al. (1985) found more asymmetry in a hatchery population (less genetic variation) than in a native, wild population. However, environmental agents such as temperature, oxygen levels, and salinity concentrations also will produce differing meristic counts, just as genetic differences will (Barlow 1961). Many investigations have shown that differences in size and shape of fish are apparent on a north to south gradient in the Northern Hemisphere. Northern, slow-growing races are often larger then their southern counterparts and usually have higher counts in meristic features (Barlow 1961). These attributes often confound the ability of researchers to differentiate species and especially subspecies by morphological and meristic traits.

Schreck and Behnke (1971) suggest that the most useful meristic characteristics for distinguishing western salmonid populations are vertebra counts, scales in lateral series, scales above the lateral line, pyloric caeca, and pelvic fin rays. Several other variables have been used (Zimmerman 1965). Spotting and coloration descriptions have been used when differentiating fish taxa (Behnke 1992). Nevertheless, morphometric and meristic descriptions are influenced by environmental variables; thus, there is danger when comparing fish raised in different environments (Leary et al. 1985; Behnke 1992). Behnke (1992) mentioned that although spotting can distinguish the Yellowstone subspecies from other cutthroat trout subspecies, they are very unreliable and can change drastically with little genetic variation.

The following are typical characteristics and counts for Yellowstone cutthroat trout from Yellowstone Lake (Behnke 1992). The author cautions that this meristic index is specific to Yellowstone Lake cutthroat trout and stream populations may differ.

Spotting of Yellowstone cutthroat trout is similar to the westslope cutthroat; however, the medium-large, pronounced, rounded spots, concentrated on the caudal peduncle, are more evenly distributed over the sides of body in the Yellowstone cutthroat trout. Vertebrae average 60-63 (typically 61-62), scales in the lateral series 150-200 (165-180), pyloric caeca 25-50 (35-43), and gill rakers 17-23 (19-20).

Several studies, including Binns (1977) and Hadley (1984), have used morphometrics to assess genetic purity of cutthroat trout. Binns (1977) applied a system of scale, pyloric caeca, and basi-branchial teeth counts, as well as spotting patterns, to classify the genetic purity of Colorado River cutthroat trout. Martinez (1988) classified Colorado River cutthroat trout based on meristic features in Colorado; however, the results were not verified by electrophoretic analysis. The variability of morphologic assessment is shown by the fact that in Montana, 63 streams were assessed as having genetically pure populations with morphometric analysis (Hadley 1984) but only 70% were genetically pure when analyzed electrophoretically (Darling et al. 1992). Bulkley (1963) compared spotting patterns, hyoid teeth counts, and coloration in seven Yellowstone cutthroat populations and found such wide natural variation that differentiation between populations was impossible based on these characteristics.

Genetic determination based on morphological and meristic features, while giving an idea of genetic purity, is not an adequate method to positively identify pure populations of Yellowstone cutthroat trout. However, if a meristic system to identify Yellowstone cutthroat trout was developed, it could indicate which populations were not pure. This would benefit managers by saving time and money that would be spent electrophoretically examining populations, while allowing them to concentrate efforts on those populations whose genetic status was unclear after meristic evaluation.

Habitat Assessment

Consistent and logical stream habitat classifications have challenged researchers for many years. Several approaches have been presented; however, no single approach is generally accepted (Hawkins et al. 1993). Several reasons hinder a general classification system: (1) too many independent and interacting variables compose stream environments to distinguish habitats on one single criterion, (2) environmental heterogeneity varies within and among streams making the number of habitat classes required unclear, (3) variation within a system is often gradual and not discrete on temporal and spatial scales, and (4) classification type and resolution needs vary with specific management or research needs (Hawkins et al. 1993). Several systems have been proposed; however, I will concentrate on discussing four used by agencies in Wyoming.

The Habitat Quality Index (HQI) was developed to estimate potential trout standing stocks in streams (Binns and Eiserman 1979); however, it requires intensive data collection to obtain values for the predictive models. Model II requires 9 stream variables to be accurately measured and calculated, including: late summer stream flow, annual stream flow variation, maximum temperature, nitrate nitrogen, cover, eroding stream banks, substrate, water velocity, and stream width. Measurements also must be taken at a standard time during August and September when conditions are conducive to data collection. Although Binns and Eiserman (1979) reported high correlation between measured standing stocks and standing stock predicted by the model, Kozel and Hubert (1989), while finding a significant correlation, found that measured standing stocks were substantially greater than the predicted stocks in the Medicine Bow National Forest. The HQI can do a good job of explaining standing stock variations and identifying potential limiting habitat factors; in some situations it may provide a less expensive, alternative method to obtain stock estimates, and may be important in habitat improvement evaluations. Because actual and visual measurements are taken according to a manual (Binns 1982), observer bias is minimized (Binns and Eisermann 1979).

Although utilization of HQI will allow comparisons with existing Wyoming Game and Fish Department stream habitat records, several limitations prevent its use within the project confines. Model development did not include the small, steep, unproductive streams within the study site, thus results may be unreliable or incomparable to existing data sets. Several variables required in model performance will be difficult to obtain during the course of the study. While Binns (1982) suggests a standard August-September sampling period, numerous study locations will be visited prior to and after this period. Late summer flow, annual flow variation, and maximum temperature will be difficult to obtain due to a lack of stream gauges and project timing. Nitrate nitrogen analysis will require several one liter bottles to be transported out of study sites. Sulfuric acid used to clean bottles and preserve samples may cause problems. Finally, HQI measurements will add an additional 2-4 hours of sampling at each site, pushing a limited time schedule. Given these constraints, HQI assessments at each sampling site are not feasible for this project; however, a few random sites could be selected for HQI analysis.

