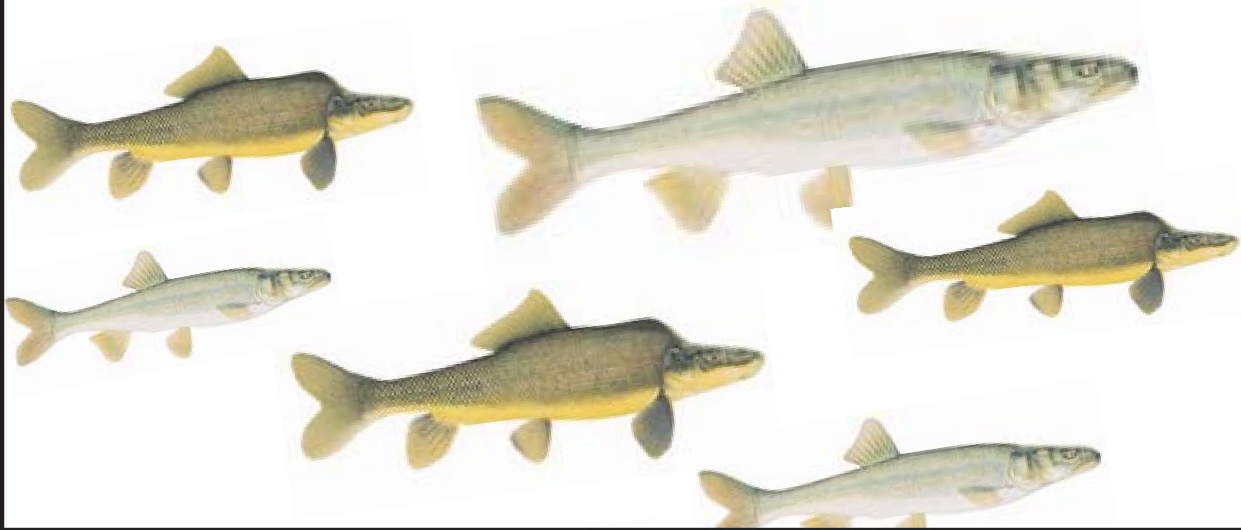

Summary of Monitoring Activities and Other Studies Conducted by the San Juan River Basin Recovery Implementation Program, 1999-2002

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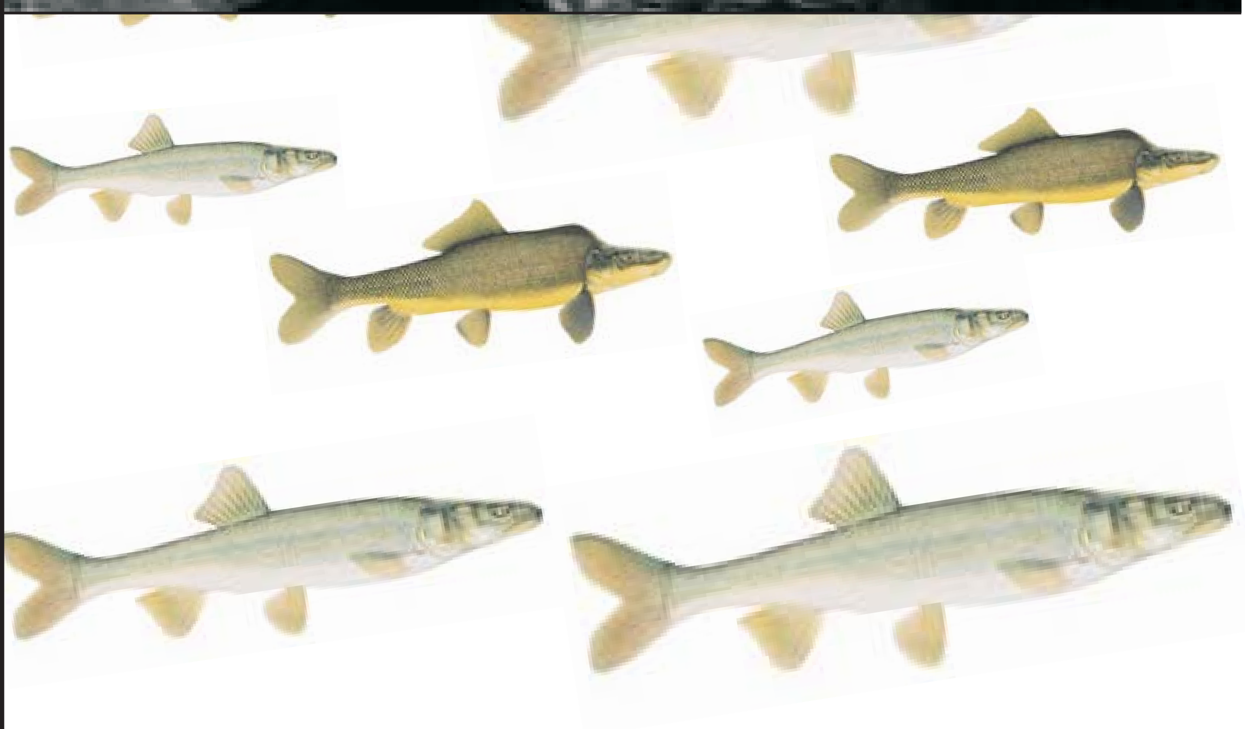

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INTRODUCTION

The San Juan River Basin Recovery Implementation Program (SJRIP) was initiated in 1992 with dual goals to (1) recover the endangered Colorado pikeminnow (*Ptychochelius lucius*) and razorback sucker (*Xyrauchen texanus*) in the San Juan River and (2) proceed with water development under federal and state laws and responsibilities. The SJRIP incorporated a 7-year research effort initiated in 1991 to study biological and physical aspects of the river ecosystem. That research effort was designed to determine factors important to recovery of the endangered fish species. The research effort ended in 1998 and two synthesis reports were prepared that summarized the results of the studies: *Flow Recommendations for the San Juan River* (Holden 1999) and *Program Evaluation Report* (Holden 2000). In 1999 the emphasis of the SJRIP shifted from research activities to monitoring and management studies. A Monitoring Plan (Propst et al. 2000) was completed that provided guidelines for monitoring activities. Monitoring activities were initiated in 1999, as were management and recovery actions. This report summarizes the results of monitoring studies from 1999-2002, as well as management and recovery actions occurring during that same time period. While data collected in 1998 may not have followed the exact protocols of the Monitoring Plan, in many cases the data were comparable with 1999-2002 data. Where 1998 data were available and comparable, they are also included in this summary. Detailed monitoring results can be found in the individual monitoring reports cited here. These reports are available from the SJRIP web site at http://southwest.fws.gov/sjrip. A more detailed synthesis of the information gathered will be forthcoming in early 2004.

MONITORING PROTOCOLS

The Monitoring Plan (Propst et al. 2000) has three major goals with associated objectives, as follows.

1. Track the status and trends of endangered and other fish populations in the San Juan River to:

    a. determine relative annual reproductive success of Colorado pikeminnow and razorback sucker; and

    b. determine population trends, including size-structure, of adult and juvenile fishes of the San Juan River.

2. Track changes in abiotic parameters, including water quality, channel morphology, and habitat, important to the fish community to:

    a. track changes in selected water quality parameters;

    b. determine changes in channel morphology and substrate composition;

c. determine changes in cobble bar characteristics, including suspected and potential spawning bars;

d. determine trends in quantity and quality of low-velocity habitats; and

e. determine trends in habitat diversity and abundance.

3. Utilize data collected under Goals 1 and 2 to help determine progress towards recovery of the endangered fish species to:

   a. produce annual summaries of monitoring results, and

   b. provide detailed analyses of data collected to help determine progress towards endangered species recovery in 3 years and thence every 5 years.

This report summarizes the annual reports for 1999-2002, as noted in 3a above. From 1999 to 2002 two major types of monitoring studies, physical studies and fishery sampling, were undertaken to meet these goals and objectives. Physical monitoring activities were directed at channel morphology, backwater/low-velocity habitat, habitat mapping, water temperature, water quality, and cobble bar studies. Channel morphology was studied using 14 cross sections of the river from RM 175 to RM 4. The river bottom at each transect was surveyed pre- and post-runoff each year. Four cobble bars in the river above RM 131 were mapped topographically each year post-runoff. In addition to mapping, depth to embeddedness, pebble counts, and particle size were determined for each cobble bar. Changes in backwater habitats were determined each year by mapping 30 backwaters from RM 180 to RM 3. Size, depth, and sediment depth were measured at each backwater each fall. In conjunction with physical monitoring, habitat mapping of the San Juan River between RM 180 and RM 0 was conducted each fall at flows of 500-1,000 cfs. Digital aerial photography of the river was produced and habitats were manually mapped on the photos for 2 of every 3 miles of the river.

