Riverine Fish Flow Investigations

Federal Aid Project F-288-R7

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Federal Aid in Fish and Wildlife Restoration

Job Progress Report

Colorado Division of Wildlife

Fish Research Section

Fort Collins, Colorado

March 2004

STATE OF COLORADO

Bill Owens, Governor

COLORADO DEPARTMENT OF NATURAL RESOURCES

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Name: Aquatic Nongame Research F-288

Title: Riverine Fish Flow Investigations

Period Covered: July 1, 2003 - June 30, 2004

Study Objective: **Quantification of impacts of the 2002 drought on native fish populations in the Yampa and Colorado rivers.**

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INTRODUCTION

Establishment of instream flows is generally considered to be a valuable tool for maintaining declining native fish populations (Espegren 1998) and also for recovery of threatened and endangered species (McAda 2003). Most instream flow recommendations are based on a modeling process that employs a hydraulic model to simulate flow conditions and a species habitat suitability index that predicts habitat availability or quality. The level of confidence in the models output is a function of the validation process that compared model output with field observations. In most situations the model projections are outside the range of the empirical data.

In 1998 the CDOW established a research project to gather population and habitat data for non-endangered native fish, for the purpose of making biologically justified instream flow recommendations. Anderson and Stewart (2003) designed a meso-habitat instream flow method that used a 2-D modeling methodology. Channel topography was surveyed at six study sites on three rivers. The methodology included development of meso-habitat suitability ratings based on density and biomass population estimates. Flows were simulated with a 2-D flow model.

The drought of record for several rivers in Colorado occurred in 2002. Extreme low base flows occurred just at the completion of the instream flow study for the Yampa and Colorado rivers. Since the populations of the target native fishes were quantified using mark and recapture electro-fishing during the years 1998 to 2001 on the Yampa River and 1999 to 2001 on the Colorado River, a baseline data set had been recently established. These flows provided the opportunity to empirically demonstrate the response of the fish community to a season of unusually low flows. This data could also be used to validate or calibrate the biomass model from the instream flow study made data from prior years.

This report also compiled available geomorphic and hydrologic data for rivers with recent fishery information. The objective of this synthesis was to present hypotheses about relationships between native fish stocks and habitat availability between rivers and within rivers over time. These hypotheses could be refined or tested by future research.

The Study Objectives:

1. Sample fish populations at the Yampa River study sites of Lily Park, Duffy, Sevens and in the Colorado River at the Corn Lake and Clifton sites.

2. Compare post-2002 (drought) population data to baseline population data.

3. Refine the biomass model made in the instream flow study based on results found in 2003.

4. Present hypotheses about the influences of macro- or meso-habitat availability on standing stocks of bluehead sucker, flannelmouth sucker and roundtail chub based on existing hydrologic and fish community structures.

STUDY AREA

Site Location

Yampa River

There were three study areas on the Yampa River. The two sites established in 1998 are called the Sevens and Duffy stations. A third site at Lily Park was added in 2000. The Sevens station, located at River Mile (RM) 63, is 1.8 mile in length. Duffy, at River Mile (RM) 109, is 4.5 miles in length (Figure 1). Sevens and Duffy were electro-fished in 1998, 1999, 2000, 2001 and 2003. The Lily Park site is located just below Cross Mountain Canyon and just above the mouth of the Little Snake River (Figure 1). The Lily Park site, from RM 52.8 to RM 54.5, is 1.9 miles in length. The Lily Park site was electro-fished in 2000, 2001 and 2003.

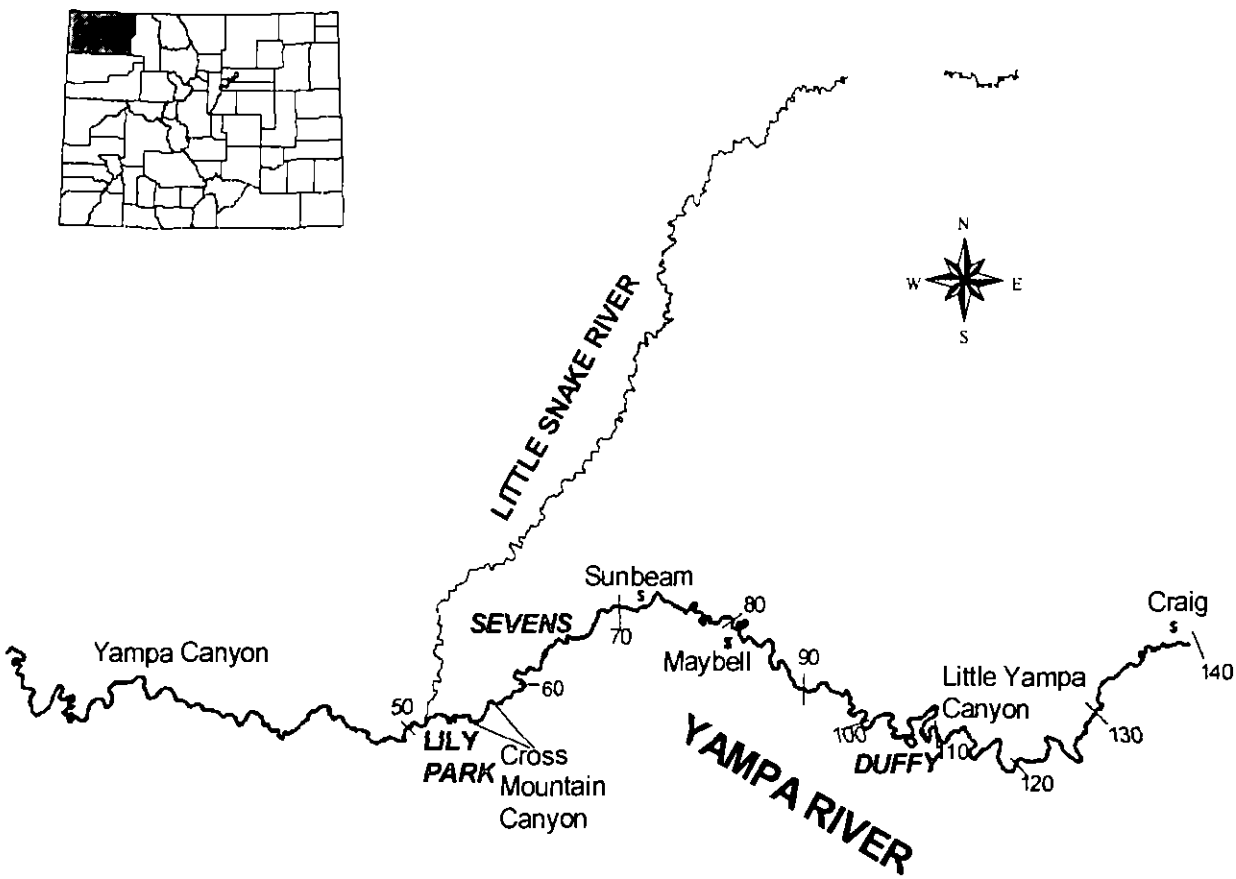

Figure 1. Yampa River study site locations for Lily Park, Sevens and Duffy.

Colorado River – 15-Mile Reach

The 15-Mile Reach of the Colorado River extends from Palisade, Colorado (RM 185) downstream to the confluence of the Gunnison River at about RM 170 (Figure 2). Two major upstream diversions divert flow from the river during the irrigation season (April 1 to November 1) and instream flows can be impacted in some years. The Government Highline diversion is located in lower Debeque Canyon (RM 193.7) and the Highline canal has a capacity of 1,620 cfs. The Grand Valley diversion dam is at RM 185.4 and the Grand Valley canal has a capacity of 640 cfs. Flows at the Palisade Gage are typically 1,200 to 1,600 cfs less than above the diversion structures in Spring and Summer. Winter (November to March) flows in the 15-Mile Reach do not appear to create fishery concerns.

There were two study sites in the 15-Mile Reach. Corn Lake was from RM 177.5 downstream to RM 175.3 (Figure 2) and was 3.9- km in length. This site was electro-fished in 1999, 2000, 2001 and 2003. The river in this section includes five small backwaters. Flow was generally confined within the main channel, as opposed to a braided channel (Anderson and Stewart 2003).

The other study site, named the Clifton Site, was added in 2000. The Clifton Site was just upstream, only a short section (about 300 m) from the Corn Lake site. The Clifton site is from RM 177.7 to 180.4 and has a total length of 4.2 km. In this section, the river has two large sections where flow is split by islands. There is an old diversion structure located at RM 179.7. An old diversion structure backs water along the north shoreline making a large backwater. Because the two sites are adjacent, it is possible and desirable to combine data into one site to serve as a single station to represent the 15-Mile Reach.

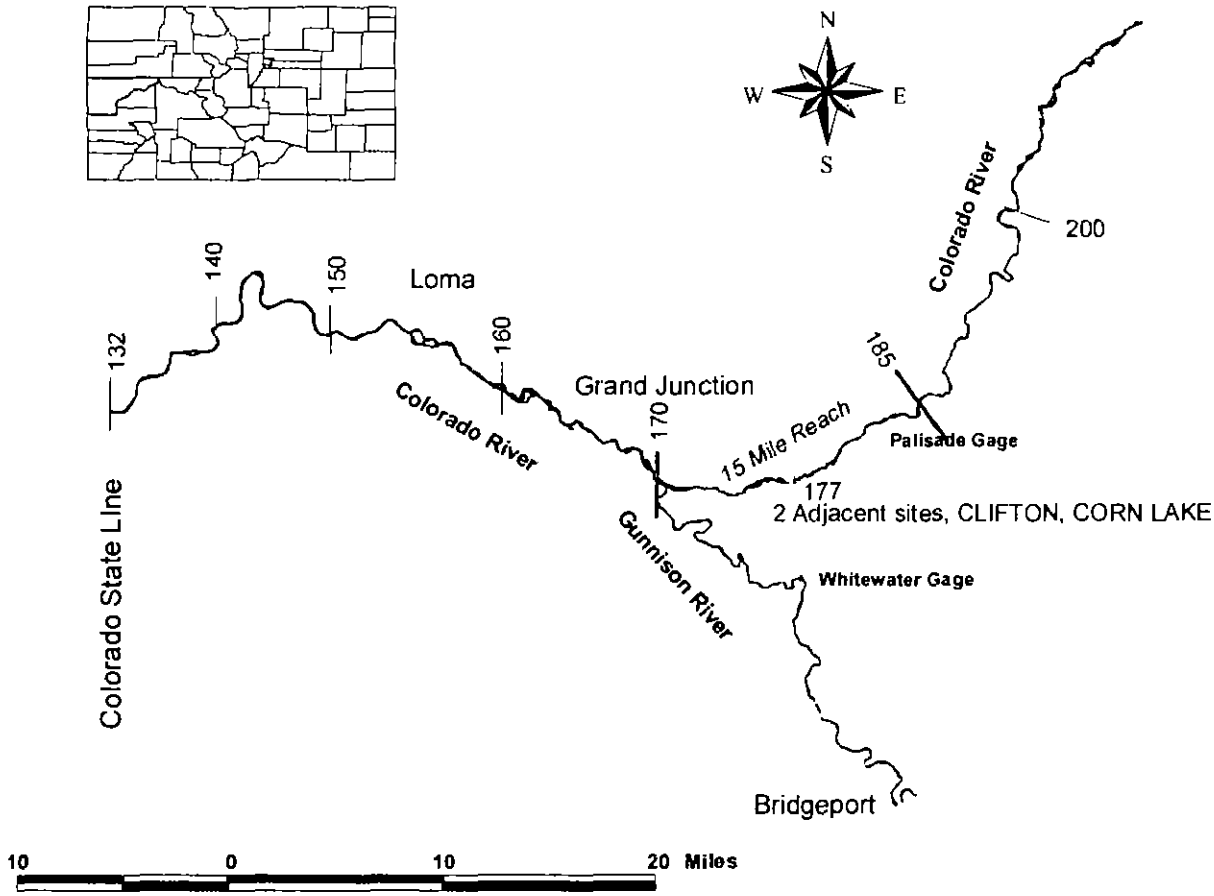

Figure 2. Colorado River study site locations in the 15-Mile Reach for Corn Lake and Clifton.

Gunnison River

The Gunnison River was sampled for the first time in 2003. The 2003 sampling was a reconnaissance for establishing one or two future 2D modeling sites and to determine the status of the fish population following the 2002 drought period.

The most upstream site was located near the town of Austin where the elevation is about 4990 ft. The river was surveyed from RM 65.0 to RM 62.7. The river was accessed at the bridge on Hwy 92 (RM 65.0) and the take out at the Hwy 65 Bridge (RM 62.5). The middle site was just downstream of the town of Delta. This site extended from the confluence of the Uncompahgre River (RM 56.3) downstream two miles to the CDOW State Wildlife Area. The lower site extended from Escalante Bridge (RM 42.7) downstream about 2.5 miles. The Escalante site was located on private property owned by the Escalante Land and Cattle Ranch. Another site was sampled near Whitewater, but a recent thunderstorm made conditions poor so sampling at this site remains incomplete.

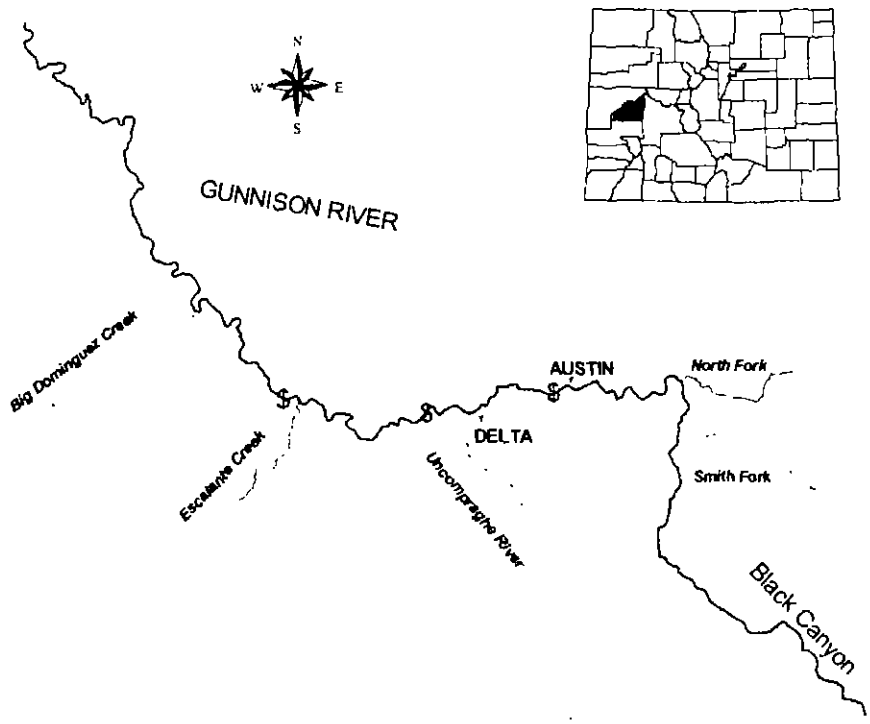

Figure 3. Gunnison River study sites locations near Escalante Creek, Uncompahgre River and Austin.

Dolores River

The Dolores River was not sampled in 2003, but data were collected during the prior study. The Dolores River headwaters in the San Juan Mountains and flows northward about 200 miles to its confluence with the Colorado River in Utah. McPhee Dam, which stores water primarily for irrigation, regulates flow for most of the river's course. McPhee Dam has a capacity of 381,000 acre feet and began storing water in 1984. The study site was located in the Big Gypsum Valley, 14 river miles downstream from the Slick Rock Bridge and 34 river miles upstream of the Bedrock boat launch (Figure 5). The study station is about 70 river miles downstream from McPhee Reservoir.

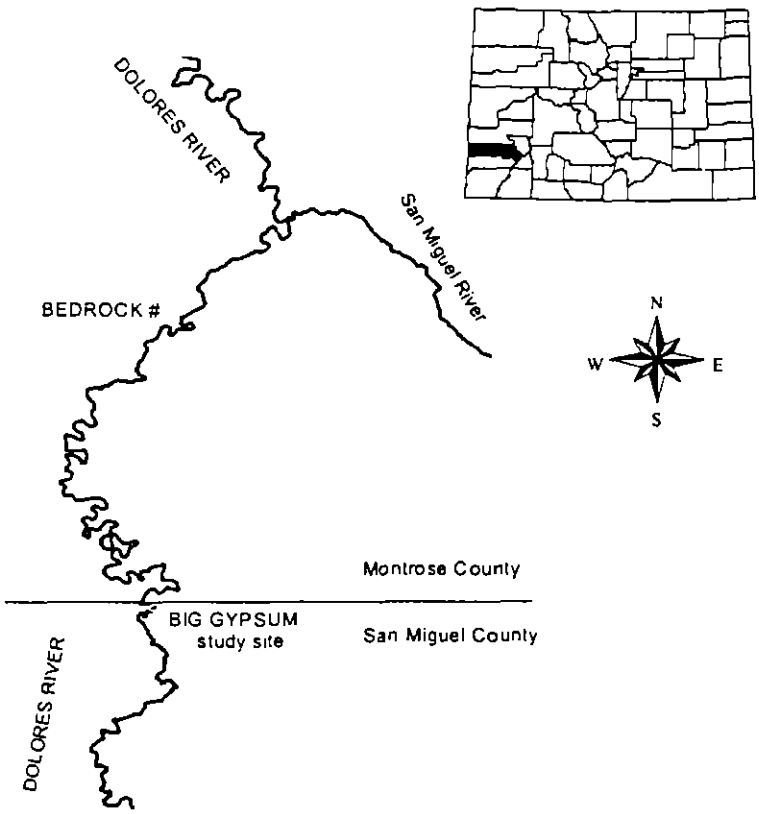

Figure 4. Dolores River study site location in the Big Gypsum Valley.

Site Geomorphology

Of the rivers described in this study, the Colorado River, upstream of the mouth of the Gunnison River, had the largest drainage area of 8,753 mi² and mean annual flow of 2,912 cfs (Palisade gage, 1991 to 2003). The Gunnison River drainage area was 7,928 mi². The mean annual flow recorded at the Whitewater gage from 1965 to 2003 was 2,507 cfs. The Yampa River at Deerlodge drained an area of 7,660 mi². The annual average flow was 2,100 cfs (1983 to 2003). The Yampa River at the Maybell gage drainage area was 3,410 mi². The mean annual flow was 1,566 cfs from 1917 to 2001 (85 years of record). The Dolores River at Bedrock drained an area of 2,024 mi² and had a mean annual flow (1972 to 2001) of 399 cfs.

The Colorado River had a mean wetted width at 600 cfs of 59 m at Clifton and 50 m at Corn Lake (Table 1). The Clifton site was wider and the Corn Lake site was narrower than the mean channel width for the entire 15-Mile Reach (Anderson and Stewart 2003). The

mean slope was 0.2% for the Clifton study site, 0.15% for the Corn Lake site so the average was 0.175%. Pitlick et al (1999) reported that the 15-Mile Reach of the Colorado River had a mean bankfull width of 134 m and a mean slope 0.175%.

The Yampa River had higher wetted width at non-runoff flows than the larger Colorado River. At a flow of 600 cfs wetted width was 68 m at the Duffy Tunnel site, 60 m at Sevens, and 57 m at Lily Park (Table 1). Mean slope was 0.06% for the study site at Duffy, 0.05% at Sevens, and 0.2% at Lily Park. Measurements obtained during the river channel survey of bankfull indicators produced a mean channel width of 85 m at Lily Park and 94 m at Sevens.

Pitlick et al. (1999) reported a mean bankfull width of 73.4 m for the Gunnison River from its confluence with the Colorado River (RM 0) to Delta (RM 57) and a mean slope of 0.12%. Pitlicks' measurements indicated the Gunnison channel was about 53% the size of the Colorado River and about 74% of the Yampa River at Sevens. Since the Gunnison River did not have a 2-D modeled site, the wetted width at 600 cfs was not available. Mean bankfull width for the Delta study area was about 73 m and the slope is 0.19% (Pitlick et al. 1999). Mean bankfull width at Escalante was about 68 m with a slope is 0.12% (Pitlick et al. 1999). Channel geometry data was not available for the Gunnison River in the Austin reach, but it appeared in the field that Austin had the highest slope of the three Gunnison sites.

Table 1. Physical attributes of Yampa and Colorado River study sites (mean velocity, length, mean width, surface area at example modeled flows) from Anderson and Stewart 2003.

	Big Gyp	**Clifton**	**Corn Lake**	**Duffy**	**Lilly**	**Sevens**
*Mean Velocity (m/s)	0.28	0.44	0.54	0.39	0.51	0.38
Length (km)	3.3	4.2	3.9	2.1	3.1	2.9
*Width (m)	22	59	50	68	57	60
Percent Slope	0.15%	0.20%	0.16%	0.06%	0.20%	0.05%
Flow (cfs)	Area (ha)					
40	6.7				12.9	11.8
100	7.1	16.4	11.2	11.6	13.1	14.3
200	7.6	19.6	16.3	12.6	14.9	15.6
400	8.0	22.4	18.5	13.6	16.7	16.7
600		24.2	19.8	14.2	17.6	17.4
800		26.0	20.7			18.0
1000		27.4	20.7			
1200		28.5	22.1			
1800		31.0	23.8			

Velocities and mean width calculated at 600cfs, except for Big Gypsum calculated at 100cfs

The Dolores River had the smallest channel. Mean wetted width at the Big Gypsum site was 22 m at 100 cfs and 25 m at 500 cfs. The Big Gypsum slope was 0.15%.

The 2-D modeling analysis simulated very similar habitat conditions for sites with similar channel geomorphology (Anderson and Stewart 2003). Meso habitat compositions based on depth and velocity criteria were very similar at all modeled flows for Lily Park, Clifton and Corn Lake.

Site Hydrology

The four rivers for which recent fish population data was available have a wide variety in hydrologic patterns. The current hydrographs for the Yampa River, Colorado River (15-Mile Reach), Gunnison River and Dolores River ranged from strongly to heavily modified from the native flow conditions. The Yampa experienced the least amount of flow modification for the spring runoff with natural flow reduced by an average of only 6% during the months of April, May and June (Modde et al 1999). In most years, however, Yampa River flows during the irrigation season were typically less than 200 cfs for much of the summer. The Gunnison River was nearly the reverse to the Yampa. Peak flows reduced by least 38% after completion of Blue Mesa Dam (Pitlick et al 1999), but base flows were typically above 600 cfs throughout the year.

The spring runoff flows in Colorado River (Cameo gage) have been reduced by at least 29% (Pitlick et al. 1999). Base flows have increased slightly in the Colorado River, but flows downstream of irrigation canal diversions can be reduced dramatically in some instances (McAda 2003). The Dolores River had both a heavily modified spring hydrograph and historically very low base flows.

Yampa River (Maybell Gage)

Andrews (1980) calculated bankfull flow for the Yampa from the Maybell Gage to be about 9,000 cfs. Peak flows recorded at the Maybell Gage were fairly similar for the years 1998, 1999 and 2000, at 10,040 cfs, 9,980 cfs and 9,830 cfs respectively. Peak flows in these three years were near the magnitude of the median peak flow of 9,980 cfs for the 87-year period of record (Figure 5). Peak flow in 2001 was 7,650 cfs, which was exceeded in 77% of the years during the period of record. The peak flow in 2002 was only 3,420 cfs, and in 2003, 12,900 cfs (Figure 5).

In most years flows during August and September were less than 200 cfs. The 87-year median (50% exceedence flow) minimum flow was 117 cfs (Figure 6). Annual minimum flows recorded at the Maybell Gage for 1997, 1998, 1999 were 320 cfs, 115 cfs, 166 cfs respectively. In 2000, 2001, 2002 and 2003 the annual minimum flow at the Maybell Gage decreased to 30 cfs, 50 cfs, 1.8 cfs and 43 cfs respectively. The 40-day low-flow represented a flow typical for a base flow period. The 40-day low-flow from the Maybell Gage for 1997, 1998, 1999, 2000, 2001, 2002 and 2003 were 718 cfs, 290 cfs, 268 cfs, 113 cfs, 110 cfs, 12 cfs and 141 cfs respectively. Peak flow, annual minimum flow and the 40th day low-flow all demonstrated the severity of the 2002 drought event.

A single or occasional low flow event may not have lasting impacts. However, two or more consecutive years of low-flows are more likely to impact the aquatic community (carrying capacity) than a single low flow year. Both 1998 and 1999 followed years that had a 40-Day minimum of over 250 cfs. In 2000, flow had not been below a 250 cfs 40-Day minimum for three consecutive years. 2001 was a second consecutive low-flow year. 2002 was the third and most dramatic low-flow year of this dry period (Figure 6). In spite of a high peak flow, 2003 was the fourth poor base flow year in a row.

Colorado River (Palisade Gage)

Pitlick (1999) determined bankfull flow to be near 22,000 cfs for the 15-Mile Reach. The median annual peak flow for the 13-year Palisade Gage history was 13,500 cfs. The annual peak in 1999 was 12,700 cfs and 13,500 cfs in 2000. In 2001 the annual peak was 8,410 cfs. It was only 2,780 cfs in 2002. The annual peak in 2003 was the highest of this five-year period at 20,300 cfs (Figure 7).

Annual minimum flows recorded at the Palisade Gage for 1997, 1998, 1999, 2000, 2001, 2002 and 2003 were 1,710 cfs, 980 cfs, 435 cfs, 543 cfs, 477 cfs, 58 cfs and 209 cfs respectively. The 13-year median (50% exceedence flow) minimum flow was 550 cfs (Figure 8). The 40-day low-flow from the Palisade Gage for 1997, 1998, 1999, 2000, 2001, 2002 and 2003 were 2,090 cfs, 1,370 cfs, 1,470 cfs, 827 cfs, 779 cfs, 99 cfs and 619 cfs respectively.

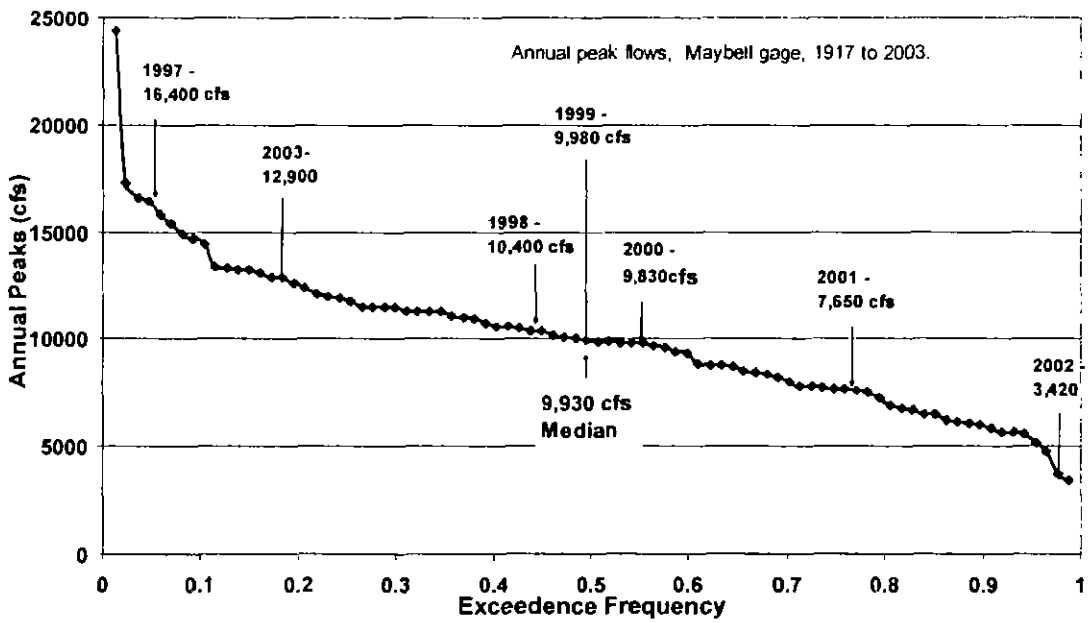

Figure 5. Exceedence frequency curve for annual peak flows at the Maybell Gage, Yampa River.

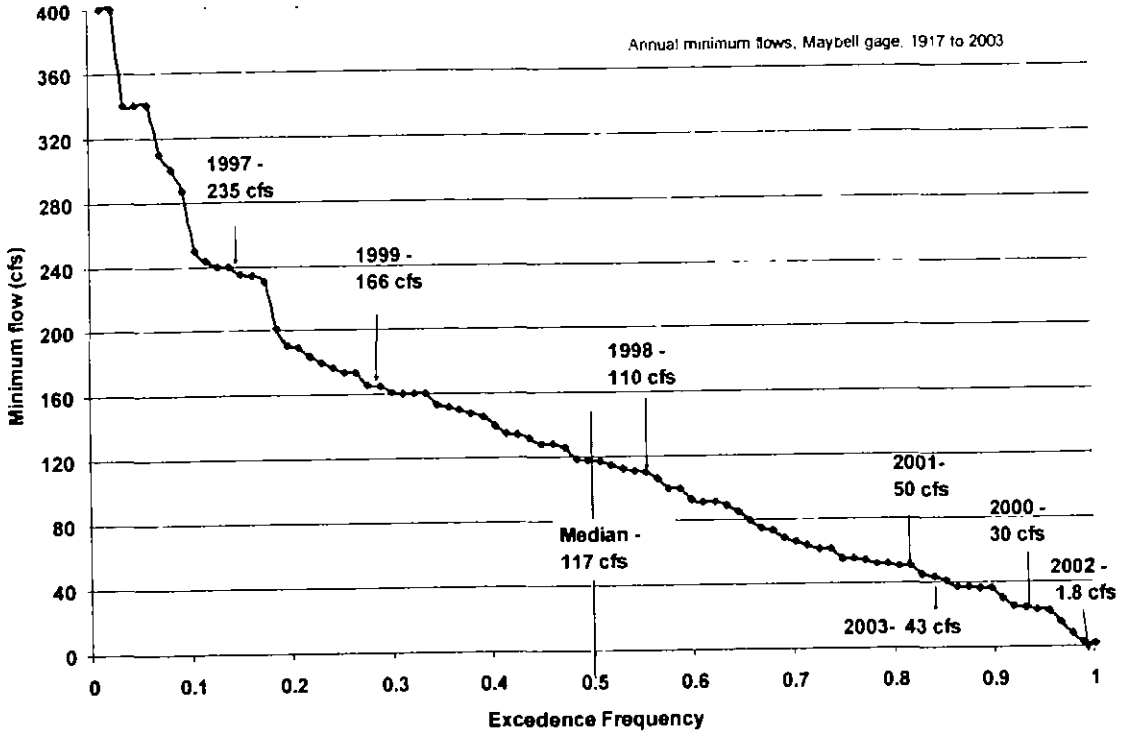

Figure 6. Exceedence frequency curve for annual minimum flows at the Maybell Gage, Yampa River.

