An Evaluation of Nonnative Fish Control Treatments in Ponds along the Colorado and Gunnison Rivers, 1996-2002

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An Evaluation of Nonnative Fish Control Treatments in Ponds along the Colorado and Gunnison Rivers, 1996-2002

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DISCLAIMER

The opinions and interpretation of the data expressed in this report are those of the author and do not necessarily reflect the views of the Colorado Division of Wildlife or the Recovery Program. Mention of trade names, commercial products, or firms and businesses does not constitute endorsement or recommendation for use by the author, the Colorado Division of Wildlife, or the Recovery Program.

List of Key Words: Nonnative fish, control, reclamation, endangered fish, centrarchid, piscicide, floodplain pond

EXECUTIVE SUMMARY

Control of nonnative fish has been identified by the Upper Colorado River Endangered Fish Recovery Program as a primary component in the recovery of four endangered fish species. Historically 12 native fish species lived in the Colorado River in Colorado. These include four listed fish species (Colorado pikeminnow, *Ptychocheilus lucius*; humpback chub, *Gila cypha*; bonytail, *Gila elegans*; and razorback sucker, *Xyrauchen texanus*). Conversely, 40 nonnative fish species have been collected in the Colorado River in Colorado; thus nonnative fish species outnumber native species by more than three to one.

Because riverside ponds may be chronic sources of nonnative fish to critical habitat the goal of this study was to reduce proliferation of nonnative fish species in floodplain habitats and minimize chronic escapement of nonnative fishes from perennial ponds. The primary objective to accomplish this goal was diminution of nonnative fish abundance in riverside ponds and reduction of nonnative fish escapement from ponds. A secondary objective was to detect reinvasion of treated ponds by nonnative fish and identify nonnative fish movement through fish screens. Ultimately, the desired effect of this study was a reduction in the abundance of nonnative fishes in riverine nursery habitats.

An inventory of the study area revealed 729 potential pond sites. Information and education efforts utilized landowner and other interested community contacts to obtain access to 329 of the 729 potential pond sites. Of the 191 ponds that were sampled and found to contain fish in the study area, 147 contained only nonnative fish (21 species) and another 43 contained both native (3 species) and nonnative fish. Only native fish species were collected in only one of the 191 ponds. The total catch from these 191 ponds was 25,393 fish, of which only 387 (1.5%) were native.

Of the 191 ponds sampled to determine species composition 86 ponds, totaling 373.8 surface acres, received nonnative fish control treatments (reclamation, screen, water management, black plastic, and re-route irrigation water). The total cost of all treatments was $310,331. The average cost per surface acre for these treatments was

$830. All fish were removed in 71 of the 86 treated ponds. Of the 71 ponds 54 were re-sampled to identify re-invasion by nonnative fish. Sixty-five percent of the 54 ponds had reinvaded. Additionally, movement of some, but not all, larval fish through screens was confirmed.

This study, as well as others, has demonstrated that re-invasion by nonnative fish has readily occurred in most waters that have been treated using mechanical or chemical control techniques. However, re-invasion of largemouth bass was a notable exception. This fish species was present in 28 of the 54 re-sampled ponds prior to treatment but it had re-invaded only two of the 54 ponds following treatment. Similarly, minor success was observed in the 12 (22%) of the 54 re-sampled ponds that had not re-invaded at the time they were re-sampled. Limited success was also observed with regard to fish screens. Though some nonnative fish larvae passed through screen apertures as small as 0.5mm, other larvae were impinged and did not pass through some screens.

Evidence of reduction in abundance of nonnative fishes in existing riverine nursery habitats as a result of nonnative fish control in floodplain ponds on a river-reach scale is nonexistent. Research conducted in the rivers within the study area under other investigations suggests no reach-wide depletive effect was observed.

Recommendations discussed in this report include the following:

1. Determine the sources of problematic nonnative fishes.
2. Evaluate potential biological control of nonnative fish with native listed/non-listed fish in a floodplain pond environment.
3. Evaluate shearing wedgewire screens with apertures < 0.5mm to determine if larval fish pass through this type of screen.
4. Examine the potential of controlling the movement of nonnative fish from floodplain ponds into critical habitat by screening return flow irrigation water.
5. Continue I&E efforts to inform the public and private aquaculturists of the existence of and changes to the CDOW Nonnative Fish Stocking (NNFS) regulation.
6. Review current NNFS regulation and make changes where necessary.

INTRODUCTION

Background

Floodplain corridors bordering the main-stem rivers in the Upper Colorado River Basin are considered an integral and necessary element for the recovery of the four endangered big river fish species (Colorado pikeminnow, *Ptychocheilus lucius*; humpback chub, *Gila cypha*; bonytail, *Gila elegans*; and razorback sucker, *Xyrauchen texanus*). Negative interactions between certain nonnative fish species and the young life stages of endangered fishes in floodplain nursery habitats are a primary concern. Lentic habitats including backwaters, embayments created by flooded terraces, and ponds created in depressions have all been identified as critical habitat components generally important to the native fish community and ecological functions supporting the endangered fishes (Irving and Burdick 1995). However, 40 nonnative fish species are present throughout the Upper Basin (Nesler 2003) and may adversely impact recovery of endangered fishes through predation and/or competition at critical life stages and/or in critical locales (Tyus and Saunders 2000, Mueller and Marsh 2002).

Nonnative fish known to occur in floodplain ponds, such as largemouth bass and green sunfish, typically seek backwater or slow moving side channel habitats upon entering the main stem river. Within these riverine habitats, centrarchids are believed to pose a significant predatory threat to the young life stages of endangered and other native fishes (Tyus and Saunders 1996, Osmundson 2003).

Study Goal, Objectives, and Approach

Goal -–– To reduce proliferation of nonnative fish species in floodplain habitats and minimize chronic escapement of nonnative fishes from perennial ponds.

Objectives -–– Objectives identified during the course of this study included the following: 1) assessment of ponds as problematic/non-problematic through inventory and sampling efforts. Problematic ponds were those that contained nonnative fish that had direct access to critical riverine habitat; 2) removal of nonnative fish via chemical reclamation, water management, and/or black plastic installation; 3) installation of screens to minimize reinvasion of ponds, escapement of fishes from treated ponds and

escapement of fishes from ponds outside the treatment area; 4) detection of reinvasion of floodplain ponds by nonnative fish species; 5) identification of nonnative fish movement through screens; 6) determination of reductions in the abundance of nonnative fishes in existing riverine nursery habitats as a result of nonnative fish control in floodplain ponds on a river-reach scale; 7) recognition of public concerns and values and incorporation of public perspectives and issues into the process of reclaiming ponds; and 8) communication with interested communities concerning the reasons for pond reclamations and endangered fish recovery.

Approach -–– Overall, the strategy to remove or prevent the movement of nonnative fish from floodplain ponds was intended to greatly reduce the number of chronic sources of centrarchid and other nonnative fish species accessing riverine habitats, thereby contributing to the recovery of endangered fishes. To accomplish this strategy control of nonnative fishes was implemented by the Colorado Division of Wildlife (CDOW) under two categories: (1) reduction of nonnative fish abundance in riverside ponds and (2) reduction of nonnative fish escapement from ponds. Floodplain and upland ponds along the Colorado (from Rifle, CO to the Colorado/Utah state line) and Gunnison (from Austin, CO to the Gunnison River confluence with the Colorado River) rivers may represent chronic sources of nonnative fish species documented or presumed to have negative impacts on early life stages of Colorado pikeminnow and razorback sucker. Reclamation strategies for ponds included 1) removal of existing nonnative fish species using piscicides and/or draining by pumping; 2) annual water management resulting in periodic pond drying; 3) installation of escapement prevention devices; 4) installation of drainage pipes to re-route irrigation water, believed to contain larval nonnative fish, away from ponds; and 5) installation of black plastic as an alternative to chemical reclamation to remove excessive aquatic vegetation and nonnative fish. This report presents the results of these nonnative fish control activities for 1996 - 2002.

METHODS

Study Area

The study area encompassed ponds along the Colorado River from Rifle to the Colorado/Utah state line and along the Gunnison River from Austin to the confluence with the Colorado River (Figure 1). Ponds of special interest were those located within the 50-year floodplain; however, ponds outside this floodplain that were potential sources of nonnative fish entering critical habitat, were also subject to control.

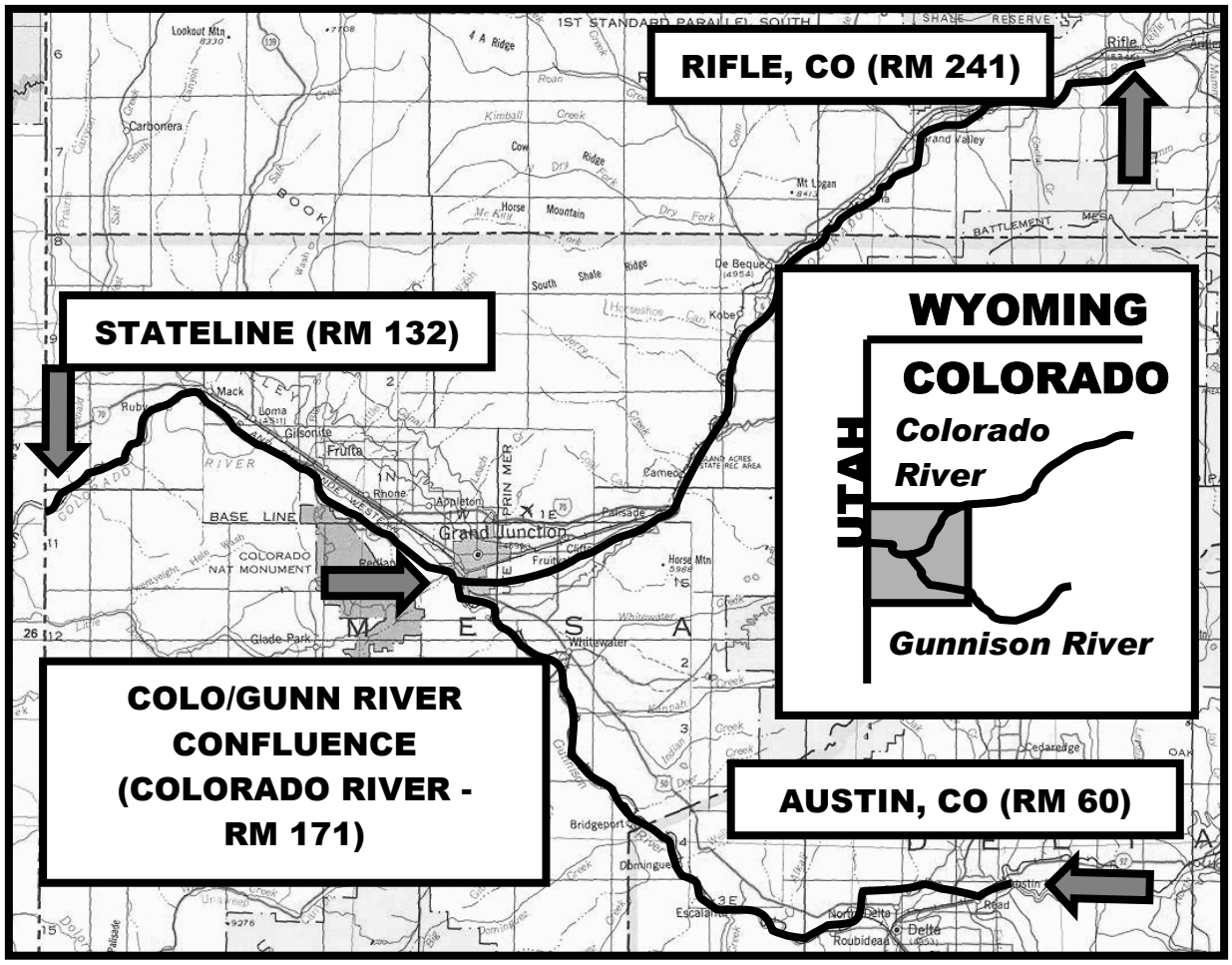

Figure 1. The nonnative fish control study area encompassed ponds along the Colorado River from Rifle, CO (RM 241) to the Colorado/Utah state line (RM 132) and along the Gunnison River from Austin, CO (RM 60) to its confluence (RM 0) with the Colorado River (RM 171).

Pond Identification, Ownership, and Access

CDOW initiated Nonnative Fish Control (NNFC) efforts in 1996 with the identification of ponds in the study area and determination of pond ownership. An inventory of ponds in the study area conducted by Mitchell (1995), though incomplete, provided a basis upon which additional ponds were identified. Once ownership was determined, private landowners were asked to voluntarily participate in the NNFC program, and were offered a monetary incentive to facilitate controlling nonnative fishes in their pond(s) via reclamation, screening, or water management. Monetary incentives consisted of paying $100/surface acre for access to ponds for fish sampling, and the same amount again for access for NNFC. A few landowners allowed access without receiving an access fee, while others requested copies of aerial photographs of their property in lieu of the monetary incentive.

Cost Estimate to Control Nonnative Fish

As a prelude to NNFC activities, the CDOW estimated the overall cost to control all ponds thought to be in the study area as of 1997. A matrix was developed that identified five control scenarios including: poisoning with rotenone and detoxifying with potassium permanganate ($KMnO_4$); pumping with three phase electricity available; pumping with the use of a gasoline generator where three phase electricity was not available; poisoning with chlorine after pumping without the availability of three phase electricity; and poisoning with chlorine without prior pumping (Martinez 1997). NNFC cost estimates were based on chemicals, supplies/equipment, and labor.

Field Sampling and Nonnative Fish Control Activities

Fish Sampling --- Fish were collected from ponds using trammel nets (1/2" inner & 6" outer mesh, 75' x 6', #104 twine; 1" inner & 8" outer mesh, 150' x 6', #104 twine; 1 1/2" inner & 12" outer mesh, 150' x 6', #139 twine; 2" inner & 16" outer mesh, 150' x 6', #139 twine), seines (40' long, 6' deep with 3/16" mesh; 6' x 6' x 4' bag with 1/8" mesh, #12 twine), and/or fyke nets (*Large net* = 1st & 2nd rectangles with 3/4" conduit - 4' x 6', 1" square mesh; 5 hoops - fiberglass - 4' diameter; tapered throats on 1st and 3rd fiberglass hoops; 75' lead; #18 twine; tarred. *Small nets* = 1st rectangle -2' x 3' steel –

either 1/4" or 3/16" mesh; 5 steel hoops – 2' diameter; 3 tapered throats on 1st, 2nd and 3rd hoops; 25' lead; treated). Trammel nets were set for no more than three hours to avoid potential mortality to endangered fish. Fyke nets were set over night. Seine hauls were done in small bays or along shallow shorelines.

All fish sampled were identified and in most cases weighed in grams (g) and the total length was measured in millimeters (mm). When large numbers of fish were collected, a subset of fish was weighed and measured and the remainder were identified and enumerated.

Native Fish Salvage -- Citizens expressed concern regarding the impact of nonnative fish removal on the availability of food for piscivorous birds (USFWS 1998a). To address this concern, native fish were salvaged from the Lewis Wash siphon in the Government Highline Canal (1999, 2000, 2001, and 2002) immediately after the canal was drained in the fall. By stocking these fish into a reclaimed pond and an isolated oxbow of the Colorado River they were made available to piscivorous birds. Excess salvaged native fish were stocked directly into the Colorado River.

