A Review Of A Quarter Century Of Native Trout Conservation In Southern Utah

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Intermountain Journal of Sciences
Vol.8, No.3:125-142
September, 2002

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ABTRACT

Status of native cutthroat trout first became a management issue in southern Utah in the 1970s after the Endangered Species Act was passed and several remnant populations of native trout were identified. Initial restoration efforts began in 1977 when individuals from a remnant population of Bonneville cutthroat trout (Oncorhynchus *clarki* utah) were transplanted to a stream that had been treated with rotenone to remove nonnative trout. Restoration efforts became a routine part of Utah's fishery program in 1980 when the state incorporated Federal Aid in Fish Restoration funding into its program, which formally included native trout. Here, we evaluate the native trout restoration program by reviewing the progress made and problems encountered during the past quarter century. Evaluations were categorized by topic: (1) implications of changing genetic identification techniques; (2) success of treating streams and lakes with rotenone; (3) sources of native trout for re-introductions; (4) use of migration barriers to isolate native from nonnative trout; (5) practical considerations in restoration of metapopulations; and (6) socio-political issues. Project delays, setbacks, and failures have occurred over time, but overall accomplishments have been positive. Consistent progress resulted from making native trout restoration a formal part of annual work plans. Stream habitat known to contain native trout has increased over 15 times since 1977. Wild brood stocks were developed from local sources of both Bonneville and Colorado River (*O.* c. pleuriticus) cutthroat trout. Plans are in progress to develop additional stream and lentic populations of native cutthroat trout, and incorporate native trout into overall sport fishery management plans.

Key words: conservation, Cutthroat trout, failure, native, quarter century, restoration, review, southern Utah, success

INTRODUCTION

Declines in abundance of native trout in Utah are attributed to factors which have been widely acknowledged to cause declines of cutthroat trout throughout western North America. These include hybridization and displacement of native trout from introductions of nonnative trouts, loss of habitat, and, to a lesser extent, exploitation from angling. Conservation and restoration of native trout in southern Utah became part of fishery management objectives for the Utah Division of Wildlife Resources (UDWR) in the 1970s after passage of the Endangered Species Act (ESA), as amended in 1973, and discovery of several populations of native Bonneville cutthroat trout (Oncorhynchus *clarki* utah; Behnke 1976). Native trout programs were well established in the 1980s once Federal Aid in Fish Restoration funding (Dingell-Johnson Act) was institutionalized in regional fishery management programs that specified native trout projects and required formal annual reports. The primary management objective was to reduce threats that might lead to federal listing of native trout under the ESA. Southern Utah conservation projects were conducted for Bonneville cutthroat trout in the Sevier River drainage and part of the Virgin River drainage and for Colorado River cutthroat trout (*O.c.* pleuriticus) in the Escalante and

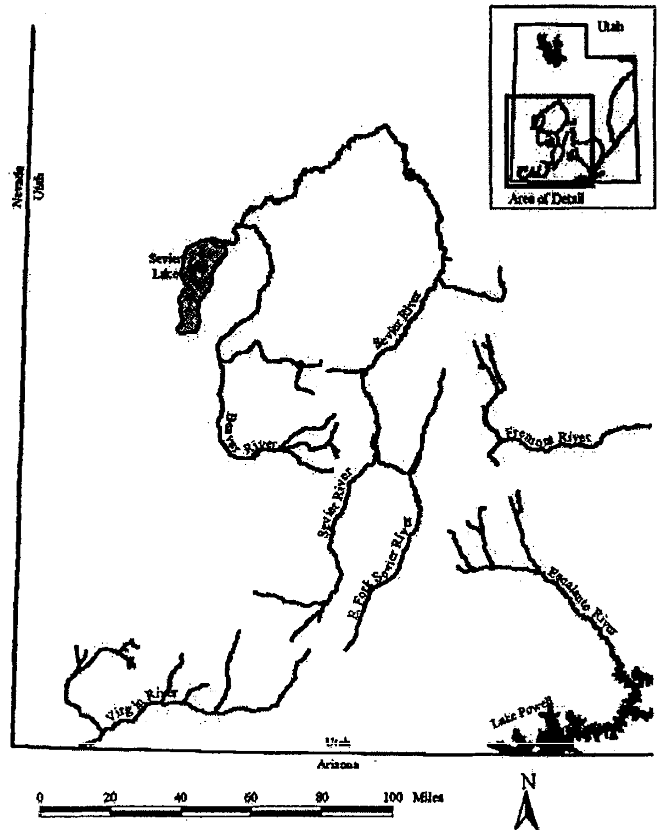

Figure 1. General location of the Sevier, Virgin, Fremont, and Escalante, river basins in th Southern Geographical Management Unit, Southern Utah, showing major rivers and tributaries.

Fremont river drainages (Fig.1). Most early work included identifying remnant populations of native trout and restoring and replicating these populations in historically occupied areas. Surveys to identify new populations and restoration projects were conducted concurrently because most of the sparse aquatic habitat in southern Utah had been previously surveyed and general distributions of native and nonnative trouts were known prior to initiation of projects targeted specifically at native trout.

Compared to earlier work, restoration efforts in the 1990s included more complex projects. Some projects included reservoirs and lakes that were connected to wild trou streams. Wild brood stocks of native trout were developed in two reservoirs that increased flexibility in management and allowed important sport fishery programs t be incorporated into restoration plans.

Our objective was to review conservation projects conducted in souther Utah since 1977 and categorize success, failures, and problems associated with specific management actions. We present 25-year history of conservation efforts wit discussion of important changes that occurred over time, including biological a social implications. Although we restricte

Table 1. Genetic tests conducted on remnant populations of native Bonneville and Colorado River cutthroat trout in southern Utah over time, and nature of barriers protecting genetic integrity. Genetic analytical techniques include meristics (M), allozymes (A), mitochondrial DNA (mD), and nuclear DNA (nD). Genetic test results include core population with <1 percent introgression (P), conservation population with <10 percent introgression (C) and sport fish population with >10 percent introgression (S).[1] Types of barriers include naturally isolated (N) due to barrier waterfalls or de-watered stream sections, planned artificial barrier constructed specifically to protect native trout (P), and unplanned artificial barrier (U) constructed as an unrelated water development project which coincidentally protected native trout.