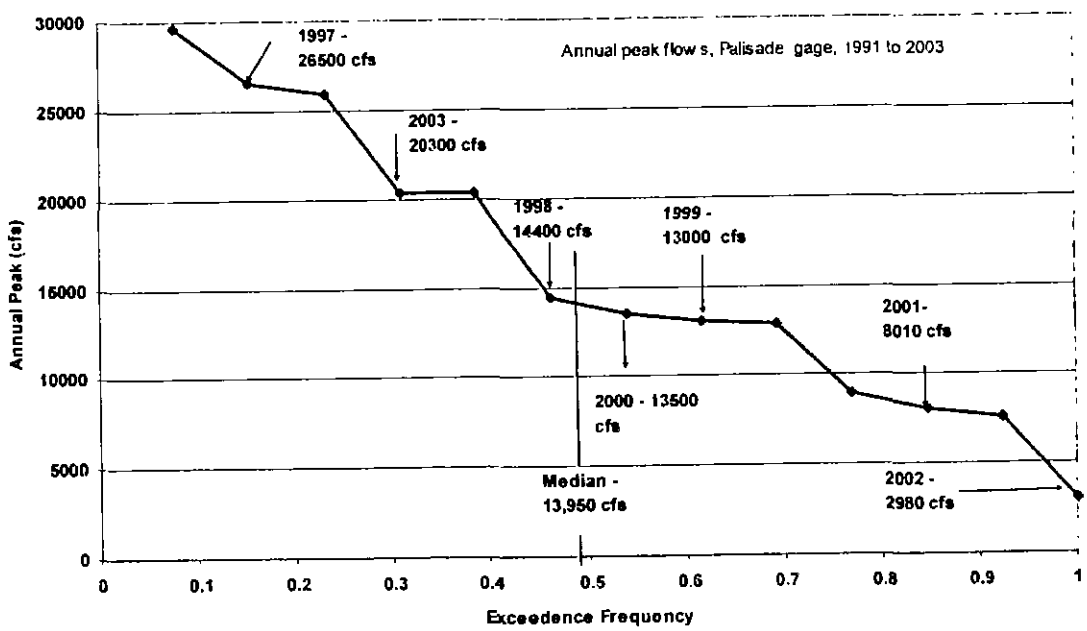

Figure 7. Exceedence frequency for annual peak flows at the Palisade gage, Colorado River for the period of record (1991-2003).

For three consecutive years (1997, 1998 and 1999) base flows were very high. They represented a period when habitat or flows were clearly not a limiting factor in the 15-Mile Reach for native fish. Base flow were moderate in 2000 and 2001, but not considered ecologically problematic. The year 2002 was the only year when flows were low for most of the summer. Base flows were again near normal in 2003 (Figure 8). Aberrations in the fish community during 2003 were generally assumed to be due to the 2002 drought.

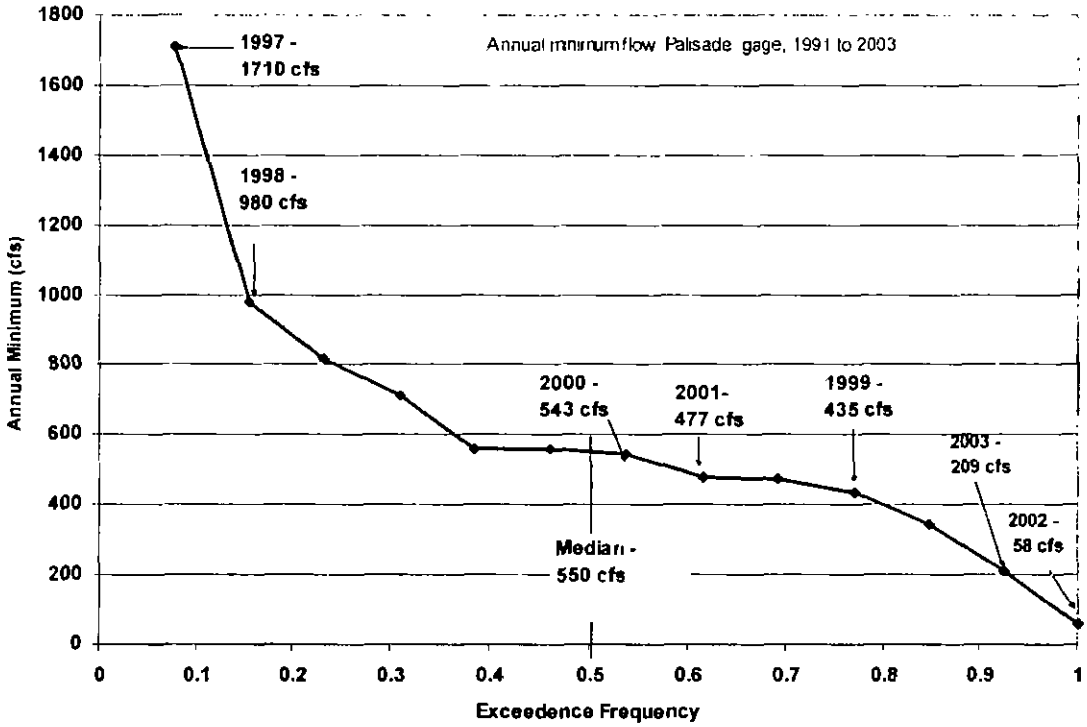

Figure 8. Exceedence frequency for annual minimum flows at the Palisade Gage, Colorado River for the period of record (1991-2003).

Gunnison River (Delta Gage/ Uncompahgre Gage)

The USGS Gage at Delta is located about five miles downstream of Austin and below the Hartland Diversion. Hartland removes about 30 to 50 cfs from the river so flows at Austin are likely somewhat higher than recorded at Delta. The period of record for the Delta Gage is from 1997 to the present. Flows from the Delta and the Uncompahgre River gages were summed to represent flows for the two sites downstream.

Peak flows have declined significantly in the Gunnison since the 1950s (McAda 2003). The median annual peak at the Whitewater Gage for the 95-year period of record is 11,750 cfs. Prior to completion of the Blue Mesa project in 1965 the median peak flow was

15,800 cfs (57 years of gage data). From 1966 to 2003 (38 years) the median peak flow dropped to 7,620 cfs.

Pitlick (1999) determined median bankfull flow to be 14,350 cfs for the Gunnison River. The median peak flow for the Whitewater Gage since 1977 was 6,535 cfs. Median peak flow was 6,626 for the sum of the Delta and Uncompahgre gages. Annual peaks in the Gunnison River (Delta and Uncompahgre) for 1998, 1999, 2000, 2001, 2002 and 2003 was 8,383 cfs, 5,676 cfs, 4,260 cfs, 4,375 cfs, 1,451 cfs and 5,379 cfs respectively (Figure 9).

Annual minimum flows summed for the Delta and Uncompahgre gages for 1998, 1999, 2000, 2001, 2002 and 2003 were 1,062 cfs, 568 cfs, 1,026 cfs, 832 cfs, 466 cfs and 319 cfs, respectively. The 27-year median annual minimum was 831 cfs (Figure 9), which was higher than the Colorado River in the 15-Mile Reach. The 40-day low-flow of annual hydrograph for 1998, 1999, 2000, 2001, 2002 and 2003 was 1,296 cfs, 1,055cfs, 1,129 cfs, 942 cfs, 608 cfs, and 519 cfs respectively (Figure 10).

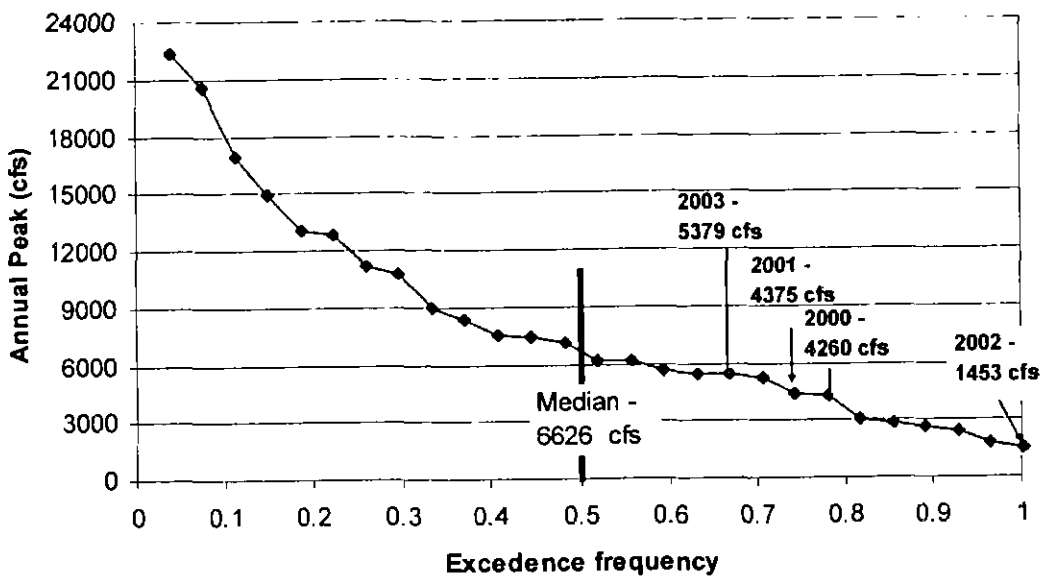

Figure 9. Exceedence frequency curve for annual peak flow for the Gunnison River (Delta and Umcompahgre gages summed) for the period of record (1977 to 2003).

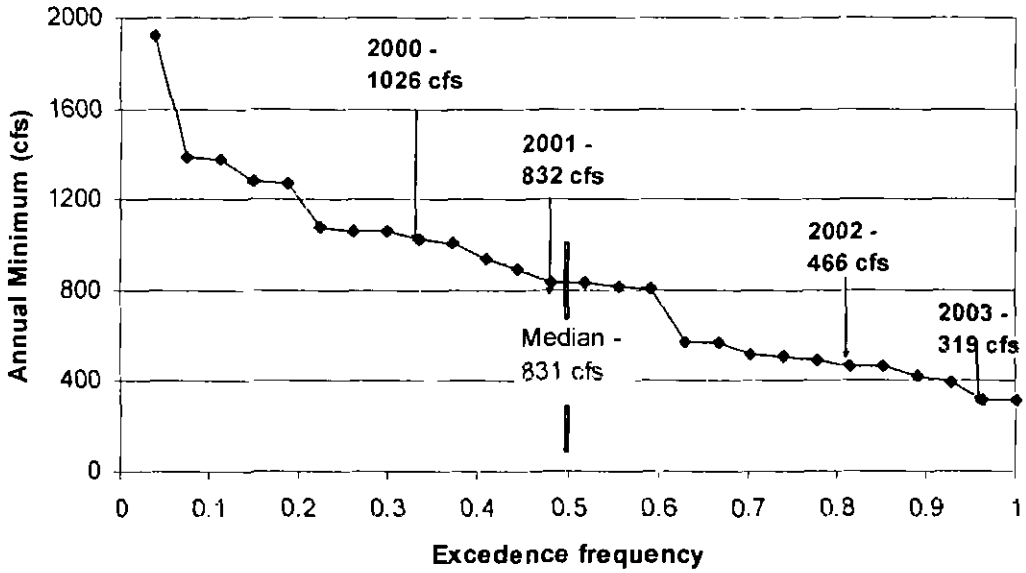

Figure 10. Exceedence frequency curve for annual minimum flows for the Gunnison River (Delta and Uncompahgre gages summed) for the period of record (1977 to 2003).

Dolores River

The Bedrock Gage was located about 34 miles downstream of the study site in Big Gypsum Valley. The highest annual peak recorded at Bedrock was 8,150 cfs in 1973. The top five highest peak flows were all above 5,000 cfs and occurred prior to 1984 (Figure 11). Since 1984 the spring hydrograph of the Dolores River has been highly modified by McPhee Reservoir which has a storage capacity of 381,000 acre feet. The median annual peak flow for the 32-year Bedrock Gage history was 3,095 cfs. The annual peak in 1999 was 3,100 and 1,170 cfs in 2000 (Figure 11). The annual peak was 522 cfs in 2001, 388 cfs in 2002 and 323 in 2003, the lowest for the period of record.

Annual minimum flows recorded at the Bedrock Gage for 1999, 2000, 2001, 2002 and 2003 were 32 cfs, 25 cfs, 24 cfs, 1.4 cfs and 6.4 cfs respectively. The 32 year median minimum flow was 22.5 cfs (Figure 12). The 40-day low-flows for 1999, 2000, 2001, 2002 and 2003 were 48 cfs, 37 cfs, 39 cfs, 2.1 cfs and 14 cfs respectively.

A noticeable change appears in the hydrograph for pre- and post-McPhee Reservoir. The median peak flow prior to 1984 was 3,660 cfs (18 years of records) and 2,060 for the period 1984 to 2003 (19 years of records). The base flows have improved in the post period. Prior to 1984 the median annual minimum flow was 4.3 cfs and the mean 40th lowest mean daily was 11.5 cfs. The median annual minimum from 1984 to the present was 32 cfs and 45 cfs for the mean 40th lowest daily flow.

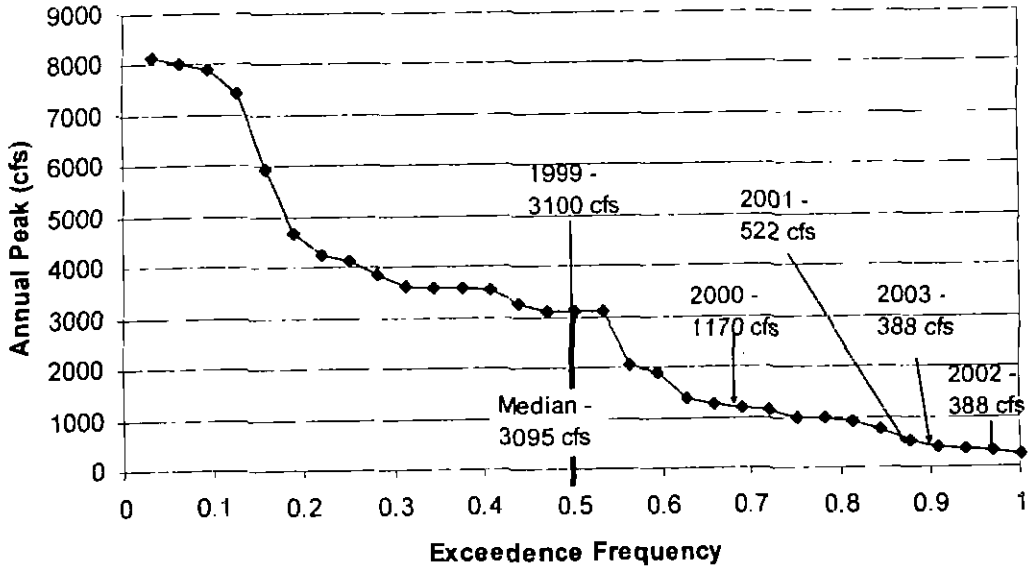

Figure 11. Exceedence frequency and annual peak flows for the Dolores River, Bedrock Gage, 1977 to 2003.

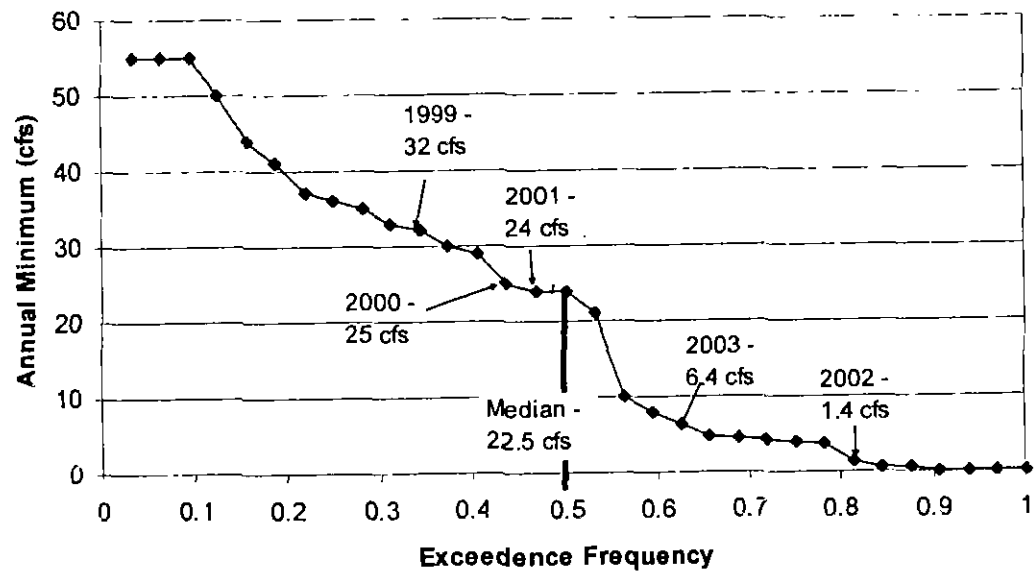

Figure 12. Exceedence frequency and annual minimum flows for the Dolores River, Bedrock Gage, 1997 to 2003.

METHODS

Fish sampling was performed by electro-shocking from a 15 ft Achilles raft from 1998 to 2000 and from a 16-ft Hyside self-bailer raft in 2001 and 2003. A Smith-Root electro-fisher, 5000-watt generator and anode array mounted on a forward boom was used in all years. The raft was maneuvered by either oars or by a battery powered 40- to 75-pound thrust trolling motor. Two netters caught as many fish as they could while the shocker was in operation. All fish were measured to the nearest millimeter. Density estimates were made for each study site on the Yampa, Colorado and Dolores rivers. Only fish over 150 mm were marked, and therefore used for mark and recapture population estimates.

The Darroch multiple mark method (Everhart and Youngs 1981) was used to make the population estimate with ninety-five percent confidence intervals. A total fish estimate was made for all species and for each species. Recapture rates generally varied between species and size-groups. In our sampling larger suckers had the highest recapture probabilities and the species with appreciably lower recapture probabilities included catfish, bass, pike and carp (the lower group). The total fish estimate represented a blend of recapture probabilities, but were expected to produce reliable comparisons for total fish abundance between years, when species and size composition was consistent. For rare species (pikeminnow, etc) with zero or one recapture in the sample, abundance was estimated by dividing the number in the sample by the mean recapture probability of the lower group.

The z-test, with an alpha of 0.05 ($z = 1.96$) was used to test for significant differences in density estimates between years at each station. At stations with three or more years of sampling, the Bonferroni inequality was also used to control the overall significance level (.05) for the simultaneous comparison of all pairs of years (Dr. David Bowden, CSU, pers. communication). At stations with four years of data, (Duffy and Sevens) the z value (2.631) corresponded to an alpha of 0.05 divided by six (0.0083).

RESULTS

This report compares data collected in 2003 (post 2002 flows) to data from earlier years. A more complete synthesis of fish data from prior years (1998, 1999, 2000 and 2001) was presented by Anderson (2002), making it unnecessary to re-present all fish data collected prior to 2003. Each annual progress report between 1999 and 2002 compared species composition, size and density data to the prior year or years. Length frequency histograms for each species at each site were presented in prior annual progress reports. Anderson and Stewart (2000) presented length data for fish sampled in 1998 and 1999. Anderson and Stewart (2001) contained length data for the 2000 sample. The 2001 sample length data was in Anderson (2002). Meso habitat preferences for depths and velocities determined for flannelmouth sucker and bluehead sucker were given in the projects completion report (Anderson and Stewart 2003).

Species composition, density and biomass data presented in the results section was for fish over 15 cm in length. Length data are inclusive for all fish captured at the site.

YAMPA RIVER

Duffy

Native fish species were uncommon to rare at Duffy during all years of sampling, averaging only 14% of fish over 15 cm for first three years, 10% in 2001 and 7% in 2003 (Table 2). Flannelmouth sucker and bluehead sucker both hybridized with non native white sucker. White-flannelmouth and white-bluehead hybrids comprised about 50% of the suckers captured during the study period. Pure native sucker represented about 10% of the catch in the baseline years and only 5% in 2003. Roundtail chub were near 3% of the catch during the study period. Colorado pikeminnow were uncommon at Duffy comprising between 1.5% to 0.6% of the total catch from 1998 and 2001. None were caught in 2003.

Table 2. Species composition (fish >15 cm) at Duffy, Yampa River 1998 to 2003.

YAMPA –REACH	DUFFY	DUFFY	DUFFY	DUFFY	DUFFY
Species	1998	1999	2000	2001	2003
Flannelmouth sucker	5%	5%	5%	2%	4%
Bluehead sucker	4%	6%	4%	4%	1%
Roundtail chub	3%	3%	4%	3%	2%
Colo. Pikeminnow	1.5%	0.6%	0.8%	0.6%	0%
White S. + hybrids	69%	72%	73%	50%	66%
Channel catfish	3%	4%	3%	4%	4%
Carp	3%	1%	1%	2%	0.3%
Smallmouth bass	8%	6%	10%	33%	18.2%
Northern pike	2.8%	2.3%	0.9%	1.1%	0.7%
Black bullhead					2%
Black crappie					2%
Sample size	1653	2092	1294	856	584

The total fish density estimates at Duffy were highest in the baseline years and lowest in 2003. The highest total density occurred in 2001 due to a higher estimate of smallmouth bass for that year (Table 3). Densities estimates for flannelmouth sucker, bluehead sucker, Colorado pikeminnow and roundtail chub were highest in the baseline years of 1998 and 1999, but lowest in 2003 (Table 3). The same trend was also found for the non-native species of white sucker, carp and northern pike. Smallmouth bass was the only species to display a strong increase in abundance during the dry years of 2001 and 2003.

Table 3. Density estimates at Duffy, Yampa River 1998 to 2003

YAMPA RIVER	Density estimate in fish per hectare				
DUFFY	No/ha	no/ha	No/ha	No/ha	no/ha
Species	1998	1999	2000	2001	2003
Total fish	62.9	65.6	51.5	69.4	40.0
Flannelmouth sucker	4.0	2.4	1.8	0.7	0.9
Bluehead sucker	3.6	3.7	4.0	2.7	0.5
Colorado pikeminnow	1.3	0.9	0.6	0.5	0.0
Roundtail chub	2.8	2.9	1.8	2.6	1.1
White S. + hybrids	39.2	39.4	33.0	29.7	20.8
Channel catfish	2.6	5.5	2.3	3.9	3.0
Carp	1.8	1.5	0.5	1.3	0.2
Smallmouth bass	5.0	6.3	6.7	27.1	13.0
Northern pike	2.5	3.0	0.6	1.0	0.5

Biomass estimates were much lower in 2003 for nearly all species compared to the baseline years (Table 4). White sucker and their hybrids were the dominant taxon at this site over the study period. This species was the best indicator of biomass potential. The large drop in white-hybrid sucker biomass indicated the fish population was negatively impacted by the flows in 2003. Bluehead sucker biomass was very low (0.2 kg/ha) in 2003. The species that displayed the least change in biomass in 2003 compared to baseline years were channel catfish and smallmouth bass.

Table 4. Biomass estimates at Duffy, Yampa River 1998 to 2003.

YAMPA RIVER					
Duffy	Kg/ha	Kg/ha	Kg/ha	Kg/ha	Kg/ha
Species	1998	1999	2000	2001	2003
Total fish	66.5	65.9	51.0	47.4	22.6
Flannelmouth sucker	4.7	2.7	2.2	0.8	1.1
Bluehead sucker	1.8	1.3	2.2	1.5	0.2
Roundtail chub	2.5	2.7	1.6	2.2	1.1
Colorado pikeminnow	2.5	1.6	0.9	0.7	0
White S. + hybrids	39.9	39.7	35	26.9	12.7
Channel catfish	4.3	6.5	3.3	4.1	3.9
Carp	7.3	6.1	2.8	6.1	1.5
Smallmouth bass	1.9	2.6	2.3	4.8	1.9
Northern pike	1.5	2.8	0.7	0.2	0.3

Mean length of white sucker and smallmouth bass was less in 2003 compared to the baseline years (Table 5). This higher presence of Age-1 white sucker and smallmouth bass in the 2003 sample (Figures A1- 19 and A1-51) indicated improved survival of Age-0 in 2002. This could be due to relaxed predation on their young-of-year (YOY) during 2002. Age-1 bluehead sucker, flannelmouth sucker or roundtail chub were not observed in the 2003 survey (Figures A1-2, A1-9 and A1-14) suggesting their YOY had poor survival rates in 2002. Also both Age-0 and Age-1 carp were not found at Duffy in 2003 (Figure A1-39).

Mean length of bluehead sucker was lowest in 2003 due to fewer large adult fish in the sample (Table 5).

Table 5. Mean length of all species collected at Duffy, Yampa River 1998 to 2003.

YAMPA RIVER	Mean length for all fish collect in cm				
SEVENS	A	B	C	D	E
Species	**1998**	**1999**	**2000**	**2001**	**2003**
Flannelmouth Sucker	48.4	47.8	49.8	47.5	49.4
Bluehead Sucker	35.7	38.0	37.6	36.2	30.9
Colorado Pikeminnow	60.8	57.4	56.4	55.5	
Roundtail Chub	43.5	40.7	44.2	43.4	44.9
White S. + Crosses	39.7	33.1	40.6	38.2	28.3
Channel Catfish	52.9	47.6	51.6	46.4	49.7
Carp	59.8	67.9	48.0	68.0	80.0
Smallmouth Bass	12.6	16.1	12.2	13.1	9.6
Northern Pike	43.3	51.7	57.6	32.2	43.2

Sevens

Composition of native fish was highly consistent from 1998 to 2001 at Sevens with native fish comprising about 73% (four-year mean) of the fish over 15 cm (Table 6). In 2003 native species were less than half of the sample at 42%. Flannelmouth sucker composition at Sevens ranged from 46% to 53% between 1998 and 2001, but it was 36% in 2003. Bluehead sucker composition for the first three years (1998, 1999 and 2000) averaged 21%. In 2001 it was 13% and only 2% in 2003 (Table 6). Roundtail chub was consistent at 3% to 4% of the sample in all years at Sevens (Table 6). Colorado pikeminnow were rare or absent at Sevens for all years with data.

Table 6. Species composition at Sevens, Yampa River, 1998 -2003.

YAMPA RIVER	SEVENS	SEVENS	SEVENS	SEVENS	SEVENS
Species	**1998**	**1999**	**2000**	**2001**	**2003**
Flannelmouth sucker	48%	46%	50%	53%	36%
Bluehead sucker	23%	18%	22%	13%	2%
Roundtail chub	5%	4%	4%	3%	4%
Colo. Pikeminnow	0.20%	0.20%	0.25%	0.00%	0%
White S. + hybrids	11%	15%	17%	16%	36%
Channel catfish	7%	7%	2%	5%	3%
Carp	4%	5%	4%	4%	4%
Smallmouth bass	1.0%	2.5%	0.5%	5.0%	13%
Northern pike	1.3%	1.8%	0.2%	0.3%	0.4%
Black crappie	0.4%	1.3%	0.1%	0%	2%
Sample size	1391	1040	807	676	832

White sucker and their hybrids were 36% of the catch in 2003 compared to about 15% of the catch in the four previous years. Smallmouth bass were 13% in 2003 compared to about 3% in prior years. In the baseline years (wet cycle) both channel catfish and northern pike were more common than in the later three years (dry cycle). Black crappie composition was highest in 2003, but still only 2%. Carp were consistent in all five years at near 4% of the catch.

The Sevens' total density estimates (all fish combined) were very similar in 1998 (179.4/ha) and 1999 (179.1/km) (Table 7). Total biomass at Sevens was also very similar (162.2 kg/ha) in 1998 and (165.4 kg/ha) 1999 (Table 8). The density and biomass estimates for 1998 and 1999 represented the baseline carrying capacity at this site. The total biomass estimate in 2000 (98.4 kg/ha) and 2001 (87.5 kg/ha) were consistent to each other, but less than the baseline years (1998 and 1999). The difference in density estimates from 1998 - 2001 were significant. They were alpha = 0.05 both between years and simultaneously. The reduced biomass in 2000 and 2001 likely indicated reduced carrying capacity since species composition was consistent. In 2003 the biomass estimate was higher than 2000 and 2001 (Table 8), but less than 1998 and 1999. An increase in total biomass in 2003 resulted from an increase in white sucker, carp and smallmouth bass (nonnative species).

In 2003 density and biomass estimates for all native species was the lowest of the study period. In the first four years at Sevens, flannelmouth sucker was the most common fish (larger >15 cm) in the catch, but ranked third in 2003. Flannelmouth sucker biomass was similar in 1998 & 1999 (baseline years), but lowered in each successive year. Flannelmouth sucker biomass in 2003 was about 50% of the baseline years (Table 8). The species with the greatest change in biomass was bluehead sucker. In 1998, 1999 and 2000 bluehead sucker biomass was about 15 to 17 kg/ha. The bluehead biomass estimate was 5 kg/ha in 2001 and only 0.6 kg/ha in 2003. Sample size was small for chub in all years and recapture rates were not high enough to produce tight confidence intervals. Given roughly equal sampling effort between years, however, it appeared that the biomass of roundtail chub also declined during the study period, but not as much as other native fish.

In contrast, the non native fish, -- white sucker, smallmouth bass and carp -- increased in densities in 2003 compared to the baseline years (1998 and 1999). White sucker density was nearly tripled in 2003 to the prior years, but its biomass was only slightly higher (Table 8) because small fish were more abundant. Yearling-sized white sucker were common in 2003 (Figure A1-18), but not in prior years. Both density and biomass of smallmouth bass was much higher in 2003 compared to the prior years and the increase was roughly ten fold for both categories. The higher number of Age-1 carp accounted for the higher carp density in 2003 (Table 7).

Table 7. Density estimates at Sevens, Yampa River, 1998 to 2003.

YAMPA RIVER	Density estimate in fish per hectare				
SEVENS	no/ha	no/ha	No/ha	no/ha	no/ha
Species	1998	1999	2000	2001	2003
Total fish	179.4	179.1	122.1	104.7	215.8
Flannelmouth sucker	63.2	60.5	47.4	42.3	31.0
Bluehead sucker	42.8	36.9	46.9	17.9	1.6
Roundtail chub	10.6	6.0	6.4	3.7	3.5
White S. + hybrids	30.4	29.2	16.7	20.8	82.7
Channel catfish	14.8	19.8	2.0	7.5	7.7
Carp	9.1	12.6	4.1	5.6	16.0
Smallmouth bass	2.4	5.6	0.5	5.8	68.2
Northern pike	3.6	4.6	0.3	0.4	1.1

Channel catfish were about half the density and biomass in the dry years (2000, 2001 and 2003) compared to 1998 and 1999 (Table 8). The lowest year for catfish density and biomass was in 2000, but its abundance rebounded in the 2001 and 2003 sample. Northern pike were much more common in 1998 and 1999 than the later years.

Flannelmouth sucker mean length did not vary much between years (Table 9). In each year very few individuals less than 20 cm were caught. This was also observed in 2003 (Figure A1-8). Mean length of bluehead sucker was less in the three dry years compared to the baseline years (Table 9). Also bluehead sucker less than 20 cm were rarely collected (Figure A1-1). Mean length of roundtail chub was less in 2003 (Table 9) than earlier years. This was due to the increased presence of fish less than 31 cm compared to prior years (Figure A1-13).

Table 8. Biomass estimates at Sevens, Yampa River 1998 to 2003.

YAMPA RIVER					
SEVENS	Kg/ha	Kg/ha	Kg/ha	Kg/ha	Kg/ha
Species	1998	1999	2000	2001	2003
Total fish	162.2	165.4	98.4	87.5	129.0
Flannelmouth sucker	66.1	66.1	50.0	39.2	35.9
Bluehead sucker	17.2	14.5	14.8	5.0	0.6
Roundtail chub	6.3	3.9	3.9	2.0	1.8
White S. + hybrids	22.9	23.2	14.4	12.3	24.6
Channel catfish	21.5	22.4	3.2	10.2	11.9
Carp	25.4	30.8	11.6	17.0	42.7
Smallmouth bass	1.2	1.9	0.2	0.9	11.1
Northern pike	1.4	2.6	0.4	0.8	0.5

Table 9. Mean lengths of all species at Sevens, Yampa River 1998 to 2003.