A second method of habitat assessment is the Basin-Wide Inventory. Limiting fish habitat studies to only one or a few aspects (physical parameters) constrains our ability to understand the factors influencing fish habitat (Herger 1993). Even if we just look at physical variables, simplifying the habitat assessment, the complexities of spatial and temporal variation in physical parameters must be considered (Herger 1993). Therefore, the manager or researcher cannot limit the scope of habitat assessment or spatial and temporal variability may not be identified (Hankin and Reeves 1988; Lewis 1969). Several advantages in habitat assessment can be found using the basin-wide inventory method (Hankin and Reeves 1988). The method is less time consuming because estimates of habitat units are made visually, allowing entire streams to be inventoried. Variability when extrapolating data from reaches to the whole streams will be decreased (Hankin 1984). Also, natural geomorphic units make up the sampling units (Herger 1993). Similar to other methods for assessing physical habitat features, biotic and behavioral factors are not considered with the basin wide inventory. And, as with most habitat assessment methods using visual estimates, observer bias may impact the inventory (Hankin and Reeves 1988; Hawkins et al. 1993; Herger 1993).

Basin-wide inventory sampling units are categorized as pool, riffle, or glide by definitions of Bisson et al. (1982). Direct physical measurements include their length, wetted width, and water depth; whereas, the extent of undercut banks, overhanging vegetation, and cover of woody debris are visually estimated

(Herger 1993).

This method, although adequate for obtaining needed habitat measurements and less time consuming than HQI, will also be difficult to use because of time constraints, observer bias between sampling crews, and the inability to compare data with existing Wyoming Game and Fish stream habitat records. A shortened form of the Basin-Wide Inventory method could be applied to sampling sites to estimate habitat variables.

A third method of habitat classification is described by Hawkins et al. (1993) as a hierarchical approach to stream habitat classification. They suggest that this scheme has both a logical and ecologically relevant foundation to classify channel units. The system, similar to basin wide inventory, uses a channel geomorphic unit as a sampling unit. The hierarchial method consists of three levels, with each being less inclusive then the previous, allowing a choice of level of habitat resolution required to meet specific management or research objectives (Frissell et al. 1986; Hawkins et al. 1993). Once habitats are classified and enumerated by this system, statistical estimates of population abundance can be made by subsampling each habitat type. The system provides a reference that facilitates communication among professionals; a big advantage with any system (Hawkins et al. 1993).

A standard stream survey procedure was designed by the Wyoming Game and Fish Department as a guide for conducting stream surveys throughout the state. The intent of these surveys is to obtain a detailed description of stream habitat and fish populations at specific sampling sites to build a statewide stream habitat database. The survey includes five major sections: (1) identification of stream class, (2) HQI attributes, (3) physical habitat, (4) water chemistry, and (5) fishery information (WDGF standard stream survey 1994).

The WDGF standard stream survey will adequately assess the objectives of this project; however, several limitations may constrain its use. Stream classification, physical habitat parameters (stream width, depth, flow, substrate, bank erosion and stability, and barriers), and fishery information data will be relatively easy and practical to collect given the sampling scheme; however, HQI variables and water chemistry may be difficult to obtain. Water chemistry variables that can be measured rapidly with water chemistry kits and meters, such as dissolved oxygen, pH, conductivity, and alkalinity, may be feasible; but those that require laboratory samples to be removed from the field would be impractical. The ability to compare the standard stream survey to a databank of similar measurements would make this method most useful to the Wyoming Game and Fish Department. The survey includes enough habitat variables to allow assessment of correlations among habitat variables and population characteristics, as well as adequately assess the habitat features the United States Forest Service is most concerned with.

The Habitat Quality Index, Basin-Wide Inventory, and the hierarchial approach to habitat assessment are all difficult to use given the project timing, constraints, and sampling scheme; therefore, the WDGF standard stream survey appears to be most appropriate method of assessing habitat. Because a large area must be sampled, this system is most adequate for our needs and will allow some comparison to existing data.

One- and three-pass electrofishing density estimation

Three-pass electrofishing will used to estimate the relative abundance of Yellowstone cutthroat trout and other trout species at selected sites, while the first pass will be evaluated as an index to relative abundance. Wide variability in Yellowstone cutthroat trout standing stocks were found in 23 mountain streams in Wyoming and Yellowstone National Park. Standing stocks ranged from 7 to 145 kg/hectare and averaged 48 kg/hectare (Varley and Gresswell 1988). Jones et al. (1979) estimated Yellowstone cutthroat trout standing stocks in two subalpine lakes to be 23 and 45 kg/hectare, respectively. Yellowstone Lake has an estimated biomass of 12-43 kg/hectare of Yellowstone cutthroat trout (Varley and Gresswell 1988).

Electrofishing catch-per-unit-effort (CPUE) has often been used as an index of density in warm- and cool-water species. Both Serns (1983) and Hall (1986) found high correlations between electrofishing CPUE and densities of walleye yearlings and largemouth bass, respectively. Electrofishing is often used to determine trout biomass in small streams using the three-pass removal depletion method (Moore et al. 1983; Bohlin 1989; Hebera et al. 1992; Lohr and West 1992); however, little information is available on a one-pass electrofishing CPUE index to density. Riley and Fausch (1992) evaluated two- and three-pass population estimates and found both underestimated abundance by 9% and 4% respectively.