Nonnative Fish Control --- NNFC techniques included chemical reclamation (liquid/powder rotenone or chlorine), installation of pond outlet/inlet screen(s), water management, use of black plastic, and/or rerouting irrigation water. Individual control treatments were determined following consultation with landowners and evaluation of site specific constraints. NNFC treatments took place an average of 7.8 months post-sampling. However, due to access constraints treatment dates ranged from two days to 50 months post-sampling. Powder rotenone (a restricted-use pesticide) and chlorine were most often applied from boats by gasoline powered pump-eductor systems. However, for ponds that were inaccessible to vehicles, liquid rotenone was dripped off the back of a cataraft. Sand mix (sand coated with rotenone and gelatin) was also applied to difficult-to-reach areas such as seeps and dense vegetation (Spateholts and Lentsch *no date*). Ponds with outlets were pumped down prior to piscicide treatment to prevent the movement of toxicant out of the treatment area.

Industry standards concerning the use of rotenone were followed (Cailteux et al. 2001, Finlayson et al. 2000). Piscicides were applied in accordance with manufacturer's labels and local, state, and federal regulations regarding the application of restricted-

use pesticides. Local authorities were notified prior to piscicide application either via a written document (Application for Fish Control and Operations Plans) or by phone. Ponds were either allowed to detoxify naturally or were detoxified with $KMnO_4$ or sodium thiosulfate when rotenone or chlorine was applied, respectively.

Toxicant application was always supervised by a lead aquatic biologist who was certified by the Colorado Division of Plant Industry (CDOPI) as a “Qualified Supervisor”, and trained to evaluate Aquatic Pest (Commercial Category 108) problems. Other permanent and seasonal CDOW employees assisting with chemical applications were also trained to comply with CDOPI specifications for “Applicator Technicians”. Applicators wore appropriate safety gear to minimize chemical exposure.

Fish carcasses resulting from piscicide application were not removed. An attempt was made to enumerate dead fish, but due to turbidity restricting visibility in most ponds, erratic distribution of dead fish on the bottom of ponds, and deposition of carcasses in windrows, this activity was abandoned. Several cages of live fish placed at different depths and locations in treated ponds served as indicator fish to determine the presence of toxicant following reclamations. Indicator fish were replaced daily until they lived 24 hours at which point it was determined the pond was no longer toxic.

In addition to chemical reclamations NNFC treatments included installation of screens, water management, installation of black plastic, and rerouting of irrigation water. Inlet or outlet screens of varying designs were installed on ponds to control the movement of nonnative fish from ponds into the rivers or the re-invasion of ponds by nonnative fish following reclamations. Though many screen designs are available and described in the literature (Bestgen et al. 2001; Miller and Laiho 1997; Smith 1982) it was ultimately local engineers who recommended each screen design after consideration of site specific constraints. Some ponds were dried annually in an attempt to remove nonnative fish through water management. Black plastic was spread over the surface of one small pond to remove nonnative fish as an alternative to using chemicals. Additionally, irrigation water was routed away from a reclaimed pond that also received spring water in an attempt to prevent reinvasion of nonnative fish.

Several ponds were sampled, three to 40 months post-control (Average 19.6 months), using the same sampling technique described above to ascertain re-invasion

of nonnative fish in reclaimed ponds. Similarly, fish screen out-flow was examined to document movement of larval fish through the screens. No sampling was conducted in the Colorado or Gunnison rivers under this investigation. To determine reductions in the abundance of nonnative fishes in nursery habitats as a result of nonnative fish control in floodplain ponds, results from other investigations that sampled these adjacent nursery habitats during the study period were utilized.

Information and Education

The public was informed of nonnative fish control activities due to the contentious nature of nonnative fish control through application of fish toxicants, and the perceived loss of fishing opportunity. Several techniques were utilized to disseminate this information which included mail, television, radio, local newspapers, and oral presentations.

RESULTS

Pond Identification, Ownership, and Access

Initially, ponds in the study area were identified and ownership was determined. An incentive package was approved by CDOW in 1998 to facilitate landowner cooperation and participation in efforts to control nonnative fishes.

Pond Identification --- Hereinafter, *pond sites* refers to those areas where ponds were thought to be present. Similarly, references to *ponds* indicate pond sites that were field investigated and the existence of a pond was confirmed. Of the 729 potential pond sites identified within the study area, 329 (45%) were investigated in the field between 1996 and 2002 (Table 1) and anecdotal information on an additional 82 (11%) was provided by private landowners and/or agency personnel or through examination of high and low flow aerial photographs. An increase in the number of ponds and other habitat suitable for sustaining nonnative fish in the study area occurred during this study with construction of new gravel pits, farm/fishing ponds, and wetlands. A Natural Resources Conservation Service (NRCS) program also facilitated the construction of 16 ponds in the last five years (1998 – 2002) in the study area.

Table 1. Number of potential pond sites and ponds known to contain fish that were examined during field investigations between 1996 and 2002 along the Colorado River between Rifle and the Colorado/Utah state line and along the Gunnison River between Austin and the confluence with the Colorado River.

Year pond was investigated	Number of pond sites investigated		Number of ponds that contained fish	
	Colorado River	Gunnison River	Colorado River	Gunnison River
1996	2	1	2	1
1997	18	2	15	2
1998	27	10	20	6
1999	141	45	73	15
2000	62		42	
2001	12	8	11	3
2002	1		1	
Subtotal	263	66	164	27
Total	**329**		**191**	

Of the 329 potential pond sites that were investigated, fish were present in 191 ponds and fish were absent in the remaining 138 pond sites (Table 2). Of those ponds that contained fish, 169 ponds were permanent, three ponds were ephemeral, one pond was nearly taken over by the river but became isolated during low flow, and 18 ponds were either stocked with endangered fish (16) or native non-listed fish (2). Of the 138 pond sites where fish were not collected, 44 permanent and 64 ephemeral ponds were identified. Ponds no longer existed at 16 of the 138 pond sites because the river had engulfed them since 1995 (Mitchell 1995). One pond was under scientific investigation as a flooded bottomland and 13 pond sites, that were mistakenly identified by Mitchell (1995) as fish ponds, were either water or sewer treatment ponds (6) or were misidentified as ponds (7).

Of the 82 pond sites that had only anecdotal information, 29 ponds reportedly supported fish and 53 were void of fish (Table 3). Comparison of high and low flow aerial photographs revealed 24 permanent ponds, 15 ephemeral ponds, and nine ponds that had been taken over by the river since 1995 (Mitchell 1995). During the period of this study, six ponds have either been stocked with endangered fish (4) or were under

Table 2. Status and number of potential pond sites, along the Colorado River between Rifle and the Colorado/Utah state line and along the Gunnison River between Austin and the confluence with the Colorado River, that were examined during field investigations between 1996 and 2002, and for which the presence/absence of fish was documented. Upland refers to ponds elevated above ponds that typically flood annually (flooded bottomland).

	Permanent		Ephemeral		Taken over by the river	T&E &/or scientific study	Misidentified as fish ponds	**Total**
	Upland	Flooded bottom-land	Upland	Flooded bottom-land				
Fish present	164	5	3		1	18		191
Fish absent	42	2	60	4	16	1	13	138
Subtotal	206	7	63	4	17	19	13	
Total	213		67		17	19	13	**329**

Table 3. Status and number of potential pond sites, along the Colorado River between Rifle and the Colorado/Utah state line and along the Gunnison River between Austin and the confluence with the Colorado River, that were identified between 1996 and 2002 by landowners, agency personnel or through comparison of high and low flow aerial photographs, and for which the presence/absence of fish was anecdotally documented. Upland refers to ponds elevated above ponds that typically flood annually (flooded bottomland).

	Permanent		Ephemeral		Taken over by the river	T&E &/or scientific study	Misidentified as fish ponds	**Total**
	Upland	Flooded bottom-land	Upland	Flooded bottom-land				
Fish present	7	16				6		29
Fish absent	1		10	5	9		28	53
Subtotal	8	16	10	5	9	6	28	**82**
Total	24		15		9	6	28	

scientific study as flooded bottomlands (2). Twenty-eight additional ponds were either water/sewage treatment ponds (22) or were misidentified as ponds (6).

Pond Ownership -— The 729 potential pond sites identified in the study area included 235 private/municipal/public owners. Of these 235 pond owners, 104 own more than one pond site, 116 own one pond site, and 15 own a portion of a pond site. The 104 owners of multiple pond sites own all (592 pond sites) or part (13.5 pond sites)

of 605.5 total pond sites, while the 15 partial owners of pond sites own a total of 7.5 ponds.

Colorado State Parks manage the most public pond sites (33) followed closely by the CDOW, Bureau of Land Management, Bureau of Reclamation, and the City of Grand Junction with 31, 30, 29, and 27 pond sites, respectively. Clifton Sanitation District owned the most municipal pond sites (15). Five private entities own a significant number of ponds, with two entities owning 12 ponds each, and three entities owning 11 ponds each.

Pond Access -–– Access was sought primarily from landowners who owned multiple ponds. However, willingness of landowners to allow access played a major role in which ponds were sampled/controlled. Between 1996 and 2002, access was obtained from 76 private, 6 public, and 10 municipal landowners to investigate 188, 75 and 66 pond sites, respectively (Table 4). The number of pond sites examined each year is reported by river basin in Table 5. More pond sites were examined in 1999 than any other year of the study. The number of landowners that declined participation in the NNFC program was not recorded.

Table 4. Number of pond sites owned/managed by private/public/municipal entities along the Colorado and Gunnison rivers, in relation to a corresponding number of landowners.

Ownership	Number of pond sites	Number of landowners	Average number of ponds per landowner
Private	188	76	2.5
Public	75	6	12.5
Municipal	66	10	6.6
Total	**329**	**92**	**3.6**

Table 5. The number of pond sites examined between 1996 and 2002 along the Colorado River between Rifle and the Colorado/Utah state line and along the Gunnison River between Austin and the confluence with the Colorado River. “Public” refers to pond sites that are open to the public while “municipal” pond sites are owned by a government entity, but are not open to the public such as water/sewage treatment ponds.

Year	Colorado River			Gunnison River			**Total**
	Private	Public	Municipal	Private	Public	Municipal	
1996		2		1			3
1997	2	15	1	1		1	20
1998	1	24	2	2	6	2	37
1999	96	18	27	36		9	186
2000	39	5	18				62
2001	5	5	2	4		4	20
2002	1						1
Total	144	69	50	44	6	16	**329**

Implementation of a monetary landowner incentive package facilitated access to private property and expedited nonnative fish reclamation efforts. Forty-five (59%) of the 76 private landowners who provided access chose to participate in the NNFC program through the incentive package, while the remaining 31 private landowners chose to participate without receiving any incentive money. A total of 39,200 incentive dollars were paid to the 45 private landowners as an access fee for fish sampling and/or NNFC. Eight of the 45 landowners were paid an access fee for both fish sampling and NNFC, while nine of the 45 landowners allowed additional access for NNFC without receiving additional access fees beyond the initial incentive fee. The remaining 28 landowners either chose to not participate in NNFC after their ponds were sampled, or their ponds did not appear to pose a threat to native fishes and NNFC was not pursued.

A total of 93 private ponds were accessed for sampling through the incentive program. Nonnative fish were controlled in 49 of the 93 privately-owned ponds. The total area of the 93 sampled ponds was 363.3 surface acres (SA). The subset of these sampled ponds that were controlled, 49 ponds, totaled 204.6 SA. The total incentive costs to sample and control nonnative fish in these ponds were $31,200 ($86/SA) and $8,000 ($39/SA), respectively. The average cost per SA for control vs sampling was less because nine private landowners that participated in the incentive package were

entitled to an access fee for both sampling and NNFC, but only accepted the fee for sampling.

Cost Estimate to Control Nonnative Fish

CDOW developed a matrix in 1997 (Martinez 1997) to estimate the cost of NNFC projects within the study area based on an inventory of ponds provided by Mitchell (1995). The original cost estimate matrix included 321 ponds of which 308 ponds were identified by Mitchell and another 13 were added by CDOW. The 321 ponds accounted for approximately 846 SA and 7,396 acre-feet. Pond ownership and position in the floodplain were also documented. However, it was later determined numerous ponds were not included in the original matrix. Among these were 141 ponds in the river corridors examined by Mitchell (1995), and 92 ponds between Rifle and Cameo (which were absent from the Mitchell report due to the unavailability of aerial photographs). More-recent estimates of the cost to control 551 ponds comprising 1,416 surface acres (449 along the Colorado River and 102 along the Gunnison River) are summarized in Table 6. While Table 6 includes ponds inadvertently omitted in the Mitchell (1995) report, newly-constructed ponds, and ponds documented in the original matrix, it does not include ephemeral ponds that were taken over by the river since the Mitchell report, ponds that are void of fish, or ponds known to contain only native fish. Similarly, ponds owned by landowners that declined to participate in the NNFC program were not included in the Table 6 cost estimate. Application of rotenone/$KMnO_4$ was the least expensive treatment scenario ($2,418,996) to control fish in all 551 riverside ponds, while the most costly scenario involved chlorine application preceded by pumping in an area where three-phase electricity was not available ($6,534,556) (Table 6). These cost estimates are based on chemical, supplies and labor in 1997 dollars, and therefore most likely underestimate future costs to control nonnative fish.

Field Sampling and Nonnative Fish Control Activities

Fish Sampling --- Of the 329 ponds that were investigated, 191 ponds contained fish. Of these 191 ponds, 147 ponds contained only nonnative fish, one pond contained only native fish, and 43 ponds contained both native and nonnative fish. Overall,

twenty-one nonnative fish species and three native fish species were collected (Table 7). Native fish represented only 1.5% of the total catch from the 191 sampled ponds. No endangered fish were sampled.

The most abundant fish species collected was fathead minnow (11,761) followed by green sunfish (5,509) (Table 7). Fathead minnow abundance exploded in a newly constructed wetland at Horsethief Canyon State Wildlife Area (HTSWA) in 2001 and accounted for 85% of all fathead minnows collected in ponds between 1996 and 2002. If the HTSWA wetland fish data are not considered, green sunfish (5,509) was the most abundant fish species collected during the study followed by black bullhead (1,844) and fathead minnow (1,761).

Brook stickleback, a fish species prohibited from introduction into Colorado State waters by CDOW regulation, was also collected and reported by the landowner to have been stocked concurrently with a shipment of fathead minnow into a pond adjacent to the Gunnison River. Several species, including grass carp, red shiner, creek chub, plains killifish, yellow perch, walleye, and bluehead sucker were captured in ponds along the Colorado River, but these species were not collected from ponds along the Gunnison River (Tables 8, 9). Smallmouth bass and walleye were rarely collected. Green sunfish was the most prevalent nonnative fish species and was sampled in 126 (66%) of the 191 ponds that contained fish (Table 10). Similarly, largemouth bass was present in 82 (43%) of the 191 ponds. Green sunfish (Figures 2, 3, 4) and largemouth bass (Figures 5, 6, 7) were most commonly collected between the towns of Palisade and Loma where the highest concentration of riverside ponds in the study area existed.

Table 6. Estimation of cost to remove nonnative fish from ponds along the Colorado River from Rifle to the Colorado/Utah state line and the Gunnison River from Austin to the confluence with the Colorado River. Best-case cost estimates reflect the cost to apply rotenone/$KMnO_4$ while worst-case cost estimates reflect the cost to apply chlorine after pumping with a pump powered by a gas generator (where three-phase electricity is not available). Both best- and worst-case scenario cost estimates are based on chemical, supplies, and labor in 1997 dollars.