YAMPA RIVER	Mean length for all fish collect in cm				
SEVENS	A	B	C	D	E
Species	**1998**	**1999**	**2000**	**2001**	**2003**
Flannelmouth sucker	45.7,d	46.5,d	45.8,d	43.8,abc	46.0
Bluehead sucker	33.5,cd	33.6,cd	31.3,abd	30.0,abc	30.8
Roundtail chub	39.0	40.0,d	39.2	37.9,b	34.5
White S. + hybrids	31.1	35.6	25.4	29.7	19.4
Channel catfish	49.0	44.8	49.4	48.1	49.8
Carp	56.7	53.3	57.5	58.6	31.3
Smallmouth bass	29.6	21.0	8.4	13.6	13.2
Northern pike	37.5	41.1	55.2	64.3	34.5

The most noticeable change in the size distribution at Sevens was with white sucker and carp, which had much higher numbers of Age-0 and Age-1 fish in 2003 than in any of the prior years (Figures A1-18 and A-38). The strong presence of younger white sucker and carp in 2003 indicated improved habitat or reduced predation in 2002 and 2003 than in earlier years for these species. Age-0 and Age-1 of native fish species were collected in 2003.

Lily Park

At Lily Park most species displayed very little variation in composition between years. Bluehead sucker were about seven to eight percent of the catch. Roundtail chub, Colorado pikeminnow, northern pike and white sucker were very rare in all years. Species composition was variable between years for flannelmouth sucker and channel catfish. Flannelmouth sucker was the most common species in the catch at Lily Park. Their composition was 48% in 2000, 68% in 2001 and 55% in 2003 (Table 10). Catfish composition had the highest variability among years with 40% in 2000, 18% in 2001 and 28% in 2003 (Table 10).

Total catch (n), density and biomass for fish over 15 cm were much higher at Lily Park than at the other Yampa River sites (Table 11). Total biomass was about four times higher than Sevens in the baseline years and six times higher in 2003. Total Lily Park biomass was about six times higher than Duffy.

Table 10. Species composition at Lily Park, Yampa River, 2000 to 2003.

YAMPA RIVER	Lily Park	Lily Park	Lily Park
Species	2000	2001	2003
Flannelmouth sucker	48%	68%	54.7%
Bluehead sucker	9%	7%	7.5%
Roundtail chub	0.02%	0.03%	0%
Colo. Pikeminnow	0.1%	0.0%	0.1%
White S. + hybrids	0.3%	0.2%	0.6%
Channel catfish	40%	18.0%	27.9%
Carp	2.1%	2.1%	3.4%
Smallmouth bass	0.8%	5.0%	5.0%
Northern pike	0.2%	0.2%	0.1%
Sample size	4058	2989	2129

An abundant channel catfish population was unique to the Lily Park site. Channel catfish density and biomass estimates were highly different between years. In 2000 the density estimate was 513 fish/ha and biomass was 224 kg/ha. In 2001 density was 137/ha and biomass was 57 kg/ha. In 2003 density was 276/ha (Table 11) and biomass was 64 kg/ha (Table 12). The variability in channel catfish composition between years resulted from the presence of a large migrating population that passed through Lily Park during the summer to upstream habitats. The low flows in July and August 2000 could have stopped migrating channel catfish at Cross Mountain Canyon. This increased their number at Lily Park that year. In 2001 and 2003 either the size of the migrating population was less or it was more dispersed.

The size and timing of the channel catfish migration wave meant their abundance can vary greatly within and between years. Recapture rates on catfish in all three years was only fair, with confidence intervals of 20 to 40% of the estimate. Even so, widely different population sizes were indicated between years.

Density estimates for flannelmouth sucker, bluehead sucker and northern pike were highest in 2000. The 2001 and 2003 estimates were lower, but similar to each other (Table 11). In contrast estimates for smallmouth bass, white sucker and carp were lowest in 2000 and highest in 2003 (Table 11). This was the same trend for the other Yampa River sites.

Biomass is a function of both density and size so when mean length is constant biomass varies only with density. Mean length varies between years mainly due to differences in year-class strength and growth rates. Typically mean length varies due to the number of Age-1 fish in the sample. During the study period Age-0 and Age-1 fish were rarely observed in the community and very few to no Age-1 bluehead sucker and flannelmouth sucker were observed at Lily Park in 2003 (Figures A1- 3 and A1-10).

Table 11. Density estimates at Lily Park, Yampa River 2000 to 2003

YAMPA RIVER	Density estimate in fish per hectare		
Lily Park	No/ha	no/ha	No/ha
Species	2000	2001	2003
Total fish	1001.5	528.9	680.00
Flannelmouth sucker	347.5	277.5	250.5
Bluehead sucker	96.8	54.8	57.1
Colorado pikeminnow	0.4	0.3	0
Roundtail chub	0.4	0.3	0
White S. + hybrids	0.9	0.3	4.0
Channel catfish	513.3	137.3	275.6
Carp	26.0	16.8	33.1
Smallmouth bass	10.6	39.0	51.5
Northern pike	2.6	1.4	1.4

Table 12. Biomass estimates at Lily Park, Yampa River 2000 to 2003.

YAMPA RIVER			
Lily Park	Kg/ha	Kg/ha	Kg/ha
Species	2000	2001	2003
Total fish	521.1	253.0	256.8
Flannelmouth sucker	218.4	143.3	122.4
Bluehead sucker	37.2	19.8	18.9
Roundtail chub	0.2	0.01	0
Colorado pikeminnow	0.6	0.7	0
White S. + hybrids	0.4	0.2	2.5
Channel catfish	224.2	56.8	64.0
Carp	29.1	21.5	38.2
Smallmouth bass	7.0	8.0	8.2
Northern pike	3.8	2.8	2.6

Biomass estimates of flannelmouth sucker and bluehead sucker were lower in 2001 and 2003 than in 2000. Also mean length of flannelmouth sucker and bluehead sucker was lowest in 2003 and highest in 2000 (Table 13). The lower mean length of bluehead sucker and flannelmouth sucker in 2003 was due to fewer large fish in 2003 compared to earlier years. In 2000 about 70% of flannelmouth sucker were 40 cm or longer and 21% were 45 cm or larger. In 2003 only 36% were at or over 40 cm and just 2% were 45 cm or larger. Bluehead sucker at or over 35 cm were typical in 2000 (49%), but were less common at 29% in 2003. The loss of larger fish could have resulted from attrition (aging) or more likely, loss of habitat availability for larger fish during the 2002 low-flow conditions.

Table 13. Mean lengths of all species collected at Lily Park, Yampa River 2000 to 2003.

YAMPA RIVER	Mean length for all fish collect in cm		
Lily Park	2000	2001	2003
Flannelmouth sucker	41.5	38.3	37.8
Bluehead sucker	34.2	33.5	32.5
Colorado pikeminnow	59.4	64.3	52.6
Roundtail chub	40.3	18.0	6.0
White S. + hybrids	26.6	28.0	35.8
Channel catfish	34.7	32.9	27.2
Carp	42.1	44.6	43.1
Smallmouth bass	12.0	15.1	16.7
Northern pike	64.6	66.7	63.7

Channel catfish biomass was much greater in 2000. Not only was channel catfish density and biomass highly variable between years, but length distribution was also highly variable between years. This variability in size distribution was another aspect of a migrating population. In 2000, 72% of the channel catfish captured at Lily Park were between 30 and 39 cm in length. In 2001, 48% of the channel catfish measured from 30 to 39 cm. Only 13% were of this size in 2003. Only 13% of the channel catfish were less than 30 cm in 2000, but 78% were less than 30 cm in 2003. The large shift in size structure at Lily Park between years likely indicated improved spawning and survival of small channel catfish in 2001 and 2002 compared to 1998 and 1999.

Survival of small channel catfish may be more a function of habitat conditions than predation rates. Higher and cooler flows during the Spring and Summer of 1998 and 1999 could mean that channel catfish spawning was located further downstream. In 1998 and 1999 younger channel catfish may not have been available or capable of moving into the Lily Park site by 2000. The presence of smaller channel catfish in 2003 would result if their spawning and nursery habitat was much closer to Lily Park. This was indicated by the capture of a 5 cm fish (YOY) at Lily Park in 2003 and two yearling fish, 14 cm and 16 cm, not observed in prior years.

The most common channel catfish size-group (mode from 30 to 40 cm) in 2000 was missing in 2003. This could be a result of poor survival in 2002 for channel catfish over 30 cm. The very strong mode of fish from 20 to 30 cm in 2003 (Figure A1-45) coincided with the drought flows of 2002 which suggested habitat for channel catfish less than 30 cm was improved given those flow conditions.

White sucker and carp had their highest biomass estimates in 2003. Smallmouth bass biomass was fairly similar for all three years in spite of the fact that bass density increased in each year.

Age-0 smallmouth bass were not collected at Lily Park in 2003 (Figure A1-52), but were common in both 2000 and 2001. The lack of YOY bass meant that the mean length of smallmouth bass (Table 16) was higher in 2003 compared to prior years. By far the

dominant smallmouth bass age group at Lily Park in 2003 was age-1 fish in the range of 9 to 18 cm (Figure A1-52). Even though mean length of smallmouth bass was highest in 2003 there were very few bass >25 cm in the 2003 sample.

Hayden, Juniper, Maybell and Lily Park - below

A joint electro-fishing and seining effort was made September 11 - 12, 2003 with Colorado College. Dr. Brian Linkhart and Dr. Ed Wick supervised shoreline and backwater seining. I collected fish from the main channel with the raft shocker. The most upstream site was just below the Hwy 40 Bridge located two miles below the town of Hayden. We accessed at the Yampa River State Park Double Bridges boat launch. About 300 m of the river was sampled. The fish sampling at Juniper was from below the CR 53 Bridge to about 300 m downstream. At Maybell electro-fishing began about 300 m above the CR 19 Bridge and ended under the bridge. At Lily Park the sampling was from just upstream of the CR 25 bridge to a low head diversion dam about 200 m downstream.

At Double Bridges at RM 148, about 50 miles upstream of Duffy, only two native fish --one speckled dace and one mottled sculpin -- were captured from a total sample of 222 fish (Table 14). Smallmouth bass were 97% of the catch for fish less than 15 cm and 77% of the total catch. White sucker and hybrids were 71% of the catch for fish larger than 15 cm (Table 14). Only one fish was captured by seining and backpack shocking (Table 15).

At Juniper Hot Springs (RM 90) smallmouth bass was 100% of the catch for fish less than 15 cm and 75% of the total catch from the main channel (Table 14). Bluehead sucker was the most common species for fish over 15 cm. All were captured from the same riffle below the Juniper Bridge. A large number of Age-0 bluehead sucker were collected from a large backwater (Table 15).

White sucker was the most common species of fish over 15 cm at the Maybell Bridge (RM 72) (Table 14). No native fish less than 15 cm were collected at Maybell with raft shocking, seining or backpack shocking (Tables 14 and 15).

At Lily Park (RM 52) channel catfish were 51% and flannelmouth sucker were 32% of the fish over 15 cm (Table 14). Smallmouth bass (99%) and green sunfish (1%) accounted for fish less than 15 cm (Table 14). Seining and backpack shocking found sand shiners and fathead minnow were abundant. Three speckled dace were the only native species. One Age-0 channel catfish were collected by seining (Table 15).

Table 14. Percent species composition for total fish and fish > 15 cm collected by boat shocker at Hayden, Juniper, Maybell and Lily Park in 2003.

YAMPA RIVER	Hayden	Juniper	Maybell	Lily Park
Species	**2003**	**2003**	**2003**	**2003**
Flannelmouth sucker		2.7 (9.3)	4.2 (15.9)	26.4 (31.7)
Bluehead sucker		17.6 (61.1)	1.3 (4.8)	0.5 (0.6)
Roundtail chub				0.5 (0.6)
Speckled dace	0.5 (0)			
Mottled sculpin	0.5 (0)			
White S. + hybrids	19.4 (71.2)	4.8(16.7)	14.6 (54.0)	
Carp			0.4 (1.6)	3.0(3.6)
Channel catfish				42.3(50.9)
Bullhead			0.8 (3.2)	
Brown trout	0.9 (3.4)			
Smallmouth bass	76.6 (20.3)	74.9 (13.0)	71.7 (7.9)	26.4(12.0)
Green sunfish				0.5(0)
Bluegill			2.1 (0)	
White crappie			3.8 (12.7)	0.5(0.6)
Northern pike	1.4 (5.1)			
Stickleback	0.5 (0)			
Redside shiner	0.5 (0)		1.3 (0)	
Sample size	222 (59)	187 (54)	240 (63)	201 (167)

Table 15. Number of fish (< 150 mm) collected with seined & backpack shocker at Hayden, Juniper, Maybell and Lily Park in 2003. Data provided by Dr. B. Linkhart (Colorado College) & Dr. E. J. Wick.

YAMPA RIVER	Hayden	Juniper	Maybell	Lily Park
Species	**2003**	**2003**	**2003**	**2003**
Bluehead sucker		194		
Speckled dace				3
Mottled sculpin				
Red shiner				56
Sand shiner				132
Fathead minnow		9	10	214
Carp		21	11	1
Creek chub		1		
White sucker	1	1	2	3
Smallmouth bass		33	19	7
Sunfish		1		
White crappie		15		
Channel catfish				1
Sample size (n)	1	275	42	417

COLORADO RIVER

15-Mile Reach (Corn Lake and Clifton)

Two adjacent study sites were used in the 15-Mile Reach for the instream flow study based on prior research (Anderson and Stewart 2003). Clifton is the upstream site and Corn Lake the downstream site. Fishery and habitat features (geomorphic differences) of these two sites were both compared. The objective of this study was to compare fish abundance between years of different base flows. Combining data from both sites was more useful for this study, since a single long station (4.2 km) and larger sample size was believed to improve statistical sensitivity to changes in the fish population between years.

The baseline years for the 15-Mile Reach were 2000 and 2001 when Summer and early Fall flows were near 900 cfs. Flows in 2002 were less than 300 cfs for 90 days and less than 100 cfs for 40 days. Flows were above 1,000 cfs during sampling in September 2003. Subtle changes were observed in species composition for fish over 15 cm in 2003 compared to pre-drought years. Several of the changes were consistent with those observed during the first year of the Yampa River's dry cycle.

For fish over 15 cm, native fish were 75% of the catch in 2000, 77% of the catch in 2001, and 76% of the catch at Corn Lake in 1999 (Table 16). In 2003 native fish comprised 66% of the catch for fish over 15 cm (Table 16).

During the baseline years, the two most common species were flannelmouth sucker averaging 36% and bluehead sucker averaging 35%. In 2003 flannelmouth composition was 33% and bluehead was 28%. Bluehead sucker was the species with the largest negative change in 2003 at minus 20%. Flannelmouth was minus 11%. Roundtail chub comprised about 5% of the catch for 2000, 2001 and 2003 (Table 16). Endangered fish were less than 1% of the catch in all years.

Carp composition in 2003 was very similar to all years sampled at 12% (Table 16). Channel catfish composition in 2003 was 8%, an increase of 52% from baseline years (5%). The composition of white sucker and its hybrids was 9%, which was about double the baseline figure (Table 16). The largest increase in composition (175%) was for centrarchids. Centrarchid composition in 1999, 2000 and 2001 was about 1%. These fish were mostly collected in backwaters and were less than 15 cm in length. Smallmouth bass were very rare in the baseline years with only zero to two individuals per year. In 2003 the number of smallmouth bass >15 cm increased to 45. The increased presence of smallmouth bass over 15 cm accounted for centrarchids increasing to 3% of the population in 2003.

Table 16. Species composition at the 15-Mile Reach, Colorado River 1999 to 2003.

COLORADO RIVER	CORN L.	CORN L.	CORN L.	CORN L.		
Species	1999	2000	2001	2003		
Flannelmouth sucker	38%	31.0%	39.8%	32.1		
Bluehead sucker	35%	36.3%	37.3%	30.7		
Roundtail chub	3%	4.3%	2.9%	4.6		
Colo. pikeminnow	0.10%	0.04%	0.03%	0.02		
Razorback sucker	0.20%	0.3%	0.05%	0.2		
White S. + hybrids	6%	4.5%	5.8%	10.4		
Channel catfish	4%	6.3%	4.7%	6.5		
Carp	11%	14.1%	6.7%	11.6		
Sunfish (all species)	0.9%	1.5%	1.2%	2.7		
Trout (all species)	0.0%	0.1%	0.25%	0.1		
Bullhead	1.3%	0.6%	1.3	0.7		
	0.1	0.1	0	0.4		
Sample size	3499	2784	3667	4279		
COLORADO RIVER	CLIFTON	CLIFTON	CLIFTON	BOTH	BOTH	BOTH
Species	2000	2001	2003	2000	2001	2003
Flannelmouth sucker	32.5%	42.0%	32.5%	31.7	41.0	32.3
Bluehead sucker	40.5%	26.8%	25.2%	38.6	31.5	28.2
Roundtail chub	5.1%	5.9%	6.0%	4.7	4.5	5.2
Colo. pikeminnow	0.03%	0.09%	0.1%	0.03	0.06	0.04
Razorback sucker	0	0.04%	0.00%	.15	0.02	0.1
White S. + hybrids	3.7%	4.1%	8.0%	4.4	4.8	9.3
Channel catfish	5.1%	5.7%	10.5%	5.6	5.2	8.3
Carp	11.7%	13.8%	12.1%	12.8	10.6	11.8
Sunfish (all species)	1.2%	1.1%	4.0%	1.3	1.1	3.3
Trout (all species)	0.1%	0.3%	0.3%	0.1	0.3	0.2
Bullhead	0.2%	0.4%	1.0%	0.4	0.8	0.8
Blue-flannelmouth hybrid	0.2	0	0.5	0.2	0.0	0.4
Sample size	3276	4485	3558	6060	8152	7864

Species composition and density data collected in 2000 was less consistent with the 1999 and 2001 data. That was attributed to variability in sampling efforts and efficiency between years (Anderson 2002). Only six passes at both sites were made in 2000 instead of seven or more for 1999 and 2001. The author felt that the true species composition was consistent for 1999, 2000 and 2001, and the discrepancy in 2000 was due to sampling bias (Anderson 2002).

Density and biomass estimates were not dramatically different in 2003 compared to earlier years (Tables 17 and 18). Significant differences in density estimates (alpha = 0.05) were identified in 2003 for bluehead sucker, roundtail chub and common carp compared against 2001. Bluehead sucker density was 22% less and biomass was 26% less in 2003 compared to 2001. Roundtail chub density and biomass was increased 42% and 31% respectively. Carp density and biomass was 53% and 52% higher in 2003 compared to 2001.

Density estimates for flannelmouth sucker, white sucker and channel catfish were not significantly different between 2003 and 2001.

The density estimates were significantly different for most species between 2003 and 2000. The density estimates for flannelmouth sucker, white sucker, carp and channel catfish were higher in 2003 than 2000. The bluehead sucker estimate was significantly lower in 2003 than in 2000. Roundtail chub was the only species not significantly different between 2000 and 2003.

Table 17. Density estimates at the 15-Mile Reach, Colorado 2000 to 2003.

COLORADO RIVER	Density estimate in fish per hectare		
15-Mile Reach	**No/ha**	**No/ha**	**No/ha**
Species	**2000**	**2001**	**2003**
Total fish	583.7	718.9	710.4
Flannelmouth sucker	220.2	268.6	258.6
Bluehead sucker	187.0	203.5	159.5
Colorado pikeminnow	0.4	0.3	0
Roundtail chub	59.9	43.0	61.1
White S. + hybrids	25.6	53.4	59.2
Channel catfish	61.3	77.5	87.8
Carp	93.4	84.5	129.6

Table 18. Biomass estimates at the 15-Mile Reach, Colorado River 2000 to 2003.

COLORADO RIVER			
15-Mile Reach	**Kg/ha**	**Kg/ha**	**Kg/ha**
Species	**2000**	**2001**	**2003**
Total fish	433.8	490.1	543.6
Flannelmouth sucker	160.9	194.6	197.4
Bluehead sucker	76.7	91.4	67.3
Colorado pikeminnow	0.6	0.7	0
Roundtail chub	12.8	11.1	14.5
White S. + crosses	8.9	18.4	19.5
Channel catfish	45.4	64.2	77.2
Carp	129.0	110.4	167.7

Mean lengths of fish in 2003 were not noticeably different from prior years (Table 19). Low numbers of Age-1 fish in the 2003 sample, however, indicated that native species did not have good reproductive success in 2002. Flannelmouth sucker had very few Age-0 (5 to 10 cm) and yearling fish (11 to 20 cm) in the catch in 2003 (Figure A1-11 & -12), but fish of these sizes were common in 2000 and 2001. The 2003 bluehead sucker histograms (Figures A1-4 & -5) were very similar for the three years, thus little was indicated about the 2002 flows impact on reproduction of this species.

Table 19. Mean lengths of all species at the 15-Mile Reach, Colorado River 2000 to 2003.

Colorado River	Mean length for all fish collect in cm		
15-Mile Reach	A	B	C
Species	2000	2001	2003
Flannelmouth sucker	38.7	39.6	41.2
Bluehead sucker	32.5	34.2	33.4
Colorado pikeminnow	59.4		63.7
Roundtail chub	24.4	21.8	27.7
White S. + hybrids			26.1
Channel catfish	40.2	41.9	42.4
Carp	42.0	34.5	40.9
Smallmouth bass			12.7
Northern pike			

It was rare in the baseline years to capture Age-0 roundtail chub, but yearlings (11 to 20 cm) were the largest mode (size-group) by far in both 2000 and 2001. Age-1 roundtail chub were rare in 2003 (Figures A1-16 & -17), which is an indication their YOY survival was poorer in 2002 than earlier years. Fewer Age-1 chub in the population explains the larger mean size of this species in 2003.

Carp had the highest variation in length distribution over the three years. In 2000 few carp less than 35 cm were observed, but in 2001 there was a large mode from 11 to 20 cm and a gap from 21 and 35 cm. In 2003, there was a large mode of carp between 13 and 35 cm, indicating survival of Age-1 carp in 2002 was good (Figures A1-41 & -42).

In both 2000 and 2001, the majority of white sucker were small, less than 20 cm. This was reversed in 2003 when there were much fewer Age-0 and Age-1 sized fish (Figures A1-21 & 22). This suggested white sucker spawning success or survival of YOY fish was less in 2002 and 2003 than in the two prior years. Nursery habitat for young fish should have been increased in 2002 with the low flows. However, low flow years were found to have increased abundance of centrarchid predators in the Yampa River. The large increase in smallmouth bass numbers in 2003 suggested predation accounted for reduced Age-0 and Age-1 white sucker in the 2003 sample.

The minimum size channel catfish in the population was about 25 cm in both 2000 and 2001, suggesting that channel catfish migrated to this area after they were already 25 to 30 cm. The collection of 14- and 16- cm channel catfish in 2003 indicated the spawning conditions (temperature) were improved by the 2002 flows compared to other years.

Variation in the length frequency between years was not observed for largemouth bass suggesting this species reproductivity did equally well in 2003 compared to earlier years (Figures A1-48 & -49). In contrast Age-0 smallmouth bass numbers were much higher in 2003 (Figures A1-53 & -54) than in any of the prior surveys.

GUNNISON RIVER

The fish populations in the Gunnison River at Austin, Delta and Escalante were distinctive. Flannelmouth sucker and bluehead sucker were common to abundant at all three locations in 2003. Native fish comprised 62.7% of the catch at Austin, 70.1% at Delta and 83.1% at Escalante for captured fish over 15 cm (Table 20). Flannelmouth sucker had the greatest variability between sites and was 17% at Austin, 41% at Delta and 29% at Escalante. Bluehead sucker composition was also variable between sites and was 44% at Austin, 23% at Delta and 42% at Escalante. Roundtail chub composition increased in the downstream direction with one percent at Austin, six percent at Delta and 13% at Escalante (Table 20).

Brown trout were common at Austin but not downstream, while carp were uncommon at Austin but common downstream. White sucker were common Austin and Delta. Water temperature difference likely explained the higher abundance of brown trout at Austin and may be a factor for white sucker.

Table 20. Species composition at the Gunnison River sites in 2003.

Gunnison River	Austin	Delta	Escalante
Species	**2003**	**2003**	**2003**
Flannelmouth sucker	17.6%	41.2%	28.7%
Bluehead sucker	44.4%	22.7%	41.8%
Roundtail chub	0.7%	6.2	12.5%
White S. + hybrids	28%	22.7%	9.6%
Carp	1.8%	6.5%	6.2%
Brown trout	6.7%	0.6%	1.1%
Rainbow trout	0.8%	0.1%	0%
Sample size	1934	1622	1475
	Austin	Delta	Escalante
White sucker	43.4%	67.9%	67.6%
White X flannelmouth	31.9%	23.6%	18.3%
White x bluehead sucker	24.7%	8.4%	14.1%

A difference was noted in the composition of white sucker and its apparent hybrids between sites. White sucker, bluehead sucker and white sucker x bluehead sucker hybrids were highest at the Austin site (Table 20). White sucker x flannelmouth sucker hybrids were also highest at Austin even though pure flannelmouth sucker were less common at Austin.

Species composition for native sucker and roundtail chub observed in 2003 (Table 20) were fairly similar to that reported for collections in 1992 and 1993 (Burdick 1995) (Table 21). However white sucker composition appeared to have increased in the Gunnison River during the past ten years (Table 21).

The native sucker percentage of total suckers (flannelmouth, bluehead, white and hybrid suckers) was similar at Austin (Reach 6) in 2003 with the 1992 and 1993 data (Table 22), but was somewhat less at Delta (Reach 5) and Escalante (Reach 4) (Table 22). These

data also suggested that hybridization between white sucker and native sucker may have increased in the ten-year period between samples (Table 22).

Table 21. Species composition at the Gunnison River sites in 1992 and 1993 (Burdick 1995).

Gunnison River	Reach 6 (Austin)	Reach 5 (Delta)	Reach 4 (Escalante)
Species	**1992 - 1993**	**1992 - 1993**	**1992 – 1993**
Flannelmouth sucker	19.3 - 23.1%	21.6 – 22.8%	34.8 – 33.3%
Bluehead sucker	34.8 – 27.2%	44.4 – 47.5%	32.3 – 37.5%
Roundtail chub	0.1 – 0.5%	6.1 – 6.1%	19.5 – 13.0%
White S. + hybrids	24.0 – 25.3%	11.4 – 7.9%	4.0 – 4.6%
Carp	8.4 – 9.0%	13.5 – 11.6%	6.9 – 9.8%
Brown trout	4 .7 – 5.8%	1.4 – 1.1%	1.4 – 1.2%
Rainbow trout	8.7 – 9.0%	1.6 – 1.5%	0.8 – 0.2%
Sample size	1565 - 1344	3632 - 2914	1347 - 1335

Table 22. Percent of native sucker in total sucker catch and percent of hybrids with cin total white sucker & hybrids catch at the Gunnison River (Burdick 1995).

Gunnison River	Reach 6	Reach 5	Reach 4	Reach 6	Reach 5	Reach 4
	% native sucker (all species)			**% hybrids (total WS & hybrids)**		
1992	69%	84%	94%	26%	13%	31%
1993	67%	88%	93%	44%	30%	43%
2003	69%	74%	88%	56%	32%	32%
	Total suckers captured (n)			WS & hybrids captured (n)		
1992	1221	2841	973	151	83	32
1993	1016	2321	1018	99	57	17
2003	1705	1379	1171	299	116	46

Channel catfish, northern pike, and smallmouth bass were not captured in the Gunnison River. Austin had the largest mean size for all species (Table 21). Brown trout may prey on small fish at Austin since flannelmouth sucker less than 40 cm and bluehead sucker less than 30 were uncommon (Figure A2- 4 & A2-1). The lack of small native sucker would also result if spawning sites are located downstream of this site.

Flannelmouth sucker and bluehead sucker less than 40 cm and 30 cm respectively were common at both Delta (Figures A2-2 & A2-7) and Escalante (Figures A2-8 & A2-3). Also Age-0 and Age-1 roundtail chub and carp were both common at Delta (Figures A2-10 & A2-25) and Escalante (Figures A2-11 & A2-26), but not at Austin (Figures A2-9 and A2-24). Escalante had the smallest mean lengths of the Gunnison River sites suggesting this area has increase nursery habitat availability (Table 23).

Age-0 and Age-1 white sucker appeared to be equally common at all three sites sampled in 2003 (Figures A2-12, A2-13 & A2-14).

Table 23. Mean lengths for all species at Gunnison River sites in 2003.

	Mean length for all fish collect in cm		
Gunnison River	Austin	Delta	Escalante
Species	**2000**	**2001**	**2003**
Flannelmouth sucker	46.0	41.1	35.6
Bluehead sucker	35.4	33.9	26.1
Roundtail chub	24.4	23.7	18.3
White S. + Hybrids	38.6	33.0	32.2
Carp	56.6	37.6	39.5

Mark recapture estimates were not available in 2003 because only two passes were made at each site. However, relative abundance was calculated by dividing catch by electro-fishing minutes at each site (CPEM). CPEM was used here as surrogate for density. Austin had the highest CPEM followed by Delta and Escalante.

CPEM of bluehead sucker was very high at Austin at nearly eight fish per minute. Bluehead CPEM at Delta and Escalante were quite high at 2.5 and 3.5 fish per minute respectively. The highest flannelmouth CPEM was at Delta followed by Austin and Escalante. CPEM of roundtail chub was highest at Escalante and lowest at Austin. CPEM of white sucker was highest at Austin and lowest at Escalante (Figure 13).

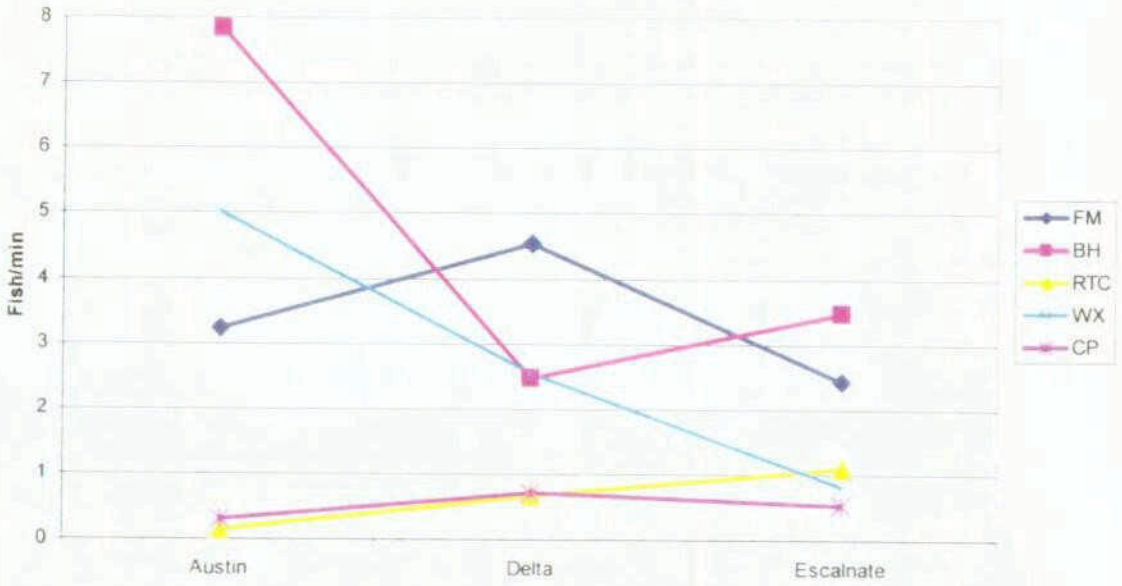

Figure 13. Electro-fishing catch rates for fish over 15 cm in the Gunnison River.