The most widely used method to estimate population size when electrofishing in a small, closed area (stream or littoral zone) is the removal method. Removal of fish to estimate population size assumes: (1) a closed population, (2) equal catchability for all individuals, (3) equal catchability among the removals, (4) capture efficiency adequate enough to substantially reduce population size, and (5) no mortality or recruitment during estimate. The maximum likelihood estimator (Zippin 1956) is one method of estimating population sizes from successive removals. Population size can be estimated with 3, 4, 5, and 7 removal passes as shown graphically by Zippin (1956); however, the three-pass method is commonly used given limited time and money.

Several studies have reported between 80 and 100% effectiveness when using the 3-pass removal technique to assess fish populations. Lohr and West (1992) report 87% mean electrofishing efficiency (based on the population estimate) during a three-pass electrofishing to remove rainbow trout, while Moore et al. (1983) captured 94.4% of brook trout and 95.4% of rainbow trout during a removal in the Smoky Mountain National Park. Rahel and DeStaso (unpublished data) removed 83% of the brook trout and Colorado River cutthroat trout with the three-pass technique in Wyoming and Regan (1966) removed 100% of the trout in a New Mexico stream. In all cases, larger fish (>100 mm) were more readily captured than smaller fish. Zippen (1958) indicated that with the three-pass method, 75% of populations ≤200 must be captured to obtain a reasonable population estimate and the method may tolerate populations as low as 50 individuals (Bohlin 1989).

Inferences can be made about the effectiveness of a one-pass electrofishing index of biomass or fish number based on the percentage of fish captured during the first pass of a 3-pass removal sequence. Thompson (unpublished data) found that 70% and 82% of the Colorado River cutthroat trout present in Nameless and Nylander Creeks, respectively, were captured on the first electrofishing pass. On East Fork Deep Creek, in the Little Snake River Drainage, 59% of the Colorado River cutthroat trout were captured during the first pass (Rahel and De Staso unpublished data). Regan (1966), working in New Mexico, removed 95% of the Gila trout (Oncorhynchus gilae) during the first electrofishing pass.

Three-pass depletion estimates, although commonly used, are time consuming and may add considerable sampling time at each site. Rahel and DeStaso (unpublished data) indicated that it took a total of 65.6 man-hours to electroshock a 2 km mountain stream reach three times, while Larson et al. (1986) found a two-person crew required 11.95 staff-days to three-pass electrofish 1.61 km of stream. As three-pass depletion estimates would probably add 6-8 hours of sampling time at each site, limiting three-pass estimates to a subsample of all sampling sites may be more reasonable within the project confines and still give adequate relative abundance estimates.

The validity of a one-pass density estimate is questionable given the wide variability in capture efficiency and standing stocks of Yellowstone cutthroat trout. Analysis of existing data sets will be completed to determine correlations between standing stock and a one-pass (first pass) density estimate exist.

Objectives

Assessment of the genetic purity of Yellowstone cutthroat trout, along with their general life history and habitat features, in the Greybull River drainage will be useful to the WDGF and U.S. Forest Service in decisions concerning the preservation and management of the subspecies in Wyoming. Six objectives have been established to guide this assessment:

(1) Determine the distribution of wild Yellowstone cutthroat trout with no evidence of hybridization with rainbow trout or other cutthroat trout subspecies in the Greybull River drainage,

(2) Assess the ability of meristic counts and morphometric comparisons to identify genetically pure Yellowstone cutthroat trout,

(3) Determine the physical and biological factors that allow pure, wild Yellowstone cutthroat trout to persist and control standing stocks,

(4) Describe general population features for wild Yellowstone cutthroat trout (age structure, growth rate, body condition), and

(5) Describe the management implications of these findings relative to the preservation of wild Yellowstone cutthroat trout.

Description and Geography of Study Area (Absaroka Range)