Drainage / stream	Genetic tests, year and (method-results)	Stream length (km)	Mean stream width (m)	Barrier
	Bonneville cutthroat trout			
Sevier River				
Birch Creek-A	1973(M-P), 1976(A-P), 1990(A-P), 1990(mD-P)	5.5	1.19	N, P
N. Fk. North Creek	1981(M-P),1981(A-P),1990(A-P), 2001(nD-C,S)[2]	3.2	2.59	N, P
Deep Creek	1976(M-S)[3], 1981(A-P),1995(mD-P), 2001(M-P)	9.7	1.86	N
Ranch Creek	1995(M-P), 1995(mD-P)	6.4	1.36	N
Virgin River				
Water Canyon	1976(M-P), 1976(A-P), 1987(M-P), 1987(A-P)	1.2	1.30	N
Reservoir Canyon	1976(M-P), 1987(M-P), 1987(A-P), 1993(mD-P)	3.2	2.35	N
	Colorado River cutthroat trout			
Escalante River				
E. Boulder Creek	1990(M-P), 1990(A-P), 1990(mD-P)	5.6	4.9	N
W. Boulder Creek	1993(mD-P) 2000(M-P)	3.2	2.6	U
W Pine Creek	1997(M-P), 1997(mD-P), 1997(nD-P)	0.4	3.2	N
White Creek	1998(M-P), 2000(M-P) 2000(mD-P), 2000(nD-P)	1.8	2.0	N
Water Canyon	1997(mD-P), 1997(nD-P)	0.7	1.2	N

[1] Before 1996 introgression was not quantified, but classified as P (core population that was essentially pure) or S (sport fish population that was introgressed).
[2] Fish tested in 2001 from the headwaters of the North Fork North Creek tested 6% introgressed (conservation population), while fish directly above the migration barrier tested 15% introgressed (sport fish population).
[3] The first samples taken from Deep Creek were confused with samples from another stream.

this review to southern Utah and adapted much of what took place to local circumstances, many of the successes and failures might have implications for conservation of native fishes in other areas.

METHODS

We reviewed data from all known populations of native trout in southern Utah, including remnant (naturally occurring) and restored populations, and ongoing restoration efforts currently in progress (Tables 1 and 2). During the late 1970s, 1980s, and early 1990s, surveys were conducted sporadically as needed to evaluate management actions with data compiled as UDWR file reports. During 1994-1995 upstream-downstream range and abundance of Bonneville cutthroat trout was determined for all known populations (Hepworth et al. 1997b). Similar surveys were conducted for Colorado River cutthroat trout in 1997 and 1998 (Hepworth et al. 2001). Surveys were repeated for most Bonneville cutthroat trout populations again during 2001 and spring of 2002 (data

Table 2. A summary of the restoration projects completed, planned, or in progress for Bonneville and Colorado River cutthroat trout in southern Utah. Types of barriers include natural barrier waterfall or de-watered section of stream (N), constructed single point **barrie** with nonnative trout immediately downstream (S), constructed barrier with additional **obstacles (O)** such as a de-watered stream channel preventing trout from occupying the stream below the barrier year-round, constructed multiple barriers (M) to create more than ε single point obstacle, and unplanned artificial barrier (U) that was constructed for a **primar** purpose other than preventing fish passage. Status classifications include self-sustaining populations (S) established since the original restoration, conditionally or partially **successfi** restoration (X) after supplemental actions taken to correct problems, **unsuccessful** (U) with problems resulting in project termination, and projects in progress (P) where native trout have not yet re-colonized areas being restored.

Drainage / stream / tributary, or reservoir	Year project initiated	Population origin	Stream length (km) or reservoir area (ha)	Mean stream width (m)	Barrier	Status
		Bonneville cutthroat trout				
Sevier River						
Sam Stowe Cr	1977, 1997	Birch Creek	4.8	1.43	O	X[1]
Pine Creek	1980	Water C., Reservoir C., Birch Creek	5.0	1.86	N	X[2]
Briggs Creek	1988	Birch Creek	1.4	1.0	N	S
Manning Res	1990	Pine Creek	23.1	--	O	X[3,4]
Barney Reservoir	1993	Manning Reservoir	7.3`	--	O	X[4]
Threemile Creek	1994	Birch Creek	11.2	1.16	N, O	X[5]
DeLong Creek	1994	Birch Creek	5.3	1.46	N	S
Indian Hollow	1994	Birch Creek	1.4	0.64	N	S
N. Fk. North Creek	1995, 1999	Remnant expanded	8.8	2.59	S	X[1]
Pole Creek	1995	N. Fk. North Creek	4.3	--	S	S
Manning Creek	1996	Manning Reservoir	17.2	2.90	N, O	S
Barney Creek	1996	Manning Reservoir	1.2	1.10	N, O	S
Vale Creek	1996	Manning Reservoir	1.6	1.70	N, O	S
E. Manning Cr	1996	Manning Reservoir	1.0	0.80	N,O	S
Sanford Creek	1999	Deep Creek	11.3	--	N, U	P
Sandy Creek	1999	Deep Creek	1.6	--	N, U	P
Birch Creek-B	2001	Manning Res	6.4	--	U	P
Tenmile Creek	2002	Deep Creek	9.7	--	O	P
Center Creek and Robs Reservoir	2002	Manning Res (planned)	12.0, 0.8	--	N	P
Virgin River						
Leap Creek	1986	Water Canyon	5.3	1.35	N	S
South Ash Creek	1986	Reservoir Canyon	7.1	2.35	N	S
Harmon Creek	1986	Reservoir Canyon	3.0	1.75	N	S
Mill Creek	1986	Reservoir Canyon	8.0	2.25	N	S
Leeds Creek	1989	Reservoir Canyon	11.3	2.71	N,U	S
Pig Creek	1989	Water Canyon	0.9	1.10	N	S
Spirit Creek	1988	Water Canyon	1.6	1.30	N	S
Horse Creek	1995	Spirit Creek	0.8	1.00	N	S
Spring Creek	1993		2.5	--	--	U[6]
		Colorado River cutthroat trout				
Escalante River						
Durfey Creek	1993	E. Boulder Creek	1.0	--	N	U[7]
Deer Creek	1994	--	2.5	--	--	U[6]

Table 2 (continued).