Catch per electro-fishing minute was also calculated for the Yampa and Colorado Rivers to compare relative abundance between the three rivers. Catch rate data for the Yampa and Colorado River were relatively consistent with the population estimates made on those rivers. Total fish-density estimates and total-fish catch rates were very low at Duffy and low at Sevens in 2003 (Figure 14). Density estimates and CPEM for total fish were fairly similar for Lily Park, Corn Lake and Clifton. These sites were much higher than Duffy and Sevens. The total fish CPEM for the Gunnison River sites was from two to four times higher than at Lily Park and the 15-Mile Reach (Figure 14).

The CPEM in 2003 for bluehead sucker at Austin was 7.8, which was higher than that for all fish species at Lily Park, Corn Lake or Clifton (Figure 14). The CPEM of bluehead sucker was 3.5 at Escalante, 2.5 at Delta, 1.5 at Corn Lake, 1.1 at Clifton, 0.3 at Lily Park, 0.03 at Sevens and 0.01 at Duffy. Habitat availability for bluehead sucker appears to be much better on the Gunnison River than the other sites.

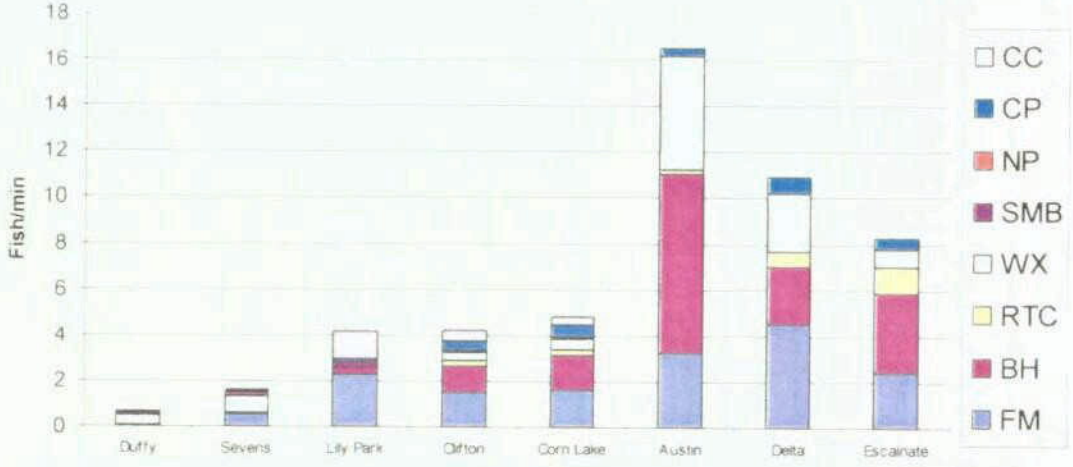

Figure 14. Fish per electro-fishing minutes at all sites surveyed in 2003.

Flannelmouth sucker also appear to be productive in the Gunnison River sites. The CPEM for flannelmouth sucker was 4.5 at Delta, 3.2 at Austin, 2.4 and Escalante, 2.3 at Lily Park, 1.6 at Corn Lake, 1.5 at Clifton, 0.5 at Sevens and 0.03 at Duffy. Roundtail chub CPEM was highest at Escalante at 1.1 followed by 0.7 at Delta, 0.28 at Clifton, 0.23 at Corn Lake, 0.15 at Austin, 0.06 at Sevens and 0.01 at Duffy.

White sucker CPEM were also highest on the Gunnison River. White sucker CPEM was 5.0 at Austin, 2.53 at Delta, 0.80 at Escalante, 0.69 at Sevens, 0.52 at Corn Lake, 0.43 at Duffy, 0.36 at Clifton and 0.03 at Lily Park in 2003. Carp CPEM was mixed with the highest CPEM 0.71 at Delta, followed by 0.58 at Corn Lake, 0.51 at Escalante, 0.47 at Clifton, 0.31 at Austin, .014 at Lily Park, 0.05 at Sevens and 0.002 at Duffy.

The Gunnison River CPEM data may have been somewhat inflated or biased high. Summer flows tended to be proportionally higher on the Gunnison River. Swifter currents

may have resulted in the electro-fishing raft traveling a greater distance in the same amount of time. Also, there was a constant supply of stunned fish on the Gunnison River. There were very few fishless habitats like large unproductive backwaters (Colorado River), long very-shallow runs (Yampa River), or deep pools that added electro-fishing time without fish. Nonetheless, the most likely explanation for the much higher fish catch per unit effort in the Gunnison River was better habitat quality. Anderson and Stewart (2003) identified increasing habitat diversity and invertebrate productivity with increasing base flows up to a threshold. The Gunnison River appeared to be an example where habitat and productivity was very good for native fish.

DISCUSSION

YAMPA RIVER

Each of the Yampa River sites had distinctive characteristics for fish composition. In the baseline years (1998 and 1999) flannelmouth sucker composition was about 5% at Duffy, 50% at Sevens and 70% at Lily Park. Bluehead sucker composition was about 4% at Duffy, 20% at Sevens and 8% at Lily Park. After three years of low base flows there were sharp decreases in native fishes and strong increases in nonnative fish species at all sites.

Fish biomass estimates were also greatly different between sites on the Yampa River. Duffy had relatively low biomass and Lily Park had relatively high biomass. Total biomass was reduced in the dry years compared to the baseline years at all sites. Native fish biomass was lowest at each site in 2003.

Smallmouth bass were likely first introduced in the Yampa River basin in the late 1970s and were uncommon during Yampa River fish surveys prior to 1992, the year Elkhead Reservoir was drained (P. Martinez, Colorado Division of Willdlife personal communication). By 1998 and 1999 Age-0 smallmouth bass were commonly collected from shoreline habitat at Duffy. The smallmouth bass population rapidly increased during the low-flow period 2000-2002. Shallow pool habitat with warmer water temperatures increase with reduced flows (Bain et al 1988). If these conditions promoted earlier spawning or a longer growing season then smallmouth bass recruitment could have been improved in drought years, because Age-0 smallmouth bass larger than 75 cm could have had higher over-winter survival rates than smaller YOY (P. Martinez, Colorado Division of Willdlife personal communication). Cooler water temperatures during the summer, a possible side effect of releases from an enlarged Elkhead Reservoir, might interfere with over winter survival Age-0 smallmouth bass.

The impact of smallmouth bass on the fish community of the Yampa River can not be underestimated. Speckled dace (*Rhinichthys osculus*) and mottled sculpin (*Cottus bairdi*), two native species, were effectively eliminated from the Yampa River by 2001 (Anderson 2002). Speckled dace occupied swiftly flowing riffle habitats and both the fish and their habitat were common in the baseline years. During the low flow years velocities in riffles became slower and riffles provided productive nursery habitats for Age-0 smallmouth bass.

By 2003 Age-0 smallmouth bass was the most common fish <120 mm collected by shocking and seining in both riffle and shoreline habitats.

The upstream extent of smallmouth bass has yet to be determined. 2003 sampling found Age-0 smallmouth bass comprised 97% of the catch for fish less than 15 cm near Hayden, Colorado. The Double Bridges site (RM 148) was upstream of the Elkhead River confluence, and mean length of Age-0 smallmouth bass was 66 cm on September 9th. Also at Double Bridge about 12% of Age-0 bass were larger than 75 cm, indicating that even at this upstream location members of the 2003 year-class were likely to recruit. Smallmouth bass was also the most common species collected at Juniper and Maybell for fish less than 15 cm. Mean length for Age-0 fish was about 71 cm (September 9th). Mean length of Age-0 smallmouth bass at Lily Park was 75 cm on September 10, 2003.

Another change in the Yampa River aquatic community during the drought period was the apparent increase in the crayfish population. Crayfish numbers were not quantified, but were much more noticeable in 2003 than baseline years. The increase in crayfish could also have been a response to altered habitats associated with low base flows. Since crayfish were utilized as forage by adult smallmouth bass, a higher abundance of crayfish may have been selectively advantageous for the smallmouth bass population.

In 2003, the Duffy and Sevens sites were shifting to a smallmouth bass, white sucker and crayfish community indicating tropic relationships had simplified during the study period. Habitat diversity was correlated with the diversity of a fish community (Scholsser 1982). The Shannon diversity index confirmed that habitat complexity in the Yampa River had also simplified due to reduced flows in the dry cycle (Anderson and Stweart 2003).

The 2002 flows were advantageous for recruitment of nonnative species. There was a large increase in Age-0 and Age- I white sucker and carp in 2003 without improvements in numbers of Age-0 or Age-I native fish at Sevens. Since white sucker had higher recruitment during 2002 their relative abundance was expected to increase at a faster pace than native sucker. A higher proportion of white sucker could further impact native sucker species through increased hybridization at Sevens, and perhaps at Lily Park.

Channel catfish have been identified for negative impacts to native fish populations in the Colorado basin (Tyus and Nikirk 1990). The coexisting populations of flannelmouth sucker, bluehead sucker and channel catfish at Lily Park in 2000 indicated native sucker have not been severely impacted by channel catfish. The lack of roundtail chub at Lily Park is consistent with negative impacts attributable to channel catfish.

The U. S. Fish and Wildlife Service conducted channel catfish removal in Dinosaur Canyon from 1998 to 2001, which is from 10 to 50 miles downstream of Lily Park. Mark Fuller of the U.S. Fish and Wildlife Service (personal communication) estimated the channel catfish population to be nearly 320 catfish/km in Dinosaur Canyon, which is about a fourth of the estimate for Lily Park. The total number of channel catfish removed from a 50-mile reach in Dinosaur Canyon in 1998 and 1999 was 4,272 fish (Modde and Fuller 2002).

The decline in channel catfish biomass, observed at Lily Park from 2000 to 2003, may have occurred regardless of the removal project. Several non-target species also experienced a large drop in density and biomass during the study period. The low summer flows in 2000 were suspected of interrupting migrating channel catfish at Cross Mountain Canyon. This would have resulted in an inflated channel catfish population in 2000 compared to a typical year.

Fuller (2003) reported a decline in mean length of channel catfish from 2000 to 2003 in Dinosaur Canyon and attributed reduced mean size in the canyon to the catfish removal project. Declines in mean length of channel catfish were also observed at Lily Park from 2000 to 2003. The reduced mean length at Lily Park was due to a very high increase in fish between 20 and 30 cm compared to prior years, indicating much improved recruitment of Age-1 and Age-2 fish at Lily Park in 2003. Changes in age composition between years may have been related to the Spring and Summer hydrograph. Warmer water temperatures in 2001 and 2002 could have altered the timing and location of channel catfish spawning. In years with warmer water temperatures spawning would likely be located further upstream making Lily Park more accessible to younger and smaller channel catfish.

Northern pike is another predator that has been suspected of having significant impacts to the native fish community. The impacts of northern pike were most obvious during the baseline years prior to the drought conditions. Abundance of northern pike appeared to decline during the drought years. Pike could recover quickly, however, given a return to improved prey and habitat availability.

Maintenance of the peak flow hydrograph in the Yampa River was identified as a high priority in regard to recovery of endangered species (Modde and Smith 1995). Peak flows appeared to have had little overall negative impacts on nonnative fish abundance during the study period. Currently, the Yampa River has a depopulated native fish community. Nonnative fish were highest in 2003, a year with an above average peak flow of 12,900 m3/s. Also, peak flows were near normal during the study period, except in 2002. Smallmouth bass numbers increased in years of normal (median) runoff flows. Also, high-peak flows may have assisted in their rapid expansion by flushing young fish to downstream habitats.

COLORADO RIVER, 15-MILE REACH

Species composition data collected in the 15-Mile Reach between 1999 and 2001 were highly consistent with U.S. Fish and Wildlife surveys made in 1994 and 1995 by Osmundson (1999).

The Colorado River experienced one year with poor flow conditions in 2002, unlike the Yampa River which had three consecutive poor base flow years. Upstream of the roller dam in Debeque Canyon, the Colorado River did not experience severe drought flows because of water deliveries to the Highline Canal. Since flows were normal above the roller dam, the fish community in that reach should not have been negatively impacted by altered habitat conditions. Excess or displaced fish from above the roller dam could migrate

downstream during the 2003 runoff. If so, this would mask the impacts of poor habitat conditions in the 15-Mile Reach in 2002.

The 2003 data did not suggest a fish community that had been stressed by a severe environmental event. In fact, the fish community data in 2003 was very similar to prior years. This indicates that one year of low flows did not have a significant negative impact on native fish. The data did suggest that nonnative fish were more resistant to drought conditions than native species. The species with the largest negative impact was bluehead sucker, which is a deep-riffle habitat species (Anderson and Stewart 2003). Deep-riffle habitat is lost at low flows making this species the most vulnerable to habitat loss during drought conditions. Adult flannelmouth sucker and roundtail chub density and biomass were stable in 2003, but a poor 2002 year-class indicated reduced reproductive success for these two species compared to baseline years.

The species with the largest increase in the 15-Mile Reach in 2003 was carp followed by channel catfish and white sucker. The carp population had been a significant part of the community in the 15-Mile Reach for a long period. Adult carp habitat at flows near 1,000 cfs appeared to be restricted to shoreline areas with cover and backwaters. Suitable habitat for carp likely increased with lower flows since area of low velocity pools increase under these conditions (Anderson and Stewart 2003).

Anderson and Stewart (2003) determined that backwater or nursery habitat availability increases with decreasing flows. This appears to suggest that lower flows, as observed in 2002, could be beneficial for recruitment of Age-0 native fish. However, the biological data found this had not happened in either the 15-Mile Reach or the Yampa River. In the 15-Mile Reach habitat diversity was maximized at flows near 1,000 cfs (Anderson and Stewart 2003). Also in 2000 and 2001, years with base flows near 1000 cfs, Age-0 and Age-1 native fish were commonly collected. The fact that the adult population of native sucker and roundtail chub appeared to be at carrying capacity further suggested recruitment of juveniles had been sufficient in years with base flows over 800 cfs. These facts indicated that reducing flows to increase backwater habitat for nursery areas for native species would be counter-productive.

Smallmouth bass made their first noticeable appearance in 2003. This coincided with the first year of low flows for the 15-Mile Reach.

It was observed in 2003 that there were much fewer Age-0 and Age-1 white sucker collected in backwater habitats compared to prior years. It was observed on the Yampa River low flow years coincided with increased abundance of centrarchid predators. Increased predation likely explained the reduced presence of Age-0 and Age-1 white sucker in 2003 in the 15-Mile Reach.

An increase in channel catfish was observed in 2003 compared to earlier years. This could be within the range of sampling variation, but it also suggested habitat was improved in 2002 compared to years with the normal 900 cfs plus flows. It was noted that at Lily Park where there was a very large channel catfish population there were very few roundtail chub.

The year with the largest channel catfish numbers in the 15-Mile Reach was also the year with the lowest number of Age-1 roundtail chub in the sample.

It appeared one year of low flows in the 15-Mile Reach was not disruptive to the fish community structure that had been established over a long period of higher flows. Flows returned to normal (@1,000 cfs) in the 15-Mile Reach in 2003 so a drought of two or more consecutive years did not occur. Significant changes in community structure did not appear on the Yampa River until the second and third years of low flows. This provided some support to the speculation that the increased presence of carp, channel catfish, smallmouth bass and white sucker observed in 2003 were not likely to persist above the baseline levels found in 1999, 2000 and 2001.

Geomorphic features including stream width and bed slope were similar for the Yampa and Colorado rivers (Anderson and Stewart 2003). The 2D modeling found that habitat availability for bluehead and flannelmouth sucker was similar in both rivers given similar flows. Therefore the differences in density and biomass of native sucker and the fish community in general could be a function of differences in their base flow regimes.

Base flow hydrographs were much different between rivers. Base flows in the Yampa River were approximately 250 cfs in 1998 and 1999, 110 cfs in 2000 and 2001 and only 12 cfs in 2003. In contrast, base flows in the 15-Mile Reach of the Colorado River were near 800 to 1,000 cfs 2000 and 2001 and dropped to 100 cfs in 2002.

GUNNISON RIVER

Severe low flows were not observed during 2002 or prior years. In 2003, there was a large population of adult-sized flannelmouth sucker, bluehead sucker and roundtail chub. Osmundson (1999) and Burdick (1995) reported high abundance of adult flannelmouth sucker, bluehead sucker and roundtail chub in the Gunnison River.

The Gunnison River did not have nonnative predators in its fish community. Without predation, population size appeared to be regulated primarily by competition for limited resources or habitat. On the Yampa River it appeared white sucker and its hybrids were more resistant to predation by smallmouth bass. Hybridization rates between white sucker and native sucker on the Gunnison River was likely regulated by meso habitat availability. Hybridization with white sucker was quite common on the Gunnison River with the site upstream of Austin displaying the highest incidence.

Burdick (1995) reported white sucker catch rates in 1992 and 1993 were three times higher than white sucker catch rates from Fish and Wildlife surveys in 1981 and 1982 by Valdez et al. (1982). Species composition for white sucker at Delta and Escalante were higher in 2003 than found in 1992 and 1993 by Burdick (1995), suggesting that white sucker have increased during the past 20 years. Also hybridization between white sucker and native sucker appeared to be increased in the 2003 samples compared to data from prior surveys. Hybridization with white sucker appeared to have had a significant negative impact to native suckers in the Gunnison River.

The Gunnison River had a very large native fish population in contrast to a very low native fish population in the Yampa River. The two most obvious factors explaining this difference were: 1) high base flows with abundant habitat availability versus low base flows that provide poor habitat availability and 2) no nonnative predators versus a high predator population.

The Gunnison River had the highest composition and population size of roundtail chub and was also the river without a channel catfish population. It was observed that the site (Lily Park) with a large channel catfish population had no roundtail chub and the sites in the 15-Mile Reach that had an intermediate channel catfish population had an intermediate roundtail chub population. This trend suggested a cause and effect relationship.

Peak flows on the Gunnison River have been severely downsized. Burdick (1995) identified an apparent Colorado pikeminnow spawning location in the Gunnison River in spite of a poor spring hydrograph for this river. Anderson (1997) found similar numbers of larval Colorado pikeminnow in the Gunnison River and the 15-Mile Reach. The persistent population of Colorado pikeminnow upstream of the Redland Diversion dam may have been related to the absence of green sunfish and bass in the community. The presence of predators in the Colorado River likely explained the poor survival of larval pikeminnow (Bestgen 1997).

DOLORES RIVER

Anderson (2002) reported fish sampling data for the Dolores River in the Big Gypsum Valley, about 35 miles upstream from Bedrock. In 2000, 54% of the total catch (1,078) was less than 15 cm in length compared to 77% (2,795) in 2001. For fish <15 cm 87% were native species in 2000 dropping to 58% in 2001. Roundtail chub and speckled dace were the most common native fish reported on the Dolores River by Anderson (2002). Valdez (1992) reported native fish composition collected by electrofishing was 86% near Bedrock and 77% near Slickrock from samples made in 1990 and 1991.

The CDOW collected data on the Dolores River about 25 miles upstream of the Anderson site. Biologist Mike Japhet collected this data from a 1,000 ft reach of the river below the Dove Creek power plant. From 1986 to 1991, the percent of fish less than 15 cm was 81%, 91%, 75%, 86% and 88%. From 1992 to 2003 nearly all fish collected were less than 15 cm (97% to 100%). Native fish ranged from 97% to 100% of the catch (excluding stocked brown and rainbow trout) for fish < 15cm from 1986 to 2000. In 2002 and 2003, native fish composition dropped to 79% and 76% respectively. These data suggested nonnative species composition increased in recent years and fish > 15 cm were very rare.

The Dolores River had a high composition of native fish, but very low biomass due to the lack of large fish in the population (Anderson 2002). Small body-sized speckled dace and mottled sculpin were common at the Dove Creek site (M. Japhet, personal comm.). Roundtail chub were also very common, but were small, rarely exceeding 15 cm. Most of the flannelmouth sucker and bluehead sucker were also small (< 20 cm). Small-sized fish appeared to have been the trend in the Dolores River at Dove Creek since sampling started in

1986. This suggested that roundtail chub had adjusted to long term low base flows by maintaining small body size.

The fact that native fish maintained a remnant population given habitat conditions that occur during long-term low-base flows indicated this population could respond positively if flow conditions improved. The Dolores River data suggested low flows would be much less problematic on the Yampa River if nonnative fish were not present in the system. Also, the situation on the Yampa River suggested that the native fish population of the Dolores River was susceptible to replacement by nonnative species such as green sunfish and smallmouth bass.

SUMMARY

Five years of fish composition, density, biomass and size structure data were summarized at Sevens and Duffy on the Yampa River. The first two years, 1998 and 1999, were identified as baseline population data, since these years had normal Summer and Fall flow conditions. The years 2000 and 2001 were the first two years of reduced base flows on the Yampa River. Very low flows occurred during 2002. Native fish density and biomass were reduced at all sites in 2003 compared to baseline years. Smallmouth bass and white sucker composition were increased in 2003 at both sites compared to the baseline years. Speckled dace, mottled sculpin and bluehead sucker were eliminated or much reduced. Flannelmouth sucker were noticeably reduced in 2003 compared to the baseline years.

Three years of fish population data were presented for the Lily Park site on the Yampa River. This site was unique in that channel catfish was the second most common species. Evidence was presented of a large migrating channel catfish population that occupied this section of the Yampa River. Channel catfish recruitment was apparently improved by the 2002 flow conditions. Density and biomass of bluehead sucker was much reduced in 2003 compared to 2000. There was a noticeable shift in size structure in 2003, with a much reduced incidence of the adult flannelmouth sucker and bluehead sucker larger than 35 cm compared to 2000.

Four years of composition, density, biomass and size-structure data were given on the Colorado River, with the baseline data from 1999, 2000 and 2001. Only subtle changes were found in the native fish population in 2003, which indicated that one year of low flows was not highly problematic for native fish in the 15-Mile Reach.

One year of composition, relative abundance and size data was given for three sites on the Gunnison River. The Gunnison River had the highest relative base flow conditions of the study rivers and also apparently had the largest population of the native bluehead sucker, flannelmouth sucker and roundtail chub. Surveys by the Fish and Wildlife Service also found higher catch rates of native species on the Gunnison River than in the Colorado River. It was concluded that the Gunnison River likely had better habitat availability for these native species than the larger Colorado and Yampa Rivers. It was also concluded that reduced peak flows in the Gunnison River were not problematic for bluehead sucker, flannelmouth sucker and roundtail chub. In spite of reduced peak flows Burdick (1995) found a small population of Colorado pikeminnow had reproduced successfully in recent years.

Data collected by a prior research project was presented along with data from electro-fishing surveys from 1986 to 2003 for the Dolores River. These data showed that native fish were still common in the Dolores River upstream of Big Gypsum Valley. However these surveys revealed that only small-bodied fish (> 15 cm) were presently common and large adult native sucker or roundtail chub were vary rare. It appeared that long-term low flows have impacted the fish community by limiting body size, which appears to be due to a lack of habitat availability for fish larger than 20 cm. There has been an increase in nonnative species in the last three years. It appeared that native fish of the Dolores River were vulnerable to replacement by nonnative predators (centrarchids).

RECOMMENDATIONS FOR FUTURE RESEARCH

1. Establish two sites on the Gunnison River for mark and recapture population estimates. These sites should be the Delta site and the Escalante Site and sampled in 2004 and 2005.

2. Collect bed topography data using the GPS and sonar approach suitable for 2D modeling at both Gunnison River sites. Collect topography data in 2004 and contract the 2D modeling in either 2004 or 2005, budget dependent.

3. Perform mark and recapture estimates at the Corn Lake site for one more year. Drop the Clifton site from sampling efforts in 2004.

4. Perform mark and recapture estimates at Lily Park and Sevens for one more year. Drop the Duffy site from sampling efforts in 2004.

5. Perform a preliminary or reconnaissance survey on the White River and locate at least one site suitable for future fish sampling and a bed topography survey.

HYPOTHESIS PRESENTATION

Hypothesis 1. Native fish composition and abundance is greater in rivers with higher base flows.

Observation: The Yampa River has had very low base flow in the past four years and the native fish population has been effectively replaced by non-natives. The Dolores River has had very low base flow for a long period. The native fish population there has very low biomass and is comprised of small-bodied fish. The rivers that have been able to maintain large and stable populations of bluehead sucker, flannelmouth sucker and roundtail chub are the Colorado River, in both the 15-Mile Reach and near Parachute (Anderson 1997), and the Gunnison River downstream of Austin. Both of these rivers have high base flows because of downstream senior water deliveries. Another river that could be used to examine this hypothesis is the White River, which historically has had high base flows. But, a lack of recent fish population data means sampling is required to use this river for this type of comparison.

Hypothesis 2. Bluehead sucker and flannelmouth sucker biomass is highly correlated with habitat availability and the meso-habitat suitability values reported in Anderson and Stewart (2003) are transferable between rivers.

Observation: Data used to generate habitat suitability values were from two Yampa River sites and two Colorado River sites. These suitability values were used by the habitat model to predict impacts of flow alternation on native sucker abundance. An independent data set is required to validate suitability values. If 2-D modeling sites on the Gunnison River confirm and validate the suitability values presented in Anderson and Stewart (2003) than instream flow recommendations methods would be greatly simplified.

Hypothesis 3. White sucker abundance and hybridization rates with native sucker are longitudinally distributed and may be a function of water temperature.

Observation: White sucker were most common in upstream sites and least common in downstream sites in the Yampa, Colorado, and Gunnison rivers. This longitudinal distribution of white sucker in these rivers gives the appearance that their range did not completely overlap with native sucker. A change in water temperatures in the Gunnison River, due to altered releases from the Blue Mesa Project, could have an unforeseen impact on white sucker abundance and distribution. This in turn could alter current hybridizing rates with native sucker. Efforts to remove white sucker with the goal of reducing hybridization rates with native sucker appears warranted in the Yampa and Gunnison rivers.

Hypothesis 4. A manned low-head permanent or temporary dam could be the most effective tool for nonnative fish control over the long term, especially for channel catfish.

Observation: The Redlands Diversion dam on the Gunnison is apparently responsible for the lack of channel catfish and may also be a factor for the lack of other nonnative predator

species such as smallmouth bass, and northern pike upstream of the structure. Channel catfish have a very large population in the Yampa and Colorado rivers. A well placed structure or weir has the potential to intercept migrating catfish and over time to deplete catfish populations upstream of the structure. Potential locations on the Yampa River could be near Echo Park or Deer Lodge. On the Colorado River a location would need to be determined based on spawning locations. For example, a weir at the 5th Street Bridge could deplete channel catfish in the 15-Mile Reach. A downstream trap might be effective for removal of smallmouth bass or northern pike. An analysis of the nonnative fish that have been removed from the Gunnison River at the fish ladder could provide an indication of potential impacts of a dam on other non-desirable species.

Hypothesis 5. There is a strong inverse relationship between the size of the channel catfish and the size of roundtail chub population.

Observation: The largest population of roundtail chub was at the Escalante site on the Gunnison River with a high number of Age-0 and Age-1 fish collected. No channel catfish were collected in the Gunnison River. The smallest population of roundtail chub was at the Lily Park site on the Yampa River, which had a very large channel catfish population. It strongly appeared that habitat availability was not limited for roundtail chub at Lily Park. The 15-Mile reach was intermediate to both the Escalante and the Lily Park sites for both roundtail chub and channel catfish. It was observed in the 15-Mile Reach that the year with the highest percent composition of channel catfish (2003) was also the year with the lowest number of Age-0 and Age-1 roundtail chub in the sample. Roundtail chub were common in the Dolores River, a river with few channel catfish. This tendency suggests that channel catfish have had a negative impact on roundtail chub.

Hypothesis 6a. Smallmouth bass recruitment is related to temperature and warmer Summer and Fall temperatures since 2000 improved Age-0 survival in the Yampa River.

Hypothesis 6b. Release of cool water from an enlarged Elkhead Reservoir could impact Age-0 survival and smallmouth-bass recruitment in the Yampa River.

Observation: Smallmouth bass larger than 75 mm at the end of the growing season tend to have much better over-winter survival than smaller fish (Pat Martinez, personal communication). YOY smallmouth bass were abundant at Duffy in 1998 and 1999, but older bass were not common. The increase in smallmouth bass could be a function of warmer water temperatures during the dry years. A temperature modeling study appears warranted to determine the merit of this hypothesis.

ACKNOWLEDGEMENTS

The baseline fish data used to quantify impacts of the 2002 drought on native fish populations in the Yampa and Colorado rivers was collected during the prior research project (Anderson and Stewart 2003). I am grateful to Phil George of the Cross Mountain Ranch for providing access to two study sites on the Yampa River. I am also very grateful to the Clifton Water District (Dave Reinertsen and Dale Tooker) for access to the Colorado River at Clifton. The other Colorado River site was on property owned by the BOR and access was facilitated by property managers Steve Yamashita and Lyle Sidener of the CDOW and also by Charlie Shannon. I greatly appreciated the cooperation of landowners on the Gunnison River. Access to the Gunnison River at Austin was provided by Carol Morrell and John Buchheim. Mike Zeaman of the CDOW provided access to the Gunnison River at the State Wildlife Area near Delta. Dick Miller graciously granted access to the Gunnison River on the Escalante Ranch and his foreman Kent Davis was very helpful. Lastly, I want to thank two exceptional temporary employees John Groves and Josh Crain for their hard work and interest in the project.

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APPENDIX

Tables and Figures

Table A-1. Length frequency histograms for fish collected in the Yampa and Colorado rivers in 2003.

Table A-2. Length frequency histograms for fish collected in the Gunnison River in 2003.

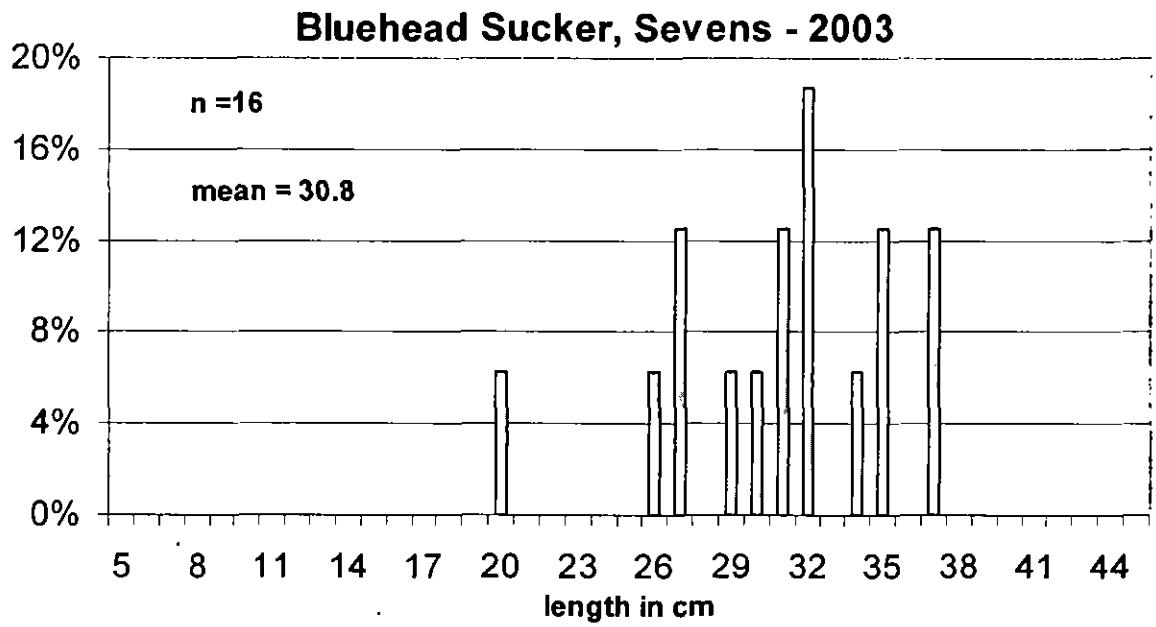

Figure A1-1. Bluehead sucker length frequency at Sevens, July and August 2003, Yampa River.