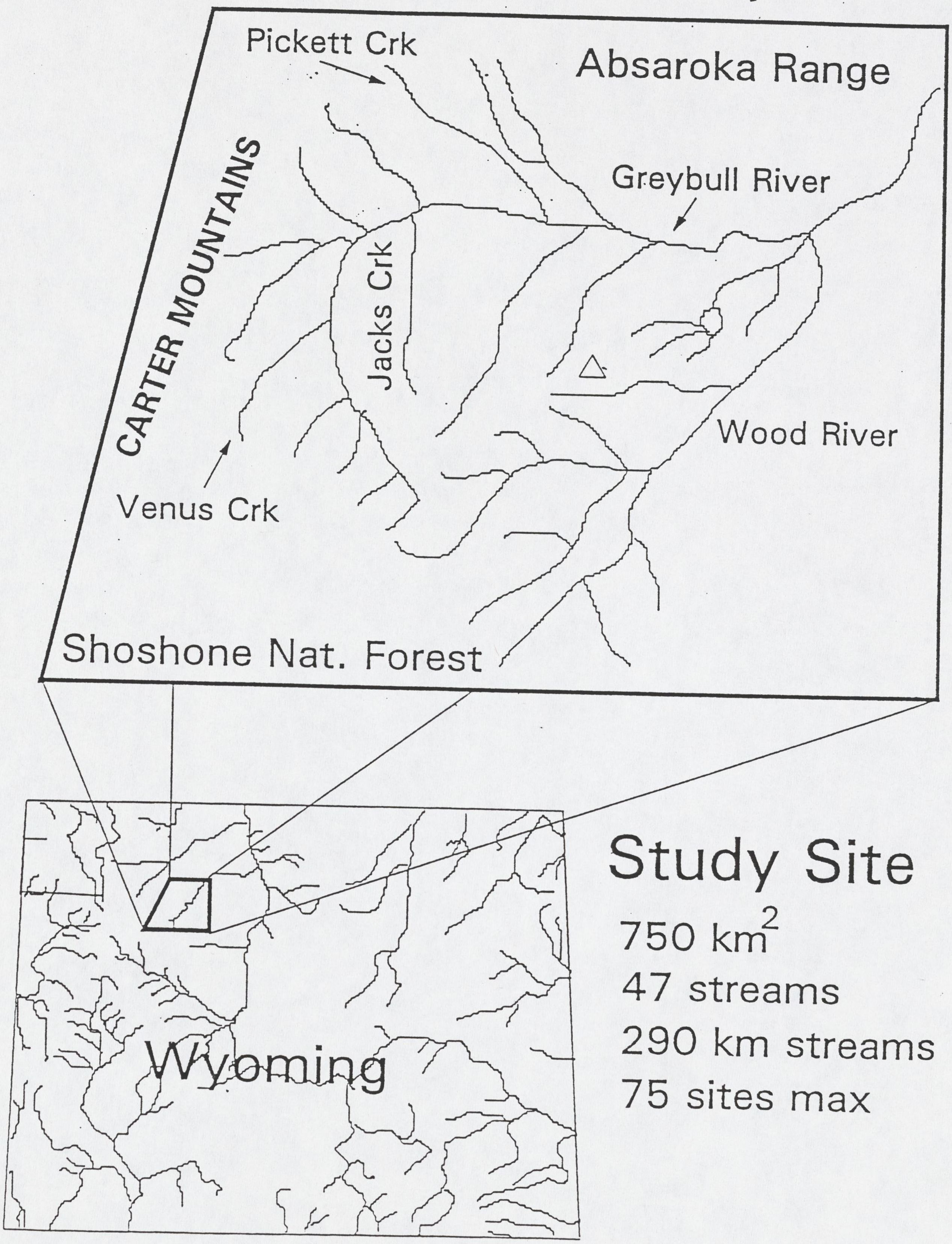
Although the wild, Yellowstone cutthroat trout distribution in Wyoming is unknown, fishery managers with the WDGF have identified drainages, including the Greybull-Wood River drainage, with high potential for locating wild, genetically pure populations of Yellowstone cutthroat trout.

The Greybull River along with its primary tributary the Wood River, drains 2,938 km^2 of northwestern Wyoming emptying into the Bighorn River near Greybull, Wyoming. The study area includes approximately 47 tributary streams (Appendix A) within 750 km^2 of the Greybull and Wood Rivers headwater drainage (Figure 3). No lakes are present within the study site. The investigation will be concentrated on the Shoshone National Forest within the Absaroka Mountain Range and its foothills, which extend from southern Montana to west-central Wyoming. Portions of approximately 290 km of tributaries to the Greybull and Wood Rivers within this area will be sampled, with a maximum of 75 standard sampling sites.

The Rocky Mountains were the result of the Laramide orogeny about 75 million years ago. This crustal disturbance contorted and uplifted the Yellowstone area into a rugged, rocky landscape. Large magnitude crustal disturbances of this type commonly produce conditions conducive to intense volcanic activity (Keefer 1972). Volcanic activity in early Eocene time (55-50 million years ago) resulted in the accumulation of the vast pile of Absaroka volcanic rock called the Absaroka Volcanic Supergroup (Nelson et al. 1980) which now compose most of the Absaroka and

Washburn ranges. Minor volcanic activity some 600,000 years ago also deposited volcanic rock and resulted in the formation of the huge Yellowstone caldera (Keefer 1972). Evidence of past volcanic activity shows in breccia deposits (angular rocks formed by hardened volcanic debris), lava flows, and calderas (depressions formed when the earth settles after a release of lava) throughout the Absaroka Range (Bown 1982). The resulting landscape is steep and rugged, with uplifted peaks and deep valleys. Rain seeping into the porous breccia and lava deposits can cause massive landslides of mud and broken rock to tumble down the mountain sides (Keefer 1972). The past geologic history along with present day rock deposits and topography combine to make the Absaroka area geologically unstable. The mountain streams originating in the study area have steep longitudinal profiles and little biological production resulting from the volcanic topography.

Figure 3. Study site - Yellowstone Cutthroat Project.



Methods

Objective 1:

Although the current distribution of wild Yellowstone cutthroat trout in Wyoming is unknown, fisheries managers have identified drainages with the highest potential for genetically pure populations. Priority drainages for assessment include: (1) Upper Greybull and Wood Rivers, (2) North and South Forks of the Shoshone River, and (3) the Clarks Fork River. This project will concentrate on surveying the upper Greybull River drainage along with the Wood River headwaters, its primary tributary (see description of study site; Appendix A).

Sampling of priority streams in the two drainages will begin in the summer of 1994 when access is available and spring flows have subsided enough to sample adequately (approximately June 15). Two crews will gather data throughout the summer until fall weather prevents continuation of sampling (approximately Oct. 1).