Drainage / stream / tributary, or reservoir	Year project initiated	Population origin	Stream length (km) or reservoir area (ha)	Mean stream width (m)	Barrier	Status
Dougherty Lake	1997	E. and W. Boulder creeks	1.5	--	N	X[3,4]
Tall Four Lake	2000	Dougherty Lake	0.3	--	N	X[4]
W. Boulder Creek	2001	Remnant expanded	9.6	2.6	M	P
Pine Creek	2001	Remnant expanded	8.0	2.7	M	P
Whiie Creek	2001	Remnant expanded	2.1	2.0	M	P
Twitchell Creek and 2 Willow Bottom lakes	2001	Dougherty Lake	5.6, 4.6	--	N, O	P
Fremont River						
UM Creek	1996	Dougherty Lake	23.7	5.72	O	P
Left Fork	2000	Dougherty Lake	5.5	1.24	O	P
Right Fork	1996	West Boulder Creek	7.9	2.93	O	S
Sand Creek	1995	West Boulder Creek	4.8	--	N	X[8]
Forsyth Res	2000	Dougherty Lake (planned)	69.2	--	U	X[9]
Pine Creek and Pine Creek Res	2002	Dougherty Lake (planned)	15.1, 1.3	--	O	P

[1] Stream re-treated or partially retreated with rotenone after barrier failure.
[2] A second unplanned treatment was conducted.
[3] Wild brood stock.
[4] Supplemental stocking necessary at present in lake or reservoir.
[5] Nonative trout removed below barrier by electrofishing.
[6] Discontinued project due to socio-political ramifications.
[7] Stream habitat was not capable of supporting wild trout.
[8] Native trout re-introduced a second time after flash flood in lower stream.
[9] Impoundment on UM Creek temporarily drained, dam undergoing repairs.

available as file reports). Other surveys were conducted during the late 1990s and early 2000s on an as needed basis to make genetic evaluations, complete disease certifications, develop brood stocks, construct migration barriers, and evaluate other problems. Issues evaluated in terms of their implication to successful restoration for this study included (1) taxonomic and genetic analyses, (2) success of treating streams and lakes with rotenone, (3) sources of trout for brood stocks and re-introductions, (4) use of fish migration barriers, (5) practical considerations in the restoration of metapopulations, and (6) socio–political issues. Habitat evaluations and habitat improvement projects have been an important part of restoration efforts but were conducted by federal land management agencies and not included in this review.

Taxonomic evaluations used to identify remnant populations of native trout varied over time and were given varying levels of emphasis at different times as the state of genetic identification evolved. Throughout the entire study, cursory field observations of morphological characteristics were used to make putative identifications. Selected populations were further analyzed by submitting samples to university laboratories for meristic, allozyme, and mitochondria1 and nuclear DNA analyses. We evaluated the consistency of genetic test results among methods over time and describe the implications of changing methodologies on restoration success. Similarly, treatment sites were evaluated by looking at successes and failures of rotenone application and subsequent restorations. We analyzed re-introductions on the basis of numbers of fish transplanted, time required to re-colonize renovated habitat, and sources of native trout with respect to utilizing wild trout and "nearest neighbors," **i.e.,** closest available source of native trout, versus hatchery-produced fish from wild brood stocks. We did not evaluate fish migration **barriers** in terms of barrier dimensions but rather evaluated their role in terms of project success and circumstances under which **barriers** should be used. We evaluated metapopulation theory in the context of advantages, disadvantages, and practicality of re-establishing large, interconnected, and complex populations of native trout where they have been lost. Socio-political aspects of the evaluation were based on interplay among state and federal laws, inter-agency conservation agreements, agency policies and directives, and public interactions. The benefits and shortcomings of these laws, rules, and directives were considered relative to completing field projects.

We assessed the status of each restoration project using the above data and knowledge of each stream and lake. Restoration projects were classified as successful, conditionally or partially successful, unsuccessful, and in progress. Successful restoration projects were those where self-sustaining populations of native trout became established and have remained as such following completion of the originally scheduled restorations. Conditionally or partially successful restoration projects required supplemental actions to correct problems during years following completion of the initial project. Unsuccessful projects were those that were discontinued because of various problems. Projects in progress include those in which native trout have not yet fully re-colonized restored areas and become self-sustaining.

Discussion

Taxonomic and Genetic Analysis

Verification of genetic purity of remnant cutthroat trout populations is essential in restoration efforts. Genetic purity of native cutthroat trout cannot be visually ascertained with certainty because hybridization can be minor and not phenotypically expressed. Also, **Bonnevill** cutthroat trout evolved from multiple origins **(polyphyletic)** and are represented by several genetically diverse groups over a relatively wide geographic area **(Hickman** and Duff 1978, Martin et **al.** 1985, **Behnke 1992, Shiozawa** and Evans 1994). **Norther** forms of Bonneville cutthroat trout fkom Bear Lake in Utah-Idaho and the Bear Rive in Utah-Idaho-Wyoming likely evolved **from** a relatively recent ancestral **salmonid** that invaded the ancient lake; they **remaine** partially isolated from more southern portions of the basin because Bear Lake an the Bear River were large systems lying outside of the once-inundated prehistoric Lake Bonneville. Similarly, both Bonneville cutthroat trout from the Deep Creek mountains in Utah's west desert and those fkom the extreme southern portion of the basin in southern Utah remain somewhat genetically distinct, despite **bein** taxonomically classified as a single subspecies.

At present UDWR minimum standards for genetic testing of each new population includes meristic analysis from a random sample of 10 fish, DNA analysis (mitochondrial and nuclear) from 30 fish, and consideration of geographic location and historical stocking records. Also, a method to quantify introgression has been established with "core populations" define as those with **<1** percent introgression, suitable for restoration of new populations, and "conservation populations" defined as those with **<10** percent introgression, designated for continued preservation **(Uta** Division of Wildlife Resources 2000).

Despite taxonomic complications, even the earliest putative identifications based on visual appearance (field observations), capture location, and stocking history were generally accurate, based on subsequent independent expert verification based on meristic, allozyme, or molecular DNA analyses (Table 1). Most remnant populations of native trout in southern Utah were each evaluated with different genetic tests over time. Some populations were tested as many as four times over a 20-year period. Although tests became increasingly more sophisticated, all populations originally given "conservation" status as far back as the 1970s have remained as such.