For all or part of the 1999-2002 time period, Optic Stowaway (Onset Computer Corporation) data loggers recorded temperature information at eight locations throughout the San Juan River. Other recorders stationed at five locations in the San Juan River recorded temperatures during parts of 1998. From 1998-2002, 19 water quality parameters were measured quarterly at 12 monitoring stations along the San Juan River. Low-flow water samples were taken each February and analyzed for 13 additional parameters.

The fishery sampling was broken into larval, small-bodied, and adult categories. Larval razorback sucker were sampled using small, fine-mesh seines in low-velocity habitats. The area sampled changed over the course of the study, but parts of the entire river from Cudei (RM 142) to Clay Hills (RM 3) were sampled each April, May, and June. Larval light traps were used at night around campsites. Colorado pikeminnow larval sampling utilized Moore Egg Collectors (MEC) from 1999 through 2001. In 2002 larval seining, similar to the technique used for larval razorback sucker, was used and has since become the standard larval sampling technique. Larval Colorado pikeminnow sampling occurred in July and August. Two sites, RM 128 and RM 53 (Mexican Hat), were sampled with MEC, but in 2002 the entire river from RM 142 (Cudei) to RM 3 was sampled with larval seines.

Small-bodied and young-of-the-year (YOY) fishes were sampled once annually, usually in September, in every third mile from RM 180 (mouth of Animas River) to RM 3. Sampling occurred in all habitats at a ratio similar to their abundance in both mainstem and secondary channels. Within each river mile sampled, all backwaters were also sampled with drag seines. Annual adult and larger juvenile fish sampling occurred concurrently with small-bodied fish sampling. Electrofishing from rafts was employed for sampling large juvenile and adult fishes. Two of every three river miles, from RM 180 to RM 3, were sampled each year.

Various other research activities took place from 1998-2002. Efforts to remove large-bodied nonnative fishes were undertaken during adult monitoring activities throughout the river and with baited hoop nets and electrofishing in two discrete reaches: RM 137.2-127.6 and between the PNM Weir and Hogback Diversion. Additional electrofishing nonnative removal efforts began in 2002 for the section of river from Mexican Hat to Clay Hills. The primary goal of this sampling effort was to monitor the distribution and abundance of lacustrine predators, primarily striped bass (*Morone saxatilis*), invading from Lake Powell.

Studies on stocked razorback sucker and Colorado pikeminnow were conducted to determine stocking success and potential spawning areas. Stocked razorback sucker and adult Colorado pikeminnow were all implanted with passive integrated transponder (PIT) tags. Some razorback sucker and Colorado pikeminnow were also implanted with radio tags. Electrofishing and seining during fall monitoring trips, nonnative fish sampling trips, and sampling geared directly at finding stocked fish provided information on retention, survival, and growth. Recapture and radio telemetry contact data provided information on stocked fish habitat use, site preference, and movement.

Since 1999, reports that present the annual results of monitoring have been produced by each of the parties involved in the monitoring. This report summarizes the information collected. More detail on methods employed or results obtained can be found in those annual reports.

RESULTS

Physical Monitoring

Flow

Peak spring flows in 1998 and 1999 were the highest flows of the 1998-2002 period (Figure 1), but these flows were still lower than those in 1997, 1995, or 1993, years of high and relatively long

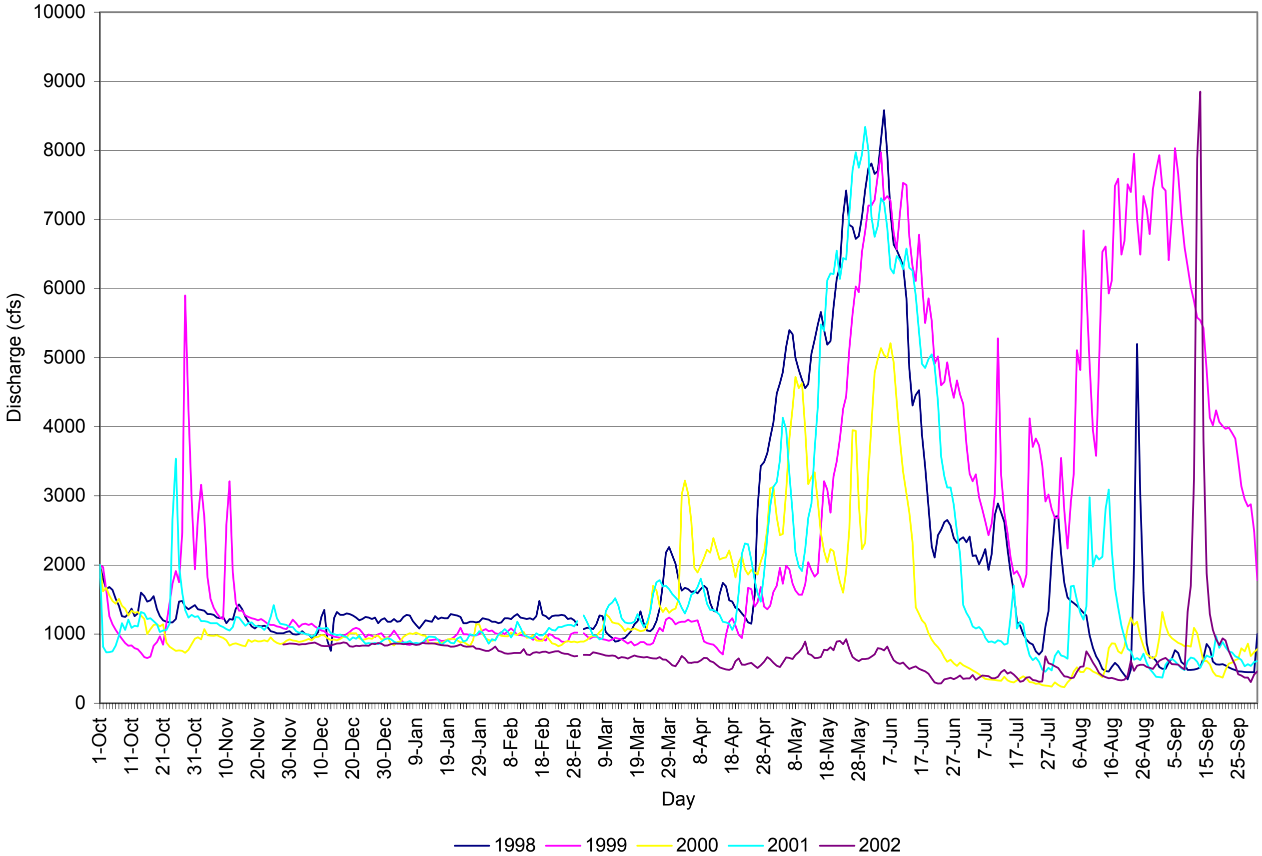

Figure 1. Average daily discharge at USGS gage# 09371010 near Four Corners, CO, from 1998-2002.

runoff. Only 1998 and 2001 had spring runoff flows above 8,000 cfs, but those flows only lasted for 2 days in 1998 and 1 day in 2001. One day with flows at 8,000 cfs also occurred in spring 2001. A large spring release (5,000 cfs for 3 weeks) from Navajo Reservoir was made in 1998, and a short spring release (1 week at 5,000 cfs) was made in 1999 (Bliesner and Lamarra 2002a). A relatively long (1 month) and large (4,000-4,500 cfs) release of water from the reservoir occurred in August and September 1999 for dam maintenance. While 1999 was technically a perturbation year, as defined by the SJRIP Flow Recommendation Report (Holden 1999), no flushing flow was made in 2000 because late season flows in 1999 cleaned out key backwater habitats. A minimal peak release was made from the dam in 2000 (1 week ramp up, 1 day at peak, 1 week ramp down). However, a larger-than-anticipated flushing release (26 days at 4,300 -5,300 cfs) was made in 2001, in part for dam maintenance. Because of drought conditions in 2002, no flushing release occurred.

Although flows above 10,000 cfs did not occur and flows above 8,000 cfs only occurred for 2 days in 1998 and 1 day in 2001, the recommendations for these flow criteria were not violated. Since extended periods of drought occur during a natural hydrograph, allowances for extended periods (6 years and 10 years, respectively) where flow criteria are not met were included in the flow recommendations. Neither of these time periods have been exceeded (Table 1). The days above 5,000 cfs and 2,500 cfs were not violated in 1998, 1999, or 2001 (Bliesner and Lamarra 2002a, 2002b, 2003). The days above 2,500 cfs criterium was not violated in 2000. Relatively low spring runoff and lack of summer storm events made 2000 a low-flow year. None of the flow statistics were met in 2002, which was a record low-flow year. The base-flow criteria of a minimum of 500 cfs below Farmington was not met in 2002 when flows less than 500 cfs occurred for several week-long periods. The SJRIP Biology Committee, recognizing the severity of the 2002 drought, authorized reducing the flows to as low as 350 cfs in critical habitat areas.