Stream sampling sites will be selected based on the following criteria. Two types of samples will be taken: (1) spot-samples to assess fish species diversity, and (2) detailed samples to assess habitat variables and relative fish abundance.

Spot-samples will be taken at approximately 1-km intervals or where access allows, on all streams to assess fish species diversity. Crews will progress upstream from where a tributary enters either the Greybull or Wood river, sampling at 1-km intervals and immediately above permanent barriers (1.5 - 3 m high falls; Stuber et al. 1988; high velocity chutes, cascades, etc.) to fish passage. At each spot-sampled site, crew members will perform a one-pass electrofishing run upstream for 10-15 minutes to determine fish species composition and numbers, as well as collect length and weight information for all species. A Smith-Root Model 12 POW battery powered back-pack electrofisher will be used to sample all sites. Site location and elevation will be identified with global positioning units (latitude-longitude) and topographic maps, stream width will be measured to the nearest 0.1 m, gradient will be determined by the change in clinometer elevation over the thalweg length in a 100 m section, and dominant substrate will be described. Video recordings of the stream and riparian habitat will be made at each location. The extent of access by humans (roads, trails, etc.) and description of barriers to fish movement will also be recorded.

Cutthroat trout captured in the spot-sample will be visually examined for potential hybridization with other trout; if rainbow trout are present in the sample or the area was know to have been previously stocked with finespotted cutthroat trout (from WDGF records), hybridization of Yellowstone cutthroat trout will be assumed. Cutthroat trout found in unstocked areas or above barriers, alone or in sympatry with brook trout will suggest pure populations of Yellowstone cutthroat trout and locations will be taken. Spot-sampling will continue upstream until fish are no longer found. Sampling will also take place immediately above any permanent fish barrier because these locations have the highest potential to contain pure Yellowstone cutthroat trout populations. Upon identification of areas with potentially pure Yellowstone cutthroat trout, fish samples (N=20 fish $\geq$ 125 mm) will be preserved for electrophoretic and meristic analysis. Also, at sites that have both cutthroat trout and rainbow trout present (potentially hybridized), samples (N=20) will be taken to use in meristic comparisons. Because it is difficult (nearly impossible) to differentiate finespotted cutthroat trout from Yellowstone cutthroat trout meristically or electrophoretically (Leary et al. 1987; Behnke 1992), the only attempt to identify which subspecies is present will be spotting patterns on the fish. Photographs of fish will be taken at each spot-sampling site for later analysis.

Leary et al. (1989) recommends electrophoresis of 15 or 25 individuals to determine hybridization of cutthroat trout with rainbow trout. The fish genetics laboratory at the University of Montana, Missoula, can detect 1% hybridization with rainbow trout or westslope cutthroat trout with 95% confidence limits on a sample of 15 individuals, while obtaining the same results with 99% confidence limits with a 25 individual sample (Robb Leary, personal communication). In most cases, a sample size of 20 will be adequate for assessing hybridization of cutthroat trout with rainbow trout both electrophoretically and meristically. Samples for electrophoresis will be collected and preserved in the field by freezing with liquid nitrogen or dry ice (Loudenslager and Kitchin 1979; Martin et al. 1985). Frozen samples will be shipped to the fish genetics laboratory at the University of Montana where all genetic analysis will be completed. Genetic assessment for a 20-fish sample will cost $550. Electrophoretic and meristic comparisons will be completed on the same fish to improve statistical comparisons. Fish will be individually labeled and bagged separately for transport to Montana.

Total cost for assessing the genetic purity of cutthroat trout populations in the Greybull-Wood River drainage will be the most costly portion of the study. An estimated 40-50 sites with potentially pure Yellowstone cutthroat trout and a few sites where hybridization with rainbow trout is likely, will be sampled (maximum of 50 x $550 = $27,500). It is likely that fewer samples will be taken because some streams are likely to be void of pure cutthroat trout or stocked with finespotted cutthroat trout.

A detailed sampling technique will be completed on 20 selected sites within the drainage where pure Yellowstone cutthroat trout are suspected upon completion of the spot survey. This sampling will consist of three-pass depletion estimates of fish abundance and completion of the standard stream survey, including measurements of physical habitat features in the HQI section. This sampling scheme will provide information to the WDGF about fish standing stocks in the study area and provide needed habitat measurements. Multiple-regression modeling, which gives predictive capabilities, can be applied to determine relationships between habitat parameters and population characteristics.

The detailed sampling scheme will be started upon completion of the drainage-wide spot survey. This will allow: (1) the habitat and population surveys to be completed under similar conditions (flow, temperature, etc.), (2) one stage of the project (spot surveys) to be completed before another begins, and (3) the fish for genetic analysis to be collected during the first stage and shipped to Montana as quickly as possible to allow extra time for genetic analysis. The spot sampling and detailed sampling will provide estimates of standing stocks and lengths of streams that contain pure Yellowstone cutthroat trout in the Greybull drainage.