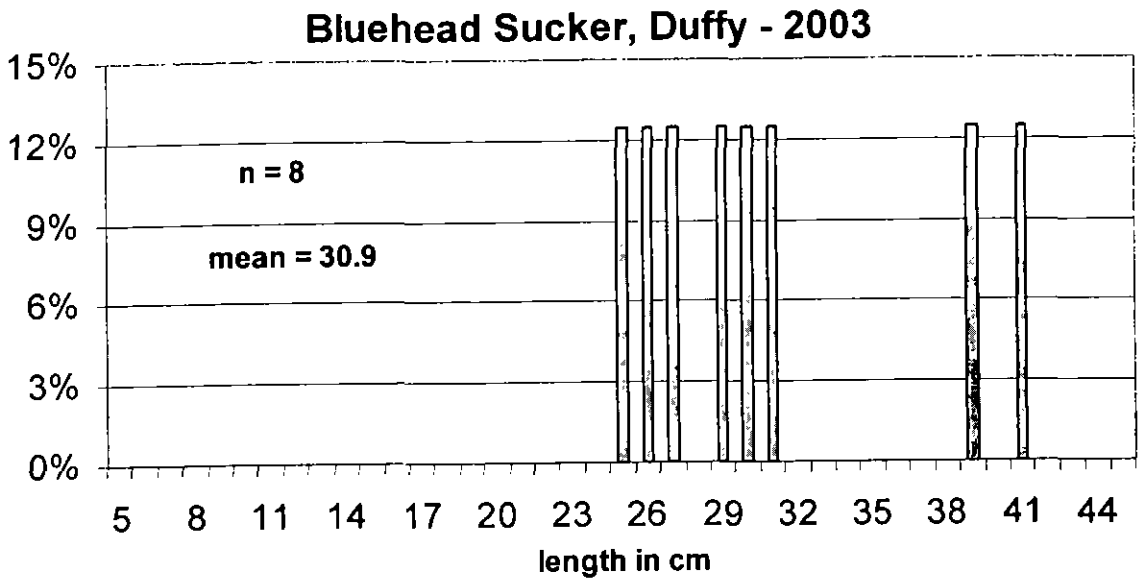

Figure A1-2. Bluehead sucker length frequency at Duffy, July and August 2003, Yampa River.

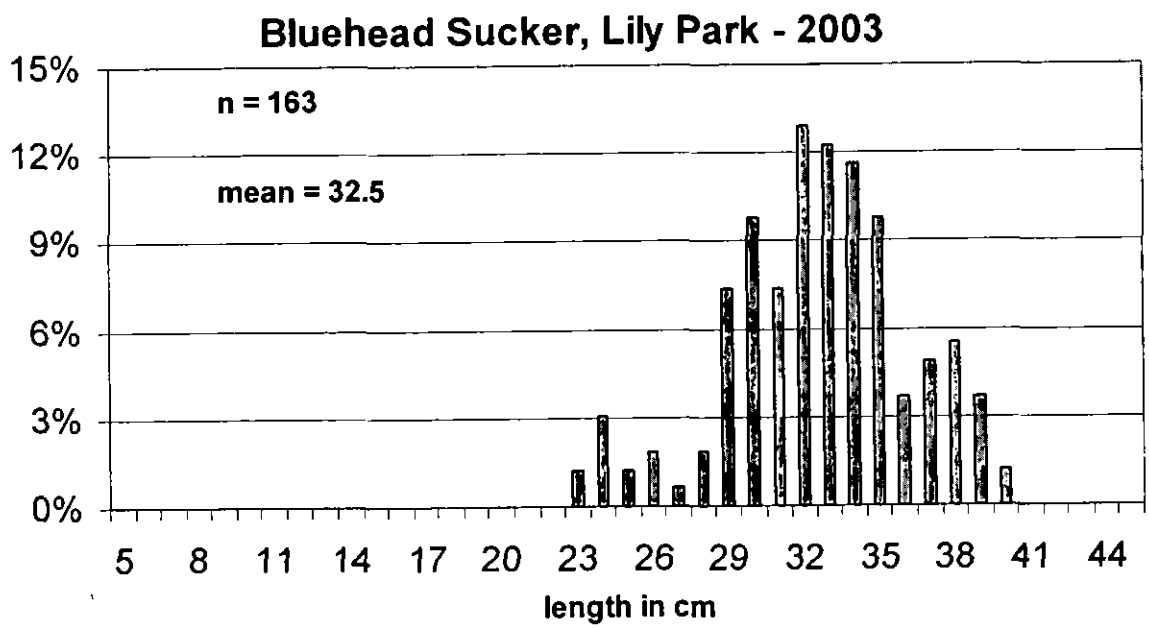

Figure A1-3. Bluehead sucker length frequency at Lily Park, July and August 2003, Yampa River.

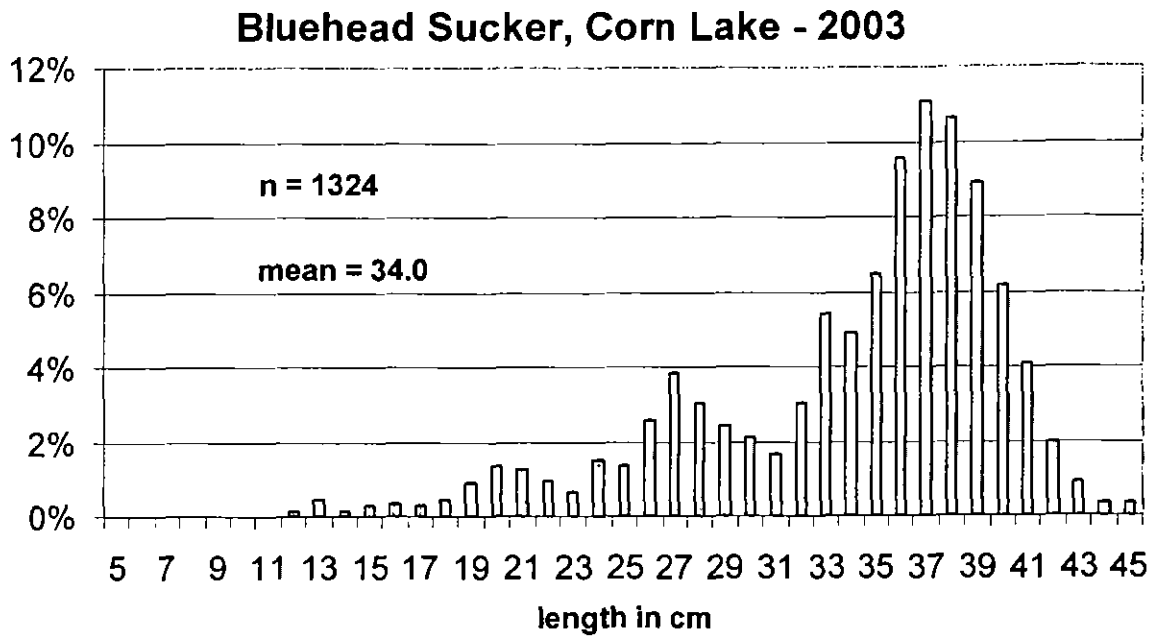

Figure A1-4. Bluehead sucker length frequency at Corn Lake, September and October 2003, Colorado River.

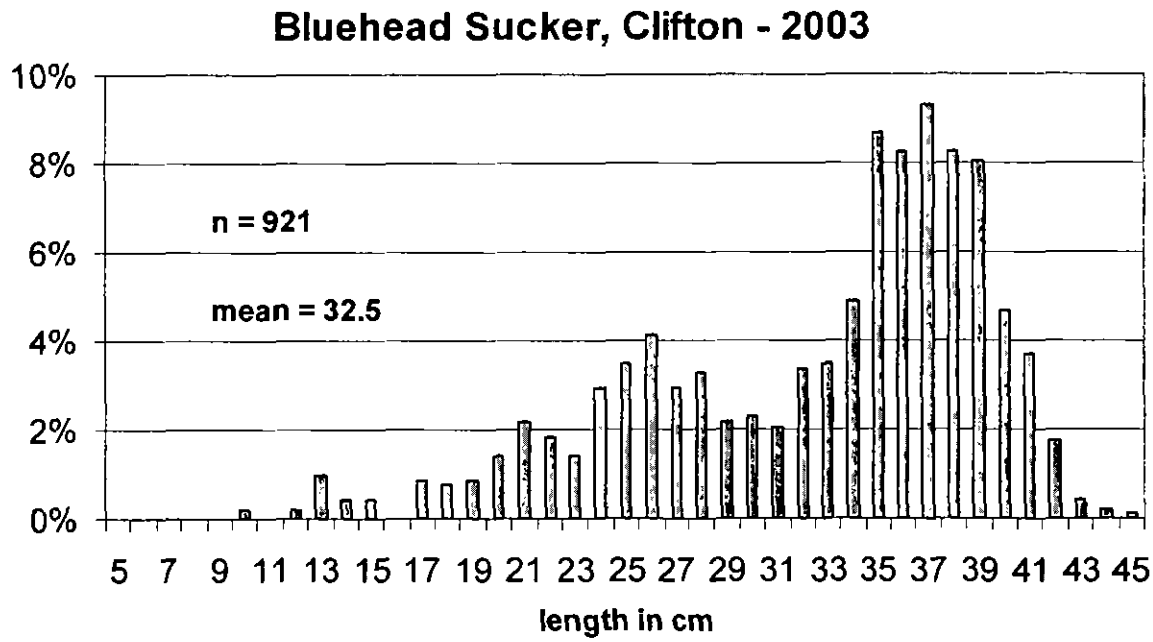

Figure A1-5. Bluehead sucker length frequency at Clifton, September and October 2003, Colorado River.

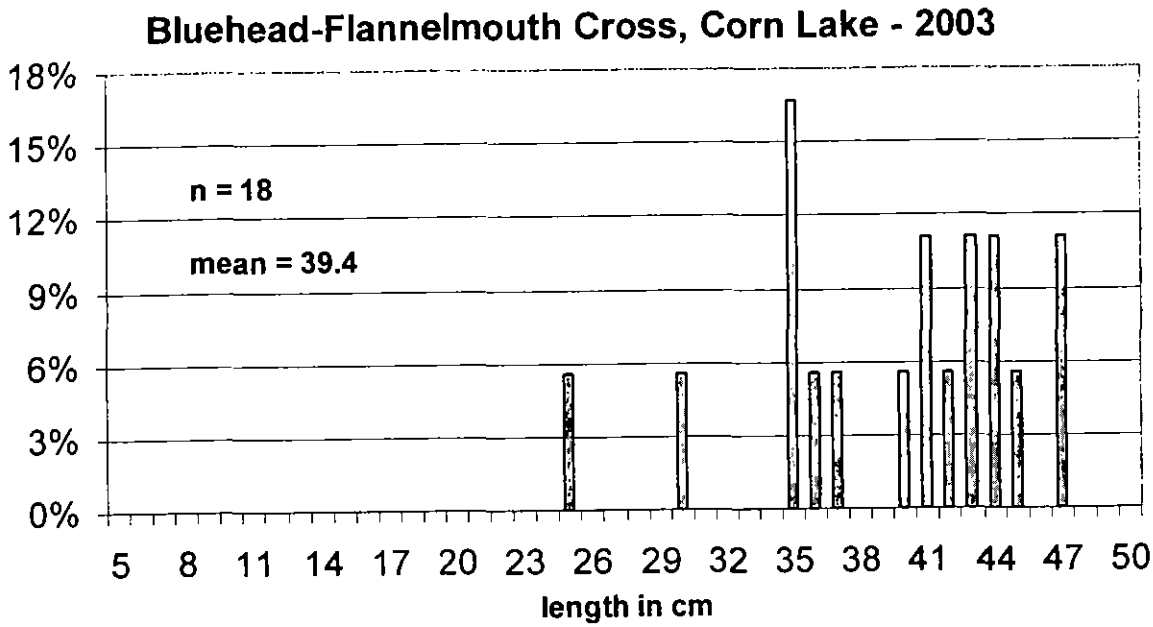

Figure A1-6. Bluehead-Flannelmouth hybrids length frequency at Corn Lake, September and October 2003, Colorado River.

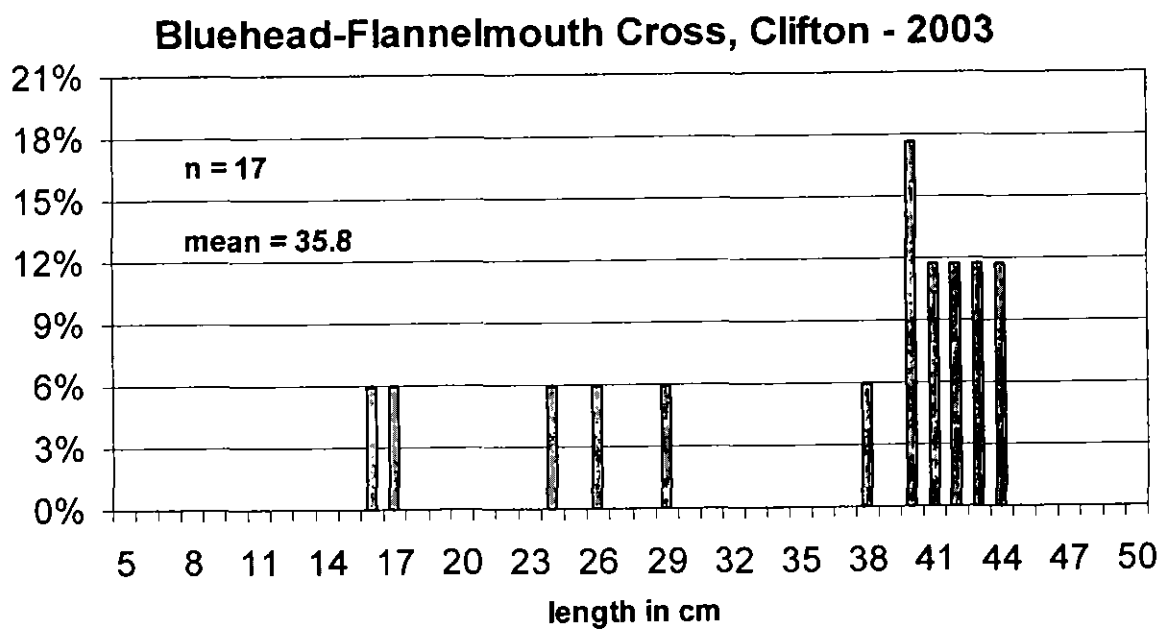

Figure A1-7. Bluehead-Flannelmouth hybrids length frequency at Clifton, September and October 2003, Colorado River.

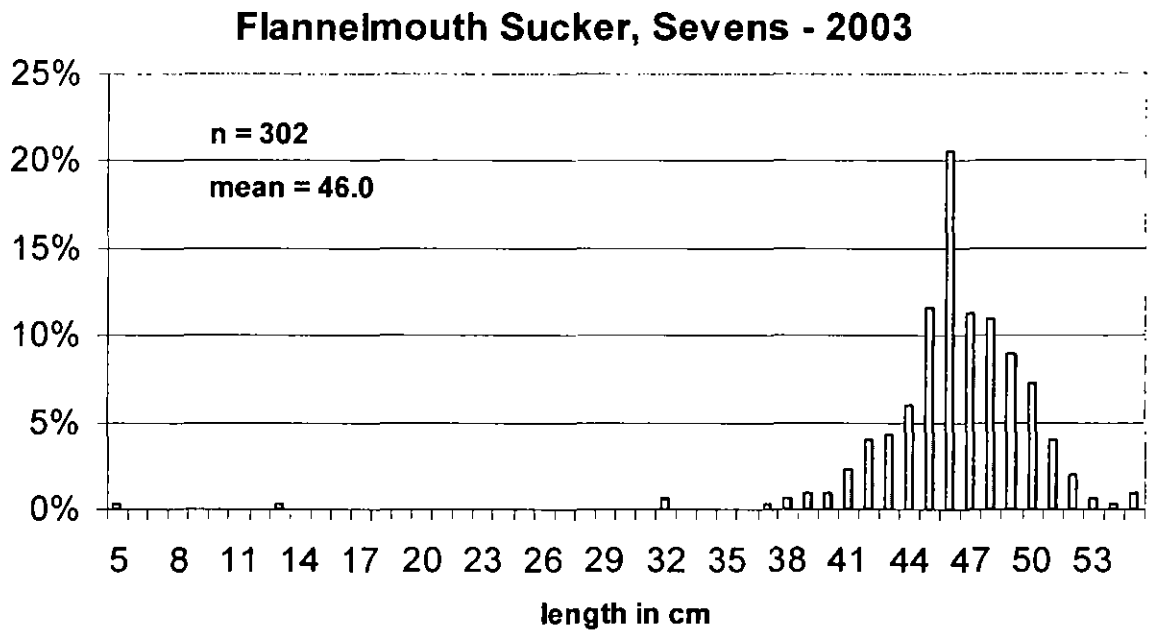

Figure A1-8. Flannelmouth sucker length frequency at Sevens, July and August 2003, Yampa River.

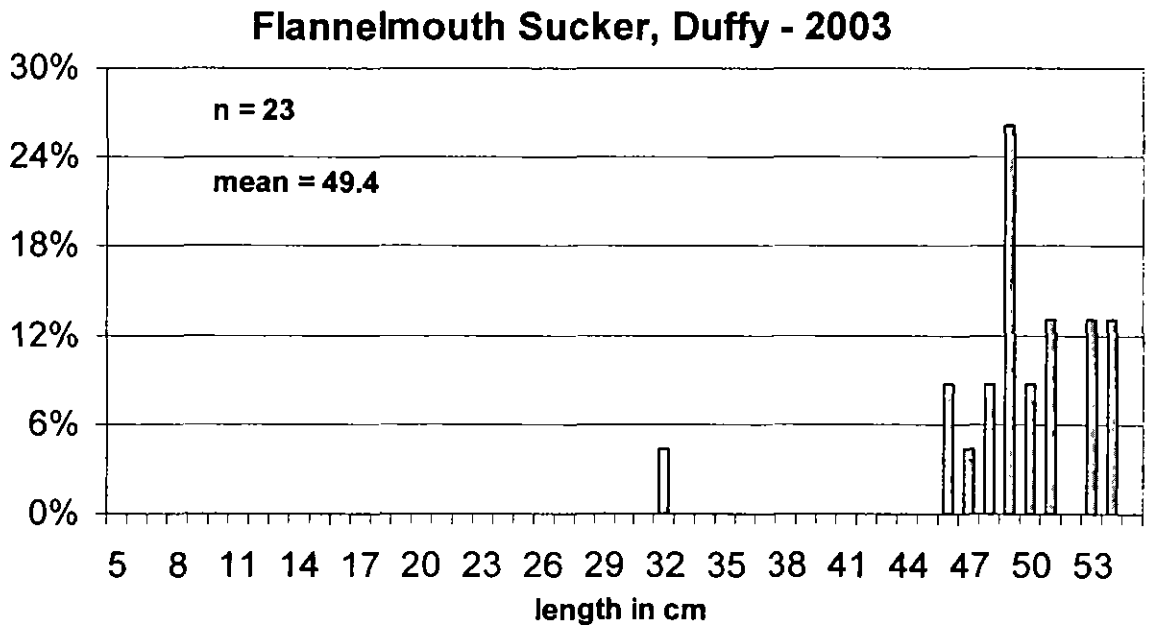

Figure A1-9. Flannelmouth sucker length frequency at Duffy, July and August 2003, Yampa River

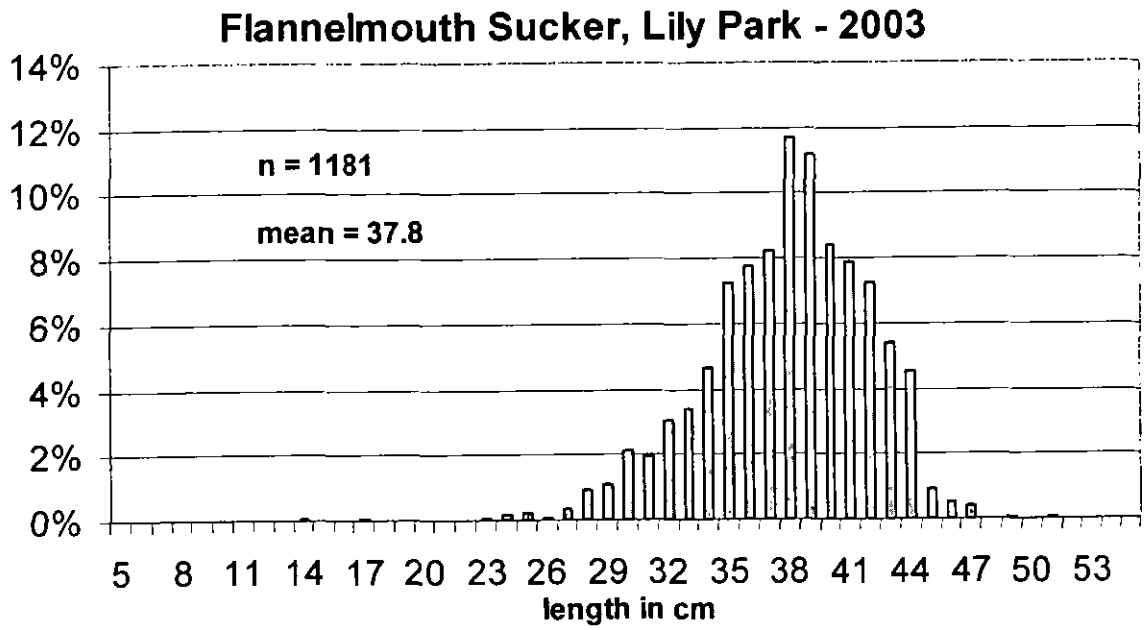

Figure A1-10. Flannelmouth sucker length frequency at Lily Park, July and August 2003, Yampa River.

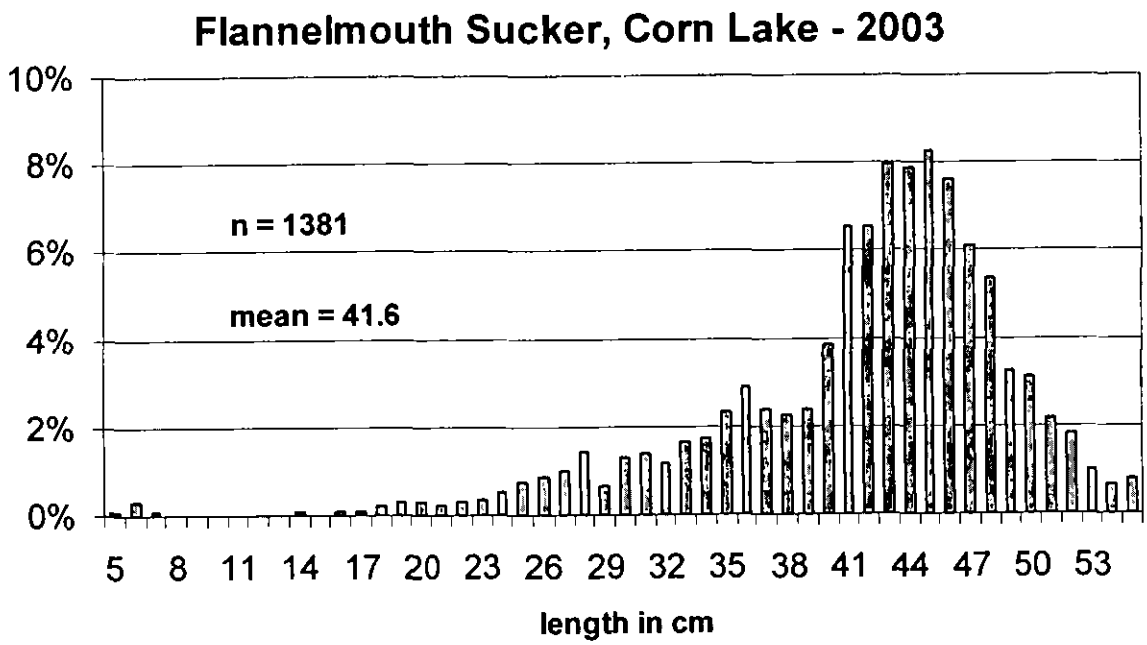

Figure A1-11. Flannelmouth sucker length frequency at Corn Lake, September and October 2003, Colorado River.

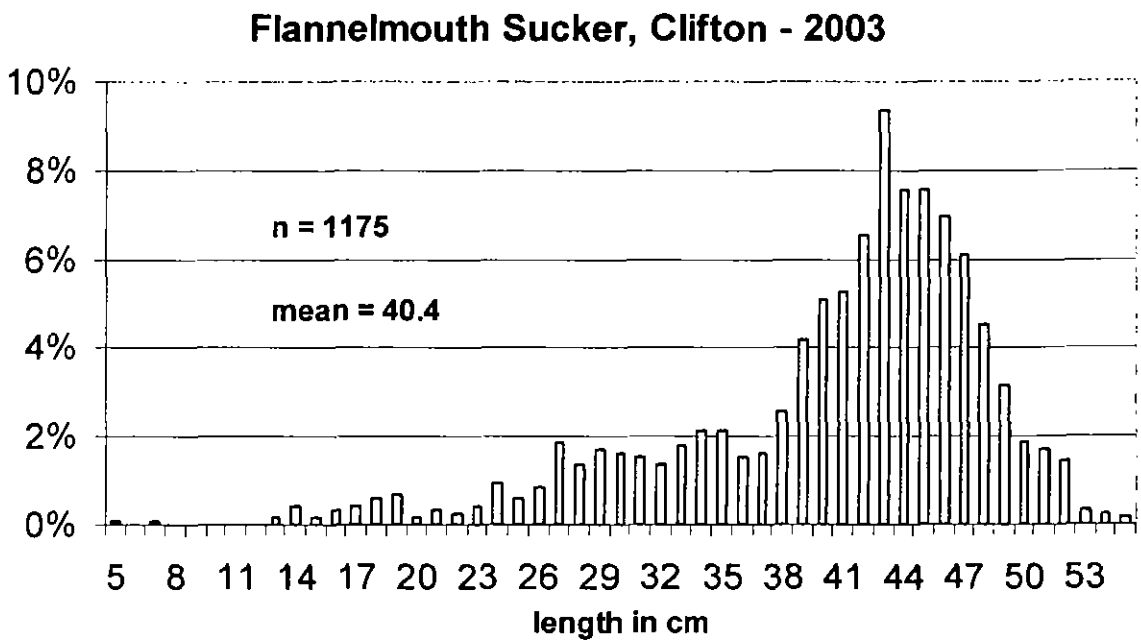

Figure A1-12. Flannelmouth sucker length frequency at Clifton, September and October 2003, Colorado River.

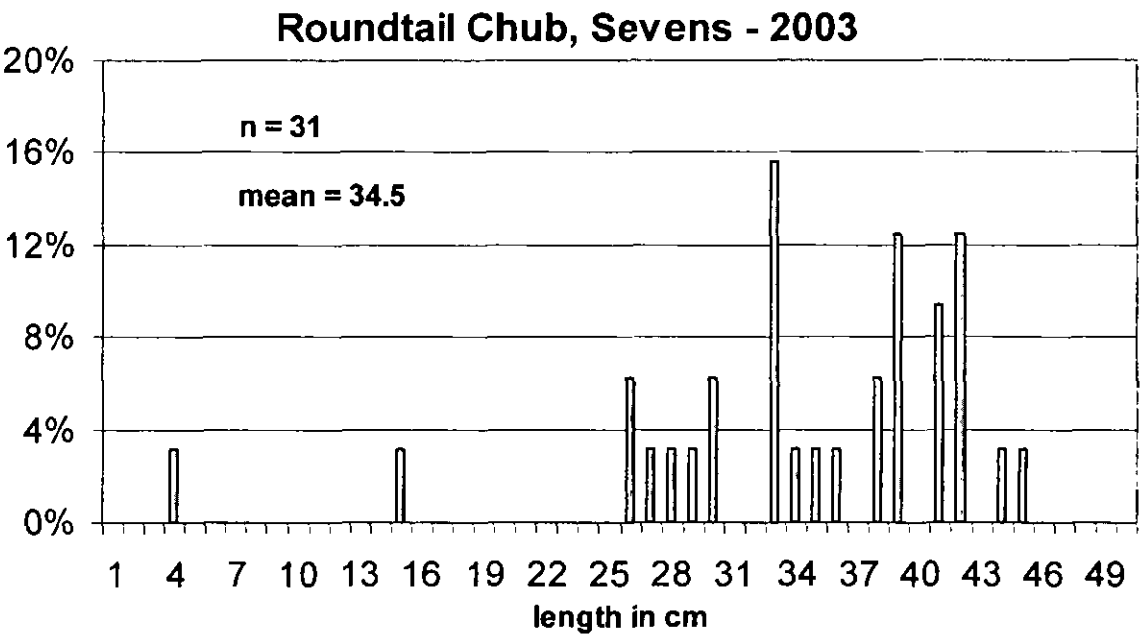

Figure A1-13. Roundtail chub length frequency at Sevens, July and August 2003, Yampa River.

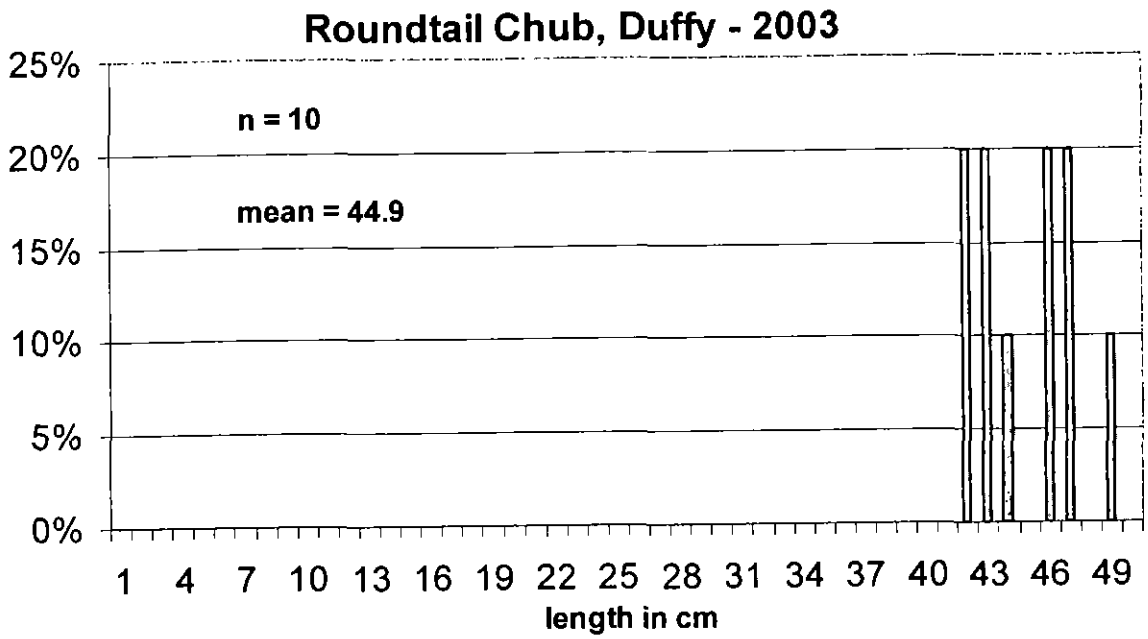

Figure A1-14. Roundtail chub length frequency at Duffy, July and August 2003, Yampa River.