Position in floodplain	Ownership	Colorado River				Gunnison River				Total cost for both rivers			
		Number of ponds	Surface acres	Worst case scenario	Best case scenario	Number of ponds	Surface acres	Worst case scenario	Best case scenario	Number of ponds	Surface acres	Worst case scenario	Best case scenario
Unknown	Private	1	1	$6,737	$3,897	20	42	$213,091	$85,447	21	43	$219,828	$89,344
0-50 year floodplain	Private	164	665	$2,607,507	$786,678	27	57	$278,637	$114,125	191	722	$2,886,144	$900,803
	Public	37	166	$623,625	$181,688	10	9	$75,057	$39,493	47	175	$698,682	$221,181
	Municipal	37	90	$416,039	$159,876	9	39	$151,012	$44,051	46	129	$567,051	$203,927
50-100 year floodplain	Private	71	110	$658,299	$292,815	5	5	$35,533	$19,646	76	115	$693,832	$312,461
	Public	11	27	$121,673	$47,553	2	1	$13,386	$7,779	13	28	$135,059	$55,332
	Municipal	16	20	$132,889	$64,596	0	0	$0	$0	16	20	$132,889	$64,596
100+ year floodplain	Private	91	114	$783,985	$370,098	16	24	$136,770	$64,691	107	138	$920,755	$434,789
	Public	11	10	$82,889	$43,408	1	1	$6,619	$3,876	12	11	$89,508	$47,284
	Municipal	10	23	$98,826	$41,724	12	12	$91,982	$47,555	22	35	$190,808	$89,279
Entire Floodplain	Private	327	890	$4,056,528	$1,453,488	68	128	$664,031	$283,909	395	1,018	$4,720,559	$1,737,397
	Public	59	203	$828,187	$272,649	13	11	$95,062	$51,148	72	214	$923,249	$323,797
	Municipal	63	133	$647,754	$266,196	21	51	$242,994	$91,606	84	184	$890,748	$357,802
Total	All owners	449	1226	$5,532,469	$1,992,333	102	190	$1,002,087	$426,663	551	1,416	$6,534,556	$2,418,996

Table 7. Total number of fish collected between 1996 and 2002 in 191 ponds that contained fish and are adjacent to the Colorado River between Rifle and the Colorado/Utah state line, and Gunnison River between Austin and the confluence with the Colorado River.

Fish species	Total number of fish collected from ponds							Total
	1996	1997	1998	1999	2000	2001	2002	
Nonnative fish								
Grass carp				4	8		1	13
Red shiner	10			3				13
Common carp	20	10	549	285	38	394		1296
Sand shiner	37		5	9	1	100		152
Fathead minnow	41	45	634	316	603	10122		11761
Redside shiner		97	63	50	65	1		276
Creek chub					3	8		11
White sucker	45	10	81	491	376	74		1077
Black bullhead	85	103	519	482	643	12		1844
Channel catfish			4	110	13	10		137
Trout		1	2		21	24		48
Plains killifish		8	312					320
Mosquitofish			138	187	166	11		502
Brook stickleback				8				8
Green sunfish	85	631	986	2421	822	561	3	5509
Bluegill		12	126	386	282	47		853
Smallmouth bass			3					3
Largemouth bass	17	77	106	332	201	49	3	785
Black crappie	3	9	12	262	50	20		356
Yellow perch			29			11		40
Walleye				2				2
Nonnative total	343	1003	3569	5348	3292	11444	7	25006
Native fish								
Roundtail chub	18	0	27	9	70	27	0	151
Bluehead sucker	0	0	2	1	5	25	0	33
Flannelmouth sucker	2	0	31	60	105	5	0	203
Native total	20	0	60	70	180	57	0	387
Grand Total	363	1003	3629	5418	3472	11501	7	25393

Table 8. Total number of fish collected between 1996 and 2002 in 164 ponds that contained fish and are adjacent to the Colorado River between Rifle and the Colorado/Utah state line.

Fish species	Total number of fish collected from ponds							Total
	1996	1997	1998	1999	2000	2001	2002	
Nonnative fish								
Grass carp				4	8		1	13
Red shiner	10			3				13
Common carp	18	6	544	277	38	378		1261
Sand shiner			4	9	1	100		114
Fathead minnow	1	45	632	87	603	10059		11427
Redside shiner		97	63	44	65	1		270
Creek chub					3	8		11
White sucker	37	10	74	474	376	74		1045
Black bullhead	85	103	491	477	643	5		1804
Channel catfish			4	109	13	10		136
Trout			2		21	22		45
Plains killifish		8	312					320
Mosquitofish			138	179	166	11		494
Brook stickleback								0
Green sunfish	24	419	796	2375	822	328	3	4767
Bluegill		12	125	386	282	47		852
Smallmouth bass			2					2
Largemouth bass	17	77	106	259	201	44	3	707
Black crappie	3	8	12	262	50	20		355
Yellow perch			29			11		40
Walleye				2				2
Nonnative total	195	785	3334	4947	3292	11118	7	23678
Native fish								
Roundtail chub	0	0	6	9	70	27	0	112
Bluehead sucker	0	0	2	1	5	25	0	33
Flannelmouth sucker	2	0	31	57	105	5	0	200
Native total	2	0	39	67	180	57	0	345
Grand Total	197	785	3373	5014	3472	11175	7	24023

Table 9. Total number of fish collected between 1996 and 2002 in 27 ponds that contained fish and are adjacent to the Gunnison River between Austin and the confluence with the Colorado River.

Fish species	Total number of fish collected from ponds							Total
	1996	1997	1998	1999	2000	2001	2002	
Nonnative fish								
Grass carp								0
Red shiner								0
Common carp	2	4	5	8		16		35
Sand shiner	37		1					38
Fathead minnow	40		2	229		63		334
Redside shiner				6				6
Creek chub								0
White sucker	8		7	17				32
Black bullhead			28	5		7		40
Channel catfish				1				1
Trout		1				2		3
Plains killifish								0
Mosquitofish				8				8
Brook stickleback				8				8
Green sunfish	61	212	190	46		233		742
Bluegill			1					1
Smallmouth bass			1					1
Largemouth bass				73		5		78
Black crappie		1						1
Yellow perch								0
Walleye								0
Nonnative total	148	218	235	401	0	326	0	1328
Native fish								
Roundtail chub	18		21					39
Bluehead sucker								0
Flannelmouth sucker				3				3
Native total	18	0	21	3	0	0	0	42
Total	166	218	256	404	0	326	0	1370

Table 10. Incidence of fish species in 191 ponds known to contain fish that are located along the Colorado River between Rifle and the Colorado/Utah state line and along the Gunnison River between Austin and the confluence with the Colorado River.

Fish species	Number of ponds where nonnative and native fish species were present		
	Colorado River	Gunnison River	Total
Nonnative fish			
Grass carp	6	2	8
Red shiner	2		2
Common carp	59	7	66
Sand shiner	6	2	8
Fathead minnow	25	11	36
Redside shiner	13	1	14
Creek chub	2		2
White sucker	71	6	77
Black bullhead	58	5	63
Channel catfish	15	1	16
Trout	10	2	12
Plains killifish	4		4
Mosquitofish	21	1	22
Brook stickleback		1	1
Green sunfish	111	15	126
Bluegill	44	1	45
Smallmouth bass	1	1	2
Largemouth bass	77	5	82
Black crappie	34	1	35
Yellow perch	6		6
Walleye	1		1
Native fish			
Roundtail chub	16	1	17
Bluehead sucker	9		9
Flannelmouth sucker	33	2	35

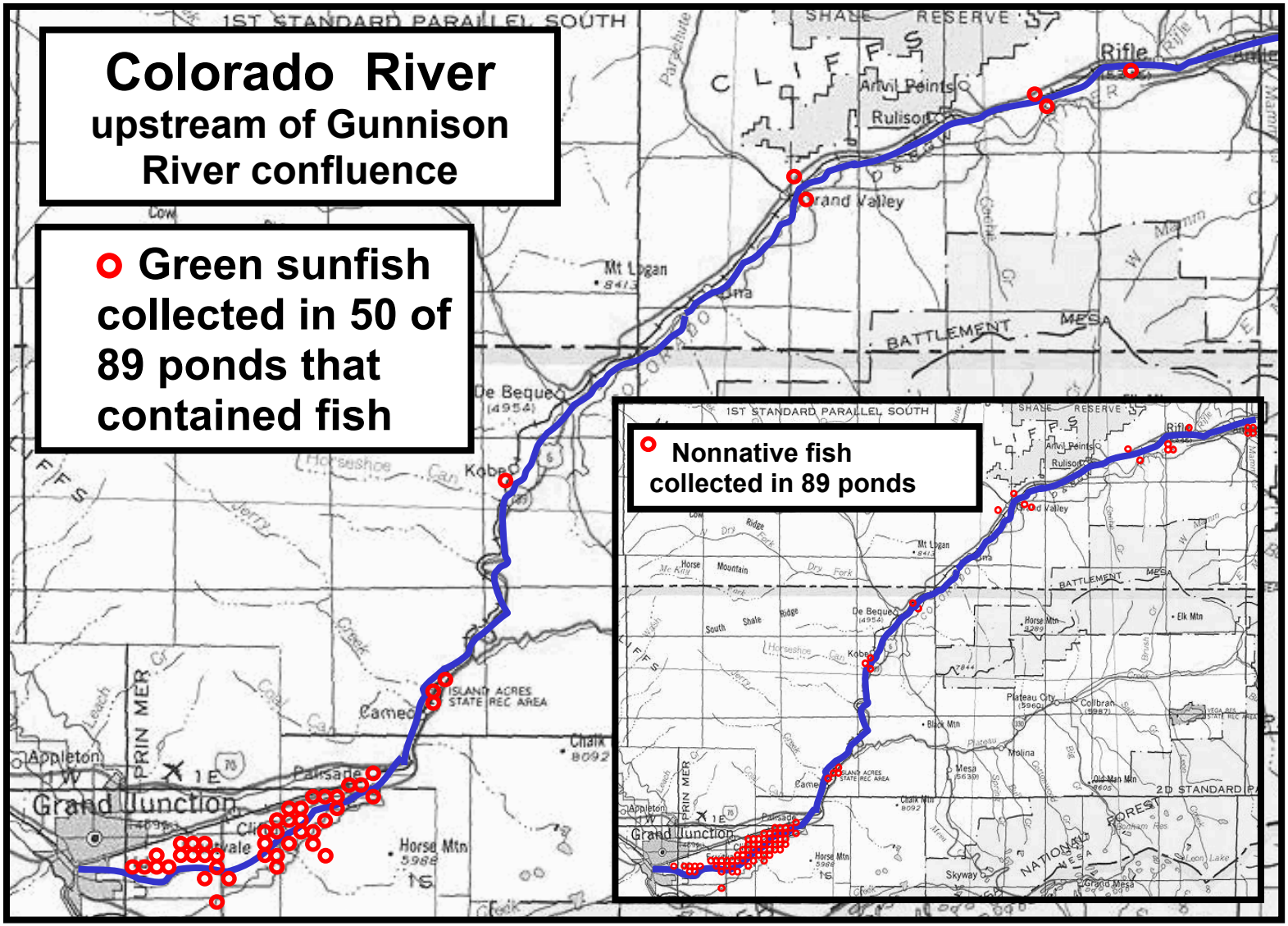

Figure 2. Distribution and number of riverside ponds that contained green sunfish and are located along the Colorado River upstream of the Gunnison River confluence and downstream of Rifle, CO.

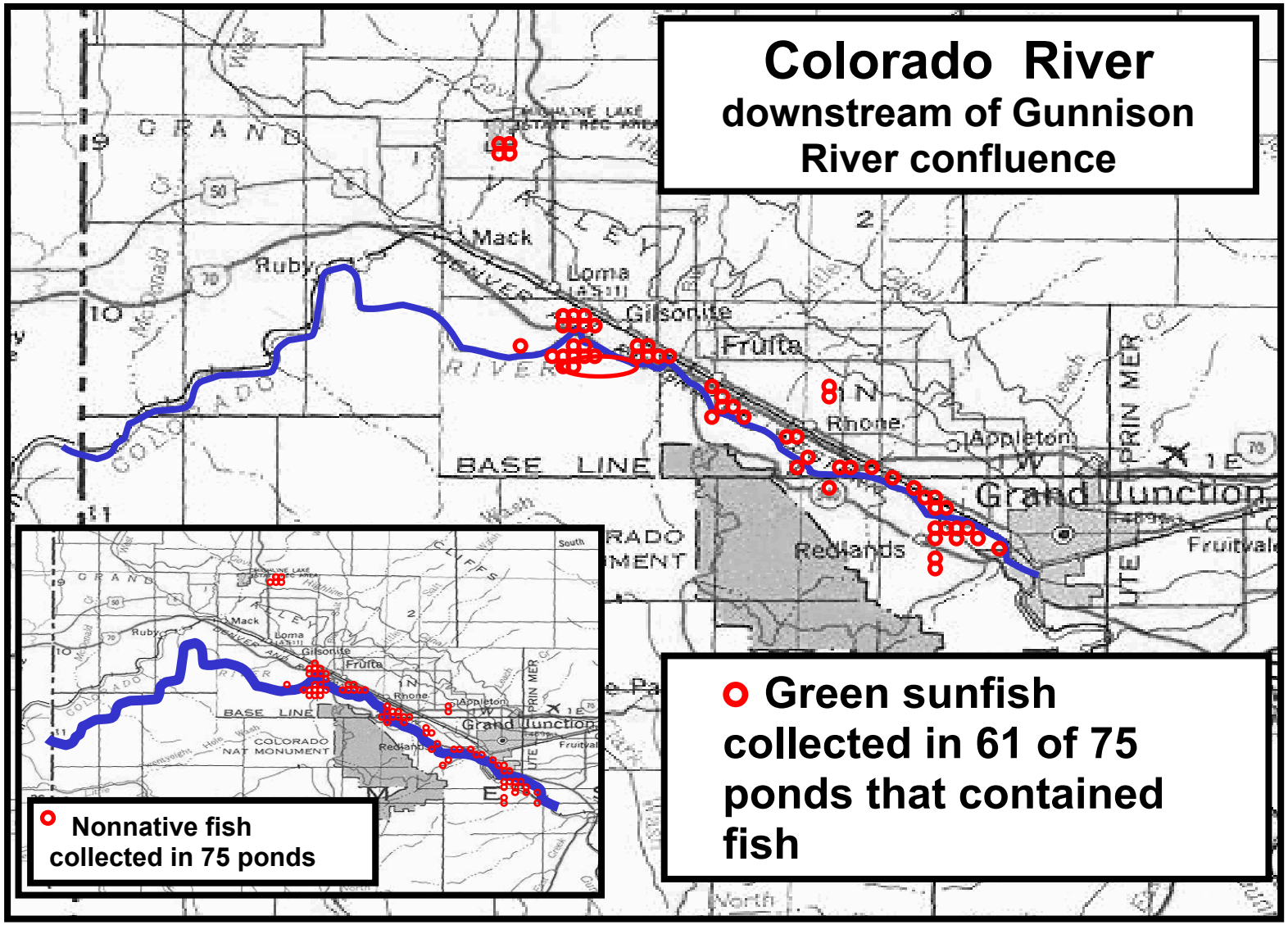

Figure 3. Distribution and number of riverside ponds that contained green sunfish and are located along the Colorado River downstream of the Gunnison River confluence and upstream of the Colorado/Utah state line.