Objective 2:

Meristic counts and morphometric comparisons will be analyzed to determine if a potential system of identifying pure populations of Yellowstone cutthroat trout can be found. A meristic identification system would be extremely beneficial in future evaluations due to the high cost of electrophoretic analysis. Binns (1977) and Hadley (1984) applied a meristic system to determine genetic purity of Colorado River cutthroat trout. The system applied by Binns (1977) used scale, pyloric caeca, and basibranchial teeth counts, as well as spotting patterns, to categorize fish into a class of genetic purity. Behnke (1992) used vertebrae, scales in lateral series, pyloric caeca, gill rakers, and basi-branchial counts as meristic variables in his discussion of western trout. Schreck and Behnke (1971) report that vertebra, scales in lateral series, scales above lateral line, pyloric caeca, and pelvic fin rays are the most useful meristic features for distinguishing western trout. However, many variables can be measured, including, eye diameter, head width and depth, peduncle depth, snout length, and parr marks (Zimmerman 1965).

Meristic counts will be completed on the same fish samples (N=20) collected for electrophoretic analysis. Counts and measurements will include those recommended by Behnke (1992) and Shreck and Behnke (1971). Meristic counts will be compared with genetic data to assess the predictive power of the meristic counts relative to hybridization with rainbow trout. Finespotted cutthroat trout have been introduced in the Greybull River drainage; however, they are closely related to Yellowstone cutthroat trout and it is difficult to differentiate the two subspecies by either electrophoresis or meristics. Thus, if finespotted cutthroat trout have been introduced into an area we will be unable to adequately assess genetic makeup of the cutthroat trout population.

Objective 3:

Physical and biological factors that may allow wild Yellowstone cutthroat trout to persist in natural areas include, permanent barriers to exotic fish movement, elevation, and habitat parameters such as channel slope and substrate. Physical barriers are comprised of falls ($\geq$ 1.5 - 3 m; Stuber et al. 1988), boulder fields, landslides, and high-gradient reaches (cascades). Any barrier encountered by survey crews will be physically described as to the type, location (GPS system), height and length, and material composing the barrier. Composition and size of a barrier will allow assumptions to be made about the length of time the barrier may have existed. Log dams, debris jams, and beaver dams will not be considered permanent barriers to fish passage. Physical barriers are important in the Yellowstone cutthroat trout survey because headwater areas above barriers have the greatest chance to contain pure Yellowstone cutthroat trout (Behnke 1976, 1992).

Effects of elevation will be evaluated based on fish species collected at sites as sampling progresses upstream to areas of increased elevation. If only cutthroat trout are found at higher elevations, it can be assumed (if no barriers present) that they are more adapted to higher, steep-gradient streams. Behnke (1992) suggests cutthroat trout function better than non-native trouts in high-altitude areas because they are better adapted to colder waters; however, this does not mean it is their optimum habitat.

The WDGF standard stream survey will be used to describe habitat features within sampling sites. In each detailed sampling site ($\geq$ 100 m, N=20) the relative abundance of three habitat types -- pool, glide, and riffle -- will be described (Bisson et al. 1982). Physical measurements at the site will include: (1) length, (2) wetted width, (3) water depth, (4) channel gradient, (5) elevation at the downstream end, (6) stream flow, and (7) velocity. Length and wetted width measurements will be taken to the nearest 10 cm at regular intervals and averaged for that site. Overall channel gradient will be estimated by elevational differences on topographic maps and sampling site gradient will estimated with clinometer elevation changes through the 100 m section (thalweg length). Visual estimates of cover features in each habitat unit will include: (1) bank soil, (2) spawning habitat rating, (3) the area of woody debris, (4) ungulate damage, (5) substrate composition, (6) beaver ponds per km, and (7) stream channel stability. Bank soil, spawning habitat, and ungulate damage will be estimated visually at each site. Woody debris is any non-living woody matter either in the water or laying over the channel within 0.3

m of water surface (Platts et al. 1983). Substrate composition includes percents of the surface area with dominant substrates of five categories: sand/silt/muck ($\leq$ 2.5 mm diameter), gravel (2.5-76 mm), rubble (76-305 mm), boulder (> 305 mm), bedrock. All visual measurements will be estimated according to the WGFD survey form. Habitat Quality Index variables will be measured following Binns (1982). Water chemistry attributes that can be measured in the field with kits and meters (alkalinity, total dissolved solids, pH, and hardness) will be taken. All habitat measurements will take place after electrofishing has been completed to minimize effects on fish sampling.

Objective 4:

General population statistics for wild Yellowstone cutthroat trout will be described for use in future management and preservation decisions. At each site containing cutthroat trout, individual lengths and weights, will be taken over a range of fish lengths. Length data will be used to construct length frequency histograms which allow visualization of size structure and suggest rate function (recruitment, growth and mortality) dynamics. Fish condition will be calculated from length-weight data. Often the coefficient of condition ($K = 10^5 * W/L^3$; Lagler 1956) has been used to calculate trout condition (Irving 1955; Sigler et al. 1983); however, there are problems with this method including the fact that K increases with fish length and it varies by species. Relative weight (Wr), a body condition index developed by Wege and Anderson (1978), is used extensively for determining condition of many warmwater species and has the advantage of comparison throughout the United States. Each species has a standard weight equation developed from population data collected across the nation allowing comparison; however, few standard weight equations have been developed for salmonid species (Murphy et al. 1991). Relative weight has yet to be completely accepted by management agencies throughout the United States, but acceptance is increasing. A cutthroat trout standard weight equation has not been developed. In this project I will obtain data sets from regions where cutthroat trout are present and implement a cutthroat trout equation for use in analyzing the length-weight data collected.