In two instances results changed over time with repeated genetic testing. The headwater population of cutthroat trout in the North Fork North Creek (Table 1) was originally suspected to be hybridized because of its proximity to rainbow trout in downstream reaches and the absense of a barrier separating the two species. Early genetic tests (meristics 1981 and allozymes 1981) did not show any hybridization, and actions were taken to prevent upstream movement of rainbow trout; however, 2001 test results (nuclear DNA) showed some rainbow trout hybridization (6.4%). Regardless, levels were low enough and within established standards to still allow a designated "conservation" status. Another population (Deep Creek) originally thought to be hybridized, due to contamination of test samples, was later determined to be pure. This mistake caused delays in replicating the Deep Creek population in other locations and resulted in continued skepticism about genetic purity because of early reports that the fish were introgressed (Behnke 1976).

Researchers in locations outside of southern Utah reported cases where only slightly introgressed populations were found after initial evaluations suggested a high probability of introgression. Neilson and Lentsch (1988) reported that hybridization of Bonneville cutthroat trout fiom Bear Lake, Utah-Idaho, was only minute despite long-term stocking of rainbow trout (0. *mykiss*). Gamblin et al. (2000) originally found high percentages of rainbow trout hybridization with Yellowstone cutthroat trout (*O. c. bouvieri*) in Henrys Lake, Idaho; however, later testing documented spawning runs of cutthroat trout with little introgression.

Management decisions were based on the best genetic techniques available at any given time. However, time to complete tests, gain clearances for field projects, and actually conduct projects was so great that new methodologies for testing would often evolve before projects were complete. Thus, there was often concern that populations should be re-tested with new techniques to make sure earlier tests were accurate. Potentially, this can cause delays in completing restoration projects and sway emphasis of work towards more genetic testing. For example, development of a wild brood stock of Colorado River cutthroat trout fiom Boulder Creek was initiated based on mitochondria1 DNA tests conducted between 1990 and 1993 (Table 1). It took several years to complete genetic tests, obtain disease clearances, transplant trout to a suitable lake, and eventually take eggs fiom spawning trout. By 1999 when the first eggs were ready to be cultured, new nuclear DNA tests had been developed and agency personnel questioned if the project should proceed without confirmation of genetic status with newer more sophisticated tests. Even in this case, re-testing would have been feasible if conducted in a timely manner, but long turnovers in laboratory times, a state-wide backlog in test samples, and acquiring funding to complete tests has resulted in periods of 1-2 years or more to complete tests. Rather than delay work, the Boulder Creek project proceeded based on available information. At times, balance needs to be achieved in accepting some risk by using older test results, by conducting field projects in a timely manner, and by deciding if re-testing populations with new techniques is warranted.

Success of Using Rotenone

As part of native trout restoration, we

renovated 29 streams with rotenone during the 25-year period under review (Table 2). Renovated streams were relatively small; the largest (UM Creek) did not exceed a base flow of **0.4** m^3/sec and included 37 **km** of main stem and tributaries. Even when treating the smallest streams, a one-time treatment with rotenone apparently could fail to remove all nonnative fishes. Trout spawning sites associated with springs and seeps presented the greatest **difficulties;** these areas provided freshwater refuges for small fish where rotenone failed to make contact. Often when trout were missed with a single application, **young-of-the-year** or eggs persisted. Second treatments, timed approximately a year after the **first** treatment, generally completely eradicated target species.

Sam **Stowe** Creek was the first renovation project conducted in 1977, consisting of a simple 4.8-km **first-order** stream, successfully completed with a one-time treatment. The second project, conducted on another first-order **5.0-km** stream (Pine Creek) in 1980, failed to totally remove rainbow trout, which led to second treatments as a standard practice. For all projects first-year application of rotenone was approximately 50 percent successful in completely eliminating target species; nonnative trout were found about half the time with second treatments. Rainbow trout, as well as brook trout **(*Salvelinus fontinalis*)** and brown trout **(*Salmo trutta*)** were target species that were often missed

UM Creek represented a unique situation where treatments were conducted on four consecutive years in attempt to completely remove brook trout. All other projects were completed in 2 years. The project was designed to protect downstream state and private fish hatcheries from whirling disease but also presented an opportunity for restoration of native trout. Similar to many other projects, large numbers of young-of-the-yearbrook trout were found during the second treatment where adults had been observed spawning the previous year. Although brook trout were removed from most of the drainage after the second treatment, they persisted in one spring until the fourth treatment. Brook trout avoided rotenone in this spring by moving less than a meter into underground caverns. Treatments were not effective **unti** a combination of rotenone and **electrofishing** gear was used at this site. Such an effort might have been effective after the second treatment, but it took 4 years to become familiar with the entire drainage and identify problem areas. Extensive post-treatment surveys of UM Creek conducted over 6 years have failed to find any additional brook trout. In fact, all treatment projects conducted with rotenone in southern Utah were successful in completely removing nonnative trout after multiple treatments.

Sources of Native Trout

In the late 1970s and throughout the 1980s little concern was expressed about origin and destination sites for relocating native trout. We avoided later criticism regarding indiscriminate movements by fortuitously selecting sources of native fish for re-introductions fiom sites in close proximity, even before more sophisticated information regarding localized and regional genetic differences in fish populations was available. For example, several streams were selected for Bonneville cutthroat trout restoration projects during the 1980s in the Virgin River drainage (Fig. 1 and Table 2). Bonneville cutthroat trout fiom the Sevier River drainage could easily have been used as source fish, resulting in an inter-basin transplant; however, local fish fiom other Virgin River tributaries were used. Local fish were a more practical choice because they were suspected to be native to this area, despite being found just outside the Bonneville basin **(Hepworth** et al. **1997a).** By the **1990s,** after inter-agency conservation team planning was established, concepts of utilizing the closes available source of native trout within the same drainage (nearest neighbor) became a standardized practice.

Defining "conservation" and "sport fish" populations in multi-agency conservation agreements helped set formal limitations on fish transplants (Lentsch and Converse 1997, Lentsch et al. 1997). Although both conservation and sport fish designations for cutthroat trout populations usually allow legalized sport angling, conservation populations (<10% introgressed) are those managed specifically with naturally reproducing wild trout to maintain genetic integrity of the subspecies. As previously noted, the definition of a conservation population was eventually subdivided to include "core" populations (<1% introgressed) designated as suitable to replicate in other areas, generally on a "nearest neighbor" basis (Utah Division of Wlidlife Resources 2000). Sport fish populations are defined to include areas managed by stocking native trout produced in state hatcheries to maintain public sport fisheries where limited or no natural reproduction occurs. Providing that stocking is not a threat to conservation populations, it can take place over a wider geographic area compared to the more restricted "nearest neighbor" concept. Sport fish populations might consist of 100 percent hatchery fish that could be genetically pure native cutthroat trout. The definition of sport fish populations of native cutthroat trout also includes wild populations that are >10 percent introgressed with nonnative trout.