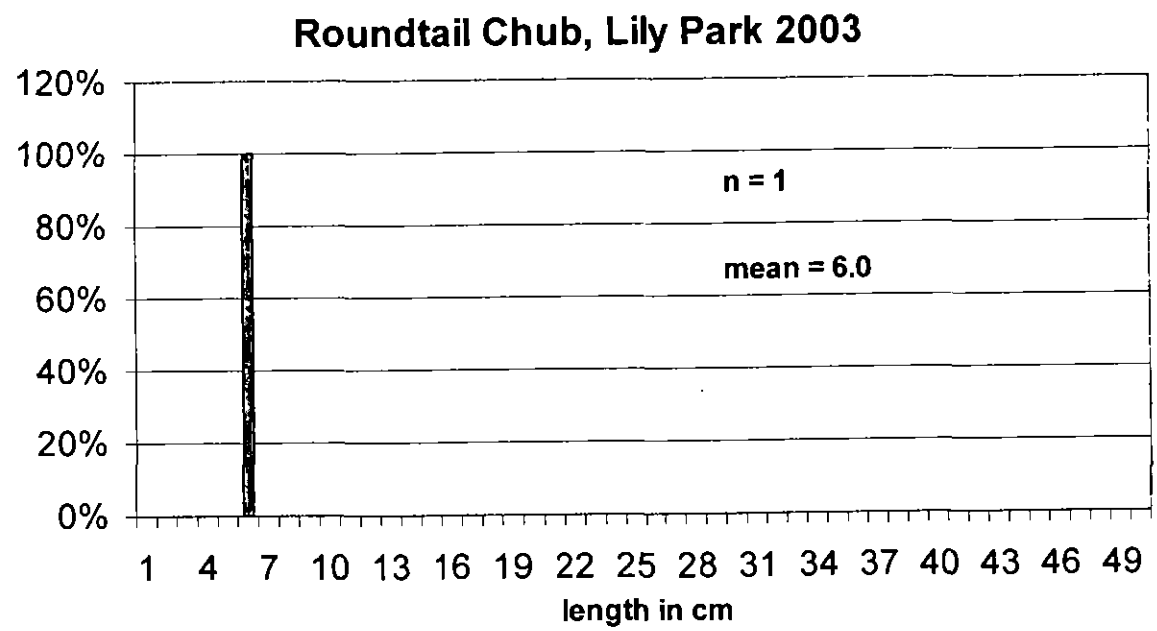

Figure A1-15. Roundtail chub length frequency at Lily Park, July and August 2003, Yampa River.

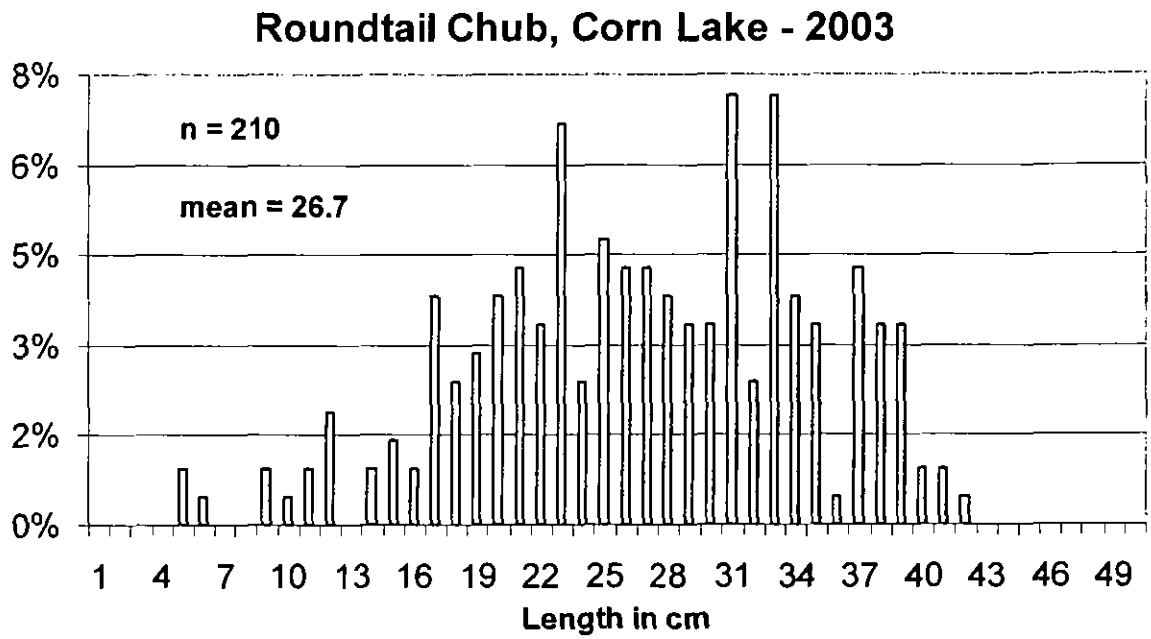

Figure A1-16. Roundtail chub length frequency at Corn Lake, September and October 2003, Colorado River.

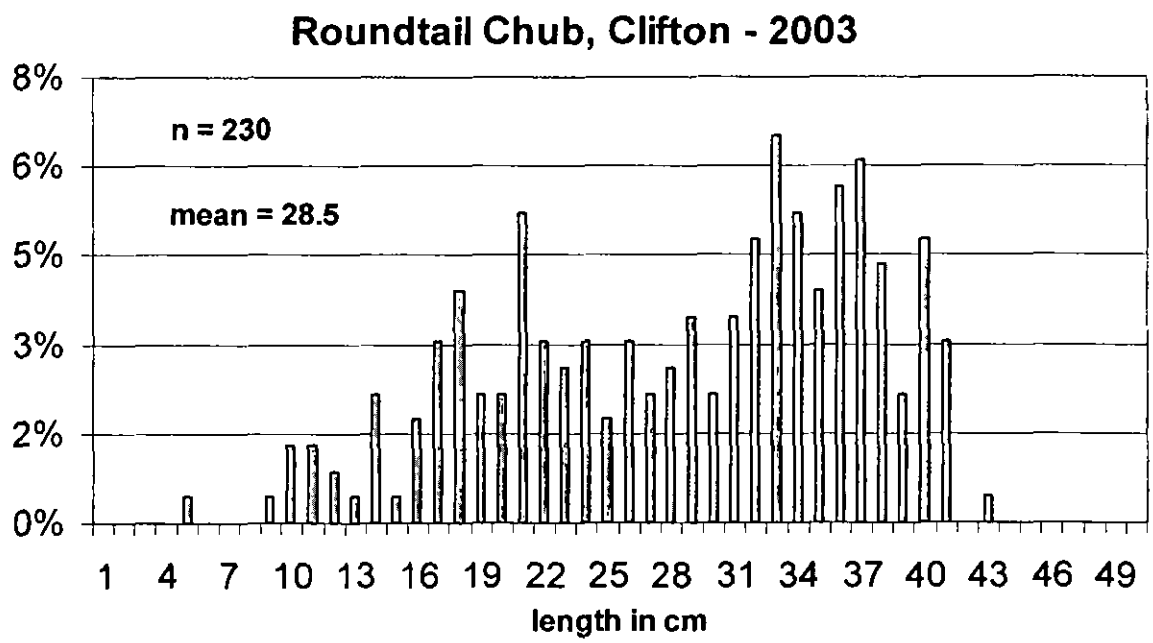

Figure A1-17. Roundtail chub length frequency at Clifton, September and October 2003, Colorado River.

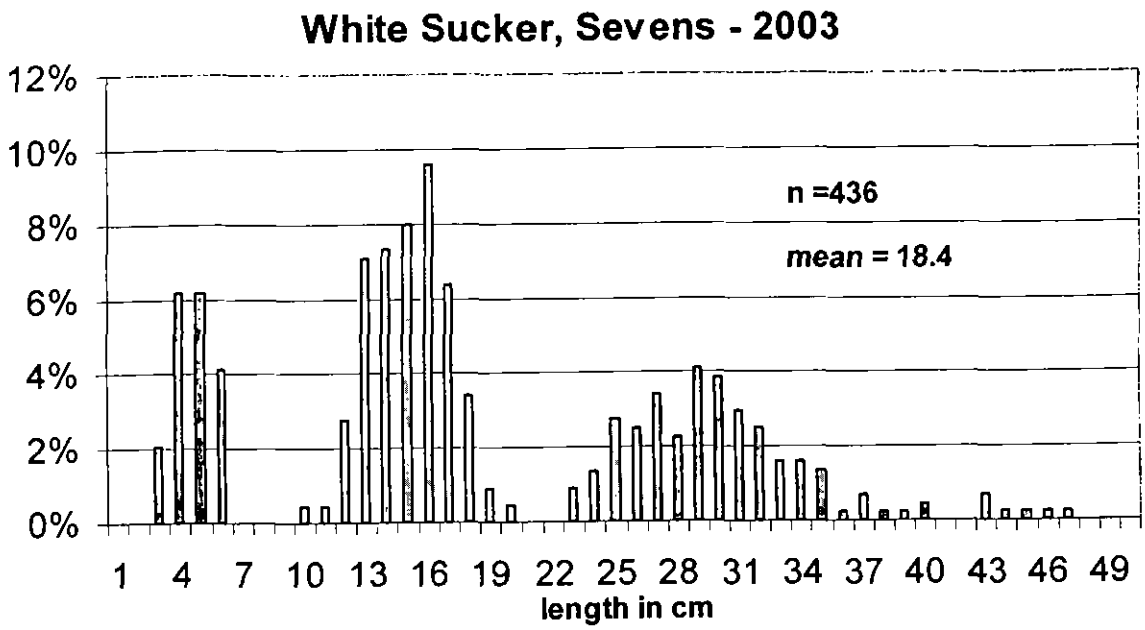

Figure A1-18. White sucker length frequency at Sevens, July and August 2003, Yampa River.

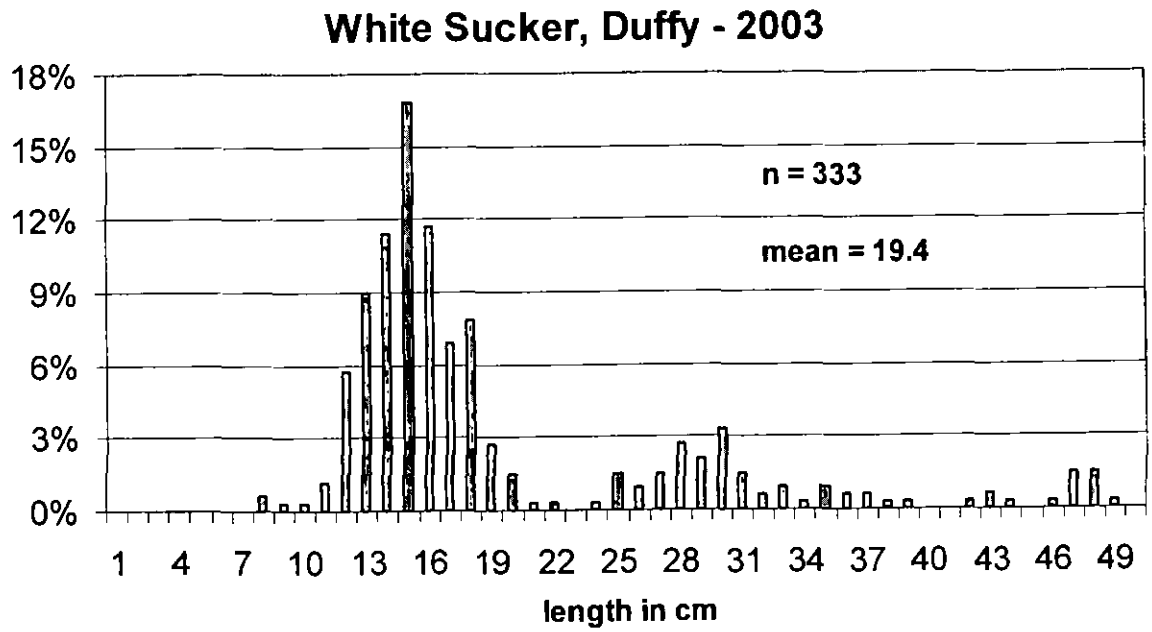

Figure A1-19. White sucker length frequency at Duffy, July and August 2003, Yampa River.

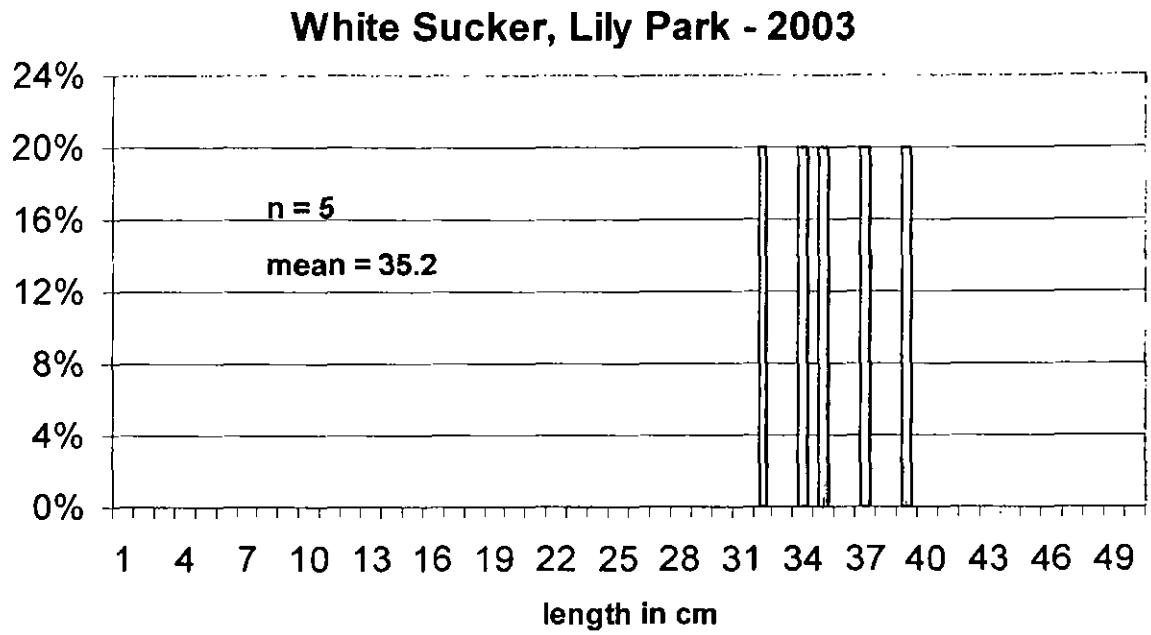

Figure A1-20. White sucker length frequency at Lily Park, July and August 2003, Yampa River.

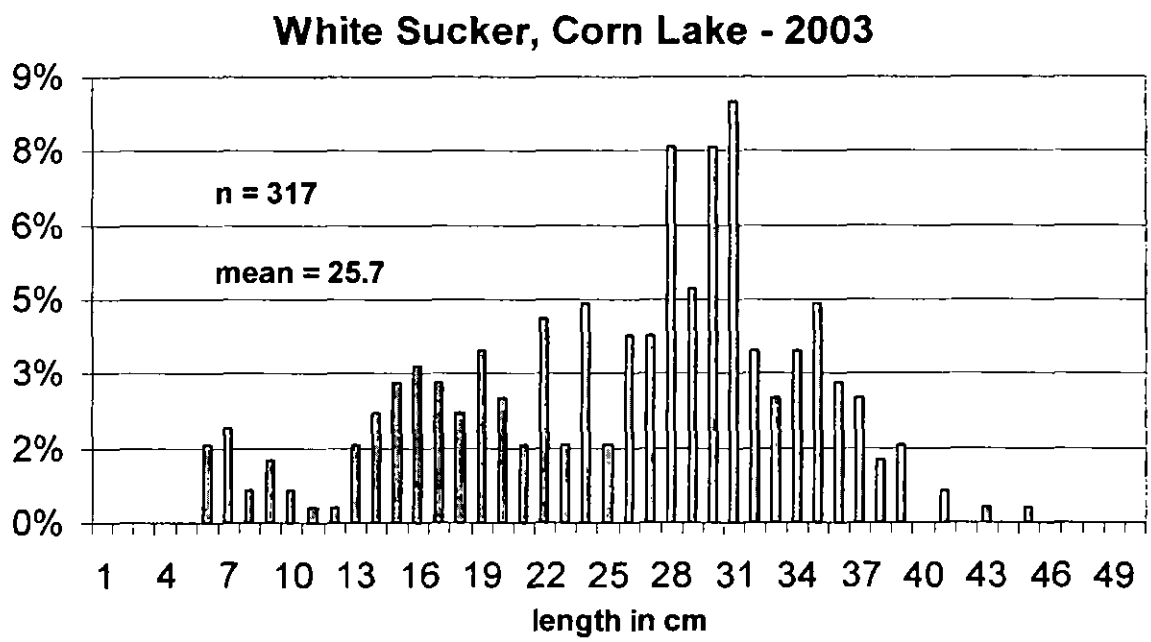

Figure A1-21. White sucker length frequency at Corn Lake, September and October 2003, Colorado River

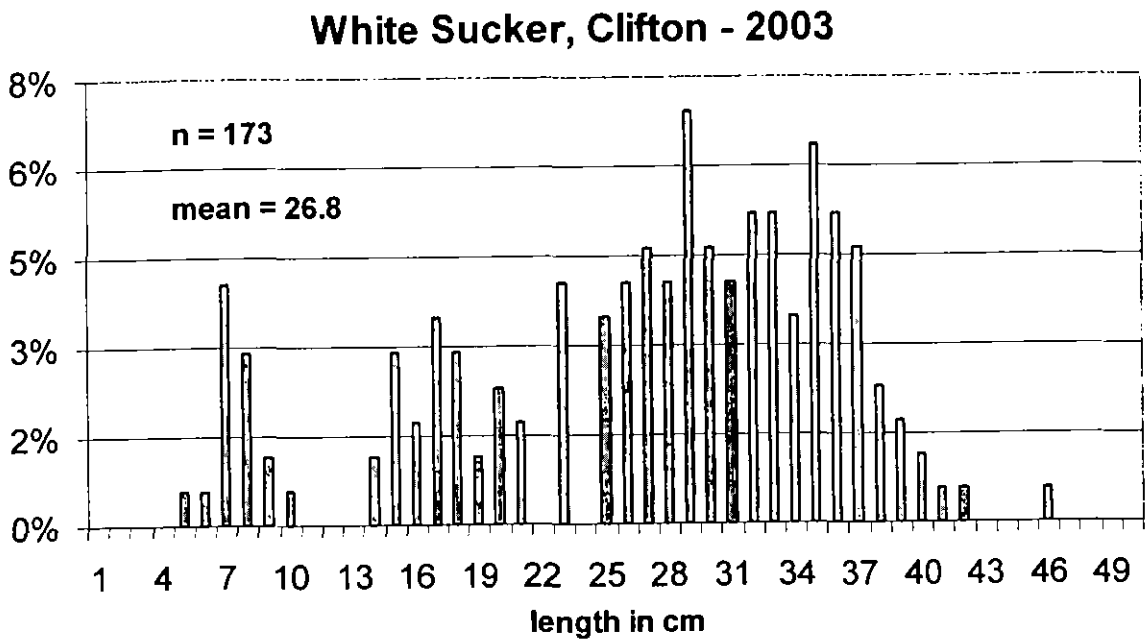

Figure A1-22. White sucker length frequency at Clifton, September and October 2003, Colorado River.

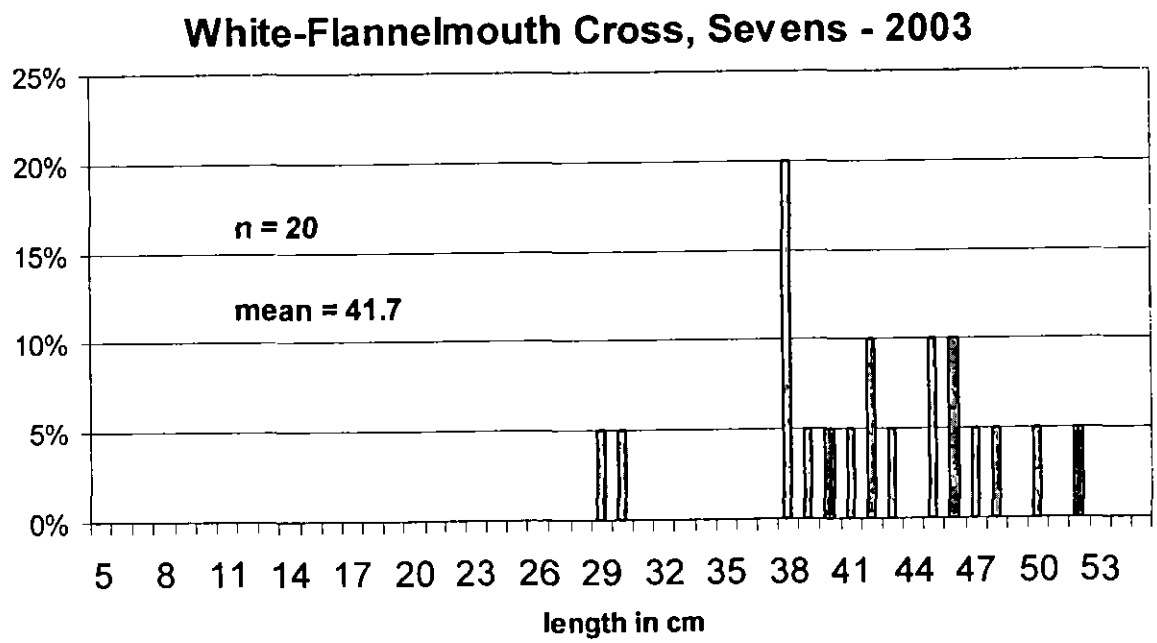

Figure A1-23. White-Flannelmouth hybrids length frequency at Sevens, July and August 2003, Yampa River.

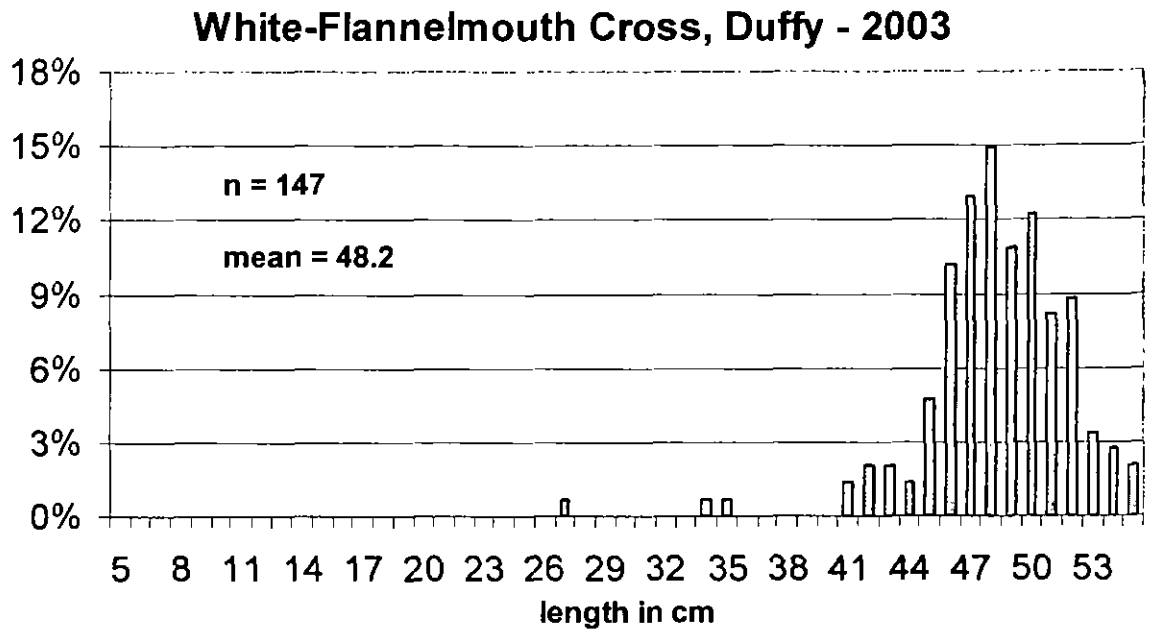

Figure A1-24. White-Flannelmouth hybrids length frequency at Duffy, July and August 2003, Yampa River.

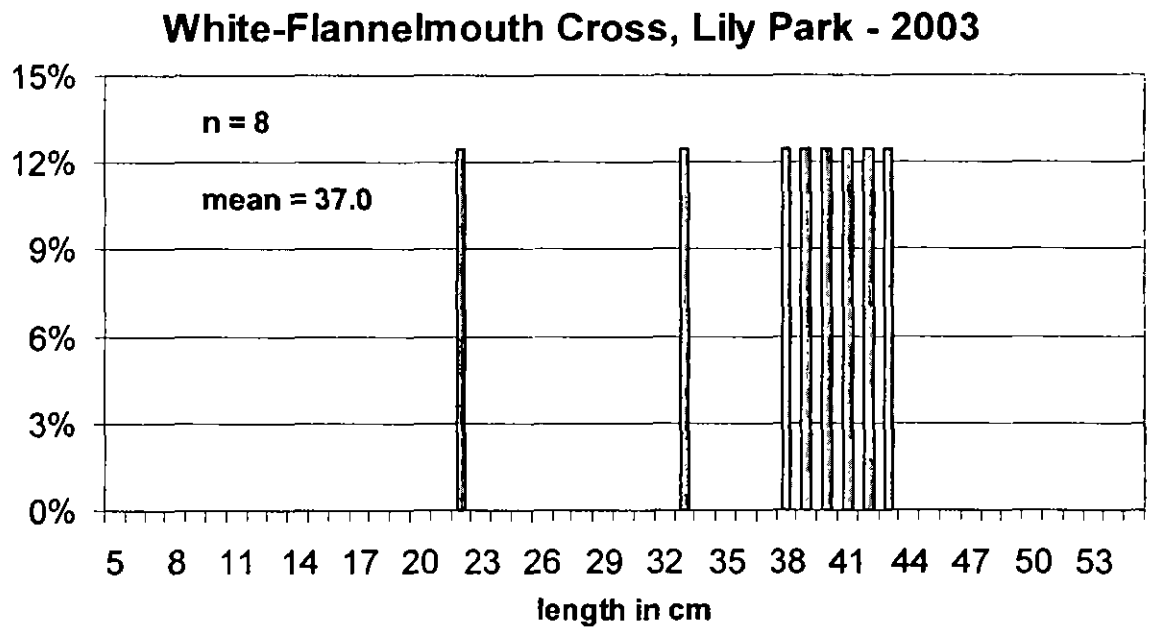

Figure A1-25. White-Flannelmouth hybrids length frequency at Lily Park, July and August 2003, Yampa River.

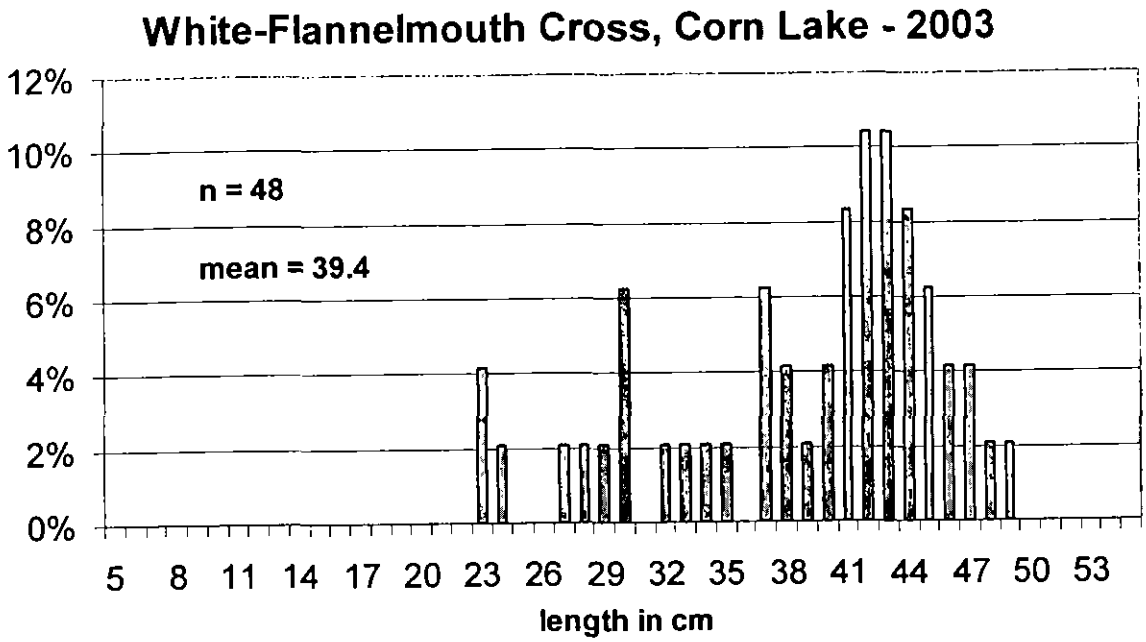

Figure A1-26. White-Flannelmouth hybrids length frequency at Corn Lake, September and October 2003, Colorado River.

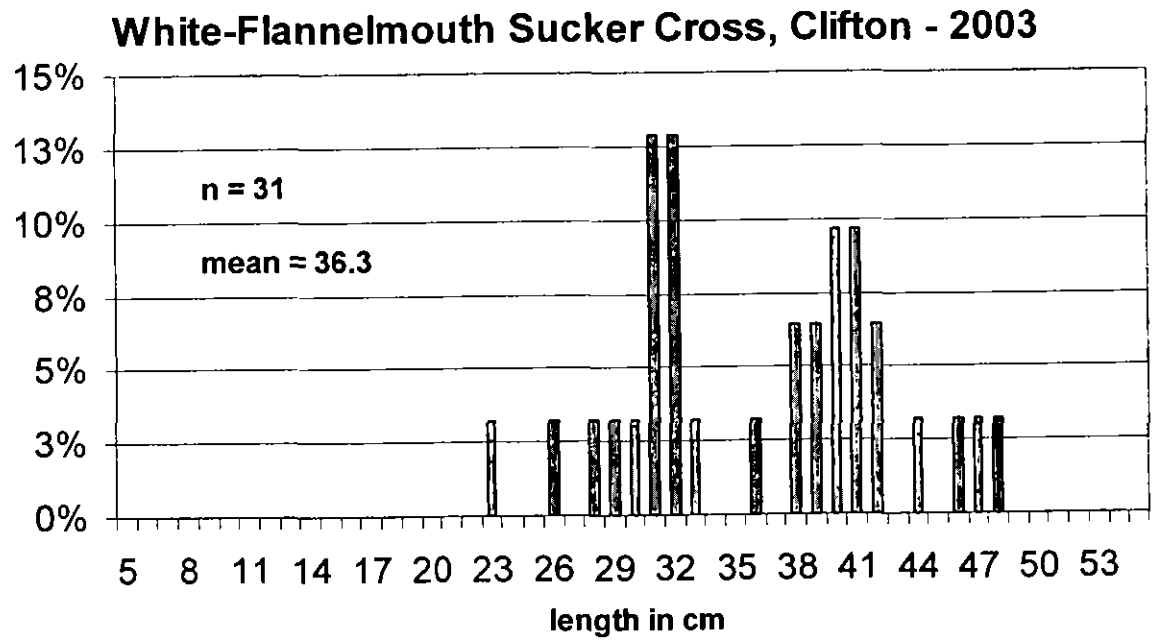

Figure A1-27. White-Flannelmouth hybrids length frequency at Clifton, September and October 2003, Colorado River.