Otolith-age readings will describe the growth history of collected specimens. Pros and cons of this method were discussed earlier. Otoliths will be obtained from the 20-fish samples taken for electrophoretic and meristic examinations and brought back to the lab to assess age. Otoliths may have to be sectioned and sanded in order to clarify annuli present, immersion in a clearing fluid (oil, alcohol, etc.) also enhances annuli (Jearld 1983). Back-calculated length at ages will be done according to Jearld (1983) with the aid of computer software. Back-calculations, which assume proportional increases in body and bony structure length, will be computed by proportional methods.

Objective 5:

The information collected in Objectives 1 through 4 will be assessed to determine the extent of Yellowstone cutthroat trout distribution in the Greybull and Wood River drainages and the physical and biological factors that enhance or limit the distribution. Once relationships have been established, management and preservation recommendations will be provided to the Wyoming Game and Fish Department and U.S. Forest Service.

Statistical analysis

Genetically pure and hybridized Yellowstone cutthroat trout populations, based on the electrophoretic assessment, will be compared using two methods. Simple comparisons between two variables (i.e. vertebra and scale counts) will be done using a t-test, while a multivariate analysis of variance (MANOVA) will be used to compare multiple meristic variables (vertebra, fin ray, scale, and pyloric caeca counts). The null hypothesis states there will be no difference in counts between genetically pure and hybridized Yellowstone cutthroat trout.

Physical parameters will be compared between areas where Yellowstone cutthroat trout are present or absent to determine if one or more variables are correlated with Yellowstone cutthroat trout existence. Again a t-test will be used to determine relationships between two variables and one-way ANOVA will be used to compare multiple habitat variables such as: elevation, channel slope, stream width, substrate, and vegetation. The null hypothesis states that no differences exist between areas where Yellowstone cutthroat trout are present or absent.

Simple linear regression will be used to assess relationships between general population features and environmental variables. Growth, age structure, and body condition will be compared to environmental variables, such as, elevation and stream slope, to determine relationships. Again the null hypothesis assumes no relationship between the population features and environmental influences.

Non-parametric statistical tests will be used if the data does not meet the assumptions of a normalized distribution.

Statistical significance will be determined at the 95% level ($P \leq 0.05$) and SAS or SPSS computer statistical software will be used to analyze data.

Publication Plans

Significant information obtained during the course of this project will be submitted for publication, upon review and approval by the U.S. Fish and Wildlife Service Editorial Office, in appropriate journals such as The North American Journal of Fisheries Management, Transactions of the American Fisheries Society, or The Great Basin Naturalist. All manuscripts will include Wayne A. Hubert and Frank J. Rahel as co-authors.

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Appendix A. Priority streams for the Greybull and Wood River.

Stream	**Length (km)**[a]	**Drainage**	**Sites**[b]
Anderson	14.6	Greybull	14
N. Fork	4.4	Greybull	8
S. Fork	6.0	Greybull	12
Avalanche (int)	3.0	Greybull	6
Beaver	6.5	M.F. Wood	6
Betty	5.0	Greybull	10
Blanchette (int)	3.2	S.F. Wood	6
Bonne	6.7	Greybull	6
Brown	5.2	Wood	10
Bull Elk Draw	3.2	Greybull	6
Calf	2.8	Greybull	4
Canyon	4.4	Wood	8
Cascade	5.0	Wood	10
Chimney	9.2	S.F. Wood	9
Cow	6.1	Greybull	6
N. Cow	2.1	Greybull	4
Deer	8.7	Wood	8
Dundee	8.0	M.F. Wood	8
East Fork	8.6	S.F. Wood	8
Deadman	5.5	E.F. Wood	10
Buckle (int)	4.0	E.F. Wood	8
Slaughter	4.0	E.F. Wood	8
Eleanor	9.2	Greybull	9
Galena	2.6	Wood	4
Haymaker	6.2	Greybull	6

Appendix A. (cont.)

Horse (int)	4.8	Wood	8
Jack	14.8	Greybull	14
Jojo	6.6	Wood	6
Last (int)	2.8	Greybull	4
Mabel (int)	3.7	Greybull	6
Meadow	6.1	Wood	6
No Name (int)	3.6	M.F. Wood	6
Pickett	20.7	Greybull	20
N. Fork	7.3	Greybull	7
Pierce (int)	3.3	Greybull	6
Piney	12.5	Greybull	12
Pyramid (int)	2.6	Greybull	4
Red	3.6	Greybull	6
Rennerberg (int)	3.1	Wood	6
Spar (int)	2.8	Wood	4
Smuggler Gulch	2.6	M.F. Wood	4
Steer	5.1	Greybull	10
Stuart	3.9	Greybull	6
Venus	14.9	Greybull	14
Vick	6.8	Greybull	6
Warhouse	9.9	Greybull	9
Yellow	3.0	Greybull	6
47 streams	288.8 km		

[a] = approximate lengths;
[b] = spot-samples

Appendix B. Budget for the field assessment of Yellowstone cutthroat trout in the Greybull and Wood River drainages for 1994.