Table 1. Flow recommendation statistics met each year.

FLOW CONDITION	STANDARD	1994	1995	1996	1997	1998	1999	2000	2001	2002
Days at 10,000 cfs or more	5	0	**11**	0	**10**	0	0	0	0	0
Days at 8,000 cfs or more	10	**13**	**27**	0	**33**	2	0	0	0	0
Days at 5,000 cfs or more	21	**49**	**72**	0	**50**	**34**	**29**	3	**33**	0
Days at 2,500 cfs or more	10	**67**	**135**	**36**	**100**	**65**	**70**	**37**	**55**	0
Years w/o meeting 10,000 cfs	10	8	0	1	0	1	2	3	4	5
Years w/o meeting 8,000 cfs	6	0	0	1	0	1	2	3	4	5
Years w/o meeting 5,000 cfs	4	0	0	1	0	0	0	1	0	1
Years w/o meeting 2,500 cfs	2	0	0	0	0	0	0	0	0	1

Note: Values in bold are those that meet or exceed the minimum standard (Bliesner and Lamarra 2003).

Geomorphology

River channel cross sections were monitored to determine if the flow recommendations are causing scour or deposition. Channel cross sections underwent a runoff peak scour and post-runoff fill pattern from 1998-2002. Cross sections in Geomorphic Reaches 3-6 maintained themselves near 1992 baseline levels. Following a period of deposition associated with high Lake Powell elevation, the lower-most cross-section in Reach 1 began to scour in 2000 as lake levels fell. The upstream cross-section in this reach continued its pattern of deposition until the end of 2002, when it indicated some scour. This reach will probably continue its pattern of scour and deposition in response to lake level. Overall, the cross sections show a slight narrowing of the river, a trend that started prior to 1992 as Russian olive (*Elaeagnus augustifolia*) invaded the system and became the dominate riparian vegetation type.

Cobble bars are important spawning areas for native fishes, especially Colorado pikeminnow. Cobble bars had variable levels of deposition and scour from 1998-2002. From 1998-2000 the cobble bar at RM 173.7 showed slight scour, but in 2001 and 2002 it showed evidence of slight deposition. Cobble bars at RM 168.4 and RM 132 continued to be depositional in 1998 and 1999, but they actually lost elevation to scour in 2000. Little change or slight deposition was found between 2001 and 2002 at all cobble bars. Cobble size increased slightly from 1998 to 1999, but no appreciable change has occurred since that time. The year with the highest abundance of deeper interstitial spaces varied amongst cobble bars, but in 2002 most cobble bars had a low abundance of deep interstitial spaces.

Both flow- and turbidity-based estimations of storm event days showed that 1999 was a perturbating year, while 2000 and 2002 were not. In 2001 the turbidity-based estimation indicated a perturbating year, but the flow-based estimation did not. The lack of storm events during the study period is symptomatic of the drought conditions that have enveloped the San Juan River drainage since 2000.

Habitat Studies

Habitat mapping occurred annually to track habitats that are thought to be important to the endangered fishes. Backwaters are key habitats for young Colorado pikeminnow. The number and area of backwaters were highest in the mid 1990s (Figure 2). The numbers and surface area of backwaters in 1998 were over 50% lower than in 1995. A slight increase in the surface area and numbers of backwaters was seen in 1999, followed by three straight years of decline. Reaches 3-5 all saw a substantial decline in the area of backwater habitat in 2002, and total backwater area for all reaches combined was at its lowest in the 10-year study period. Reach 5 has maintained the most consistent proportion of backwater area, while Reaches 1, 3, and 4 have shown more fluctuation.

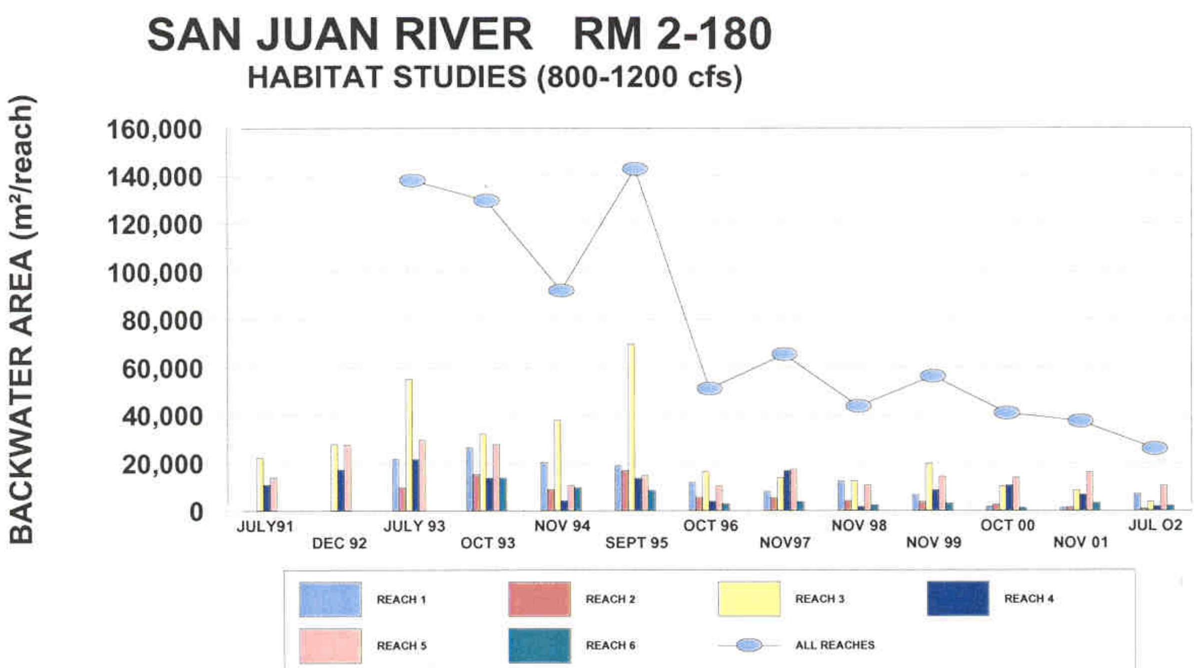

Figure 2. Surface area of backwater habitats in the San Juan River between RM 2 and RM 80 from 1991-2002 (Bliesner and Lamarra 2003).

Fall backwater sediment depths, a measure of backwater quality, increased from 1999 to 2001 and fell slightly in 2002. However, both 2001 and 2002 backwater sediment depth increased between spring and fall. The geomorphic reach with the deepest backwater sediment has varied over the last 5 years. Only Reach 2 had the greatest sediment depth twice, once in 1999 and again in 2002.

Water Quality

As would be expected, average water temperatures are lowest near Navajo Dam and increase progressively at downstream stations. Little annual fluctuation in temperature is seen immediately below the dam, but average temperatures fluctuate from near freezing in the winter to over 25° C below the Four Corners area.

Water quality parameters have not exceeded State of New Mexico standards from 1998-2002 and have generally been similar to samples collected from 1994-1997. State sampling has shown that *E. coli* bacteria have exceeded standards at a number of stations on the San Juan River; however, these water quality levels would not be expected to be detrimental to the native fishes.

Biological Monitoring

Larval Fish Monitoring

Razorback Sucker Sampling

Numbers of larval razorback sucker collected during monitoring have increased every year since 1998. Using the new larval seine technique, over 13,000 fishes representing 14 species were captured in 1998 during several trips between RM 127.5 and Bluff (RM 77.5) (Brandenburg 2000). Two razorback sucker were collected, one at RM 80.2 and one at RM 88.8. Both razorback sucker larvae were collected in backwaters. Table 2 provides the number of razorback sucker larvae captured during each year of sampling from 1998-2002. The capture of the two razorback sucker in 1998 provided the first documentation that stocked razorback sucker were successfully reproducing in the San Juan River. Additionally, 4 Colorado pikeminnow and 18 roundtail chub (*Gila robusta*) larvae were collected in 1998. The Colorado pikeminnow most likely were part of 10,500 small, young Colorado pikeminnow that were stocked by the Utah Department of Wildlife Resources to study larval Colorado pikeminnow habitat use.

Since the larval seining technique was successful at documenting the presence of larval razorback sucker in 1998, this study was expanded to encompass the San Juan River from RM 127.5 to Clay Hills Crossing (RM 2.9) in 1999 (Brandenburg 2000). Sampling was divided between an Upper Reach (RM 127.5 to Bluff [77.5]) and a Lower Reach (Bluff to Mexican Hat or Bluff to Clay Hills). Larval light traps were also sporadically deployed in 1999. Collections in 1999 yielded over 20,000 fishes representing 11 species, including 7 razorback sucker and 5 roundtail chub. No Colorado pikeminnow larvae were captured in 1999. Razorback sucker larvae were captured at RM 96.2, 82.5, 16.5, 13.1, and 11.5. Two of the seven razorback larvae were collected in light traps.