Designating "geographic management units" in conservation strategies (Lentsch and Converse 1997, Lentsch et al. 1997) also encouraged transplants, stockings, and wild brood stock development to occur within the bounds of natural watersheds, avoiding inter-basin fish transfers. The Southern Geographic Management Unit for Bonneville cutthroat trout included the Sevier River drainage and a small portion of the Virgin River drainage (Fig. 1), but even within these areas the proximity of sub-drainages and individual streams were considered when making transplants. For Colorado River cutthroat trout, the Southern Geographic Management Unit consisted of the Escalante and Fremont river drainage. Since no remnant populations of native trout have been found or are likely to be found in the Fremont River drainage, native trout fiom the Escalante River drainage were used to restore populations in the Fremont fiver drainage because they were the "nearest neighbor."

Wild brood stocks of both Bonneville and Colorado River cutthroat trout were established at Manning Meadow Reservoir and Dougherty Lake, respectively, for sport fish and conservation management purposes (Table 2). Brood stocks were created from multiple stream sources within respective geographic management units to maximize the initial size of the transplanted populations, increase genetic diversity, and avoid bias fiom over-use of any single fragmented population that might not be representative of native fish from the overall geographic management area. Most restoration projects were conducted without using fish produced fiom wild brood stocks by transplanting individuals fiom core populations to establish conservation, or core, populations in other locations (Table 2). Nevertheless, some restoration projects were not feasible without a brood stock of native trout. For example, UM Creek involved a large area and required a relatively short period of time between removal of nonnative trout and re-establishment of sport fishing opportunities in order to avoid a significant public controversy. Transplanting limited numbers of wild trout could not satisfy recreational demands. Thus, hatchery trout produced from wild brood stock were used. In other cases lakes and reservoirs that required stocking for sport fishing purposes were connected to wild trout streams (Barney and Manning reservoirs – Manning Creek; Willow Bottom lakes – Twitchell Creek; Robs Reservoir – Center Creek; Pine Creek Reservoir – Pine Creek; Forsyth Reservoir – UM Creek; Table 2). Such areas can be restored if stocking relatively large numbers of native trout is an option. Once all nonnative trout are removed, lakes dependent on stocking can be maintained by stocking native trout while streams become self-sustaining with native trout. This also creates the potential to enhance spawning habitat for lake populations, if possible, eventually managing lakes entirely with wild trout.

In a few cases, sterile tiger trout (Salmo ***trutta*** X ***Salvelinus*** fontinalis) were stocked after rotenone treatments to replace popular sport fisheries and then phased-out as re-introduced native trout expanded fiom natural reproduction. Tiger trout were used in Manning Meadow and Barney reservoirs, and UM Creek (Table 2). Growth, survival, and catchability of tiger trout was sufficient to produce sport fisheries in both reservoirs and streams. When tiger trout were **first** produced in Utah in the **1990s,** it appeared availability would be limited because of **difficulty** in culturing large numbers of fish. Egg survival was typically about 4 percent; however, subjecting eggs fiom this hybrid cross to a hot water bath producing triploids increased egg survival to more normal production rates of **70-80** percent (Scheerer and Thorgaard 1983) and allowed greatly expanded use of these fish. **Stocking** rates were monitored and adjusted to avoid excessive competition and predation between tiger trout and native trout and then discontinued as native trout became available for stocking or as native trout naturally expanded into areas where tiger trout had been stocked. The greatest problem encountered with tiger trout was that they often became more popular with anglers than native cutthroat trout. Public pressure was exerted in several situations to maintain **stocking** of tiger trout, in contrast to conservation plans that emphasized native trout. We partially alleviated this problem by shifting tiger trout **stocking** to other sites.

We limit the number of native trout transplanted fiom source populations to protect these areas. The number of fish transplanted is based on size of the source population and its ability to replenish itself. We limit the number of fish transplanted, leaving behind young-of-the-year and large adult fish, by taking a wide variety of intermediate ages and sizes (both adults and sub-adults). Also, a portion of each source population is set aside as a refuge area fiom which transplanted fish are not collected. Less than 20 percent of the stream length of a source population is subjected to removal of fish in any single year. These conservative guidelines are partly based on an experience where **1024** Bonneville cutthroat trout were removed fiom Pine Creek (Table 2) between **1988** and 1991; the population was affected by removals but ultimately recovered. Pine Creek, a 5-km stream, was originally restored in 1980 with the intent to increase numbers of Bonneville cutthroat trout to provide fish for a wild brood stock. By **1984,** Pine Creek contained 298 cutthroat **trout/km.** State policy governing state fish hatcheries and wild brood stocks require 3 years of disease certification before moving fish into or out of these locations. Certification was completed on Pine Creek by sacrificing 120 Bonneville cutthroat trout annually fiom 1988 to 1990 for disease tests. In addition, 469 and 245 fish were transplanted fiom Pine Creek to Manning Meadow Reservoir in 1990 and 1991, respectively. By 1991 it was apparent that the Pine Creek population was suppressed, as the stream distance and effort needed to collect 245 fish was far greater than what was needed for equivalent collections in previous years. Nevertheless, by 1995 (Hepworth et al. **1997b)** the population had recovered to 228 cutthroat **trout/** km (270 in 2001) with numerous sizes and ages of fish. Despite the high number of fish removed and temporary reduced population size, there did not appear to be a **long-term** affect.

Restored streams generally received a minimum of 100 fish transplanted fiom core populations and **>200** if possible. These values originally resulted **from** number of fish available fiom core populations and time required for transplanted fish to re-populate renovated streams. Sam **Stowe** Creek was restocked with 39 fish in 1977 (Table **2),** and after 7 years the full 4.8 km of available stream habitat was not fully repopulated. In comparison, Pine Creek (5 km) was restocked with 245 fish in **1981**, which repopulated all available habitat within 3 years. Transplanted fish were a mixture of adults (≥age-3) and sub-adults, but most fish were likely mature within a year after being moved. In some cases we transplanted fish over several years to increase overall numbers. Although we did not specifically base number of transplanted fish on genetics and effective population size, i.e., number of breeding adults within a population, numbers were likely sufficient to prevent genetic drift and inbreeding depression. Franklin (1980) suggested that an effective short-term population size of 50 was sufficient to prevent loss of genetic diversity in small populations if in the long-term effective population size expanded to at least 500.