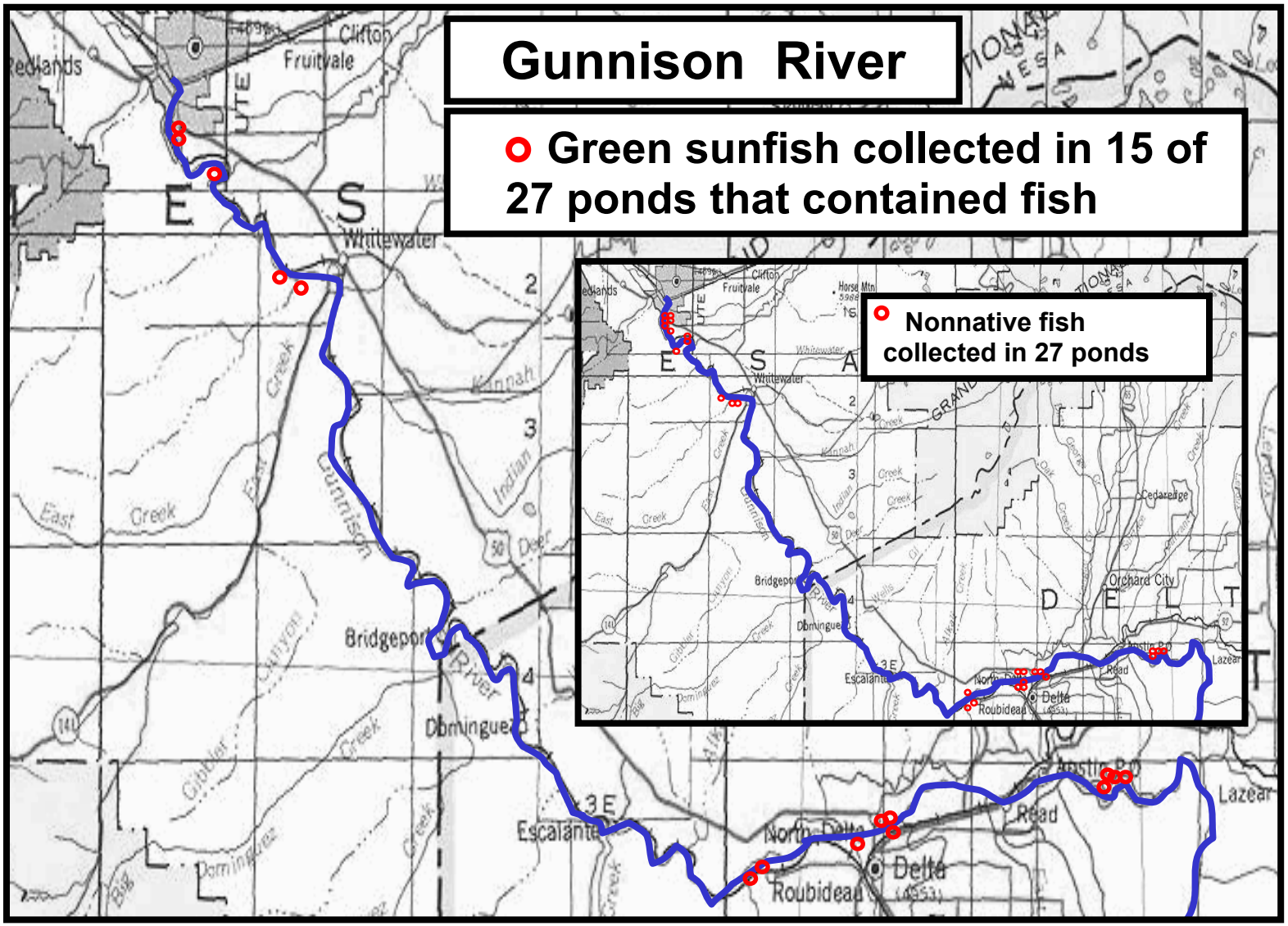

Figure 4. Distribution and number of riverside ponds that contained green sunfish and are located along the Gunnison River downstream of Austin, CO and upstream of the Gunnison River confluence with the Colorado River.

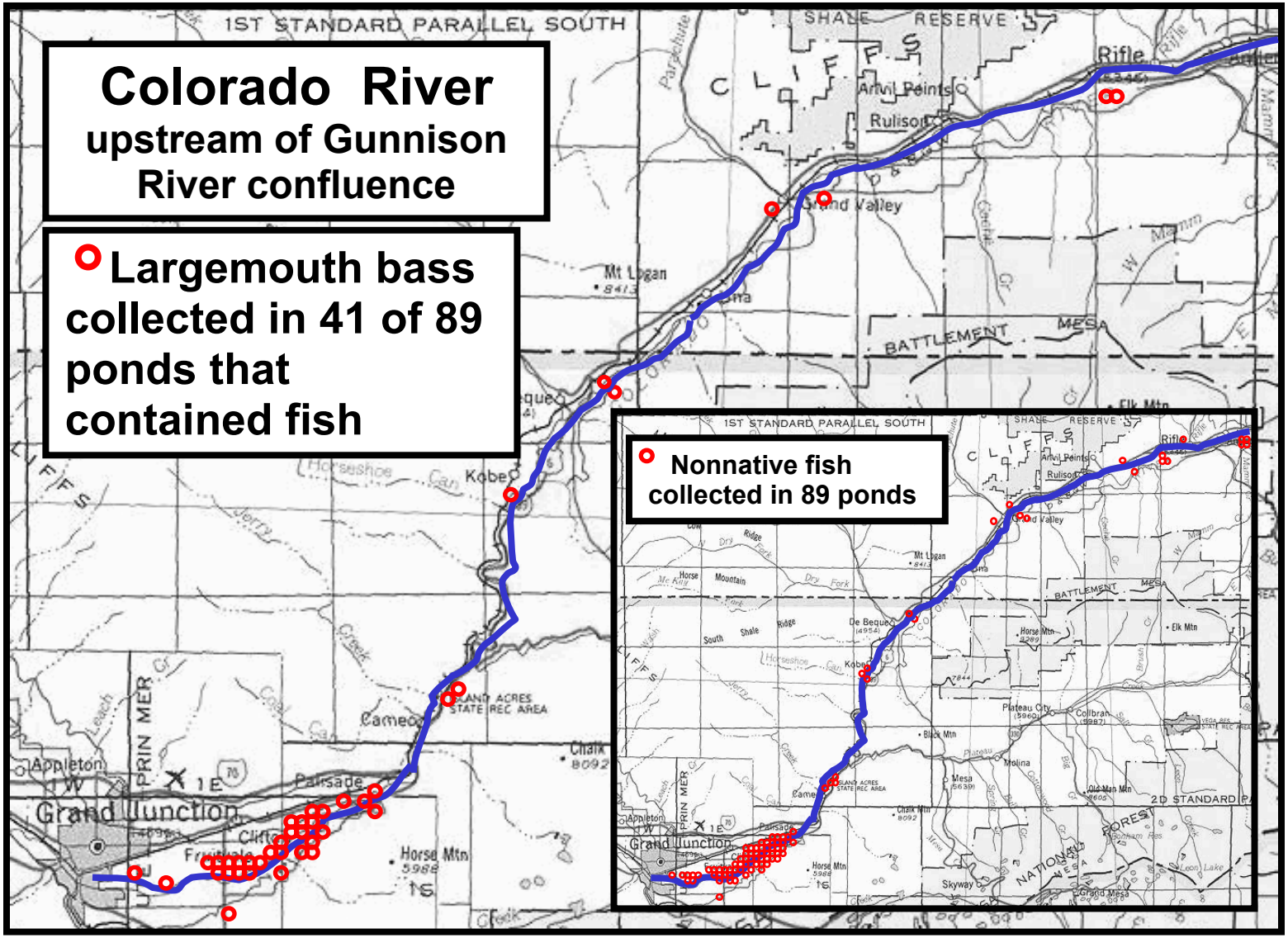

Figure 5. Distribution and number of riverside ponds that contained largemouth bass and are located along the Colorado River upstream of the Gunnison River confluence and downstream of Rifle, CO.

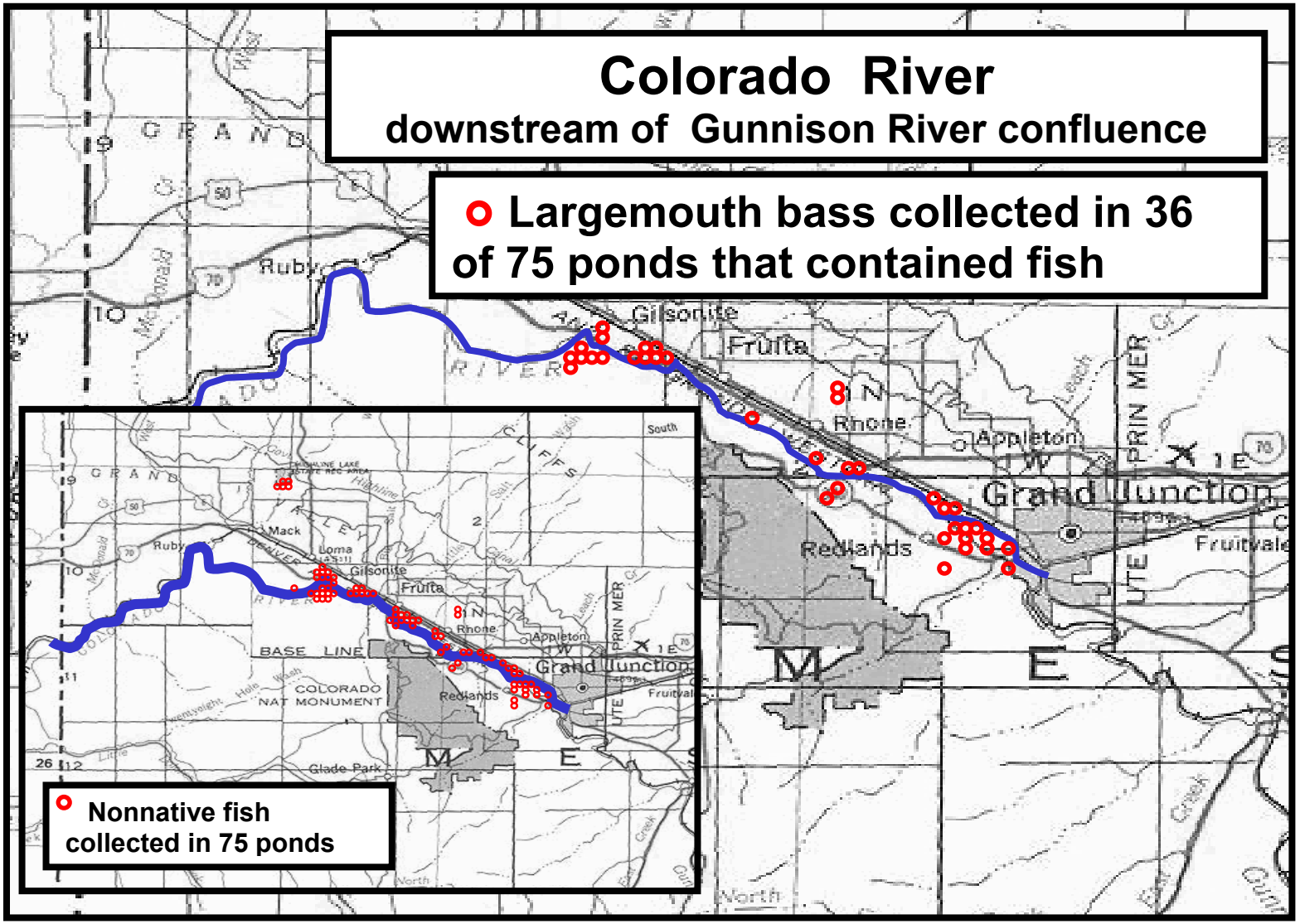

Figure 6. Distribution and number of riverside ponds that contained largemouth bass and are located along the Colorado River downstream of the Gunnison River confluence and upstream of the Colorado/Utah state line.

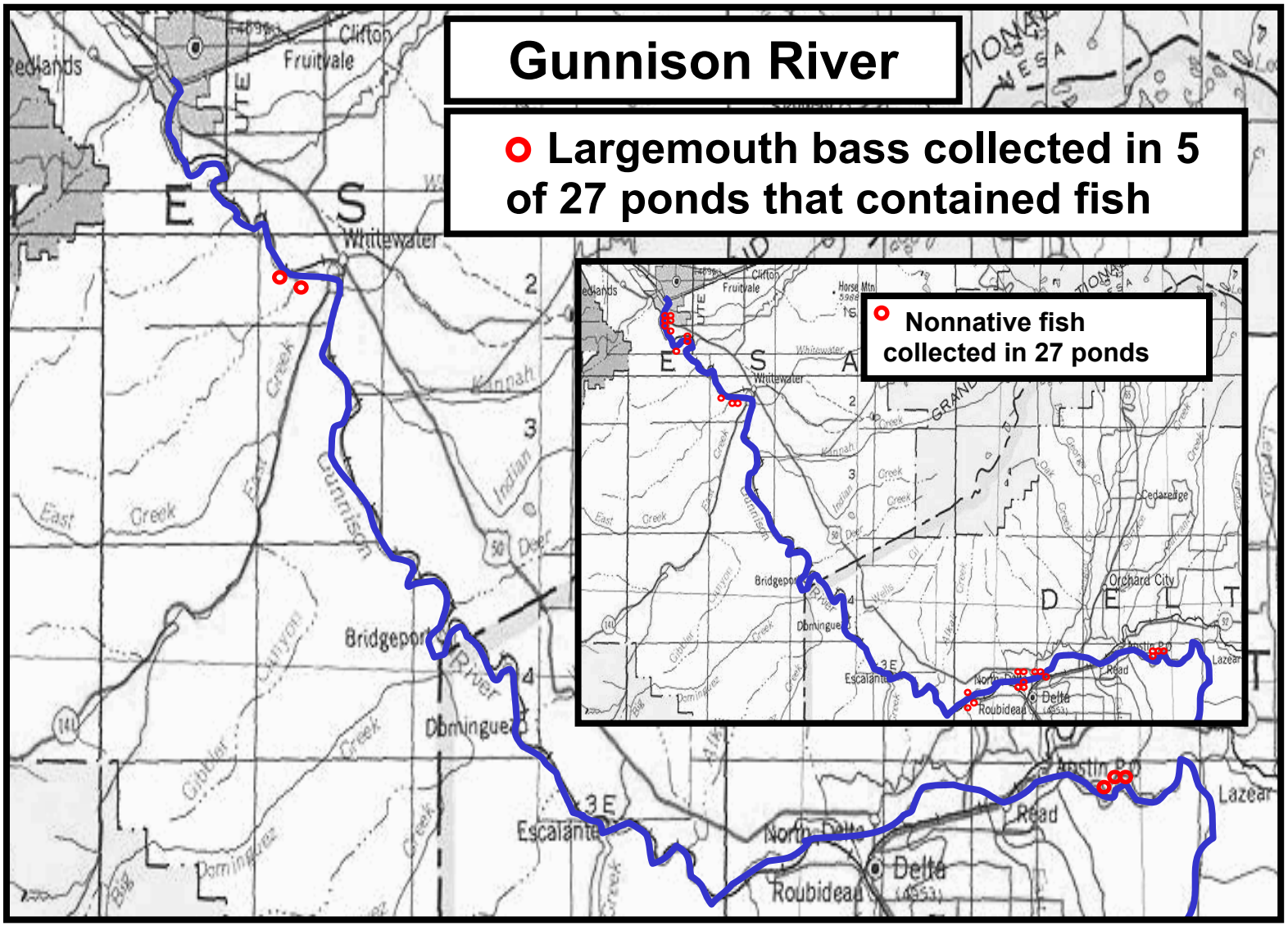

Figure 7. Distribution and number of riverside ponds that contained largemouth bass and are located along the Gunnison River downstream of Austin, CO and upstream of the Gunnison River confluence with the Colorado River.