Table 2. **Number of larval razorback sucker captured with larval seines and light traps above (Upper Reach) and below (Lower Reach) Bluff, UT, from 1998-2002 (Brandenburg 2000, Brandenburg et al. 2001, Brandenburg et al. 2002, Brandenburg et al. 2003).**

YEAR	UPPER REACH	LOWER REACH	TOTAL
1998	2	n/a	2
1999	4	3	7
2000	27	102	129
2001	4	46	50
2002	242	570	812

In 2000 four trips were made between RM 127.5 and Bluff (Upper Reach), and three trips were made between Bluff and Clay Hills (Lower Reach). Over 11,000 fishes representing 13 species were collected (Brandenburg et al. 2001). While no Colorado pikeminnow or roundtail chub were collected, 129 individual razorback sucker were collected in 21 separate collections. All but four of the razorback sucker were collected below Aneth. Below Aneth at least one razorback sucker was found in every 10-mile section except RM 30-40. A large concentration of razorback sucker (86) was collected in a single sample made in a large backwater with inundated vegetation near RM 8.1. The continual increase in numbers of larval razorback sucker suggested that more of the stocked razorback sucker were becoming reproductively viable or that spawning success was increasing.

In 2001 three trips were made in both the Upper and Lower Reaches. An additional trip was made in the Upper Reach, with the upstream boundary extended to the Cudei Diversion (RM 142). Collections in 2001 yielded over 95,000 fishes representing 13 species (Brandenburg et al. 2002). Fifty razorback sucker were collected beginning in mid May. Once again no Colorado pikeminnow or roundtail chub was found. Only four razorback sucker were collected in the Upper Reach, and 88% of the razorback sucker collected were taken in a 4-mile section of the Lower Reach between RM 13.1 and RM 8.1. Two of the razorback sucker collected in this area were juvenile fish (26.8 and 28.8 mm), marking the first time that razorback sucker juveniles were collected in the larval study.

The Upper Reach encompassed from Cudei to Bluff for all three trips in 2002. Three trips were also made in the Lower Reach in 2002. Over 56,000 fishes representing 11 species were collected. Razorback sucker numbers increased dramatically, with a total of 812 specimens collected in both larval seines and light traps (Brandenburg et al. 2003). Razorback sucker were collected in 67 separate samples taken from RM 134.5 to RM 2.9 from late April to late June. Twenty of the samples had more than ten razorback sucker, and five of the samples had more than fifty razorback sucker. The greatest concentration was 91 razorback sucker collected in one sample taken near RM 21.2. Razorback sucker were more evenly distributed throughout the river in 2002, when almost 30% of the fish were captured above Bluff. Almost 16 percent of the razorback sucker collected were juvenile fish, including one 62 mm fish.

In addition to the rare and endangered fishes collected in this study, relatively large numbers of other native catostomids and nonnative cyprinids were also collected. From 1998-2000, native fishes, particularly flannelmouth sucker (*Catostomus latipinnis*), dominated catches in areas above Bluff and the nonnative red shiner (*Cyprinella lutrensis*) dominated in areas below Bluff. In 2001 red shiner comprised 87% of the catch, while in 2002 red shiner and fathead minnow (*Pimephales promelas*) combined to dominate the catch. From 1998-2001 native fishes dominated light trap collections. In 2002 red shiner and fathead minnow dominated the light trap catch.

Colorado Pikeminnow Sampling

Sampling drift from 1998-2001 produced 1 Colorado pikeminnow. The Colorado pikeminnow was collected in 2001 when no stocking occurred; hence this fish was likely a wild-spawned Colorado pikeminnow. Over 90,000 fishes were captured after changing to larval seining in 2002 (Farrington et al. 2003), indicating that the shift in methods was successful in capturing more small fish. This was over four times the number of fish taken in drift sampling from 1991-2001. No Colorado pikeminnow or roundtail chub were collected, but two juvenile razorback sucker (56 and 58 mm SL) were collected in mid July in the Upper Reach (S. Gottleib, University of New Mexico, Museum of Southwestern Biology, personal communication). Red shiner dominated the catch and, together with fathead minnow, comprised 98.7% of the specimens collected. Speckled dace (*Rhinichthys osculus*) was the most common native species collected.

Small-bodied Fish Monitoring

Small-bodied fish monitoring continued to produce species and show trends similar to those seen during the 7-year research effort. Sampling the primary channel for small-bodied fish began in 1998 (Propst, Hobbes et al. 2003). Red shiner was the most common species in primary channel collections from 1998-2002. Six native species, eight nonnative species, and one sucker hybrid were collected over the 5-year period (Table 3). Four Colorado pikeminnow were collected in Geomorphic Reaches 3, 4, and 5 in 1998, but none have been collected since that time. The lengths of the Colorado pikeminnow were 72, 72, 83, and 134 mm (SL). The three Colorado pikeminnow under 83 mm were probably from the fall 1997 stocking, while the 134 mm Colorado pikeminnow was probably from the fall 1996 stocking. Additionally, one roundtail chub was collected in 1998 and 1999, but none were collected in 2000-2002. Speckled dace was the second most common species collected in every year except 2000 and 2002, and the most common native species collected in every year.

Statistical analyses of the primary channel data revealed no significant trends between years or reaches (Propst, Hobbes et al. 2003; Propst, Kingsbury et al. 2003). In general, relative abundance of native species declined from Geomorphic Reaches 5 and 6 downstream. The lowest density for native species was seen in 2000, when nonnative fish densities, particularly red shiner, were at their highest. Primary channel species diversity was also lowest in 2000 in all reaches except Reach 1. Reach 1 saw an increase in primary channel species diversity and native fish density between 1999 and 2001.

Table 3. **Number of fishes collected in San Juan River primary channels during fall small-bodied fish monitoring (Propst et al. 2000; Propst, Hobbes et al. 2003; Propst, Kingsbury et al. 2003).**

SPECIES	1998	1999	2000	2001	2002
Bluehead Sucker	3	3	23	13	23
Flannelmouth Sucker	7	8	38	41	66
Sucker Hybrid	0	1	0	0	0
Speckled Dace	464	335	163	387	452
Colorado Pikeminnow	4	0	0	0	0
Roundtail Chub	1	1	0	0	0
Red Shiner	592	1,071	18,570	2,765	7,125
Fathead Minnow	32	48	209	148	1,091
Common Carp	0	1	7	0	23
Plains Killifish	1	0	4	3	15
Western Mosquitofish	2	0	904	63	162
Channel Catfish	189	7	23	10	232
Black Bullhead	0	0	0	0	4
Green Sunfish	1	0	0	0	0
Largemouth Bass	0	0	0	1	0
Mottled Sculpin	1	0	0	0	0
Total number of fish	1,297	1,475	19,941	3,431	9,193
Total area sampled	1,601	4,883	4,510	3,091	3,564
Total density	0.810	0.302	4.422	1.11	2.571
Native density	0.3	0.07	0.05	0.14	0.152
Nonnative density	0.51	0.23	4.37	0.97	2.419

Small-bodied fish monitoring efforts in secondary channels from 1998-2002 produced six native species and 11 nonnative species (Propst et al. 2000; Propst, Hobbes et al. 2003; Propst, Kingsbury et al. 2003; Table 4). Mottled sculpin (*Cottus bairdi*) and rainbow trout (*Onchyrhynchus mykiss*) were two new species collected during the 1998-2001 time period. Colorado pikeminnow were collected in secondary channels from 1998-2000. One Colorado pikeminnow was collected in 1998 (167 mm SL) and 1999 (124 mm SL), and three were collected in 2000 (75, 75, and 93 mm SL). All of the Colorado pikeminnow were collected in backwaters. The Colorado pikeminnow captured in 1998 was probably from the fall 1997 stocking, while the Colorado pikeminnow captured in 1999 may have been from the small group of fish stocked in 1998. The three Colorado pikeminnow captured in 2000 were probably from the group of larval Colorado pikeminnow stocked in summer 1999. Two roundtail chub were collected in 1998 and one was collected in 1999. As in the primary channel sampling, red shiner was the dominant species every year. Speckled dace was the most common native species every year and the second most common species in 1998 and 1999. Fathead minnow was the second most common species in 2000 and 2001.

Table 4. Number of fishes collected in San Juan River secondary channels during fall small-bodied fish monitoring (Propst et al. 2000; Propst, Hobbes et al. 2003; Propst, Kingsbury et al. 2003).