Item	Cost
Trucks (4x4) (4000 mi x $0.42/mi)	1,680
4 Smith-Root shockers (4 x $3085)	12,340
Solar charger	900
12 batteries (12 x $170)	2,040
Global Positioning System (3 x $800)	2,400
Radios (2 x $750)	1,500
Bear-proof panniers (6 x $150)	900
Housing (4 months x $400)	1,600
Technicians	
crew leader (1000 hrs x $7.50/hr)	7,500
4 technicians (1000 hrs x $6/hr)	24,000
Genetic analysis	27,500
Nitrogen Refrigerators (2 x $500)	1,000
Rain gear (4 x $100)	400
Hip boots/Waders (8 x $80)	640
Sleeping bags (4 x $200)	800
Bear mace	300
Tools	200
Video cameras (2 x $1500)	3,000
Miscellaneous equipment	500
Film and development	400
Horses (6)	7,000
Tents (2 x $250)	500
Camping Gear	
Lanterns (2 x $40)	80
Stoves (2 x $40)	80
Utensils (2 x $40)	80
Water Filters (2 x $210)	420

Appendix C. Equipment list for assessment of Yellowstone cutthroat trout populations in the Greybull and Wood River drainages.

Item	Number
4x4 trucks	2
pack animals	6
sets of tack	6
packs	6
Smith-Root Model 12 battery backpack shockers	4
dip nets	4
electrofishing probes	4
pairs insulated gloves	5
hip boots/waders	4
repair kit for boots	
batteries for shockers	14
3-man tents	2
tent repair kits	
sets rain gear	4
sleeping bags	4
camping stoves	2
sets camping equipment	2
lanterns	
utensils and dishes	
miscellaneous equipment	
tarps	
Global Positioning Systems (GPS)	3
hand held radios	2
nitrogen refrigerators	2
5-gallon buckets	4
sample bags and labels	
7.5 minute quad maps of study area	
scale envelopes	
formalin	
measuring boards	
gram spring scales	
knifes	
100 m measuring tapes	
depth poles	
data sheets	
mechanical pencils	
clipboards	
thermometers	
bear mace	
food supplies	
rope	1,000 ft
microfiche reader	
microscope	
camera and film	
clinometer	
tool sets	2
video camera	2
pulleys	15

Appendix D. Tables and Figures.

Table 1. Length (millimeters) at age for some populations of Yellowstone cutthroat trout.

Drainage	Age (years) 1	2	3	4	5	6	Reference
Blackfoot	117	213	321	403	442	473	Thurow (1982)
Henrys Lake	149	284	380	437	479	515	Irving (1954)
Teton River	99	151	214	270	334		Irving (1979)
South Fork Snake River	86	184	277	343	410	450	Moore and Schill (1984)
Willow Creek[a]	79	142	219	299	380	437	Corsi (1988)
Willow Creek[b]	81	139	198	242			Corsi (1988)

[a]Main-stem migratory stocks
[b]Nonmigratory tributary stocks

Table 2. Comparison of karyotypes of *Salmo clarki* subspecies (from Loudenslager and Thorgaard 1979).

Common name	2n
Alvord cutthroat	64
Lahontan cutthroat	64
Yellowstone cutthroat	64
Coast cutthroat	68-70
West-slope cutthroat	66

Appendix D (continued).

Table 3. Differentiating loci for three salmonid species (Marnell et al. 1987; Forbes and Allendorf 1991).

Enzyme	Abbreviation	Relative allelic mobility		
		Rainbow	Westslope	Yellowstone
Creatine kinase	Ck-2	100	84	84
Glucophosphate isomerase	Gpi-3	100	92	100
Isocitrate dehydrogenase	Idh-1	100	100	-75
Isocitrate dehydrogenase	Idh-3,4	100,40 71,114	100,86 71,40	100 71
Malic enzyme	Me-1	100,57	88	100
Malic enzyme	Me-4	100,75	100	100
Sorbitol dehydrogenase	Sdh	40,100 200	40	100

Appendix D (continued).

Table 3. Differentiating loci for three salmonid species (Forbes and Allendorf 1991; Marnell et al. 1987).

Enzyme	Abbreviation	Relative allelic mobility		
		Rainbow	Westslope	Yellowstone
Creatine kinase	Ck-2	100	84	84
Glucophosphate isomerase	Gpi-3	100	92	100
Isocitrate dehydrogenase	Idh-1	100	100	-75
Isocitrate dehydrogenase	Idh-3,4	100,40 71,114	100,86 71,40	100 71
Malic enzyme	Me-1	100,57	88	100
Malic enzyme	Me-4	100,75	100	100
Sorbitol dehydrogenase	Sdh	40,100 200	40	100

Appendix E. Time schedule for completion of project.

Fall 1993:

Twelve hours of course work (8 credit, 2 seminar, 2 thesis)
Complete work plan by December 1
Organize project logistics and purchase some equipment

Spring 1994:

Twelve hours of course work (10 credit, 2 thesis)
Establish graduate committee
Attend WGFD and Forest Service coordination meeting for the Shoshone National Forest
Organize and purchase equipment for field work
Hire bio-aides for project

Summer 1994:

Sample Greybull and Wood River drainage for Yellowstone cutthroat trout and gather data to adequately address project objectives

Fall 1994:

Complete sampling of Greybull and Wood River drainage
Analyze and computer entry of data
Laboratory meristic analysis
Observe genetic work at University of Montana fish genetics laboratory
Complete two independent studies on electrofishing CPUE and a cutthroat Wr equation
Three hours of course work (3 credit)

Spring 1995:

Data analysis
Twelve hours of course work (6 credit, 1 seminar, 5 thesis)
Present data at professional meetings
Begin writing thesis

Summer 1995:

Complete and defend thesis

WG 7 generic mixing → pleuritic ar