Total length and frequency of all fish that were measured are reported in Table 11. The following fish spanned many of the 26 length categories: common carp (25 categories), largemouth bass (25), white sucker (24), and flannelmouth sucker (23). Green sunfish were most abundant in the 6-8 cm length category.

Native Fish Salvage -- To address a concern expressed by citizens during the environmental assessment phase of the NNFC program (USFWS 1998a) regarding the impact of nonnative fish removal on the availability of food for piscivorous birds, native fish were removed from the Government Highline Canal (GHC) at the Lewis Wash siphon in 1999, 2000, 2001 and 2002 and stocked into a native fish refuge (1999), an isolated oxbow on the Colorado River (2000) and/or directly into the Colorado River (2000, 2001, 2002). Our intent was to use the native fish in this refuge as a source of fish to stock reclaimed ponds, thus providing prey items for piscivorous birds. However, establishment of additional fish refuge ponds did not occur because potential stocking sites were either stocked with listed fish species, reinvaded with nonnative fish species, or access was denied. The abundance of native fish collected in November in each of these years from the Lewis Wash siphon varied widely with 550, 12,300, 12,000, and <1000 collected in 1999, 2000, 2001 and 2002, respectively (Table A-1).

The species composition of the 550 native fish collected in 1999 comprised approximately 63% (347) roundtail chub, 33% (181) flannelmouth sucker, and 4% (22) bluehead sucker. These fish were stocked in a previously reclaimed pond owned by the Bureau of Land Management (BLM) near Rulison, Colorado on November 17, 1999. Follow-up sampling of this reclaimed pond in July of 2000 indicated the native fish had grown and at least one of the three native fish species (though unidentified) had reproduced.

Nonnative Fish Control --- Several techniques were used to control fish in 86 ponds Table 12, Figures 8, 9, 10). The most commonly used control technique was chemical reclamation (69 ponds) followed by screen installation (2 inlet screens and 13 outlet screens).

Table 11. Total length and frequency of fish collected between 1996 and 2002 in 191 ponds that contained fish and are adjacent to the Colorado and Gunnison rivers (GCP-grass carp, RDS-red shiner, CPP-common carp, SAH-sand shiner, FHM-fathead minnow, RSS-redside shiner, CRC-creek chub, WHS-white sucker, BBH-black bullhead, CCF-channel catfish, TRT-trout, PKF-plains killifish, MSQ-mosquitofish, BST-brook stickleback, SNF-green sunfish, BGL-bluegill, SMB-smallmouth bass, LMB-largemouth bass, BCR-black crappie, YPE-yellow perch, RTC-roundtail chub, BHS-bluehead sucker, FMS-flannelmouth sucker).

Total length (cm)	Frequency of nonnative fish																				Frequency of native fish		
	GCP	RDS	CPP	SAH	FHM	RSS	CRC	WHS	BBH	CCF	TRT	PKF	MSQ	BST	SNF	BGL	SMB	LMB	BCR	YPE	RTC	BHS	FMS
0-2					25	4			1			3	66		56								
2-4			54	13	220	42		10	45			54	246	8	569	32		16			2		2
4-6		10	78	30	802	159	2	2	65	3		94	50		883	8		55			3		
6-8		1	88	4	533	19	1	3	34			113	11		926	41		58	5		8		
8-10		2	105		74	1			181			54			869	45		56	14	4	1		2
10-12			37				7	22	107			1			190	86		45	6	1	26	1	12
12-14			35				1	7	64						326	290		43	35	2	28	1	6
14-16			31					6	92						339	149		13	115		10		3
16-18			18					19	268	1					124	77		14	72	3	1	4	2
18-20			14					17	260						91	19		45	72	3		1	1
20-22			20					45	311						79	7	2	36	11	3	5	3	3
22-24			14					138	127		1				30	6		33	3	6	3	8	5
24-26			9					168	155		1				11	2		22	10	4	3	6	5
26-28			11					122	52	2	3					1		42	4		1	3	2
28-30			5					91	30		1					1		57	6	12	1		6
30-32			11					86	16	3	2							35		2	3	2	8
32-34			20					64	9		2							27			3	2	8
34-36			26					71	11	3	4							40	1		7		7
36-38			32					79	4	2	8						1	36			5	1	13
38-40			39					66		5	5							30			9		12
40-42			53					29		2	4							22			2	1	31
42-44			128					17		3								16			1		18
44-46			173					7		3	1							17					12
46-48			96					2		1								6					6
48-50			52					2		4	1							4					14
≥ 50	2		102					2		8	2							7					25
Total	2	13	1251	47	1654	225	11	1075	1832	40	35	319	373	8	4493	764	3	775	354	40	122	33	203

Table 12. Number of riverside ponds located along the Colorado River between Rifle and the Colorado/Utah state line and along the Gunnison River between Austin and the confluence with the Colorado River where various nonnative fish control techniques were employed from 1996 to 2002. Off-site screen refers to screens that control the movement of fish into or out of pond(s) from a distant upstream or downstream location.

Nonnative fish control technique(s)	Number of ponds		
	Colorado River	Gunnison River	**Total**
Chemical reclamation	35	9	44
Chemical reclamation + pumping	5	2	7
Chemical reclamation + screening	2	1	3
Chemical reclamation + pumping + screening	1		1
Chemical reclamation + off-site screen	10	1	11
Chemical reclamation + pumping + off-site screen	1		1
Chemical reclamation + pumping + screening + rerouting irrigation water	1		1
Chemical reclamation + off-site screen + water management	1		1
Screening	7		7
Off-site screen	8		8
Screen + black plastic	1		1
Water management	1		1
Total	73	13	86

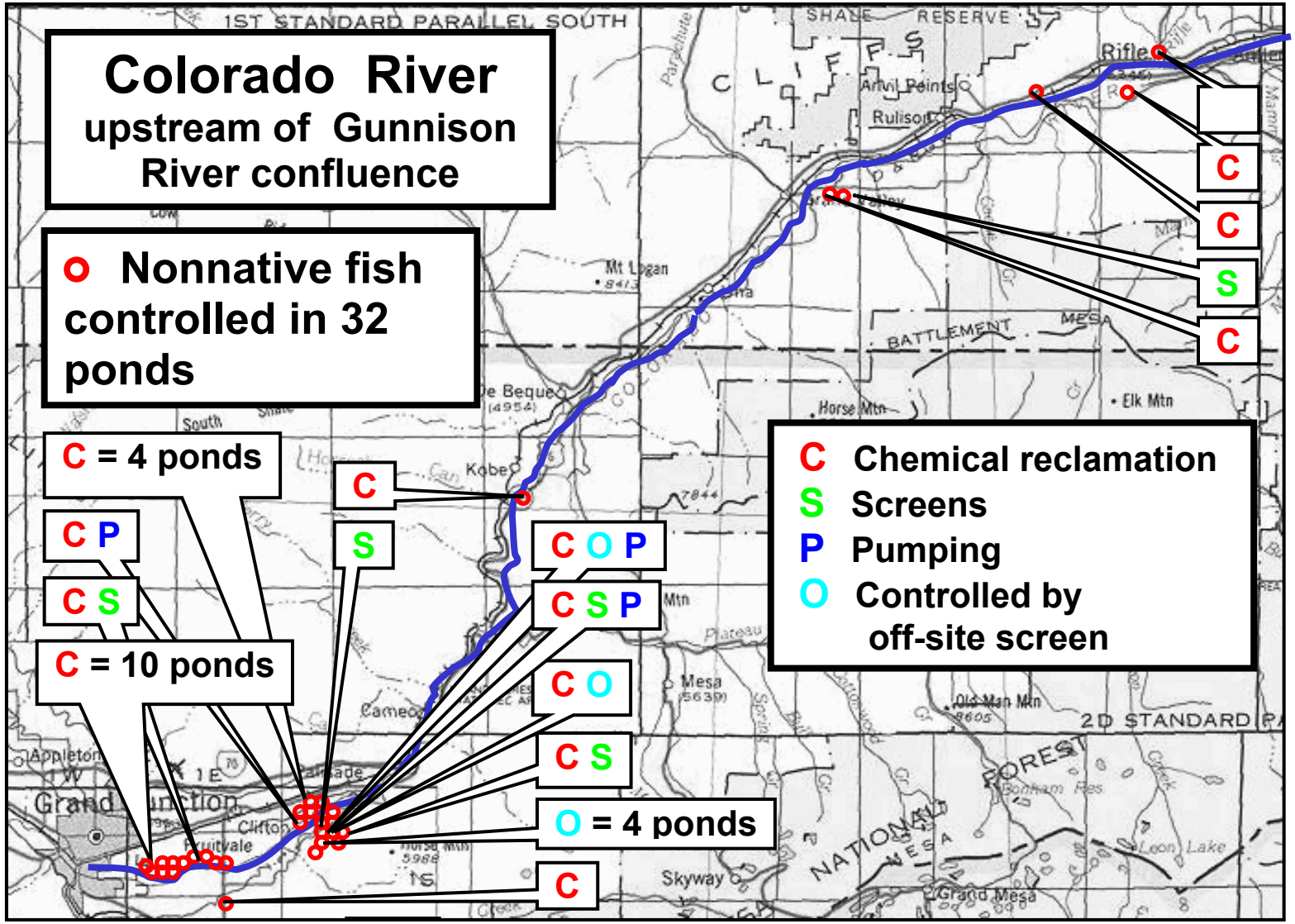

Figure 8. Nonnative fish control techniques used from 1996 to 2002 in riverside ponds that are located along the Colorado River upstream of the Gunnison River confluence and downstream of Rifle, CO. Off-site screen refers to screens that control the movement of fish into or out of pond(s) from a distant upstream or downstream location.

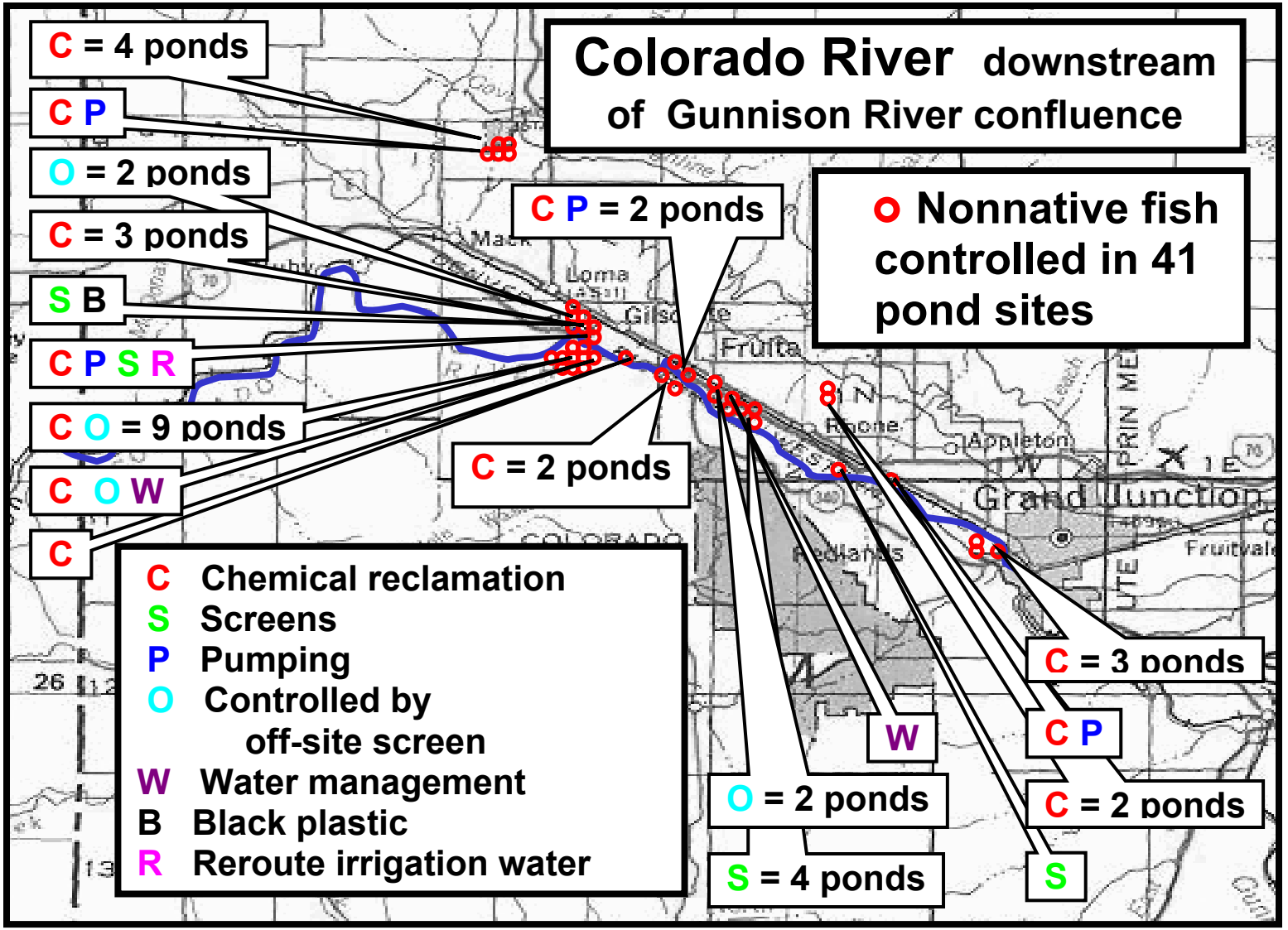

Figure 9. Nonnative fish control techniques used from 1996 to 2002 in riverside ponds that are located along the Colorado River downstream of the Gunnison River confluence and upstream of the Colorado/Utah state line. Off-site screen refers to screens that control the movement of fish into or out of pond(s) from a distant upstream or downstream location.