SPECIES	1998	1999	2000	2001	2002
Bluehead Sucker	2	4	0	2	47
Flannelmouth Sucker	13	4	44	12	78
Speckled Dace	434	335	163	387	208
Colorado Pikeminnow	1	1	3	0	0
Roundtail Chub	2	1	0	0	0
Red Shiner	741	272	16,371	1,828	6,344
Fathead Minnow	162	20	1,467	208	1,781
Common Carp	2	0	314	0	19
Plains Killifish	4	0	4	18	70
Western Mosquitofish	113	3	1,191	81	452
Channel Catfish	138	4	27	18	36
Black Bullhead	0	0	0	2	8
Yellow Bullhead	2	0	18	1	0
Green Sunfish	0	1	0	0	0
Largemouth Bass	0	0	13	0	0
Rainbow Trout	0	0	0	1	0
Mottled Sculpin	0	1	0	0	0
Total number of fish	1,777	426	19,579	2,344	9,043
Total area (m^2)	1,904	1,356	1,914	1,346	1,468
Total density (#/m^2)	0.93	0.31	10.23	1.74	6.160
Total native density (#/m^2)	0.32	0.09	0.09	0.14	0.179
Total nonnative density (#/m^2)	0.61	0.22	10.14	1.6	5.981

Statistical analyses showed no differences in fish density between primary and secondary channel sampling. As in the primary channel sampling, fish density was highest in secondary channels during 2000 because of an increase in red shiner numbers (Table 3). Secondary channel sampling showed a general decrease in species diversity from 1998-2000, with a slight rebound in 2001. When the 1998-2001 secondary channel data were combined with data from the 7-year research period, significant relationships were observed between discharge and fish density (Propst, Hobbes et al. 2003). In Geomorphic Reach 5 native fishes showed a significant positive relationship to discharge and nonnative fishes showed a significant positive relationship to the number of days with summer discharge below 500 cfs. In Reach 4 native fish density had a significant positive relationship with spring discharge. Similar to Reach 5, nonnative fish density in Reach 4 had a significant positive relationship with the number of days with summer discharge below 500 cfs, but it was also significantly negatively related to mean summer discharge. No significant relationships between fish density and flow were found in Reach 3.

Backwater sampling for small-bodied fishes began in 1999 and continued through 2002. Small-bodied fish monitoring efforts in backwaters revealed low densities of native fishes in all reaches and years. Four native species and 10 nonnative species were collected between 1999-2001. A single Colorado pikeminnow was collected in backwater sampling in both 1999 (Reach 5, 226 mm SL) and 2000 (Reach 3, 93 mm SL). Fewer backwaters were available in 1999 than in 2000-2001. Nonnative fish densities in backwaters were higher in 2000, and red shiner dominated all samples.

Adult Fish Monitoring

Large-bodied fish monitoring from 1998-2001 produced 14 nonnative and 6 native species, along with 4 different sucker hybrids (Ryden 2000a, Ryden 2003a). Catch per unit effort (CPUE) for Colorado pikeminnow was at its highest in 1998 when 95 individual Colorado pikeminnow were captured, including one wild adult (the other 94 were juveniles or adults from the 1996 and 1997 YOY stockings or the 1997 adult stocking) (Figure 3). The number of Colorado pikeminnow captured in 1999 fell to 10 stocked fish, and by 2001 only five stocked Colorado pikeminnow were recaptured. This decline in Colorado pikeminnow catch was the result of the growth of the young fish stocked in 1996 and 1997, and perhaps the loss of those fish as they grew. Since only larvae were being stocked in 1999-2000, no new stocked fish were in the river to be recaptured. It also reflects the gradual loss of the adult Colorado pikeminnow stocked in 1997.

Unlike Colorado pikeminnow CPUE, stocked razorback sucker CPUE remained low and consistent from 1998-2000 (Figure 4). In 2001 razorback sucker CPUE during adult monitoring increased as a total of 11 stocked razorback sucker were recaptured. Additionally, one suspected razorback sucker x flannelmouth sucker hybrid was captured in 2001. Only two roundtail chub were collected during the adult monitoring effort, both in 1999.

Statistical analyses of the large-bodied fish data were restricted to the four most common species which are, from most common to least common, the native flannelmouth sucker, the nonnative channel catfish (*Ictalurus punctatus*), the native bluehead sucker (*Catostomus discobolus*), and the nonnative common carp (*Cyprinus carpio*). The CPUE of flannelmouth sucker has significantly increased in Geomorphic Reaches 4-5 from 1998-2001 but declined in Reaches 1 and 2 (Ryden 2003a). The apparent decline in flannelmouth sucker seen during the 7-year research period has stopped and abundance has increased significantly except in the lowest portions of the river. Declines in flannelmouth sucker in Reach 1 appear to be related to inundation of a waterfall near Lake Powell in 1995 that allowed predators from the lake to invade the river (Ryden 2003a).

Monitoring showed that bluehead sucker continued to be abundant in Reach 6, but CPUE declines downstream and these fish were absent in Reach 1. In Reaches 3-5 there was an increase in bluehead sucker CPUE in 1999-2000, but in 2001 the CPUE was similar to that seen during the 7-year research period. The CPUE of age-0 flannelmouth and bluehead sucker was exceptionally high in 2000 above the PNM Weir, but no increase in larger juveniles was noticed in 2001.

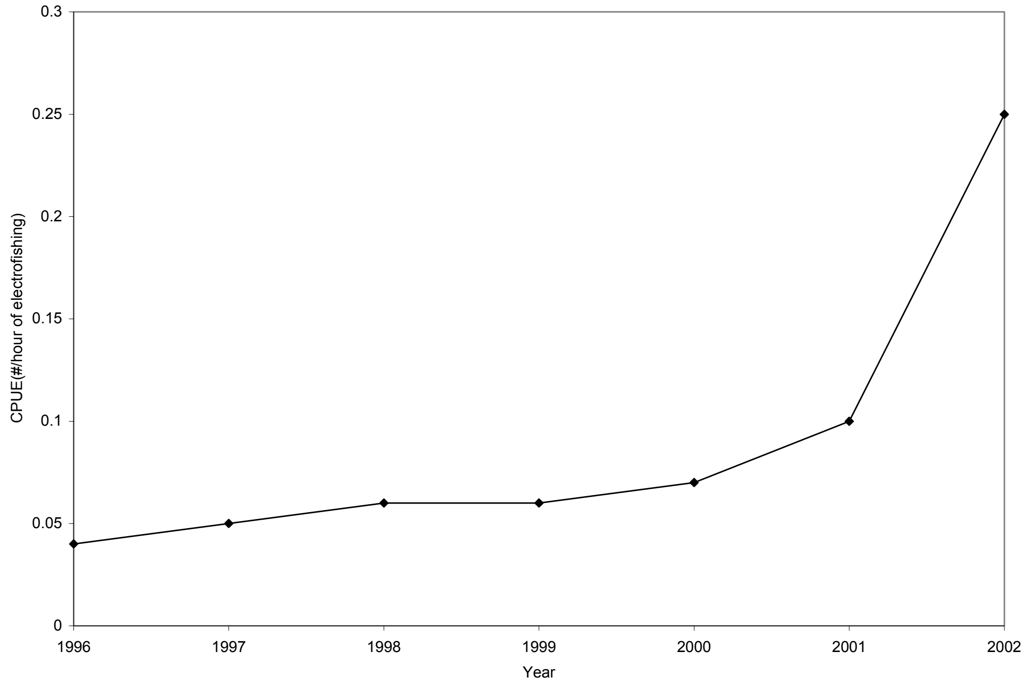

Figure 3. **Catch per unit effort (CPUE) in number of fish per hour of electrofishing for Colorado pikeminnow during fall adult monitoring (Ryden 2003a).**

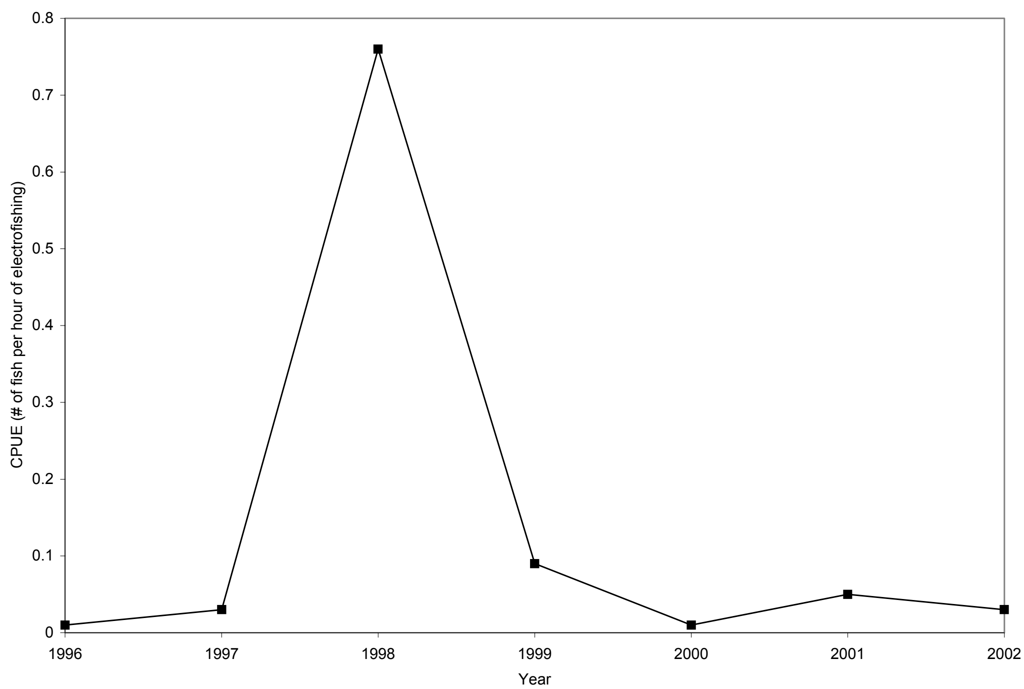

Figure 4. **CPUE in number of fish per hour of electrofishing for razorback sucker during fall adult monitoring (Ryden 2003a).**