Migration Barriers

Naturally existing fish migration barriers protected most of the remnant populations of native trout in headwater streams in southern Utah and were responsible for their persistence (Table 1). Of 11 remnant populations, seven were isolated by multiple natural waterfalls or a combination of waterfalls and naturally intermittent stream sections. A hydroelectric power diversion that created a barrier falls and a de-watered section of stream isolated another remnant population in West Boulder Creek. Two remnant populations (East Boulder Creek and White Creek) persist in remote locations upstream fiom simple single-point barrier falls with populations of nonnative trout directly downstream. The North Fork North Creek and West Pine Creek were the only two remnant conservation populations that persisted in headwater areas without obvious physical barriers and in contact with nonnative trout. Some form of physiological attribute likely allowed native trout to retain a competitive advantage over nonnative trout in these areas, but in the case of the North Fork North Creek, minor introgression occurred. The West Pine Creek population persisted in the presence of brown trout and was not threatened with hybridization (Hepworth et al. 2001).

As such, artificial barriers were deemed necessary to protect restored populations of native trout (Table 2). Barriers can, however, potentially create problems by increasing fragmentation and limiting natural fish migrations (Kershner 1995, Young 1995b). Rather than further fragment existing native trout populations, we used barriers as part of restoration projects to increase the range of native trout and decrease fragmentation. Populations of native trout were restored in areas where they had been totally extirpated; barriers used to isolate these locations from nonnative trout. In other situations, remnant populations were expanded by constructing barriers at downstream locations, removing nonnative trout above the barriers, and allowing headwater populations of remnant native trout to expand into the renovated stream sections. Plans include reconnecting the remnant population in West Pine Creek with a putative population in North Pine Creek, thus reducing fragmentation by use of barriers constructed near the lower end of the main stream. Similarly, other restoration projects included second and third order streams with multiple tributaries (Table 2) whereas remnant populations of native trout had been restricted to simple first order streams (Table 1).

Most barriers were constructed of large, selectively placed rock to form check dams and waterfalls of at least 1.5 m. Road culverts were used to do the same thing when projects could be coordinated with road work in suitable areas. Over time, it became apparent that effective barriers required splash pads to prevent formation of plunge pools at the base of the falls, thus limiting the ability of trout to jump barriers.

Barriers that worked best were adjacent to other obstacles that limited fish movement such as seasonally de-watered stream segments (Birch Creek, Table 1; Sam Stow Creek, Manning Meadow Creek, Tenmile Creek, and Pine Creek, Table 2). The only barrier constructed as a single-point structure, where nonnative fishes had a continual presence immediately downstream, partially failed because of formation of a plunge pool (North Fork North Creek; Table 2). The remnant headwater population of native trout in the North Fork North Creek was likely conserved although efforts to expand these fish were **only partially** successful. Although fish above the barrier phenotypically appeared to be cutthroat trout, genetic tests conducted in 2001 found fish fiom the restored stream section to be more **introgressed** (15%) than headwater fish (6%).

We relied on an intermittent stream section and a road culvert to function as barriers for the original 1977 renovation of Sam **Stowe** Creek. Road construction in the **1980s** altered the culvert, and high spring flows in the early 1990s allowed rainbow trout to migrate into this stream even though it was thought to be isolated. Another barrier had to be constructed and the entire project was re-conducted in 1997.

Brown trout regained access into lower **Threemile** Creek as a result of high water flows through a normally de-watered stream section. These fish did not, however, move past a barrier that was constructed as part of the 1994 renovation project, and brown trout were selectively removed fiom the lower stream segment by **electrofishing** 500 m of stream.

In cases where construction of barriers with secondary obstacles was not possible, we opted in recent years to construct multiple barrier waterfalls (West Boulder Creek, Pine Creek, and White Creek, Table 2), similar to many natural situations where multiple obstacles protected remnant populations. Multiple barriers created a buffer zone that could be easily monitored and readily renovated should nonnative fish gain access above the lowest barrier and assured overall project success should a single barrier fail.

In general, barriers should be considered temporary or constructed with an understanding that they will likely require long-term maintenance. Given enough time without maintenance, they will likely fail. Even if barriers are needed for 15-20 years, long-term plans should focus on their **elimination** by expanding populations within larger portions of overall watersheds, providing that both biological and socio-political solutions can be satisfied.

Restoration of Metapopulations

Conceptually, metapopulations have a greater probability of long-term persistence than smaller populations. Cutthroat trout metapopulations have greater demographic stability than smaller populations; they allow large-scale fish movement and migrations, interconnect smaller populations, allow replacement after stochastic or catastrophic losses of fish fiom individual streams, and provide for large and diverse gene pools **(Kershner** 1995, Young **1995a, 1995b).** Thus, restoration efforts logically would attempt to restore native trout over larger areas; however, we found that larger and more complex restoration projects that had metapopulation characteristics were subject to more potential problems and failures than smaller projects. This discrepancy resulted fiom complications of human impacts on natural systems and because of greater difficulty removing all nonnative fishes with rotenone in larger systems.

Metapopulation **function** and theory is **often** viewed as it applies to natural situations without regard to human influence, but human impacts cannot be overlooked in practical management situations. Gresswell et **al.** (1994) found numerous human impacts affected the Yellowstone Lake metapopulation of cutthroat trout even with park protection and noted that a single illegal introduction of rainbow trout could threaten this entire complex of native trout. **Mangel** and Tier (1994) explained that risk of extirpation fiom catastrophic events can be as high for large populations as it is for small populations, and that corridors connecting populations can provide pathways for catastrophic losses and extinction. This was especially true for cutthroat trout, given that the foremost factor credited to population declines in the late 1800s and early **1900s** was the introduction of nonnative trouts (Behnke 1992, Kershner 1995, Young 1995b, Hepworth et al. 2001). These nonnative fishes spread throughout interconnected waterways and replaced native cutthroat trout, including native trout in the major river systems in southern Utah (Popov and Low 1950, Cope 1955).