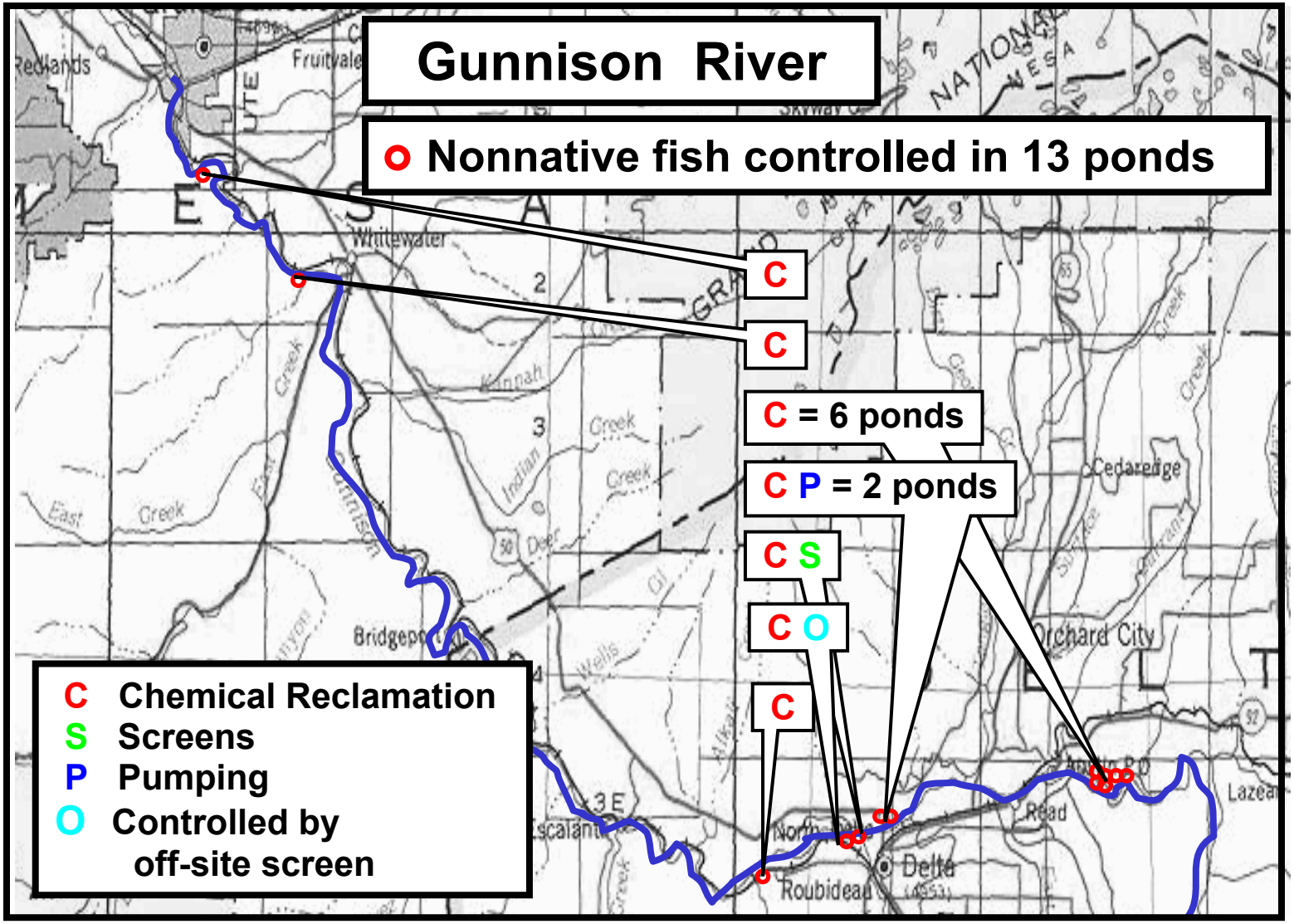

Figure 10. Nonnative fish control techniques used from 1996 to 2002 in riverside ponds that are located along the Gunnison River downstream of Austin, CO and upstream of the Gunnison River confluence with the Colorado River. Off-site screen refers to screens that control the movement of fish into or out of pond(s) from a distant upstream or downstream location.

Chemical Reclamation -- A USFWS *Biological Opinion* and a *Finding of No Significant Impact* determined that reclamations could occur year round without adverse affect to listed species (USFWS 1998b, USFWS 1998c). Sixty-nine ponds were chemically reclaimed with rotenone (66 ponds), chlorine (2 ponds), or both (1 pond – winter application of chlorine resulted in an incomplete fish kill, rotenone was then used the following summer and a complete fish kill was obtained). Chlorine was used instead of rotenone for winter reclamations because rotenone toxicity is diminished in colder water temperatures (Spitler 1986). Another pond reclamation using chlorine was not successful and resulted in an incomplete fish kill. Like the pond described above that was treated with chlorine and rotenone, this pond was treated a second time with chlorine and all fish were removed. An attempt was also made to induce a summer kill by applying an herbicide to ultimately create an oxygen deficit in the water column of two densely vegetated ponds. This was unsuccessful in both cases and rotenone was later applied. Endangered fish mortality was not observed following these 69 reclamations.

Re-invasion – In the 71 ponds where fish were removed, the most common fishes in terms of incidence (number of ponds containing species) were green sunfish, common carp, largemouth bass, and black bullhead (Table 13). Of the 71 ponds, 54 were later re-sampled to determine incidence of re-invasion. Of these 54 ponds, 35 (65%) had re-invaded with nonnative fish and two of the 35 also contained native fish. Some of the 35 ponds were sampled within three months of treatment and had re-invaded, while re-invasion of others occurred within 37 months post-reclamation (Table 14). However, the exact time of re-invasion for each of the 35 ponds is unknown. Re-invasion may have occurred immediately following detoxification of reclaimed ponds or just prior to re-sampling. Green sunfish and fathead minnow were present in 26 (74%) and 13 (37%), respectively, of the 35 re-invaded ponds (Table 15). Largemouth bass were only sampled in two of the 35 re-invaded ponds but were present in 28 of the 54 re-sampled ponds prior to treatment. Additional nonnative fish species that re-invaded one or more of the 35 ponds included common carp, goldfish, sand shiner, white sucker, black bullhead, and mosquitofish (Table 15). Nonnative fish

Table 13. Incidence of fish species in 71 ponds, located along the Colorado and Gunnison rivers, prior to nonnative fish control treatments (69 reclamations, 1 black plastic, 1 water management).

Fish Species	Colorado River	Gunnison River	**Total**
Nonnative Fish			
Grass carp	4	2	6
Red shiner	2		2
Common carp	32	7	39
Sand shiner	4	2	6
Fathead minnow	12	4	16
Redside shiner	10		10
White sucker	18	4	22
Black bullhead	23	4	27
Channel catfish	3	1	4
Trout	3	2	5
Plains killifish	2		2
Mosquitofish	3		3
Brook stickleback		1	1
Green sunfish	46	9	55
Bluegill	18		18
Smallmouth bass	1		1
Largemouth bass	32	4	36
Black crappie	13		14
Yellow perch	4		4
Native Fish			
Roundtail chub	2		2
Flannelmouth sucker	6	1	7

Table 14. Determination of the presence or absence of fish in 54 ponds, three to 38 months following removal of all fish through nonnative fish control treatments.

Number of Months from Control to Post-Treatment Sampling	Number of Ponds		
	Reinvaded	Void of Fish	Dry
3	3	1	
7	2		
8	5		1
9		1	
11	1		
12		1	
14			2
15	1		
16	1		
18	1	2	
21	3		
22		3	
23	1		
24	6		1
26	4	1	
31	5	2	
33	1		3
37	1		
38		1	
Total	35	12	7

Table 15. Incidence of fish species in 54 ponds prior to and following removal of all fish through nonnative fish control treatments. Of 54 ponds that were re-sampled following control treatments, 35 (29 – Colorado River and 6 – Gunnison River) had re-invaded with nonnative fish and two of the 35 also contained native fish.

Fish Species	Pre- Nonnative Fish Control			Post- Nonnative Fish Control		
	Colorado River	Gunnison River	Total	Colorado River	Gunnison River	**Total**
Nonnative Fish						
Grass carp		2	2			
Red shiner	1		1			
Common carp	25	6	31	1	1	2
Goldfish				1		1
Sand shiner	2	1	3	2		2
Fathead minnow	10	2	12	8	5	13
Redside shiner	9		9			
White sucker	12	3	15	1		1
Black bullhead	19	4	23	6		6
Channel catfish	2	1	3			
Trout	3	2	5			
Plains killifish	2		2			
Mosquitofish	2		2	1		1
Green sunfish	33	7	40	21	5	26
Bluegill	15		15			
Smallmouth bass	1		1			
Largemouth bass	25	3	28	2		2
Black crappie	10		10			
Yellow perch	4		4			
Native Fish						
Roundtail chub				2		2
Flannelmouth sucker	2	1	3	1		1

re-invasion often occurred via larval fish transported in irrigation water. An isolated 21 SA pond had re-invaded with sand shiners when river water was pumped into the pond for irrigation of lawns. Similarly, landowners have reported seeing larval fish in irrigation head boxes.

Screen Installation -- Inlet/outlet screens have the potential to control the movement of nonnative fish from floodplain ponds to critical riverine habitat. One screen that required minimal maintenance was installed below a pond outlet pipe (Figure 11). This screen was constructed of an expanded aluminum grate that was covered with window screen and supported on an aluminum frame. The screen was placed horizontally with a slight tilt in which the corner furthest from the outlet water was lower than the other three corners while the corner closest to the outlet water was higher than the other three corners. This tilt allowed debris to be pushed off the edge of the screen by the out- flowing water pressure. This screen effectively removed fish from the out flowing water and required little maintenance. A similarly constructed screen had a box design and was also placed below an outlet pipe (Figure 12). The effectiveness of this screen was not determined. An additional screen design, which was placed on a surface release outlet pipe, fouled frequently in spite of regular cleaning and was eventually removed from the outlet structure (Figure 13).

Two screens designed, constructed, and installed by Irrigation Systems Company of Western Colorado employed a gravel filter design (Figure 14) and a self-cleaning, rotating, flat plate screen design (Figure 15). Fouling was a concern with the gravel screen when it was first installed due to excessive filamentous algae and small gravel size (1”). To rectify this situation, the gravel was removed, larger cobbles (3”-4”) were installed, and a fence was placed approximately five feet from the screen to reduce fouling of the screen by floating algae. The flat plate screen had been designed for irrigation ditches and used solar energy as a power source. Moving parts included a rotating brush with two heads and a perforated flat-plate screen. Both screens were installed in the summer of 2000 and functioned well in 2001 and 2002.

Shearing wedgewire screens (also known as Coanda screens) were installed on the inlet water to Horsethief Canyon State Wildlife Area’s (HTSWA) fields, waterfowl ponds, wetland (Figure 16) and endangered fish grow-out ponds (Figure 17). These

Figure 11. An outlet screen constructed of window screen covering an expanded aluminum grate was supported on an aluminum frame and mounted at a slight tilt off horizontal.

Figure 12. A box screen constructed of window screen covering an expanded aluminum grate was supported on an aluminum frame and placed below a pond outlet.

Figure 13. Frequent fouling of a surface release outlet screen resulted in its removal from the outlet structure.

Figure 14. Gravel filter screen used on the outlet structure of a pond with a jurisdictional dam required an unobstructed outlet (tube in center of gravel) in the event the screen failure. This screen was designed, constructed, and installed by Irrigation Systems Company of Western Colorado (Fruita, CO).

Figure 15. Self-cleaning, rotating, flat-plate screen was used on the outlet of a small farm pond. This screen was designed, constructed, and installed by Irrigation Systems Company of Western Colorado (Fruita, CO).

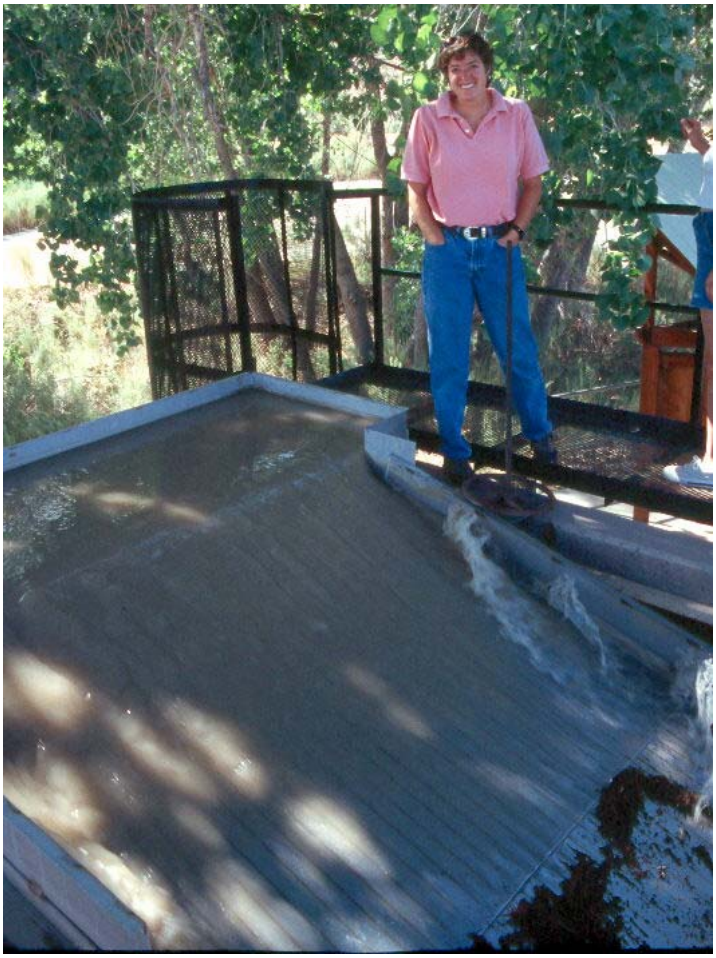

Figure 16. Large shearing wedgewire screen used on the inlet structure to Horsethief Canyon State Wildlife Area's fields, waterfowl ponds, and wetland. This screen was designed and installed by Aquadyne Inc. (Healdsburg, CA).

Figure 17. Small shearing wedgewire screen used on the inlet water to Horsethief Canyon State Wildlife Area's threatened and endangered fish grow-out ponds. This screen was designed by Aquadyne Inc. (Healdsburg, CA).

screens impede the movement of nonnative fish into 10 reclaimed waterfowl ponds/wetlands, and six T&E grow-out ponds. The aperture of these screens was 0.5mm (Figure 18) and the tilt of the wire was five degrees, which imparts a shearing effect. Fouling was a significant problem with the larger screen used on the field, pond, and wetland inlet. It was installed at too shallow of an angle (15 degrees) on the intake box to impart a self-cleaning effect (Figure 19). This screen required cleaning at least once a day depending on the debris load in the river. However, the smaller screen on the inlet water to the endangered fish ponds was set at a 45 degree angle, and has required no maintenance (Figure 20). We observed larval fish impinged on the large intake screen (Figure 21). However, green sunfish, fathead minnow, common carp, and mosquitofish (in order of incidence) were also sampled in ponds on the property following reclamations, and are believed to have passed through this intake screen as larvae. Similarly, larval/juvenile fathead minnow and red shiner were sampled in the endangered fish ponds after they had been emptied, dried and refilled with screened inlet water (Figure 22).

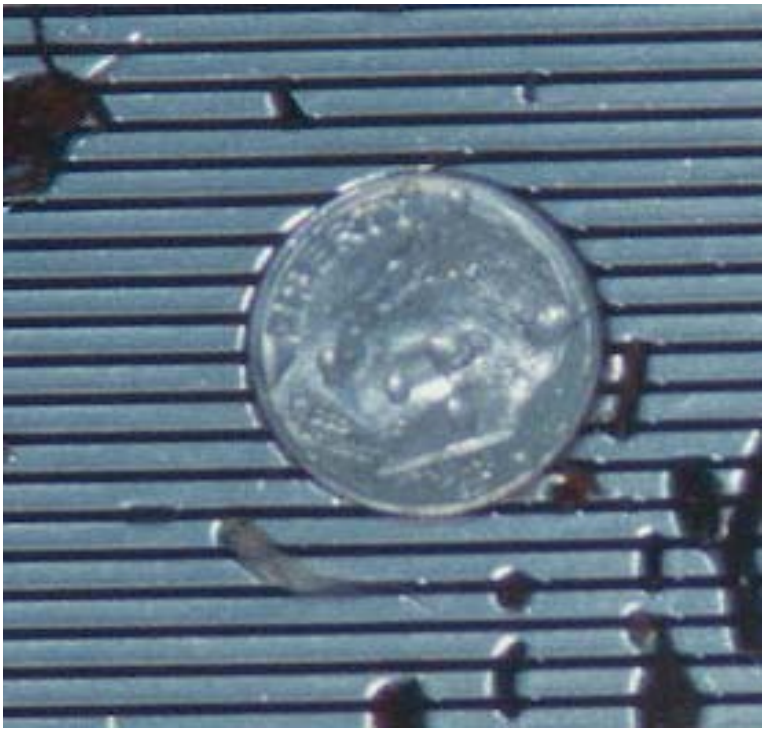

Figure 18. Close-up view of a wedgewire screen with a 0.5mm aperture. Both inlet screens at Horsethief Canyon State Wildlife Area, (Fruita, CO) were constructed of wedgewire. Each wire was tilted at a five degree angle to impart a shearing effect.