Channel catfish continued to be the dominant large-bodied nonnative species below the PNM Weir from 1998-2001. The CPUE for juvenile and adult channel catfish was variable throughout 1998-2001 sampling. Reaches 5 and 6 showed an apparent increase in channel catfish CPUE from 1999-2001 over 1996-1998. Large numbers of age-1 catfish captured in 2001 indicate that 2000 was a good reproductive year for channel catfish, even though large numbers of YOY channel catfish were not seen in the 2000 small-bodied fish monitoring. While CPUE appears to have increased from 1999-2001, the average size of channel catfish and the number of channel catfish larger than 525 mm has decreased. This may be attributable to mechanical removal of channel catfish throughout the San Juan River.

Common carp remained the second most common large-bodied nonnative fish from 1998-2001. The CPUE for juvenile common carp was higher in 2000 than most other years, especially in Reach 6. Despite this influx of YOY common carp, a general decline in common carp CPUE was seen during fall adult fish monitoring in lower Reach 6, which may be a function of the intense mechanical removal program in this area. The CPUE for common carp below PNM Weir was generally twice what the CPUE was above PNM Weir. However, those common carp found above the PNM Weir were in better condition.

Some other nonnative predatory fishes of concern were also captured during the 1998-2001 adult large-bodied fish monitoring, including largemouth bass (*Micropterus salmoides*), striped bass, and walleye (*Stizostedion vitreum*). Very few walleye were captured from 1998-2001, but relatively large numbers of largemouth bass and striped bass were captured in 2000 during a summer of exceptionally low, clear flows. The CPUE for both these species fell again in 2001, indicating that the low, clear flows in 2000 may have been responsible for the increased presence of these species.

Other Research

Nonnative Removal Projects

In 1998 and 1999 removal of nonnative species during adult monitoring trips was continued throughout the whole river (Smith and Brooks 2000). The CPUE of channel catfish increased between 1998 and 1999, and continued to be higher in 2000-2001 (Figure 5, Davis 2003). The increase appears to be a function of an increase in the catch rate of juvenile channel catfish. While mean total length decreased between 1998 and 1999, mean total length of channel catfish increased riverwide from 1998-2001. Despite the increase in mean total length, there appears to have been a shift toward smaller fishes, and a larger percentage of the channel catfish caught have been ranked in smaller size classes. Channel catfish captured in Geomorphic Reaches 5 and 6 were generally larger than those captured in Reaches 1-4. Riverwide common carp catch rates were extremely variable and no trends in CPUE or size structure were identified. As mentioned in the adult and small-bodied fish monitoring sections, the CPUE for juvenile common carp was significantly higher in 2000 (Ryden 2003a). Intensive channel catfish removal began in 1998 between RM 137.2 and 127.8. In 1999 the river section between the PNM Weir and Hogback Diversion was added to the study. In 2000-2001 intensive removal continued in the PNM Weir to Hogback section. Overall,

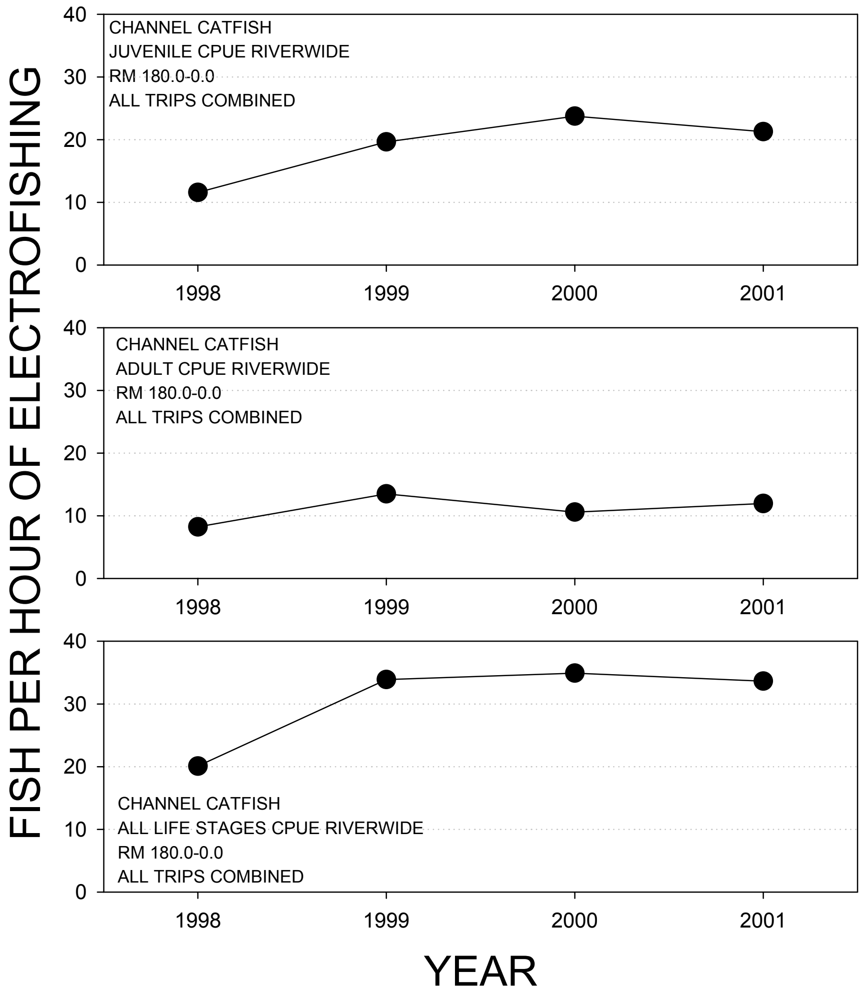

Figure 5. Riverwide CPUE for channel catfish removed during all sampling in the San Juan River from 1998-2001 (Davis 2003).

channel catfish CPUE was similar in the RM 137.2-127.8 section between 1998 and 1999 (Smith and Brooks 2000). Mean total length increased in this section between 1998 and 1999. From 1999-2001 increased effort was applied to mechanically remove nonnative fishes between the PNM Weir and Hogback Diversion. The CPUE for channel catfish increased slightly between 1999 and 2000, but mean total length decreased significantly (Davis 2003). In 2001 catch rates for channel catfish began low and increased dramatically after spring runoff. Mean total length for channel catfish in 2001 was lower (396 mm) than both 1999 (456 mm) and 2000 (405 mm). Common carp catch rates were variable between the 3 years and showed no trend. However, a similar dramatic increase in common carp catch rates was seen after spring runoff subsided in 2001. Regression analyses showed that both common carp and channel catfish catch rates were inversely related to flow at the time of sampling.

A study to evaluate timing of striped bass movement into the river and remove nonnative fishes below Mexican Hat was initiated in 2002 (Jackson 2003). During six trips between March and June, 6 Colorado pikeminnow (4 adults and 2 subadults) and 28 razorback sucker were collected. One of the Colorado pikeminnow was a recapture from 1999 and had grown 161 mm since that time. Razorback sucker seemed to be congregated around Slickhorn Rapid (RM 17.6), potentially for spawning. Channel catfish was the most abundant species in these collections, followed by common carp. Since only nonnative and endangered species were netted on these trips, the entire fish community is not represented. Striped bass were first collected in early May and their catch rate peaked in late June, when they were found as high as Mexican Hat (RM 53). Low flows precluded sampling in July and August. A 10,000 cfs storm flow event preceded fall sampling efforts, but no striped bass were found. None of the 21 striped bass collected had native fish remains in their stomachs, but native fishes were common in stomachs of striped bass captured during nonnative removal efforts in New Mexico. Fourteen walleye were collected between mid-March and early June. Preliminary analyses indicate a relationship between Lake Powell temperatures and the timing of striped bass appearance in the San Juan River.

Stocking and Monitoring of Stocked Fish

Stocking experiments for Colorado pikeminnow continued in 1998-2000 as larvae were stocked (Jackson 2001), and adults were stocked in 2001 (Ryden 2003a). Table 5 shows the numbers and approximate sizes of Colorado pikeminnow stocked from 1998-2001.