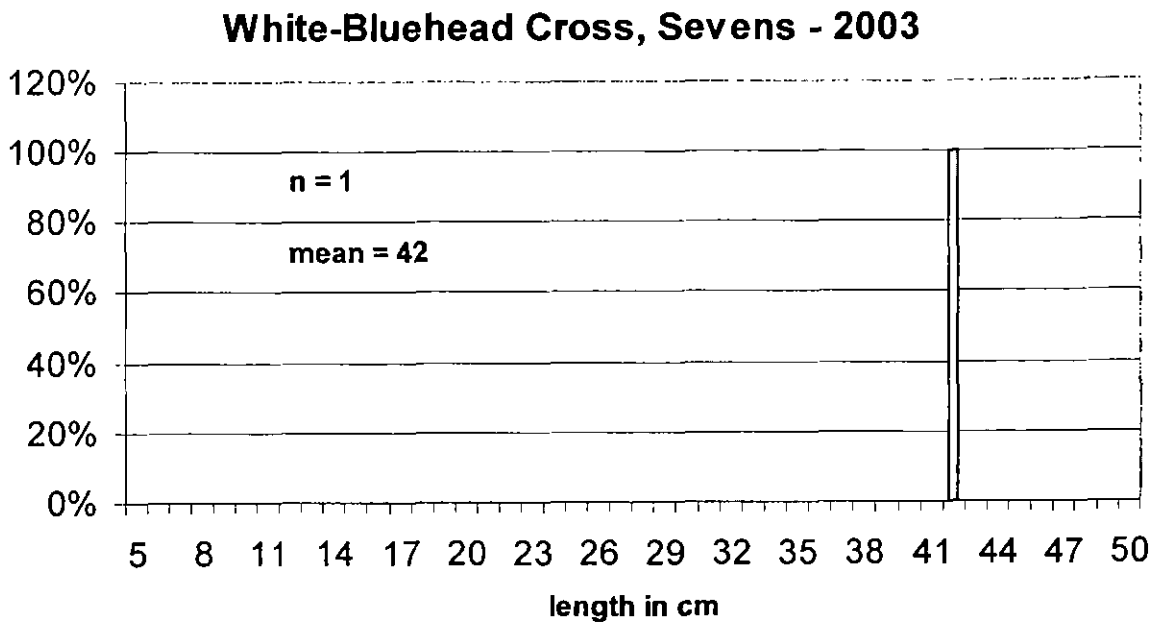

Figure A1-28. White-Bluehead hybrids length frequency at Sevens, July and August 2003, Yamp8 River.

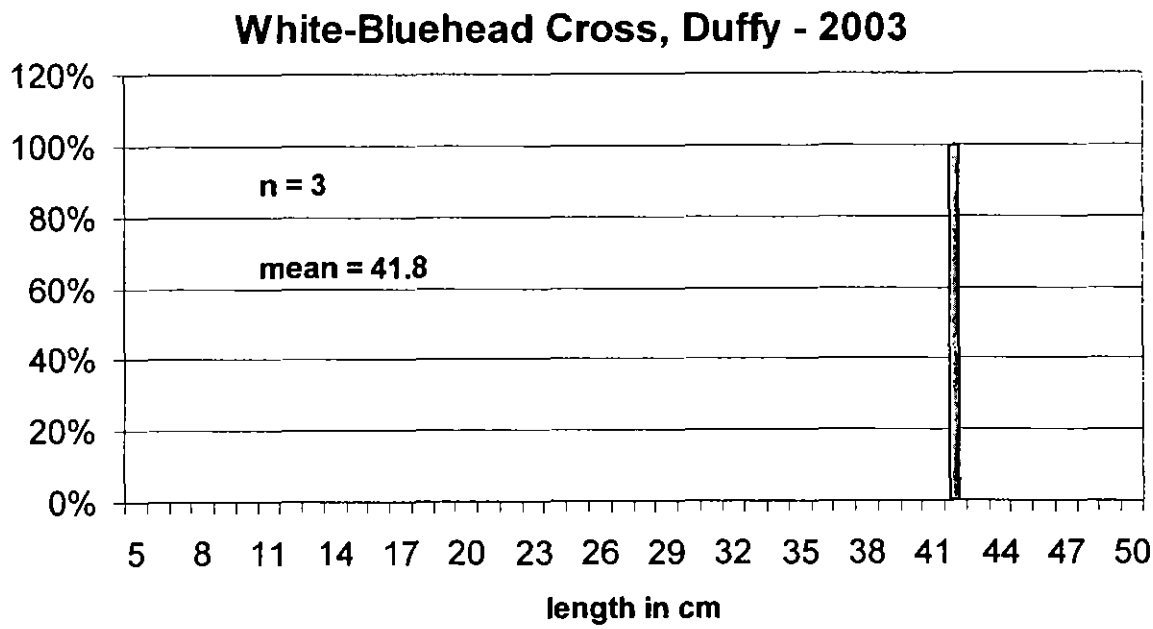

Figure A1-29. White-Bluehead hybrids length frequency at Duffy, July and August 2003, Yampa River.

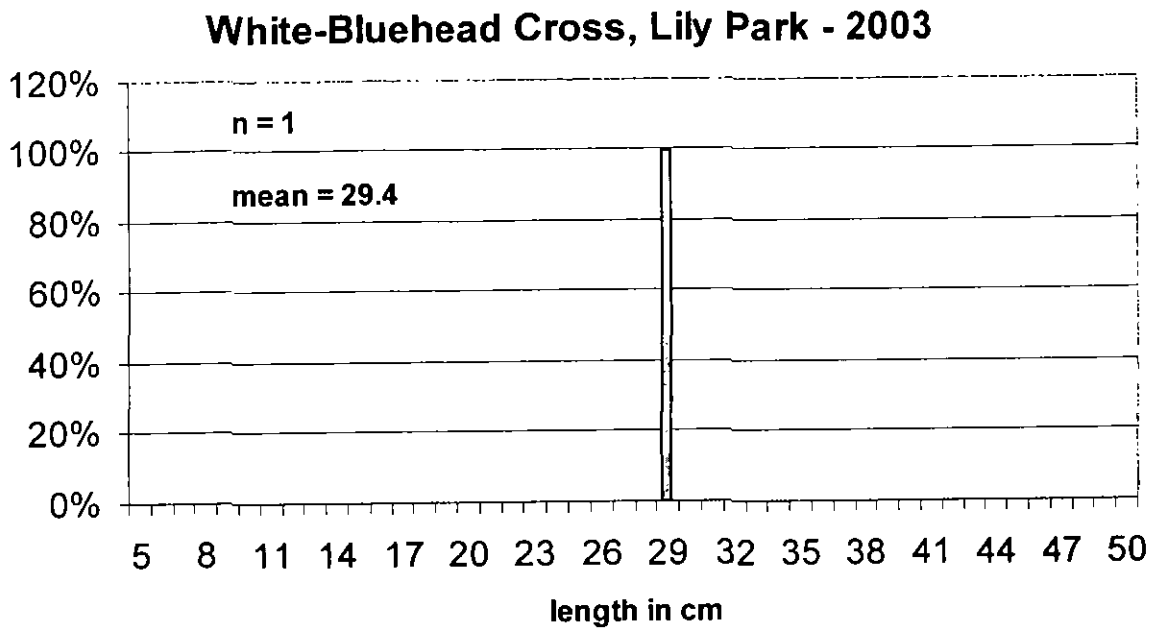

Figure A1-30. White-Bluehead hybrids length frequency at Lily Park, July and August 2003, Yampa River.

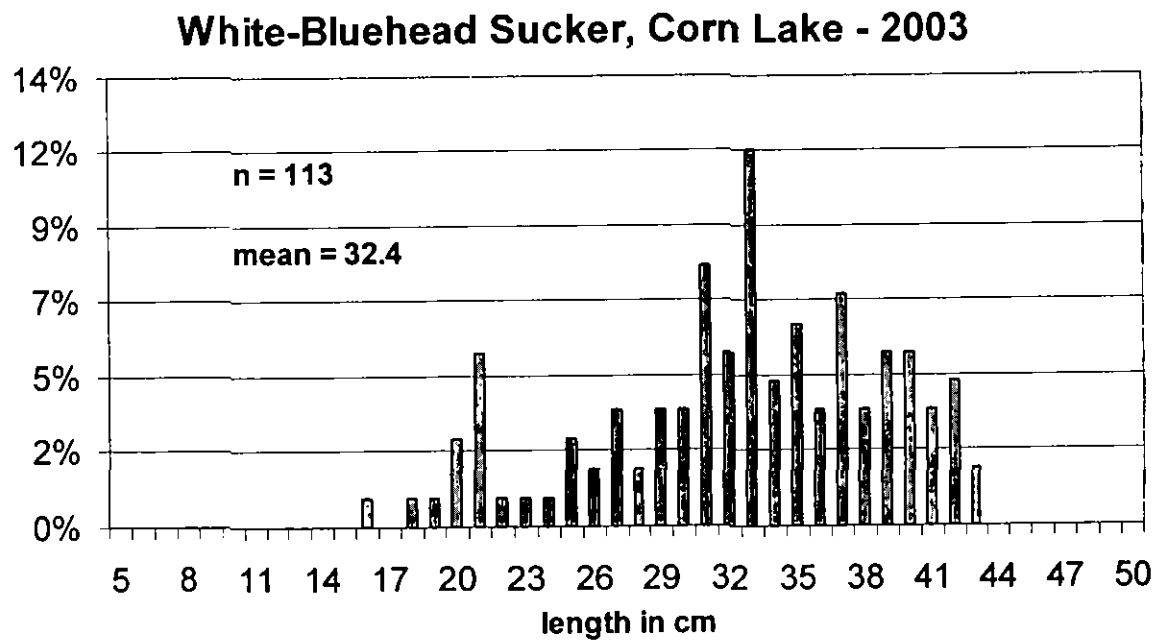

Figure A1-31. White-Bluehead hybrids length frequency at Corn Lake, September and October 2003, Colorado River.

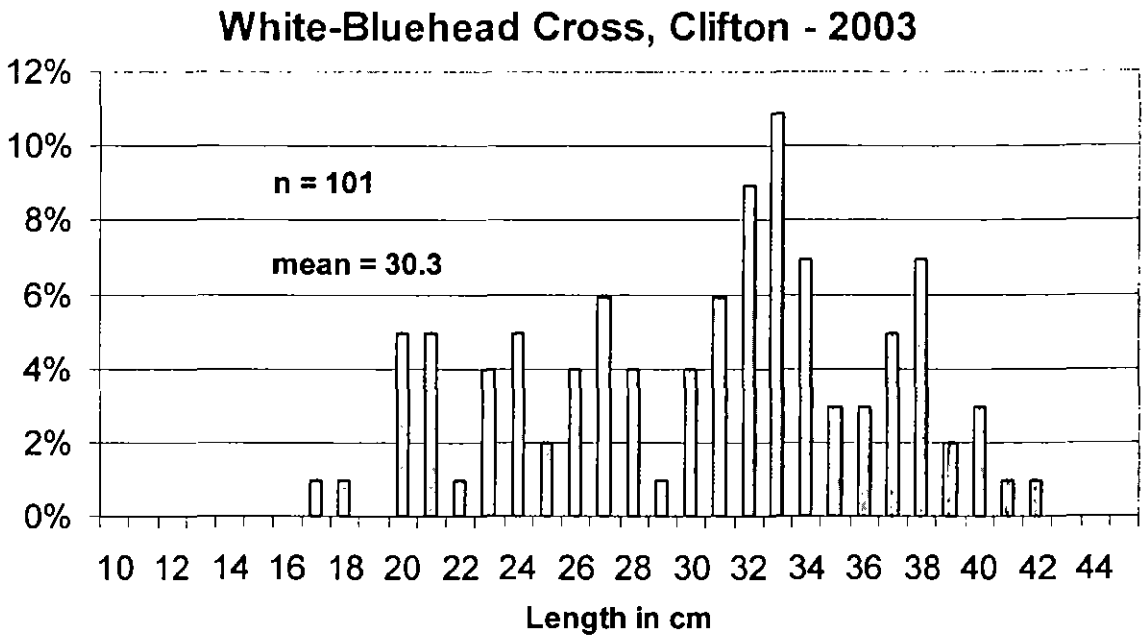

Figure A1-32. White-Bluehead hybrids length frequency at Clifton, September and October 2003, Colorado River.

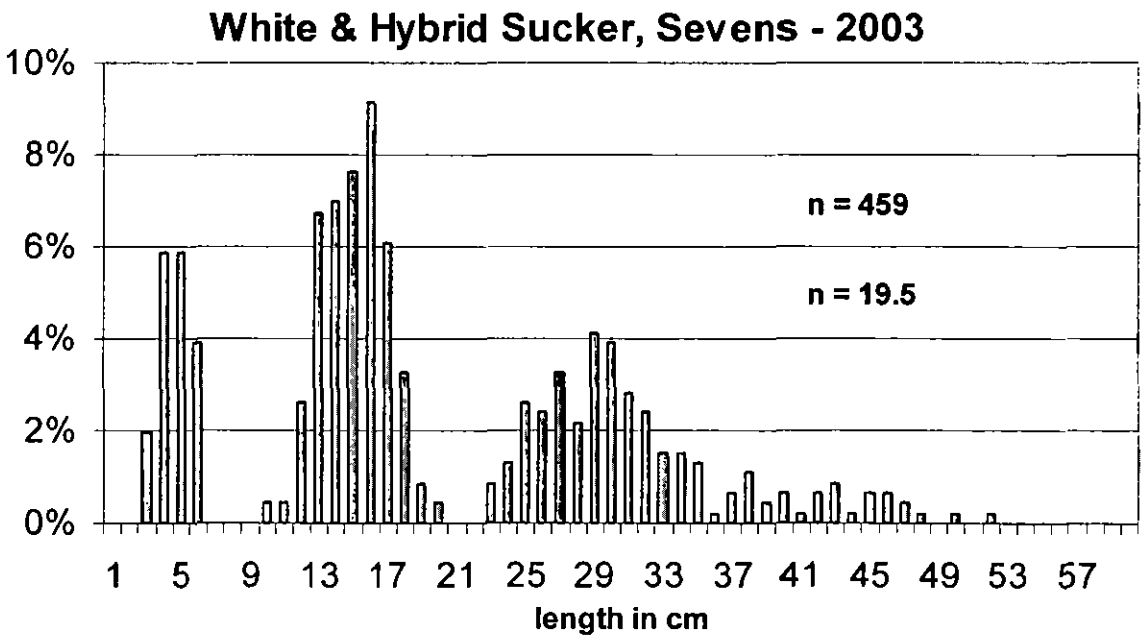

Figure A1-33. White & Hybrid Sucker length frequency at Sevens, July and August 2003, Colorado River.

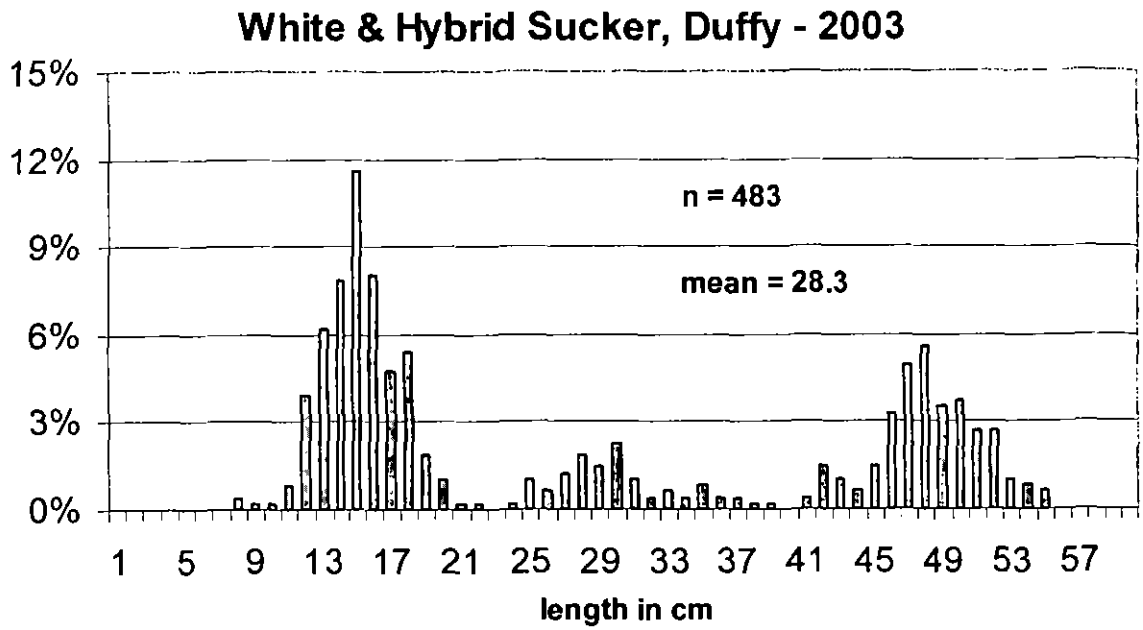

Figure A1-34. White & Hybrid sucker length frequency at Duffy, July and August 2003, Colorado River.

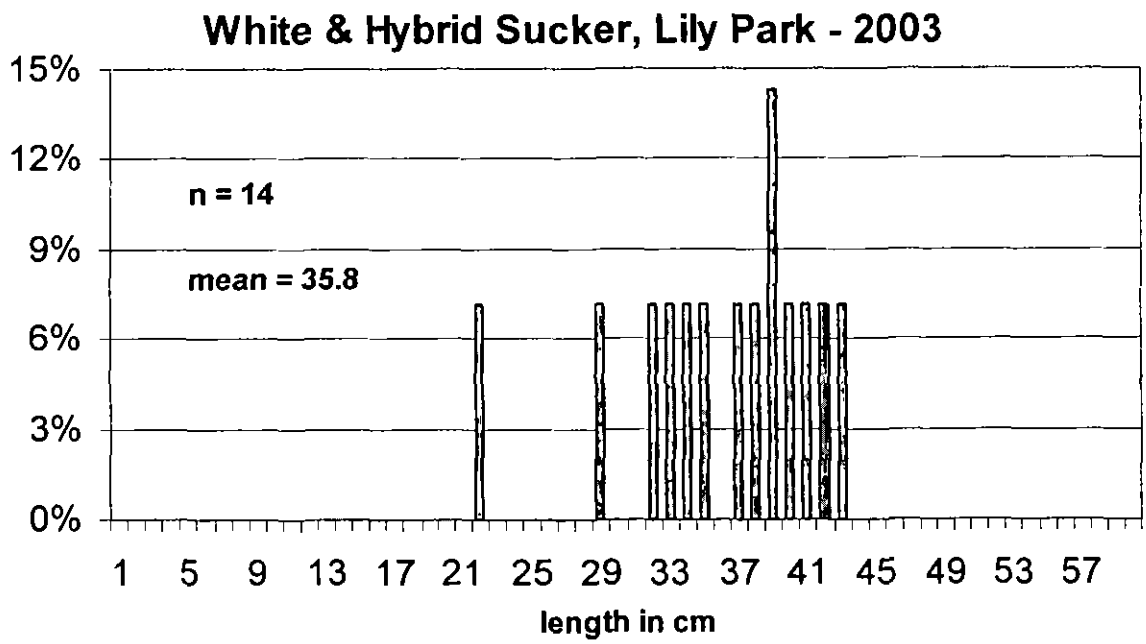

Figure A1-35. White & Hybrid sucker length frequency at Lily Park, July and August 2003, Colorado River.

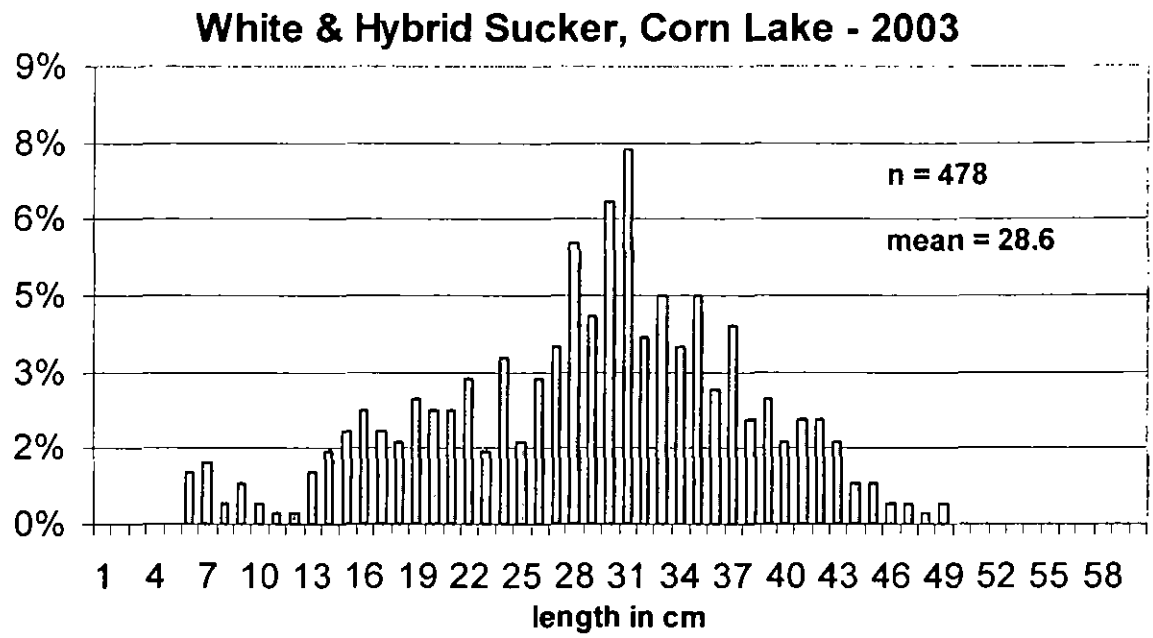

Figure A1-36. White & Hybrid sucker length frequency at Corn Lake, September and October 2003, Colorado River.

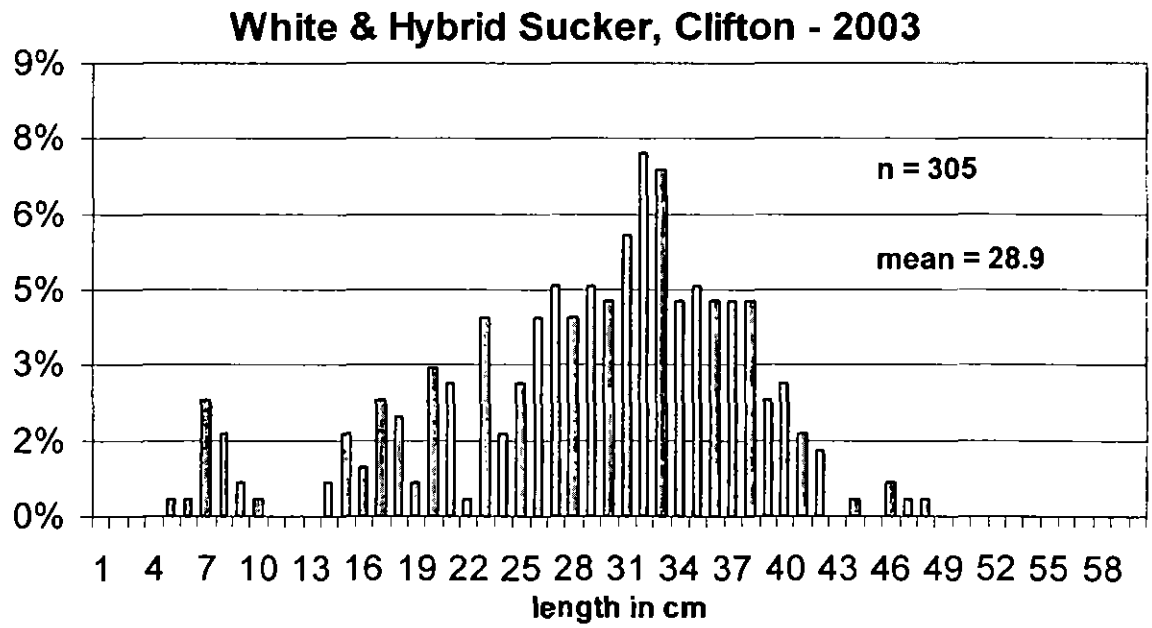

Figure A1-37. White & Hybrid sucker length frequency at Clifton, September and October 2003, Colorado River.

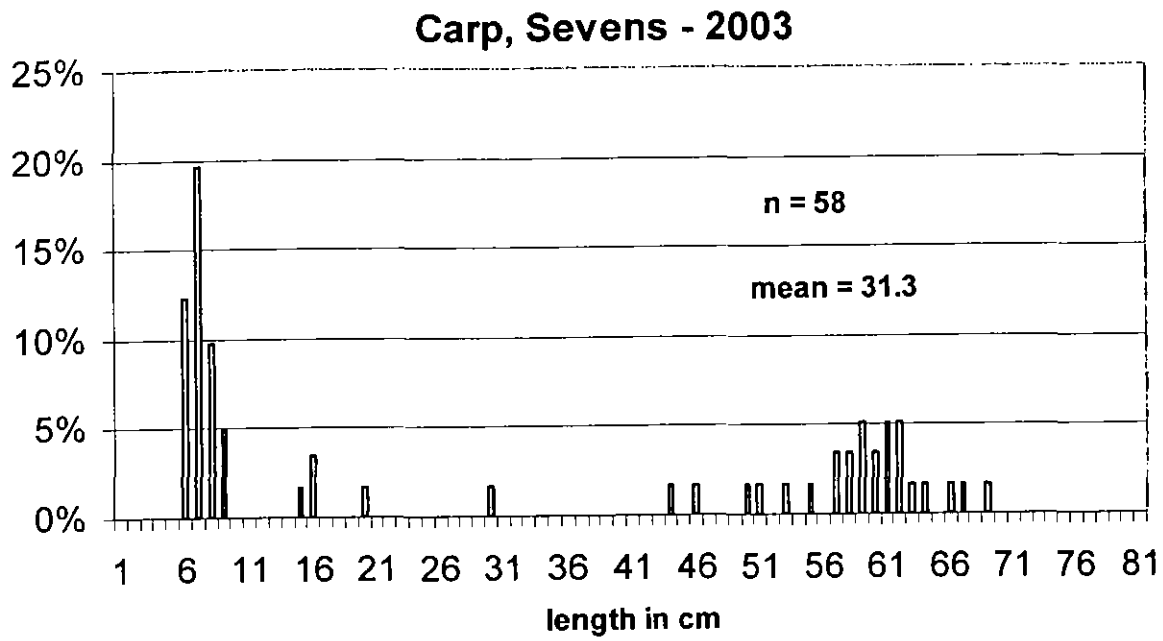

Figure A1-38. Carp length frequency at Sevens, July and August 2003, Yampa River.

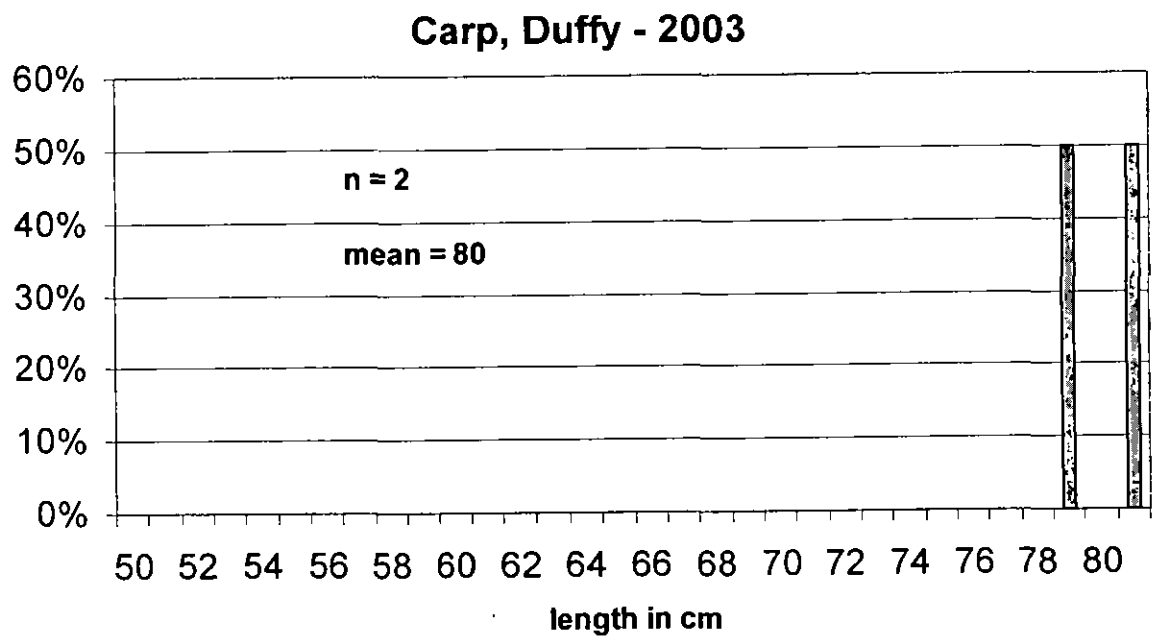

Figure A1-39. Carp length frequency at Duffy, July and August 2003, Yampa River.

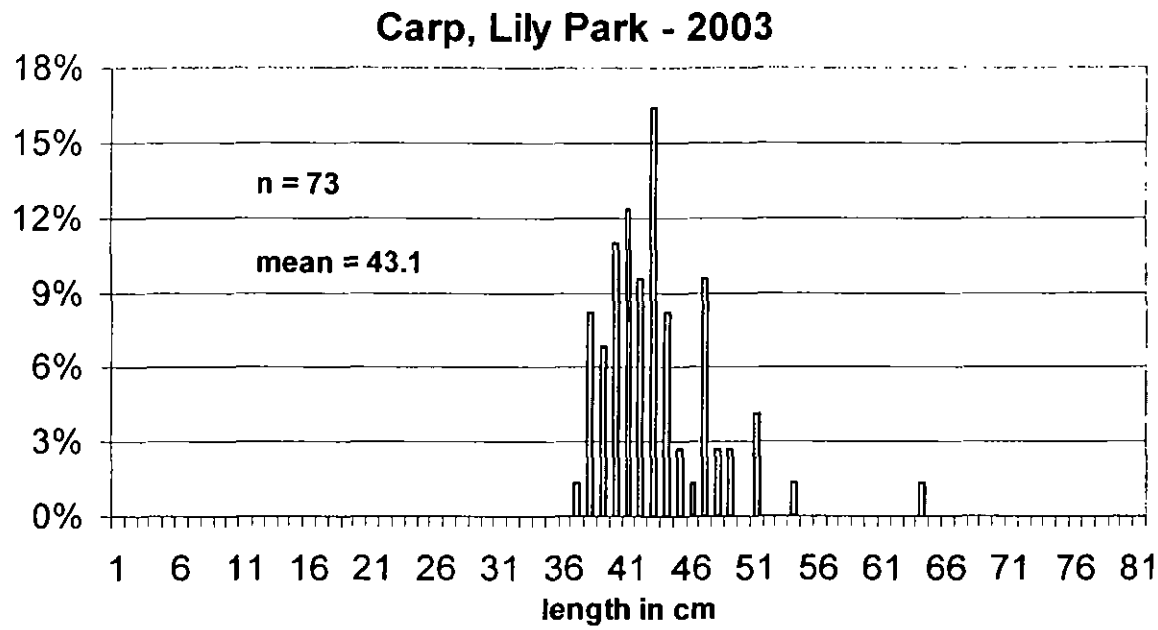

Figure A1-40. Carp length frequency at Lily Park, July and August 2003, Yampa River.