Figure 19. Daily cleaning was required on the large shearing wedgewire screen that was installed at a 15 degree angle on the inlet to the fields, waterfowl ponds, and wetland at Horsethief Canyon State Wildlife Area (Fruita, CO).

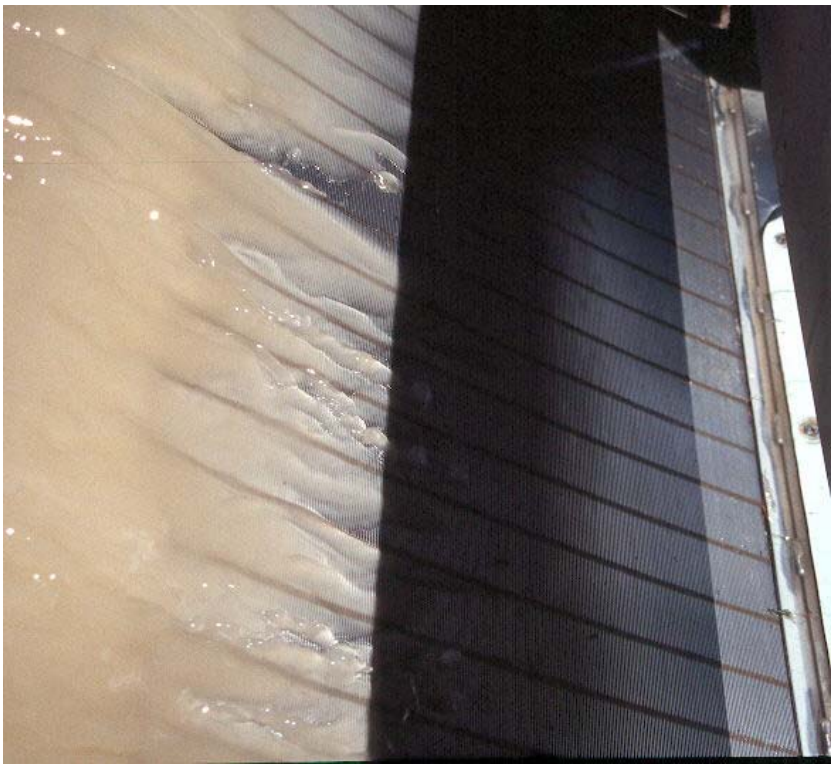

Figure 20. No maintenance was required on the small shearing wedgewire screen that was installed at a 45 degree angle on the inlet to the threatened and endangered fish grow-out ponds at Horsethief Canyon State Wildlife Area (Fruita, CO).

Figure 21. Size of larval fish found impinged on the large shearing wedgewire screen installed on the inlet to the fields, waterfowl ponds, and wetland at Horsethief Canyon State Wildlife Area (Fruita, CO). Dime used for scale.

Figure 22. Juvenile fathead minnow captured in an endangered fish grow-out pond at Horsethief Canyon State Wildlife Area (Fruita, CO).

Alternate Nonnative Fish Control Techniques -- Water management, which utilized an annual cycle of filling and drying of ponds, was investigated as another possible NNFC technique. This technique was not successful at HTSWA where the high water table did not allow annual drying in spite of reshaping a pond to make it shallow. When irrigation water no longer flowed to this pond, the water depth decreased to approximately 2”-3”. Given these conditions, winter kill was expected, but did not occur. Water management was successful in another pond located higher in the floodplain where a fall/winter drying cycle eliminated all fish that were present.

Another NNFC treatment utilized black plastic (Figure 23). A landowner expressed a desire to remove dense aquatic vegetation and a stunted green sunfish population from his 0.5 surface acre pond without the use of chemicals. To accomplish this, black plastic was laid over the surface of the pond for two weeks in August, the hottest part of the summer. All green sunfish and the aquatic vegetation were successfully removed using this technique. Increased water temperature, reduced oxygen or both may have contributed to the death of the fish.

Re-routing irrigation water away from a reclaimed pond was another NNFC technique used to prevent re-invasion by inlet water laden with larval fish (this pond has spring water as an alternate water source). Unfortunately, nonnative fish were sampled in this pond post-reclamation. The presence of fish either resulted from failure of the reclamation to kill all fish and/or re-invasion from neighboring ponds.

Figure 23. Black plastic was used as an alternative to chemical reclamations. It was spread over the surface of a 0.5 surface acre pond to remove a stunted green sunfish population and excessive filamentous algae.

Information and Education

Both the Recovery Program and the CDOW recognized the need to disseminate information concerning nonnative fish control due to several misconceptions and concerns held by various publics regarding: 1) the use of fish toxicants and their impact on non-target wildlife; 2) the perceived loss of fishing opportunity; 3) the source of revenue used in the NNFC effort; 4) the feared loss of landowner rights if endangered fish were collected in privately owned ponds; 5) the alleged value of sport fish over that of native fish; and 6) the impact of the recently adopted CDOW west slope nonnative fish stocking regulation on private fish vendors (CDOW et al. 1996). The Recovery Program and CDOW provided funding for the following information and education efforts to address these concerns.

The Institute for Participatory Management and Planning (1997) described a consent building tool called a Responsiveness Summary / Listening Log. This technique was employed to inform all interested parties of nonnative fish control activities. In an effort to be more responsive and to communicate to as many interested parties as possible the following Listening Log "rules" were provided to affected interests in the first mailing:

1) Any input, concerns, questions, or criticisms are welcome. Public comments such as letters to the editor, articles in sport magazines, and remarks at public meetings will also be included in the "Listening Log".
2) All input will be recorded in the "Listening Log".
3) All input must be accompanied by the name of the person providing the input. Anonymous input will neither be considered nor will it receive a response.
4) Input may be verbal or written.
5) All participants in the "Listening Log" will receive a copy of all comments, name of individual who made the comment, and CDOW's response.
6) Participants in the "Listening Log" may be added or deleted at any time upon their request.
7) All input should be directed to my (the author's) attention at the phone number, FAX, email, or address provided.
8) Second hand input will not be accepted to prevent distortion of original comments.
9) Future mailings of the "Listening Log" may be sporadic and depends entirely on citizen participation.

This process also provided a venue for individuals to share their support, concerns, or objections regarding nonnative fish control with all Listening Log recipients. Responses to concerns or objections were also provided to all Listening Log participants. Eight editions of the Listening Log were distributed between 1998 and 2001 to a variety of interested parties including: private landowners; legislators; sportsmen, sportsmen clubs, and sporting good stores; local, county, state, and federal government personnel; private aquaculturists; environmental groups; and the local Grand Junction newspaper (the "Daily Sentinel"). The number of individuals/organizations receiving the Listening Log in each mailing ranged from 439 to 498 over the four years. The Listening Log mailing list was also used to distribute four editions of "Swimming Upstream" (Winter 1999, Fall 2000, Winter 2001, Winter 2002), the Upper Colorado River Endangered Fish Recovery Program newsletter.

KJCT (Channel 8), a local Grand Junction television station, aired eight "Bill's Backyard's" (a television news segment concerning CDOW wildlife activities) between 1998 and 2001 addressing recovery of endangered fishes. The topics included: 1) protecting endangered fish while providing a pond sport fishery in Fruita (7/26/98); 2) acquiring easements for razorback sucker grow-out ponds (6/13/99); 3) stocking bluegill in Highline Lake and the Highline Lake Screen (8/29/99); 4) using filter screens to prevent the movement of nonnative fish out of riverside ponds (7/9/00); 5) re-introducing bonytail in Dinosaur National Park (7/16/00); 6) contributing to the nongame checkoff benefits endangered fish (3/31/01); 7) stocking bonytail by the CDOW (4/21/01); and 8) the Redlands Fish Ladder (8/25/01). Two additional news stories were aired on KKCO (Channel 11) on July 11, 2001 and KREX (Channel 5) on July 12, 2001 concerning the impact of low water levels on endangered fish. Similarly, on August 28, 1998, Colorado Public Radio reported the benefits of nonnative fish removal to endangered fish recovery.

Several articles in the Daily Sentinel concentrated on fish reclamations. These articles were entitled, "Results vary for fish in DOW pond poisonings" (7/21/98), "Fish kill cleans lake" (4/4/01), and "DOW poisons ponds to kill non-native fish" (7/31/01). An additional Daily Sentinel article concerning the Redlands Canal Fish Ladder was printed on August 21, 2001.

To promote an understanding of the Recovery Program and the need for nonnative fish control to recover endangered fishes, oral presentations followed by discussions were given to students of all ages. Twenty-one presentations were provided to students, including CSU (11/00, 11/01, 11/02), Mesa College (9/99, 9/00, 3/01, 9/01, 4/02), DeBeque High School (4/00), Palisade High School (9/00), Delta High School (10/00), Choices Program High School (10/01), Durango High School (11/01), Mt. Garfield Middle School (9/99), Taylor Elementary School (9/00, 5/01, 9/01, 4/02), Project Wild Teachers (9/00, 4/01), and 13 visiting Russians (9/00).

Similarly, five presentations were provided to CDOW personnel including the Aquatic Section Senior staff, researchers, and biologists (2/00); West Region Habitat biologists (3/00); West Region Senior staff (11/01 & 3/02); and District Wildlife Manager trainees (1/02). Presentations were also provided to the Colorado River Water

Conservation District (7/98); Colorado Division of Water Resources – Dam Safety Engineers (12/01); and Upper Colorado River Recovery Program at the Management Committee bus tour (7/98), 23rd Annual Recovery Program Researchers meeting (1/02) and Nonnative Fish Control Workshop (2/02). An informal presentation was made to the Biology Committee (6/02) on the potential use of screens in areas of centrarchid concentration (hot spots) and handouts were provided.

A public notice was published in the Daily Sentinel and the Montrose Daily Press in 2001 and 2002 to promote private landowner compliance to the CDOW's west slope Nonnative Fish Stocking Regulation (Figure 24). This regulation was also tabulated to facilitate its understanding and was supplied to private aquaculturists (Table 16).

SUMMARY

1. A total of 729 potential pond sites were identified through an inventory of the study area. Of these 729 pond sites, 329 were investigated. Of the 329 investigated sites, 191 had ponds containing fish.
2. Of the 191 ponds that contained fish, 147 contained only nonnative fish, one contained only native fish, and 43 contained both native and nonnative fish. Centrarchids (green sunfish and largemouth bass) had the highest incidence of all nonnative fish species and flannelmouth sucker had the highest incidence of all native fish species in the 191 ponds. The incidence (ponds containing species) of green sunfish, largemouth bass and flannelmouth sucker was 126 (66%), 82 (43%), and 35 (18%), respectively. Overall, 21 nonnative and three native fish species were collected totaling 25,393 fish of which only 387 were native.

ATTENTION

- WEST SLOPE PRIVATE LAND/POND OWNERS -

Colorado Division of Wildlife Regulations Require a Stocking Permit to Stock *ANY* Fish Species in *ANY* Water on the Western Slope. Depending on the Location of the Pond/Stream Section to be Stocked the Permit Must be Obtained by Either the Landowner or the Private Fish Vendor.

Please Contact One of the Following Division of Wildlife Employees to Determine if the Landowner OR Vendor Must Obtain the Permit and to Request Fish Stocking Application Forms and Packet by E-mailing, Calling, Mailing, or Faxing.

Linda Stafford
Special Permits Unit
PO Box 128
Brush, CO 80723
– OR –

linda.stafford@state.co.us
Phone: 970-842-6303
FAX: 970-842-6329

Lori Martin
CDOW
711 Independent Ave.
Grand Junction, CO 81505

lori.martin@state.co.us
Phone: 970-255-6126
FAX: 970-255-6111

Figure 24. A public notice was published in the Daily Sentinel (Grand Junction, CO) and the Daily Press (Montrose, CO) in 2001 and 2002 to promote private landowner compliance to the new CDOW west slope Nonnative Fish Stocking Regulation.

Table 16. Tabulation of nonnative fish stocking regulation.

Where nonnative fish may be stocked with regard to critical habitat on the western slope of Colorado (based on Nonnative Fish Stocking Regulation). The light shaded areas are taken directly from the CDOW Regulations while the dark shaded areas are interpretations of the CDOW Regulations by the Attorney Generals office. **Stocking permits or lake licenses may be required prior to stocking fish in ponds or streams**.

Fish Species	Position of Ponds									Flowing Water		
	Within critical habitat[2] (below the 50 year floodplain)				Within critical habitat[2] (between 50 and 100 year floodplain[1])		Outside critical habitat[2] and below 6500' elevation		Anywhere above 6500' elevation[5,11] and anywhere in the San Juan drainage	Streams & rivers in critical habitat[2]	Streams & rivers outside critical habitat[2] and below 6500' elevation	Streams & rivers outside critical habitat[2] and above 6500' elevation[5,11] and anywhere in the San Juan drainage
	with screen[3] with berm[1]	without screen[3] without berm[1]	without screen[3] with berm[1]	with screen[3] without berm[1]	with screen[3]	without screen[3]	with screen[3]	without screen[3]	screens[3] and berms[7] are NOT required above 6500'			
							berms are NOT required outside of critical habitat below 6500'					
Trout[4]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Largemouth Bass	Yes	No	No	No	Yes	No	Yes	No	Yes[6]	No	No	Yes[6]
Black Crappie	Yes	No	No	No	Yes	No	Yes	No	Yes[6]	No	No	Yes[6]
Bluegill	Yes	No	No	No	Yes	No	Yes	No	Yes[6]	No	No	Yes[6]
Triploid Grass Carp[9]	Yes	No	No	No	Yes	No	Yes	No	Yes[9]	No	No	No[9]
Mosquitofish	No	No	No	No	Yes	No	Yes	No	Yes[6]	No	No	Yes[6]
Channel Catfish	No	No	No	No	No	No	Yes	No	Yes[6]	No	No	Yes[6]
Fathead Minnow	No	No	No	No	No	No	Yes	No	Yes[6]	No	No	Yes[6]
Smallmouth Bass	No	No	No	No	No	No	Yes[8]- When this activity benefits the recovery of threatened and endangered fish and when receiving water is	No	Yes[8]- When this activity benefits the recovery of threatened and endangered fish and when receiving water is screened	No	No	No
Northern Pike	No	No	No	No	No	No		No		No	No	No
Tiger Muskie	No	No	No	No	No	No		No		No	No	No
Goldfish & Aquaria Fish	No	No	No	No	No	No	No	No	Yes[10]	No	No	No[10]
Additional Fish Species	No	No	No	No	No	No	No	No	Yes[11]	No	No	Yes[11]

Revised 4/23/02

Table 16. Legend.

[1] Berms are required if the ponds are within the 50-year floodplain. Berms are NOT required above the 50-year floodplain. Berms must isolate ponds from 50-year flood events and be built to FEMA specifications.

[2] Critical habitat refers to segments of the Colorado, Gunnison, White, Green, and Yampa rivers and their 100-year floodplains. See the CDOW regulations for exact location of each river segment.

[3] Screens are used to isolate ponds from critical habitat. Screen mesh size must not exceed 1/4 inch. Ponds that are naturally isolated (have no outlet) are treated the same as screened ponds. Screens are always required if the landowner has a private or commercial lake license.

[4] Trout may be stocked in any riverside pond above or below 6500' and in streams and river reaches outside critical habitat. Screens and berms are not required

[5] There are no specific regulatory stocking restrictions above 6500'. However, there are general restrictions (see footnote 11).