Table 5. Date, number, and approximate size (TL) of Colorado pikeminnow stocked from 1998-2001 (Ryden 2003a; D. Ryden, USFWS, personal communication).

DATE	NUMBER	APPROXIMATE SIZE
07/02/1998	10,571	18-28
07/07/1999	500,000	not specified (larvae)
06/11/2000	105,000	not specified (larvae)
4/11/2001	148	442-641

Catch Per Effort (CPE) during monitoring for the Colorado pikeminnow stocked in 1998 was lower in the initial sampling trip than it had been in 1996 and 1997: 0.7/100m^2 versus 4.3/100m^2 and 3.3/100m^2, respectively (Trammell and Archer 2000). However, numbers of Colorado pikeminnow stocked in 1998 were 10% or less of those stocked in 1996 and 1997. The spring monitoring capture rate of fish stocked in 1998 was also lower than the capture rate for fish stocked in 1996 and 1997 (Trammell and Archer 2000). Unlike the follow-up monitoring for the 1996-1998 stocking efforts, no Colorado pikeminnow were captured during monitoring of the larval Colorado pikeminnow stocked in 1999, and only four of the stocked Colorado pikeminnow were captured during monitoring in 2000 (Trammell 2000, Jackson 2001). Studies of drift rates in 1998 and 1999 suggested that large numbers of stocked larval Colorado pikeminnow could be lost to Lake Powell and irrigation diversions (Dudley and Platania 2000a, b). These experiments suggested that stocking larvae was not a viable augmentation method in the San Juan River. One hundred forty-eight adult fish that were generally in good condition were stocked in 2001 near Farmington. Since stocking they have moved down river somewhat and declined in numbers. These fish are generally in poor condition, apparently because adjusting to the river environment is taking some time, and the few remaining are concentrated in the area between the PNM Weir and Hogback Diversion (Ryden 2003a).

After the completion of the Augmentation Plan for Colorado pikeminnow (Ryden 2003b), stocking efforts shifted to YOY Colorado pikeminnow as a result of the success seen in 1996 and 1997. Twice the number of YOY Colorado pikeminnow were stocked in 2002 versus 1996 and 1997 (200,000 versus 100,000), but December monitoring of Colorado pikeminnow stocked in 2002 had a CPE of $1.6/100m^2$, which was lower than the 1996 and 1997 stocking efforts (BIO-WEST, unpublished data).

From 1994-1996 a total of 940 razorback sucker were stocked into the San Juan River (Ryden 2000b). Various numbers of these fish were recaptured over the next several years, indicating that stocked razorback sucker were surviving (Ryden 2000b). A 5-year Augmentation Plan was initiated in 1997 (Ryden 1997), which led to razorback sucker being stocked in the San Juan River every year from 1997-1998 and 2000-2002. In 1997 2,885 fish were stocked at mean sizes between 185 and 229 mm (SL) (Ryden 2003a). Through 2001 a total of 6,836 razorback sucker were stocked into the San Juan River. Table 6 shows stocking dates and numbers, and approximate sizes of razorback sucker stocked in the San Juan River from 1998-2002.

During adult monitoring, nonnative fish removal sampling, and monitoring efforts designed specifically to recapture stocked razorback sucker, a total of 127 unique fish stocked between 1994 and 2001 were collected (Ryden 2003a). From 1998-2001 69 new captures of stocked razorback sucker were recorded. Table 7 shows the number of new razorback sucker captures according to the year that the captured fish were stocked. A few aggregations of razorback sucker in spawning condition have been found, primarily near the mouth of McElmo Creek (RM 100), but no spawning site has been identified.

Table 6. Stocking dates and numbers, and average sizes of razorback sucker stocked from 1998-2001 (Ryden 2003a).

DATE	NUMBER	AVERAGE SIZE TL (mm)
04/22/1998	57	420
05/28/1998	67	417
10/15/1998	1155	232
10/20/2000	1044	214
11/01/2001	688	410

Radio Telemetry and Recapture Information

One of the goals of the razorback sucker stocking program was to identify habitat preferences and utilization of the stocked fish. Implanting stocked fish with radio tags and tracking them using radio telemetry was one of the tools used to meet this objective. In the 1994-1996 stocking study, 57 of

Table 7. Number of new stocked razorback sucker recaptures from 1998-2001 by the year they were stocked (Ryden 2003a).

YEAR STOCKED	1998	1999	2000	2001
1994	3	5	5	5
1995	0	0	0	2
1996	0	1	0	0
1997	3	1	1	1
1998	2	8	3	3
2000	0	0	0	26
2001	0	0	0	0
Total	8	15	9	37

the stocked fish were implanted with radio tags (Ryden 2000b). By the end of the experimental stocking period, only one tag was still active (Ryden 2000c). The fish carrying this tag was tracked intermittently throughout September 1998.

Four additional razorback sucker were implanted with radio tags in 1998. Three of the four tags were never relocated, and the fourth tag was only located once. In 1999 four more razorback sucker were implanted with radio tags, and again only one of the fish was located after release (Ryden 2001). Two contacts were made with this fish before it disappeared. Five more razorback sucker were implanted with radio tags in 2000 (Ryden 2001). Contacts with some of these fish continued through spring 2001.

The combination of information from radio tracking and stocked fish recaptures between 1994 and 1997 showed three sites in the San Juan River where razorback sucker seemed to congregate: a backwater near RM 38.6; close to Aneth, UT, near RM 100.2; and a large backwater just above Sand Island, UT, near RM 77.3 (Ryden 2000b). Contacts with radio-tagged fish and 1998-2001 collections of razorback sucker near RM 100.2 and RM 77.3 support the idea that these areas are important habitats for stocked razorback sucker. Collection of multiple ripe razorback sucker near RM 100.2 indicates that this may be a spawning area.

Sparse habitat preference information collected from the few razorback sucker contacts with radio-tagged fish between 1998 and 2001 has shown some support for data collected between 1994 and 1997. However, two fish have been found using swift main channel habitats, which is atypical of findings from the stocking study and elsewhere in the Colorado River Basin (Ryden 2000c, Ryden 2001). Movement data from the stocking study showed that after an initial period of downstream displacement, razorback sucker can maintain their position in the river and even move upstream. Unfortunately, some fish move as far downstream as Lake Powell after being stocked as far upstream as Hogback Diversion. Data collected from 1998-2001 support the movement data collected from 1994-1997.

Colorado pikeminnow radio telemetry continued in 1998 and resumed in 2001 with radio-tagged, adult, hatchery-reared fish. In 1998 seven of fifteen radio tags implanted in Colorado pikeminnow stocked in 1997 were still active (Miller and Ptacek 2000). Stocked fish generally dispersed downstream and then exhibited little movement. The majority of the stocked fish did not use a diversity of habitats and did not behave like wild Colorado pikeminnow (Miller and Ptacek 2000; D. Ryden, USFWS, personal communication). These fish were relatively old (15 + years) and had been subjected to a variety of experiments before stocking, which rendered them in poor health and would have destroyed them if they had not been stocked in the San Juan River. In spite of their poor health, one of the fish was found in a new potential spawning area near Hatch Trading Post (RM 168.4), which has habitat characteristics similar to spawning sites identified for wild Colorado pikeminnow. Since a number of cobble bars in this portion of the river have spawning bar characteristics, it is not known if this may have just been coincidental. In 2001 14 more hatchery-reared, adult Colorado pikeminnow were implanted with radio transmitters. Only five of these fish were still alive in 2002. Tracking the Colorado pikeminnow tagged in 2001 has shown results similar to those for hatchery-reared fish stocked in 1998 (D. Ryden, USFWS, personal communication).

DISCUSSION

The 1998-2002 physical monitoring has shown that while no major changes have occurred at cross sections and cobble bars outside of Reach 1, some changes in habitat are occurring throughout the river. Flows were lower from 1998-2002 than they were during the 7-year research period, and 2002 was a record low-flow year. The quantity and quality of backwater habitats in the San Juan River also declined over the 1998-2002 time period. The low flows between 1998-2002 may have resulted in changes to channel geomorphology including a reduction in the number, surface area, and quality of secondary channels and backwaters. Since these habitats are important for native fishes, especially young Colorado pikeminnow and razorback sucker, their loss is disconcerting.

The most promising results of monitoring from 1998-2002 was the fairly rapid increase in the number of razorback sucker larvae and juveniles collected. This increase in numbers of small fish collected is probably the result of the increasing number of stocked fish that are entering the spawning population. Monitoring results suggest that numbers of both native and nonnative fish are remaining fairly static in the river. Since 1991 the more common native fish species continue to be found in about the same numbers. Although some annual variations are seen, no major changes have occurred that can be tracked from year to year. This suggests that some of the annual variation seen in the data is caused by sampling bias. Since few native fish are being collected via small-bodied fish monitoring, the question of whether sampling protocols may need to be changed is being posed.