By 1977 the only native trout remaining were remnant populations restricted to first order streams composed of headwater tributaries to the larger rivers. We restored native cutthroat trout populations in relatively simple stream systems in the 1970s and early 1980s (Table 2) and then progressed into larger drainages with multiple tributaries (South Ash Creek, Leeds Creek, Threemile Creek) starting in the late 1980s as opportunities and methodologies allowed. By the 1990s with development of conservation strategies, restoration goals expanded to include re-establishing native trout in larger and more complex systems, if possible, with increased connectivity and at least some characteristics of metapopulations. By the late 1990s we began restoring multiple tributary streams interconnected with lakes and reservoirs (Manning Creek, Manning Reservoir and Barney Reservoir; UM Creek and Forsyth Reservoir). These larger systems were restored systematically as a combination of smaller projects completed over multiple years. At the same time we continued to restore smaller, first order streams (Birch Creek-B, Tenmile Creek, and White Creek).

In our evaluation small projects conducted in fragmented streams were less subject to negative interventions by man compared to larger systems. Illegal movement of nonnative fish was not a problem while working with small isolated streams that were of little interest to the public for sport fishing. Conversely, this risk and difficulty of removing nonnative fishes increased as restoration projects expanded into larger areas with greater amounts of sport fishing. Although most restoration projects remain successful, public complaints have been common and requests have been made to stock nonnative trout in UM Creek, Dougherty Lake, and Manning Meadow Reservoir. Most southern Utah reservoirs >100 ha have had illegal fish introductions within the last 25 years.

Managers also should consider threats to native trout in regard to time and set management priorities on that basis. It does little good to attempt to prevent long-term threats such as inbreeding depression by establishing metapopulations if short-term problems such as expansions of nonnative fishes are not dealt with first. This can be true even if the short-term actions appear temporarily detrimental to long-term considerations.

We suggest restoring native trout in multiple historic sites, working with both large and small-scale systems. Managers should consider a variety of projects realizing that threats can be both natural and human-caused, and that project feasibility and potential for success can vary in different situations. For example, ***conservation*** of an existing metapopulation might be a high management priority regardless of the risks. In contrast, complete ***restoration*** of a metapopulation might not be justified although some attributes of a large interconnected system appear attractive. Even if high risk is only associated with a single threat, time and agency resources put in jeopardy by such a risk might be too great to justify the project under these conditions.

Socio-political Issues

Obtaining regulatory clearances to conduct recovery projects has increasingly become more complex and difficult. In the 1970s restoration projects received little resistance or concern, but there was little funding and few programs to support such work. Increased awareness that a subspecies of cutthroat trout could be listed under the ESA and the establishment of state and USDA Forest Service sensitive species lists helped establish funding mechanisms and justify expenditures on programmatic approaches to conservation. At the same time, these actions had some negative affects. Opposition developed to transplanting cutthroat trout because of their sensitive status and the associated implications they might have on other land management issues. Restoration projects on Spring Creek in 1993 and Deer Creek in 1994 were canceled after considerable planning effort because of conflicting issues with other land uses and promises UDWR had made with the local counties to avoid such problems. Even while the USDA Forest Service officially supported native trout restoration through conservation agreements, some district rangers and land use specialists opposed transplants simply to avoid associated complications and controversy. More importantly, county governments expressed opposition to expansions of native trout because of possibile federal listing and subsequent restrictions on resource use. At times local governments were often skeptical of state agency objectives, wondering whether we wanted to prevent federal listing or rather wanted sensitive species to drive land use policy. Over time, obtaining regulatory clearance for use of rotenone has become more difficult. It remains unclear how the National Environmental Policy Act (NEPA) applies to state restoration projects conducted on federal lands. Inconsistencies in implementing NEPA processes persist among agencies and even among National Forests.

To help alleviate concerns over sensitive species listings, inter-agency conservation agreements for native cutthroat trout in Utah were established in 1997 among the UDWR, Utah Department of Natural Resources, Utah Reclamation Mitigation and Conservation Commission, USDI Fish and Wildlife Service, USDA Forest Service, USDI Bureau of Land Management, and USDI Bureau of Reclamation (Lentsch and Converse 1997, Lentsch et al. 1997). The objective of the agreements was to remove threats to cutthroat trout that could lead to federal listing under the ESA. The agreements reduced local concerns over the sensitive status of cutthroat trout by allowing transplants and introductions to take place without giving new populations sensitive species status; **naturally** existing populations and populations established prior to the agreements retained sensitive status. However, about the time that conservation agreements were being finalized and implemented, local government concerns culminated with passage of a 1998 state law in Utah requiring county approval of written plans for any transplants of state or federal sensitive species (1998 Utah Code 23-14-21). In addition, the Endangered Species Protection Fund was established in Utah the same year, sponsored by rural legislatures (1998 Utah Code 63-34-14). Its purpose, in part, is to provide funding to the State to pro-actively manage sensitive species, thus preventing the need for federal listing under ESA.

To comply with the transplant law, recent restoration projects (Table 2) were planned by the UDWR and then approved by local counties. The development of county approved plans was incorporated into the NEPA process and includes writing an Environmental Assessment although an actual need for this level of NEPA compliance remains unclear. Cost of project planning and approval has greatly increased and is generally much greater than the cost of actually completing field work. It is no longer cost and time effective to work on plans for small individual streams because small projects require as much planning effort as large projects. We have partially solved this problem by developing Environmental Assessments that include restoration plans for up to 10 or more lakes and streams.

To date, the new transplant law has not resulted in project terminations. Counties have shown a willingness to grant approvals, knowing they now have considerable authority in the process and knowing that projects will be terminated if listing status changes, which would void current plans. For instance, stocking of Bear Lake Bonneville cutthroat trout by the state of Utah would have to be discontinued in Bear Lake, Utah-Idaho according to the 1998 Utah law if Bonneville cutthroat trout were listed under the ESA – at least until a new plan was developed and approved by the local county. As a result, federal listing poses a more serious predicament for state managers than it did prior to the 1998 Utah law. Behnke (1992) cautioned that compromise needs to be reached in application of the ESA to avoid a public backlash against the act and not have conservation efforts immobilized. Federal listing of Bonneville and Colorado River cutthroat trout under the ESA could stop, at least in Utah, culture from wild brood stocks, annual stockings, annual introductions of millions of native trout, and millions of dollars of management and hatchery programs that might be difficult to reinstate.

Ironically, the greatest remaining threat to continued native trout conservation in Utah by UDWR could be the ESA. Although federal law would pre-empt state law, it might not be an issue. The 1998 state law simply requires local govemment participation in the planning process for restoration projects. Under current conditions, cooperation has evolved among local, state, and federal agencies because of a mutual goal to pro-actively prevent federal listing. Considerable cooperation and incentive among agencies could be lost as a result of federal listing and replaced with mandates attempting to force conservation, which would likely meet local resistance and an even larger adversarial presence in development of conservation plans. Granted, in other situations where management actions for a species might be lagging, listing under ESA could be the most appropriate method to stimulate agency response.