[6] Prohibition against exotic species may affect whether this species can be stocked. Exotic for this purpose is defined as: any species not currently found in the drainage in question (Chapter 0 Article IX #009 B.1. of CDOW regulations). Drainage is defined by USGS hydrologic code (Chapter 0 Article I #000 B.2. of CDOW regulations).

[7] There are no regulatory berm requirements above 6500'

[8] CDOW Regulation Chapter 0 Article IX B.5.c. states: Smallmouth bass, northern pike, and tiger muskie may be released except in critical habitat, within the Upper Colorado River Basin, and then only if: 1) the fish are acquired within the basin from an existing population below 6500' in elevation; and 2) the receiving water already contains the species and is isolated or its outlets are screened to prevent the escape of the fish or their progeny. All such relocations of fish must be authorized in advance and in writing by the Division.

[9] Grass carp is a prohibited species. As such, they may be released into standing waters if the Director determines the fish do not pose a threat to Colorado wildlife resources (Chapter 0 Article IX #009 B.4. of CDOW regulations). Screens are required on inlet/outlet structures. Screen mesh size must not exceed 1/4" for ponds located below 6500' elevation in the upper Colorado River basin and 1 1/4" for ponds located above 6500' in the upper Colorado River basin and in the San Juan drainage. Upper Colorado River basin includes the Green, White, Yampa, Colorado, Gunnison, and Dolores rivers.

[10] To stock goldfish/aquaria fish, the pond must be in a closed system (no connection to state waters) or the landowner must obtain a commercial/private lake license, or a stocking permit. Screens would be required if a commercial or private lake license is obtained.

[11] The desired fish species must not be on the prohibited species list (Chapter 0 Article VIII #008 A.1. of CDOW regulations) or exotic (Chapter 0 Article IX #009 B.1. of CDOW regulations) or restricted (Chapter 0 Article IX #009 B.3. of CDOW regulations).

Revised 4/23/02

3. More fathead minnows were sampled than any other fish species (11,761). However, if the wetland at HTSWA is not considered due to the extreme abundance of fathead minnows at this location, then the most abundant fish would have been green sunfish (5,509) followed by black bullhead (1,844), fathead minnow (1,761), and common carp (1,296). Flannelmouth sucker was the most abundant native fish (200).
4. The number of ponds and other habitat suitable for sustaining nonnative fish in the study area continues to increase with construction of new gravel pits, farm/fishing ponds, and wetlands. A Natural Resources Conservation Service program also facilitated the construction of 16 ponds in the study area during the last five years (1998 – 2002).
5. Eighty-six ponds totaling 373.8 surface acres were treated to control nonnative fish (reclamation, screen, water management, black plastic, and re-route irrigation water). The total cost of all treatments was $310,331. The average cost per surface acre for these treatments was $830.
6. Fifty-four of the 71 ponds where all fish were removed (69 reclamations, 1 black plastic, and 1 water management) were investigated to identify re-invasion. Of these 54 ponds, 35 (65%) had reinvaded with nonnative fish and 12 (22%) had not re-invaded. The remaining seven (13%) ponds were dry at the time of the follow-up investigation. Largemouth bass were only collected in two of the 35 re-invaded ponds but were originally present in 28 of the 54 re-sampled ponds.
7. Of the 14 screens installed, the only maintenance-free screen was the shearing wedgewire screen installed at a 45^{o} angle. However, this screen has limited application and requires water pressure (head) to function properly.
8. Some, but not all, larval nonnative fish were able to pass through 0.5mm wedgewire screens installed at Horsethief Canyon State Wildlife Area. Wedgewire is available with apertures as small as 0.1mm. It might be possible to exclude nonnative fish larvae with apertures <0.5mm.

DISCUSSION

Increased Nonnative Fish Habitat

Floodplain corridors bordering the main-stem rivers in the Upper Colorado River Basin are considered an integral and necessary element in the recovery of the four endangered big river fish species. Lentic habitats comprised of backwaters, embayments created by flooded terraces, and ponds created in depressions all have been identified as a critical habitat component in the life histories of the listed species, and generally important to the native fish community and ecological functions supporting the endangered fishes (Irving and Burdick 1995). Unfortunately these habitats may also be important to the survival and reproduction of many nonnative fish species found throughout the Upper Basin.

The connection of the Colorado River to most ponds in the Grand Valley through irrigation cannot be disputed. It is well accepted that fish enter and move through the canals of the Grand Valley. From these canals some fish transverse fields via irrigation water and immigrate into farm ponds. Other ponds and gravel pits may be isolated from the canal system of the Grand Valley but receive water and fish directly from the river through pumping or flooding.

Native fish were rare in the 191 floodplain ponds (387 native fish out of 25,393 total fish) sampled in this study. We also observed an explosion of nonnative fish in a newly constructed wetland immediately following filling. Given these observations, wetlands that have direct connectivity to critical habitat may also pose a significant threat to endangered fish recovery in spite of seasonal filling and drying. Similarly, a continued increase in the number of farm ponds, gravel pits and wetlands, as seen during the timeframe of this study, will undoubtedly hinder recovery efforts through the creation of additional nonnative fish habitat if strategies to control emigration of nonnative fish from these habitats are not developed and implemented.

Future Control Efforts

The goal of reducing nonnative fish numbers in riverine habitats critical to the survival of early life stages of native/listed fishes may not be possible without reduction of nonnative fish abundance in riverine habitat ***and*** reduction of escapement from ponds, gravel pits, and/or wetlands. Previous independent control efforts of nonnative fish in riverine and lentic habitats have had limited to no impact on the abundance of native/listed fishes in critical riverine nursery habitat. Trammell et al. (2002) documented rapid and extensive re-invasion of backwaters following depletive removal of nonnative fishes with seines. Osmundson (2003) also did not observe a depletive effect on centrarchid populations following removal efforts in backwaters by electrofishing. Similarly, re-invasion of ponds, though slower than that observed in backwaters, occurred in 65% of the controlled ponds and seems inevitable in all of the controlled ponds given time.

The source(s) of nonnative fish to critical riverine habitat has yet to be determined, although research to identify the provenance of nonnative centrarchids through isotopic analysis is underway. Questions surrounding efforts to identify the origins of nonnative centrarchids are: 1) do isotopic markers exist to reliably identify whether a fish originated from a pond or within the river; 2) can the percentage of fish in backwaters, originating from ponds or the river, be determined to see which is the primary source of nonnative centrarchids; and 3) is it feasible to identify point or reach sources of the bulk of target nonnative fishes to maximize the ecological and economic efficiency of controlling their abundance in critical habitat.

Chemical reclamation and screening of the numerous ponds found in the Grand Valley on an individual basis does not appear to be logistically or fiscally possible. However, the movement of nonnative fishes from numerous ponds into the river may potentially be arrested with screens in return flow irrigation ditches. A long-term biological control of nonnative fish entering recently reclaimed ponds as larvae/juvenile may also be possible with adult native fish that exhibit piscivory, such as roundtail chub (G. Mueller, personal communication). However, removal of nonnative fish from river reaches with established nonnative fish populations and complex geomorphology is more problematic and will require innovative thinking to develop new control techniques.

Education

Numerous accounts/observations from various publics including children, anglers, landowners, and recreationists of transferring live nonnative fish from one site (pond or river) to another off-channel site have been received by CDOW personnel. This illicit activity should be addressed through continued education via newsletters, newspaper articles, and television news reports. In addition, education of landowners, private fish growers, agency personnel including law enforcement, and the general public must continue concerning Colorado's current nonnative fish stocking regulation due to past confusion and recent updates to the regulation. If future data indicates stocked nonnative fish are entering critical riverine habitat it may be necessary to revise this regulation or prohibit stocking of certain nonnative fish species on the western slope of Colorado.

CONCLUSIONS

Nonnative fish dominated floodplain pond habitat in the study area as demonstrated by fish species composition and numbers in 191 sampled ponds. A total catch of 25,393 fish comprised 98.5% (25,006) nonnative and 1.5% (387) native fish. Control of nonnative fishes was implemented under two categories: 1) reduction of nonnative fish abundance in floodplain habitat and 2) reduction of escapement from waters serving as sources of nonnative fishes to critical habitat reaches.

Control treatments in 71 ponds temporarily reduced nonnative fish numbers. However, 65% (35 ponds) of 54 ponds sampled post-treatment had re-invaded. Due to this high re-invasion rate it is highly probable that re-invasion will occur in the remaining 22% (12 ponds) that had not re-invaded at the time of subsequent sampling.

Similarly, movement of juvenile and adult fish into riverine habitat was inhibited by installation of several pond outlet screens. However, due to screen aperture size, some larval fish could pass through these screens. Larval fathead minnow and red shiners were able to pass through 0.5mm wedgewire inlet screens while other unidentified larval/juvenile fish were impinged and did not pass through.

Efforts to control nonnative fish in floodplain ponds appear to have had limited or no long-term effectiveness. The failure to observe a reduction in nonnative fish

abundance in backwaters as a result of nonnative fish control treatments in ponds is most likely attributable to rapid re-invasion of treated ponds, movement of larval nonnative fish through fish screens, the small number of controlled ponds on a river-reach scale (86, or 12%, ponds were controlled out of a possible 729 ponds), and the abundance of nonnative fishes in riverine habitats.

RECOMMENDATIONS

1. **Determine the sources of problematic nonnative fishes.**

   The origin(s) of nonnative fishes present in the Colorado River has not been determined. Further, a question exists as to whether or not nonnative fish numbers in the river are the result of continual addition from along the river's course through the Grand Valley (non-point scenario) or if certain sites in the river and its floodplain (point sources) are responsible for the bulk of nonnative fish in backwaters. Application of isotopic techniques should be employed to determine the source of nonnative fish in the river.

2. **Evaluate potential biological control of nonnative fish with native listed/non-listed fish in a floodplain pond environment.**

   Biological control of nonnative fish with native fish may be accomplished in riverside ponds, if large native fish are introduced to recently reclaimed ponds. The aggressive feeding behavior of bonytail and roundtail chub may be able to control an invasion of larval nonnative fish that commonly enter ponds through irrigation water. If adult native fish are established prior to nonnative fish invasion, native fish may be able to out-compete the nonnative fish for food and space, and may prey upon larval and juvenile nonnative fish. The author has observed the growth and reproduction of native fish (roundtail chub, flannelmouth sucker and bluehead sucker) in an isolated pond that was established as a native fish refuge (Martinez 2001). Similar growth and reproduction has been documented in Arizona for razorback sucker and bonytail in Cibola High Levee pond (Mueller and Minckley In Progress) and provides additional credence to consider employing this strategy in the Upper Basin.

Invasion of many ponds in the Grand Valley area occurs by the movement of nonnative larval fishes through irrigation water. Of the numerous ponds that have been reclaimed in the NNFC study area, 65% have re-invaded with nonnative fish. We sampled fish in these ponds prior to reclamation and following re-invasion. The author proposes that four of these ponds be reclaimed again and stocked with adult native fish when irrigation water is not flowing. These ponds should then be monitored following the onset of irrigation to document the ability of the native fish to control invasion/establishment of nonnative fish. Monitoring should also attempt to document successful reproduction and recruitment of native/nonnative fish if possible.

3. **Evaluate shearing wedgewire screens with apertures < 0.5mm to determine if larval fish pass through this type of screen.**

This study has shown that larval nonnative fish can pass through a shearing wedgewire screen with an aperture of 0.5mm. Though one of the screens investigated in this study did not function well from a maintenance perspective the other proved to be maintenance free. Screen maintenance was the first concern of landowners that participated in NNFC treatments, and fouling resulted in the removal of some outlet screens by landowners. Shearing wedgewire screens have the potential of both controlling the movement of nonnative fish and being maintenance free.

4. **Examine the potential of controlling the movement of nonnative fish from floodplain ponds into critical habitat by screening return flow irrigation water.**

It may be difficult, costly and infeasible to screen many individual floodplain ponds. Because there are a limited number of return flow irrigation ditches it may be possible to control the movement of nonnative fish from ponds located in a larger floodplain or drainage with a single screen in a return-flow irrigation ditch. It may also be possible to reduce the number of centrarchids in areas of the Colorado River that have been identified as “hot spots” (Martinez et al. 2002) if screens are installed in return flow irrigation ditches that are located in or near these “hot spots”.

5. **Continue I&E efforts to inform the public and private aquaculturists of the existence of and changes to the CDOW Nonnative Fish Stocking (NNFS) regulation.**

   In addition to NNFC treatments, a nonnative fish stocking regulation was developed in Colorado from guidance provided by a multiagency task force (CDOW et al. 1996) to address control of nonnative fish from a stocking perspective. This regulation went into effect in January 1999 and was revised in March and November of 2002. Therefore, continued I&E efforts are needed to ensure the public and private fish vendors are aware of and compliant to this new regulation.

6. **Review current NNFS regulation and make changes where necessary.**

   Consider changing screen aperture requirements for individuals that wish to stock only mosquitofish or fathead minnow as a method of controlling mosquito larvae. Currently, the NNFS regulation requires a ¼ inch mesh screen when stocking nonnative fish below 6500' elevation within the upper Colorado River basin. This aperture readily allows adults of these two species to emigrate from ponds and provides an avenue for landowners to question the need for a screen.

   Screens are not required on outlet structures of ponds above 6500' on Colorado's western slope except when a private or commercial lake license is in place or the landowner stocks grass carp. It is inconsistent to require screens on ponds managed under private/commercial lake licenses and not require similar screens on ponds that are stocked under the statewide aquaculturist permit.

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APPENDIX A

Native Fish Salvage from the
Government Highline Canal

Table A-1. Number and percent of native and nonnative fish collected from the Government Highline Canal at the Lewis Wash Siphon.

Fish Species	Year			
	1999	2000	2001	2002
Native Fish				
Number Collected	550	12,300	12,000	<1,000
Roundtail chub	63%	82%	90%	Not identified
Speckled dace		10%	2%	
Flannelmouth sucker	33%	8%	7%	
Bluehead sucker	4%		<1%	
Razorback sucker		<1%	<1%*	
Nonnative Fish				
Number Collected	Not enumerated or identified	Not enumerated or identified	3,000	Not enumerated or identified
Fathead minnow			59%	
White sucker			30%	
Common carp			9%	
Brassy Minnow			1%	
Green Sunfish			1%	

* PIT tag numbers 53182B4E02, 5316035D0A

In 2000, the 12,300 native fish collected from the GHC were stocked into an isolated oxbow of the Colorado River near the town of Palisade (4,600 fish) or directly into the Colorado River near Corn Lake (7,700 fish). Fish in a representative sub-sample were identified, weighed, and measured. The sub-sample contained 161(82%) roundtail chub, 20 (10%) speckled dace, 15 (8%) flannelmouth sucker, and one (<1%) razorback sucker. A PIT tag scanner was not available to scan the single razorback sucker. It was returned to the Colorado River.

In 2001, the 12,000 native fish removed from the GHC were stocked into the Colorado River at either the Corn Lake or Connected Lakes boat ramps. A sub-sample of these native fish comprised 595 (90%) roundtail chub, 45 (7%) flannelmouth sucker, 15 (2%) speckled dace, two (<1%) bluehead sucker, and two (<1%) razorback sucker (PIT tag #'s 53182B4E02 and 5316035D0A). In addition to the 12,000 native fish collected in 2001, approximately 3,000 nonnative fish were identified and counted and a sub-sample of these fish included 49 (59%) fathead minnow, 25 (30%) white sucker, seven (9%) common carp, one (1%) brassy minnow, and one (1%) green sunfish. Additional sampling of the Lewis Wash Siphon occurred in 2002 by the Fish and Wildlife Service and resulted in the collection of less than 1,000 native fish (C. McAda personal communication).