Attempts to mechanically lower numbers of large-bodied, nonnative fishes are producing mixed results. Riverwide CPUE for channel catfish increased from 1999-2001. At the same time channel catfish seem to be smaller throughout the river and in intensive removal areas. The shift in size class may be related to removal efforts and could signify that lower CPUE of channel catfish will soon follow. Reducing the size of channel catfish may decrease depredation on large, subadult native fishes, but smaller catfish can still compete with and potentially prey upon larval and YOY native fishes.

As specified in the Augmentation Plan for Colorado pikeminnow (Ryden 2003b), over 200,000 YOY Colorado pikeminnow were stocked in October 2002 (Ryden 2003a). Early indications are that the retention of these fish was lower than in 1996 and 1997. Young Colorado pikeminnow are thought to have an affinity for backwater habitat, and the loss of this habitat may have contributed to the poor retention and survival of stocked Colorado pikeminnow in 2002. The retention of larval pikeminnow stocked in 1998 and 1999 may also have been affected by the loss of backwater habitat. However, other factors, such as river conditions, spate events, timing of stocking, size of the fish stocked, and river temperature, probably also played a role in producing low retention. The summer 2002 collection of two subadult Colorado pikeminnow in the lower San Juan River, probably fish from the 1996 or 1997 stocking of YOY pikeminnow, provides hope that some of the Colorado pikeminnow stocked during earlier efforts have survived, even though they have not been seen in the standardized monitoring.

Because of problems obtaining the number of razorback sucker called for in the 5-year Augmentation Plan (Ryden 1997), far fewer razorback sucker were stocked from 1998-2001 than anticipated. However, razorback sucker augmentation has still started to show positive results. Data collected on adult monitoring trips have shown that CPUE for razorback sucker has steadily increased from 1998-2002. Information collected from recapturing PIT-tagged individuals and contacts with radio-tagged razorback sucker has shown the presence of preferred areas and potential spawning areas. Perhaps most importantly, larval razorback sucker monitoring efforts have found rapidly increasing numbers of larval and juvenile razorback sucker, indicating successful reproduction of the stocked fish.

Monitoring from 1998 to 2002 has shown two major changes to the San Juan River and its fish fauna. A significant reduction in backwater and other low-velocity habitats has occurred (Bliesner and Lamarra 2003), and a dramatic increase in numbers of larval razorback sucker has been noted. Since low-velocity habitats are primarily important to young Colorado pikeminnow and augmentation of Colorado pikeminnow has just begun, it is difficult to know whether the habitat reduction will impact recovery efforts. It is also uncertain whether these habitats will reappear if flows above 8,000 or 10,000 cfs occur in the next year or two. The increase in the number of razorback sucker larvae is a strong indication that our recovery strategies appear to be producing substantial, positive results for this species.

LITERATURE CITED

Bliesner, R. and V. Lamarra. 2002a. Hydrology /Geomorphology/Habitat 1999 Final Report. Prepared by Keller-Bliesner Engineering and Ecosystems Research Institute for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Bliesner, R. and V. Lamarra. 2002b. Hydrology /Geomorphology/Habitat 2000 Final Report. Prepared by Keller-Bliesner Engineering and Ecosystems Research Institute for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Bliesner, R. and V. Lamarra. 2003. Hydrology /Geomorphology/Habitat 2001-2002 Draft Report. Prepared by Keller-Bliesner Engineering and Ecosystems Research Institute for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Brandenburg, W.H. 2000. Razorback sucker larval fish survey 1998 and 1999. Prepared by University of New Mexico, University of Southwestern Biology, Division of Fishes for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Brandenburg, W.H, M.A. Farrington, and S.A. Gottleib. 2003. Razorback sucker larval fish survey 2002. Prepared by University of New Mexico, University of Southwestern Biology, Division of Fishes for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Brandenburg, W.H, M.A. Farrington, and S.A. Gottleib. 2001. Razorback sucker larval fish survey 2000. Prepared by University of New Mexico, University of Southwestern Biology, Division of Fishes for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Brandenburg, W.H, M.A. Farrington, and S.A. Gottleib. 2002. Razorback sucker larval fish survey 2001. Prepared by University of New Mexico, University of Southwestern Biology, Division of Fishes for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Dudley, R.K. and S.P. Platania. 2000a. Downstream transport rates of passively drifting particles and larval Colorado pikeminnow in the San Juan River 1998. San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM. 33 p.

Dudley, R.K. and S.P. Platania. 2000b. Downstream transport rates of passively drifting particles and larval Colorado pikeminnow in the San Juan River 1999. San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM. 33 p.

Davis, J. 2003. Non-native species monitoring and control, San Juan River 1999-2001. Prepared by U.S. Fish and Wildlife Service, New Mexico Fishery Resources Office for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Farrington, M.A., W.H. Brandenburg, and S.J. Gottleib. 2003. Colorado pikeminnow larval fish survey in the San Juan River during 2002: Draft Report. Prepared by University of New Mexico, University of Southwestern Biology, Division of Fishes for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Holden, P.B. (Editor). 1999. Flow recommendations for the San Juan River. San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Holden, P.B. 2000. Program evaluation report for the 7-year research period (1991-1997). San Juan River Basin Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Jackson, J. 2003. Nonnative control in the Lower San Juan River 2003: Draft interim progress report. Prepared by Utah Division of Wildlife Resources for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Jackson, J.A. 2001. Evaluation of stocked Colorado pikeminnow into the San Juan River: 2000. Utah Division of Wildlife Resources, Salt Lake City, UT. Publication # 01-09.

Miller, W.J. and J.A. Ptacek. 2000. Colorado pikeminnow habitat use in the San Juan River, New Mexico and Utah. Prepared by Miller Ecological Consultants, Fort Collins, CO, for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Propst, D.L., A.L. Hobbes, and R.D. Larson. 2000. Small-bodied fish monitoring in the San Juan River 1998 and 1999. Prepared by New Mexico Department of Game and Fish, Conservation Services Division for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Propst, D.L., A.L. Hobbes, and R.D. Larson. 2003. Small-bodied fish monitoring in the San Juan River 1998-2001. Prepared by New Mexico Department of Game and Fish, Conservation Services Division for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Propst, D.L., A. L. Kingsbury, and R. D. Larson. 2003. Small-bodied fish monitoring in the San Juan River 2002. Prepared by New Mexico Department of Game and Fish, Conservation Services Division for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Propst, D.L., S.P. Platania, D.W. Ryden, and R.L. Bliesner. 2000. San Juan River Monitoring Plan and Protocols. San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Ryden, D.W. 1997. Five-year augmentation plan for razorback sucker for the San Juan River. U.S. Fish and Wildlife Service, Grand Junction, CO. 27 p.

Ryden, D. 2000a. Long-term monitoring of sub-adult and adult large-bodied fishes in the San Juan River, 1998 and 1999. Prepared by the U.S. Fish and Wildlife Service, Colorado River Fishery Project for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Ryden, D. 2000b. Monitoring of experimentally stocked razorback sucker in the San Juan River: March 1994 through October 1997. Prepared by the U.S. Fish and Wildlife Service, Colorado River Fishery Project for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Ryden, D. 2000c. Monitoring of razorback sucker stocked into the San Juan River as part of a five-year augmentation effort: 1997-1999 interim progress report. Prepared by the U.S. Fish and Wildlife Service, Colorado River Fishery Project for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Ryden, D. 2001. Monitoring of razorback sucker stocked into the San Juan River as part of a five-year augmentation effort: 2000 interim progress report. Prepared by the U.S. Fish and Wildlife Service, Colorado River Fishery Project for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Ryden, D. 2003a. Long term monitoring of sub-adult and adult large-bodied fishes in the San Juan River: 1999-2001 integration report. Prepared by the U.S. Fish and Wildlife Service, Colorado River Fishery Project for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Ryden, D.W. 2003b. Augmentation plan for Colorado pikeminnow for the San Juan River. U.S. Fish and Wildlife Service, Grand Junction, CO.

Smith, J.R., and J.E. Brooks. 2000. Non-native species monitoring and control, San Juan River 1998-1999. Prepared by U.S. Fish and Wildlife Service, New Mexico Fishery Resources Office for the San Juan Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Trammell, M. 2000. Evaluation of reintroduction of young of year Colorado pikeminnow into the San Juan River: 1999 annual report. San Juan River Basin Recovery Implementation Program. USFWS, Albuquerque, NM. 17 p.

Trammell, M. and E. Archer. 2000. Evaluation of reintroduction of young of the year Colorado pikeminnow in the San Juan River 1996-1998. Pages 4-1 to 4-33 *in* Archer, E., T. A. Crowl, and M. Trammell, editors. Age-0 native species abundances and nursery habitat quality and availability in the San Juan River, New Mexico, Colorado, and Utah. Utah Division of Wildlife Resources, Salt Lake City, UT.