More recently, as restoration projects were expanded into larger and more complex systems, anglers expressed increased concern over potential loss of nonnative but popular sport fisheries. In response, we have stressed the importance of using native trout in ways to improve angling (Hepworth et al. 1999,2000). In one case, native cutthroat trout stocked in a small reservoir were found to have higher over-winter survival than rainbow trout. In other situations, stunted brook trout in small lakes are being replaced with native cutthroat trout that will attain larger sizes and be more attractive to anglers (Willow Bottom lakes, Robs Reservoir, and Pine Creek Reservoir, Table 2). Projects should be planned to increase support for native trout, rather than create public opposition.

CONCLUSIONS

We found by trial and error that restoration projects fail because of various reasons. As previously discussed, problems were encountered with incomplete removal of nonnative trout with rotenone, barrier failures, and potentially from surreptitious stockings. Another factor that can influence project success is habitat suitability. Durfey Creek (Table 2) was fish-less prior to introducing Colorado River cutthroat trout. The introduction likely failed because of cold water temperatures which did not exceed 10° C. Some of the transplanted fish persisted for at least 3 years but failed to reproduce. Harig et al. (2000) described failure rates >50 percent for transplanted populations of native trout in Colorado and New Mexico streams due to low water temperature, small stream size, and degraded habitat. We evaluated habitat suitability for restoration sites based on present conditions for nonnative trout and the histories of trout in these streams. Most restoration projects we conducted were selected because they had habitat that supported healthy nonnative trout populations. The USDA Forest Service recommended Threemile Creek as a restoration site because changes in livestock grazing had already been made without native fish being an issue. Riparian habitat and stream conditions had improved prior to restoring native trout in 1994.

In other situations we discontinued restoration projects on Spring Creek in 1993 and Deer Creek in 1994 (Table 2) because of socio-political issues. Livestock grazing apparently was going to become an issue on

Spring Creek, and we had committed to local government officials that restoration work would be conducted in a non-controversial manner. At Deer Creek it became apparent that it would be difficult to remove all nonnative trout with rotenone, stay within the defined project area, and not cause a controversy with local sport fisheries. Although failure of these latter two projects was disappointing, it afterwards added credibility to overall restoration efforts when additional project approvals were sought and we claimed that conflicts with other land uses would be avoided as they had been in the past.

Overall, we found five important factors in selecting sites for restoring populations of native trout. Projects should:

(1) have habitat capable of supporting multiple year-classes of wild trout over many years;

(2) be cost and time effective in regard to the size of the restoration project and justify renovation efforts;

(3) be feasible by having a high probability that all nonnative fishes can be removed with rotenone and prevented from returning;

(4) avoid major land use conflicts; and

(5) have support from the public and land management agencies.

Although finding a perfect restoration site is difficult in light of the above factors, advantages can be weighed against disadvantages. For any given location, potential problems can be recognized and pro-active plans made to deal with these concerns or avoid problems by selecting an alternate site.

Success and failure rates are not a valid means to evaluate overall restoration success. Potential restoration projects often arise from circumstances other than those considered primarily for native trout. UM Creek was restored due to efforts to control whirling disease (Table 2). Leeds Creek and Birch Creek were restored because wild fires resulted in large losses of nonnative trout present at the time of the fires. Durfey Creek was selected as a transplant site because it was a fish-less stream where a transplant could be conducted without approval to conduct a rotenone treatment. Although habitat at some sites might be marginal or other problems such as whirling disease might be present, an opportunistic restoration attempt does little harm as long as fish are available for transplant without jeopardizing source populations. Greater risk in some situations might be associated with the potential for greater gain. It is important to understand why projects fail, but keeping score of failure rates has little overall value. Total restoration progress gained versus time and money spent is a more useful way to evaluate success.

Maintaining successfully restored streams and lakes requires frequent monitoring and a long-term commitment. We scheduled population surveys on all native trout streams every 7 years. This allowed time to conduct restoration projects between monitoring populations, which in turn, gave direction in planning new restoration projects. Nevertheless, we suggest more frequent spot-checks to survey key areas, check recently treated areas, maintain migration barriers, monitor habitat conditions, and evaluate re-colonization of restored areas by recently introduced fish. Some of these concerns should be evaluated annually in recently restored areas, then evaluated less frequently after it is determined that projects were initially successful and as such, reached a higher level of security. For example, UM Creek has been monitored annually since 1996 to evaluate progress as the native trout population develops, while South Ash Creek was restored in 1986, watched for a few years, and then surveyed in 1995 and 2002. Unless some problem becomes evident, South Ash Creek will likely not be surveyed again until 2009.

Altogether, restoration projects were conducted on 42 streams and lakes within southern Utah during the past 25 years (Table 2). Seventeen of these projects have been successful in establishing self-sustaining populations from the time the projects were first completed. Ten projects were conditionally or partially successful after supplemental actions were taken to overcome problems that occurred subsequent to the initial restoration effort. Thee restoration projects failed and there was no other attempt to restore these sites. An additional 12 restoration projects are still in progress where self-sustaining populations are expected to become established. Despite some problems and delays, native trout increased from just three remnant populations in about 9.9 km of stream known to occur in 1977, to established populations in 33 streams and over 150 km by the year 2002. Restoration projects in progress, if successful, will increase stream habitat by another 105 km and lake habitat to a total of 108 ha (9 lakes and reservoirs) managed as native trout conservation populations. Additional projects are planned for the future. In addition, expanded use of native cutthroat trout produced from wild brood stocks was developed for general sport fish management applications. Stocking of all nonnative cutthroat trout was discontinued in Utah after 1999. Native trout restoration has been successful because it was an important part of the state's annual work plan with a dependable budget, interest and commitment increased among other resource agencies, and the ESA posed a common objective among agencies and local governments to prevent listing.

ACKNOWLEDGEMENTS

Restoration projects were funded, in part, by Federal Aid in Sport Fish Restoration Project F-44-R, Utah. We would like to thank the Utah Division of Wildlife Resources Aquatic Section administration for supporting this work and the many biologists, hatchery personnel, and other land management agency personnel that made this work possible.

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Received 15 September 2001
Accepted 15 October 2002

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