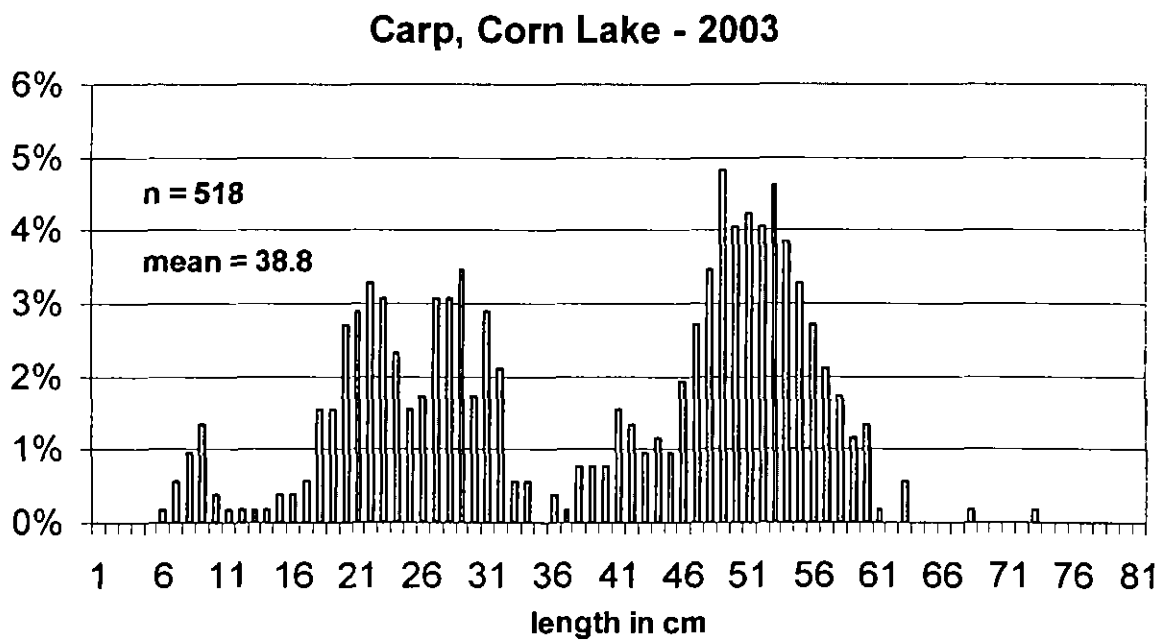

Figure A1-41. Carp length frequency at Corn Lake, September and October 2003, Colorado River.

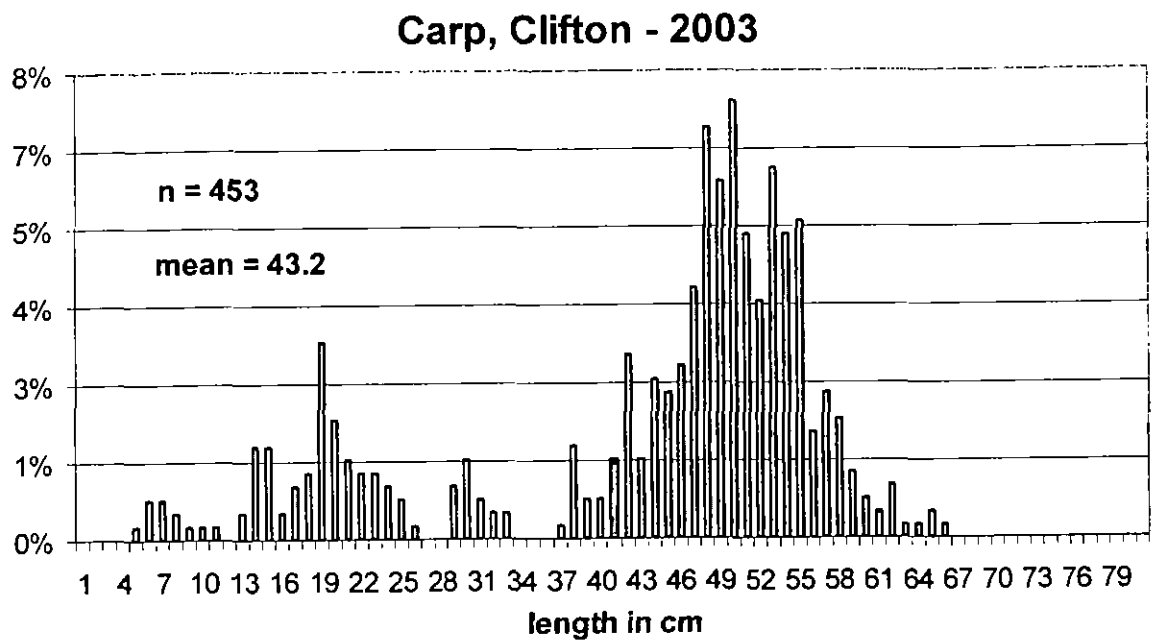

Figure A1-42. Carp length frequency at Clifton, September and October 2003, Colorado River.

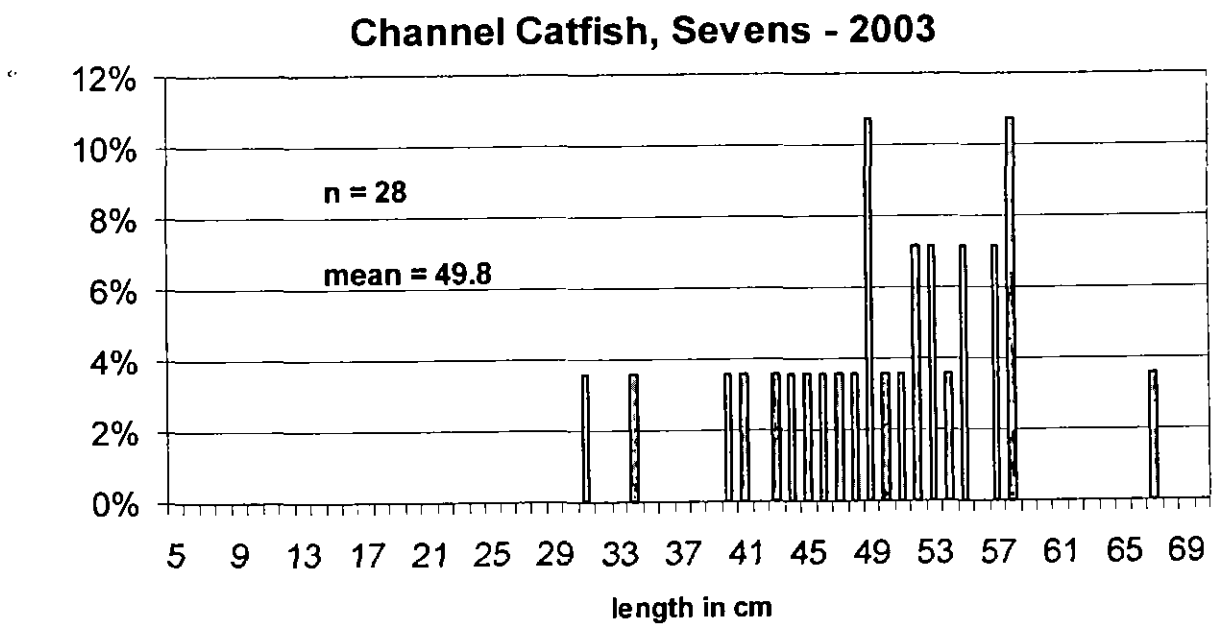

Figure A1-43. Channel catfish length frequency at Sevens, July and August 2003, Yampa River.

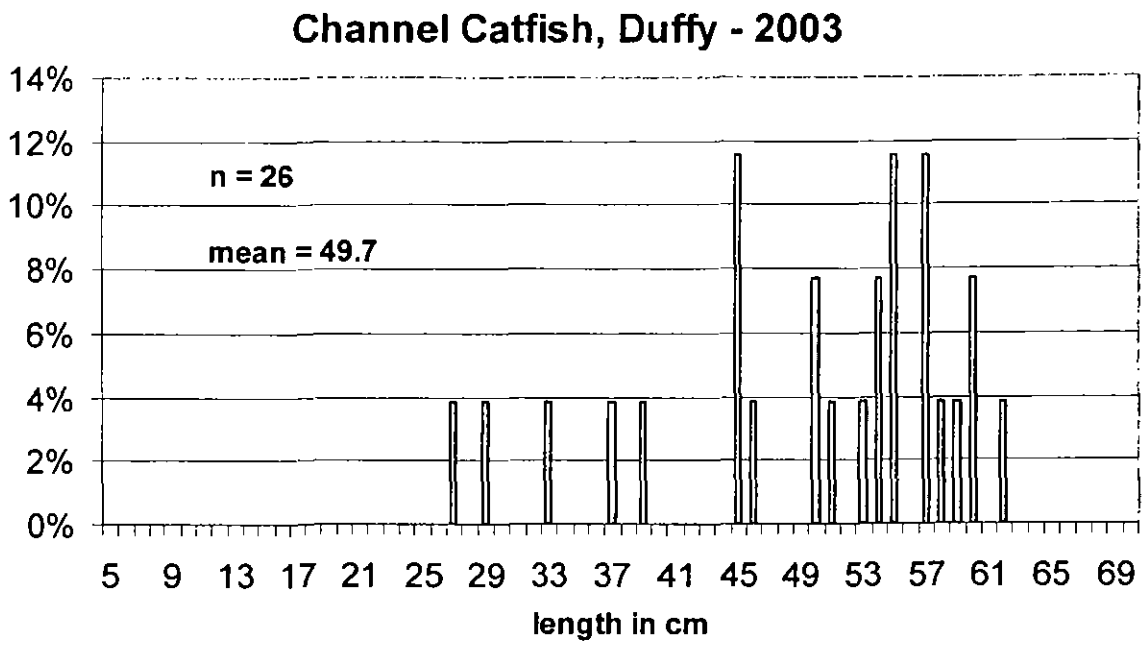

Figure A1-44. Channel catfish length frequency at Duffy, July and August 2003, Yampa River.

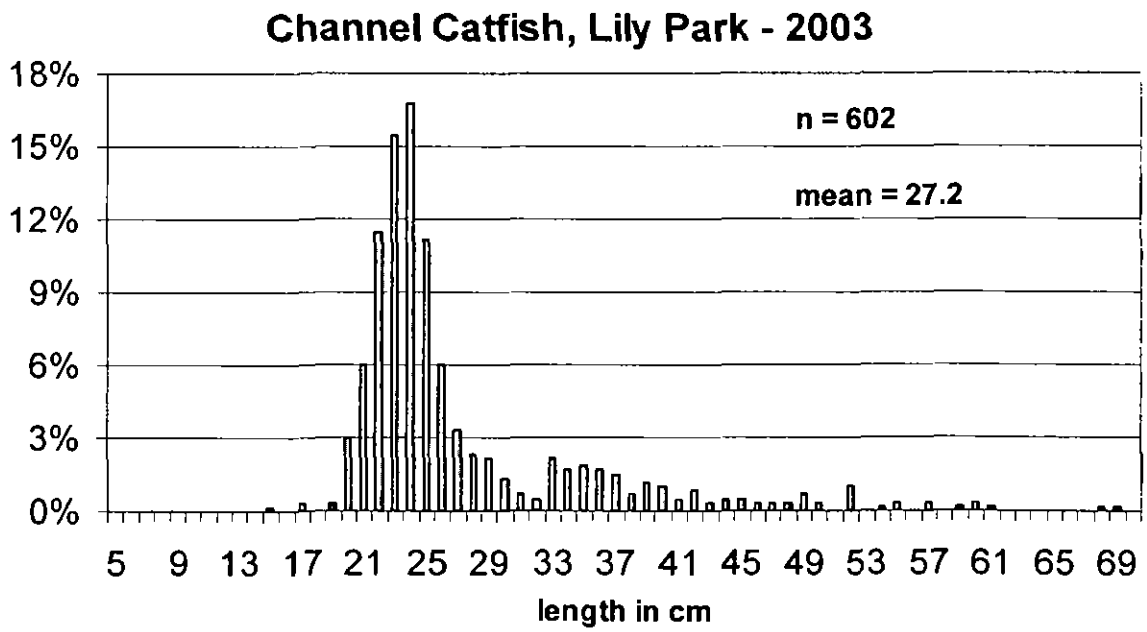

Figure A1-45. Channel catfish length frequency at Lily Park, July and August 2003, Yampa River.

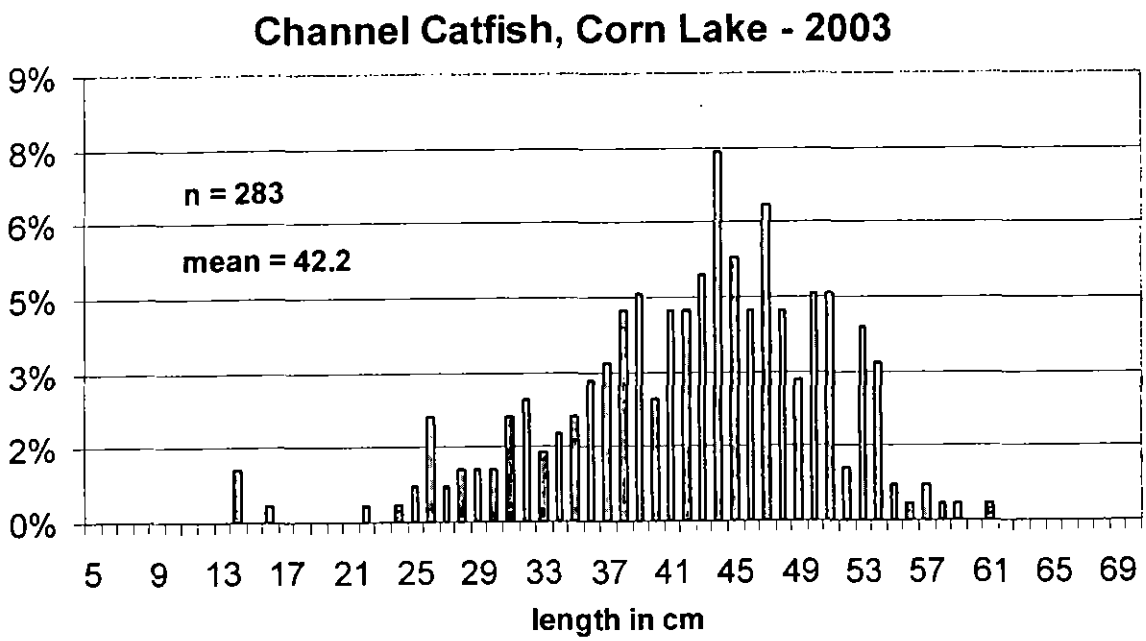

Figure A1-46. Channel catfish length frequency at Corn Lake, September and October 2003, Colorado River.

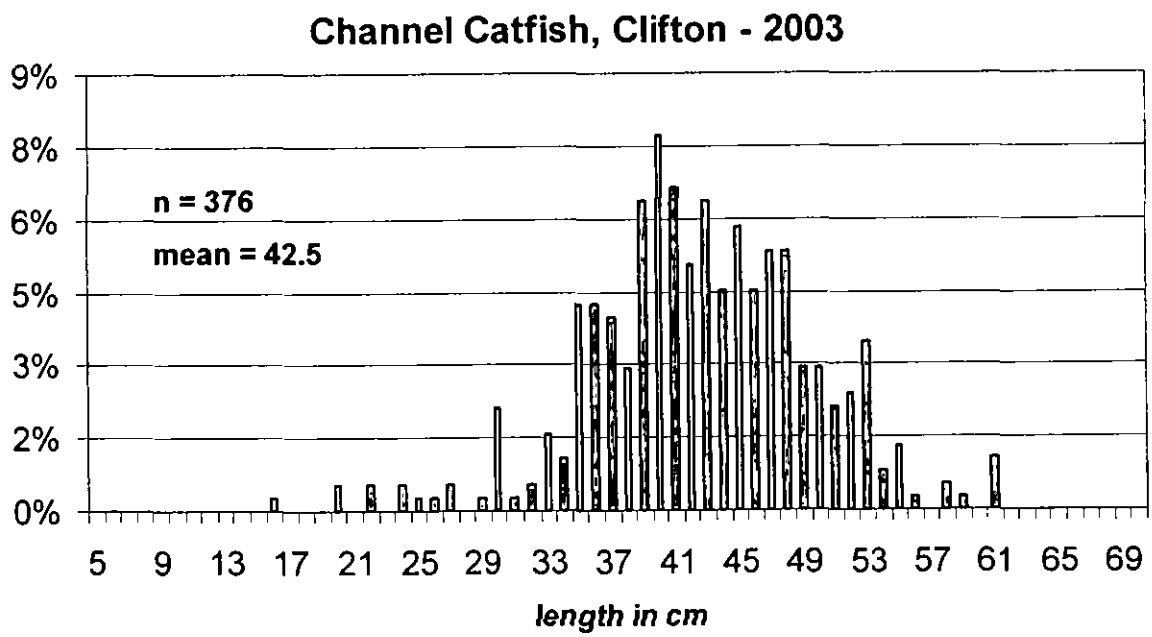

Figure A1-47. Channel catfish length frequency at Clifton, September and October 2003, Colorado River.

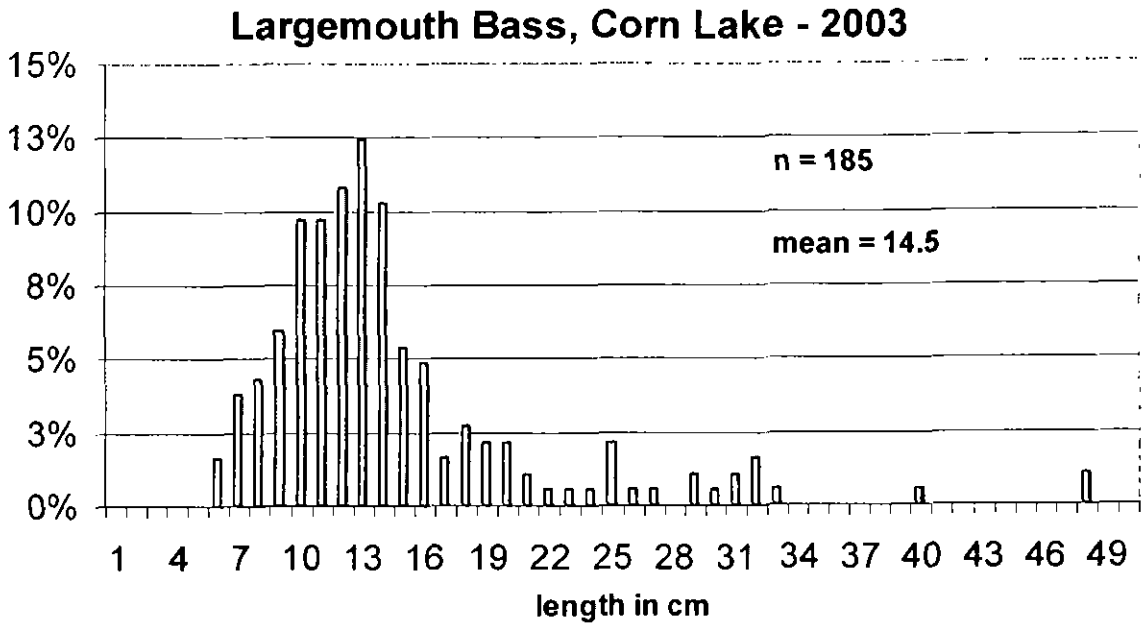

Figure A1-48. Largemouth bass length frequency at Corn Lake, September and October 2003, Colorado River.

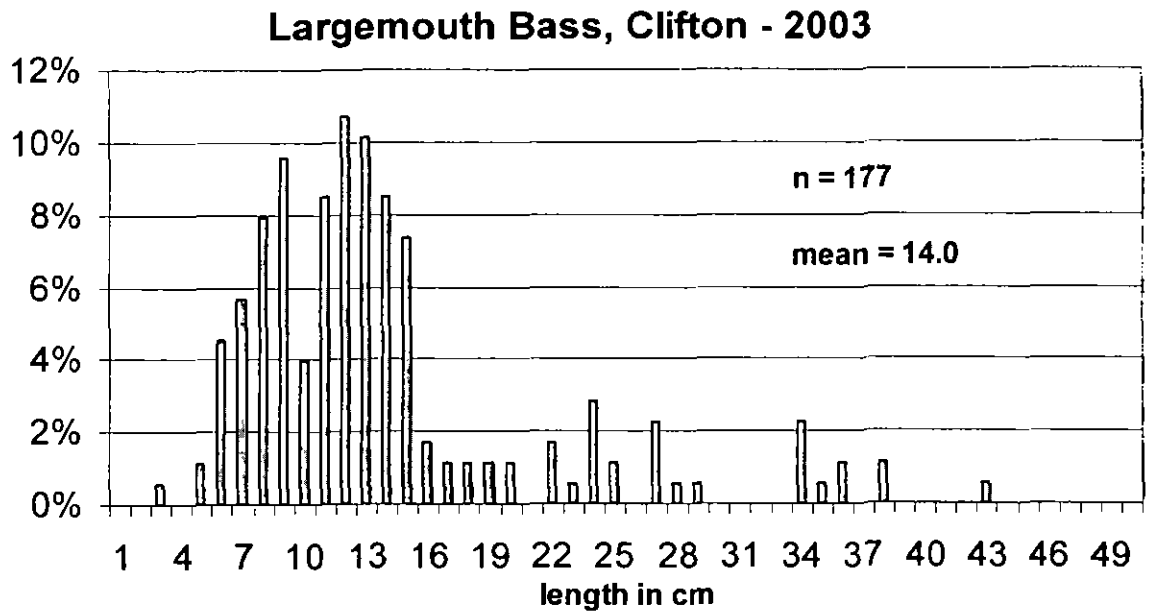

Figure A1-49. Largemouth bass length frequency at Clifton, September and October 2003, Colorado River.

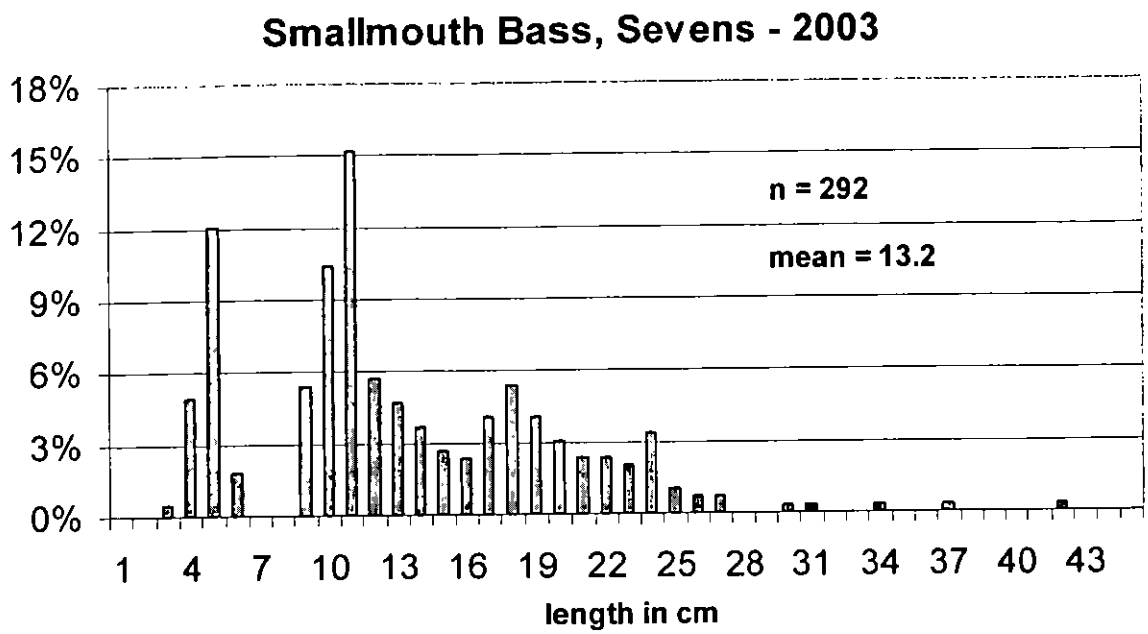

Figure A1-50. Smallmouth bass length frequency at Sevens, July and August 2003, Yampa River.

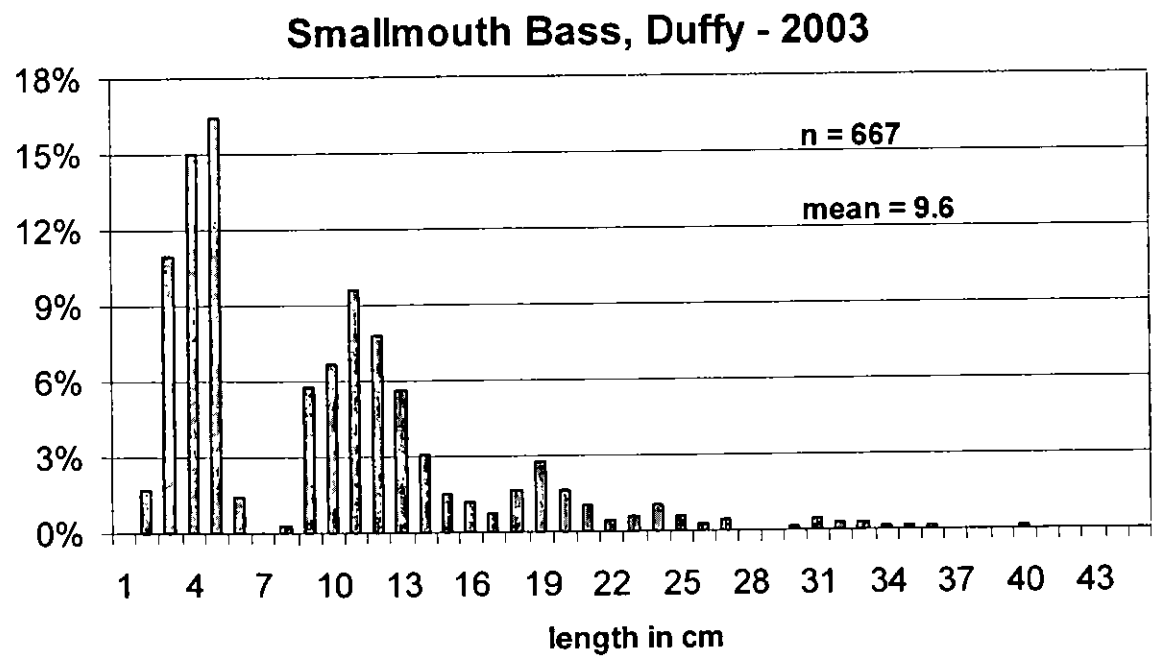

Figure A1-51. Smallmouth bass length frequency at Duffy, July and August 2003, Yampa River.

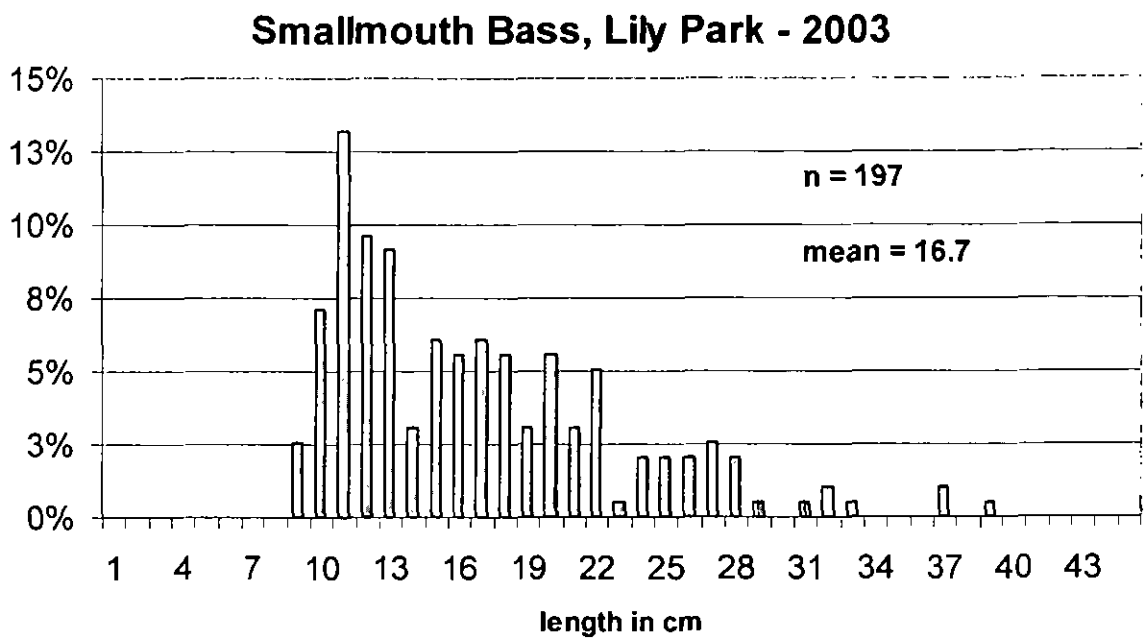

Figure A1-52. Smallmouth bass length frequency at Lily Park, July and August 2003, Yampa River.

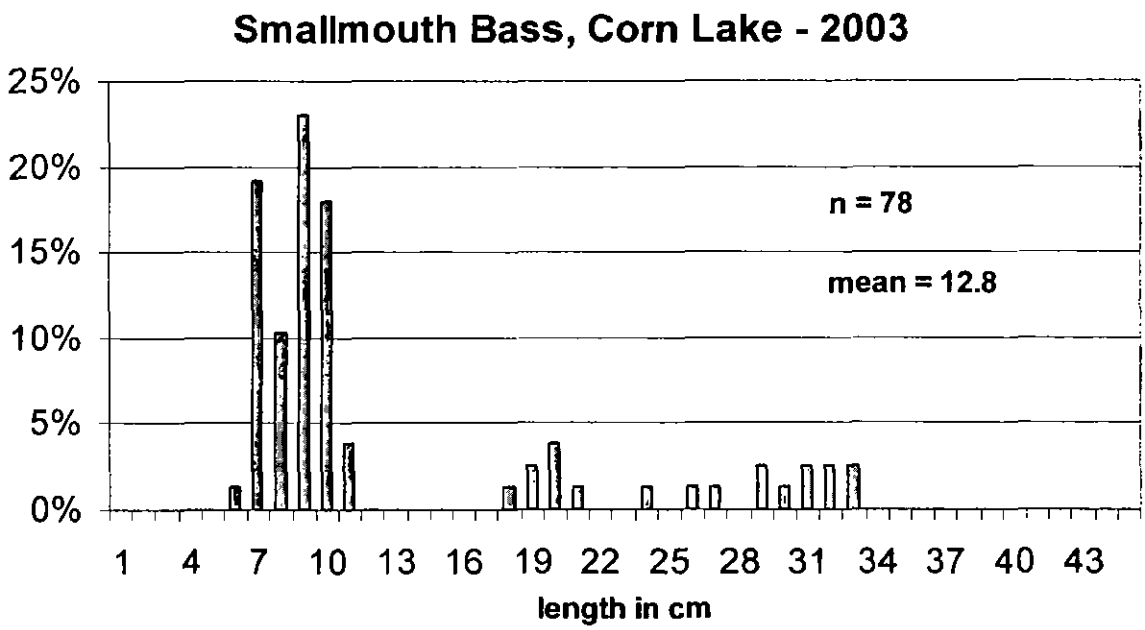

Figure A1-53. Smallmouth bass length frequency at Corn Lake, September and October 2003, Colorado River.

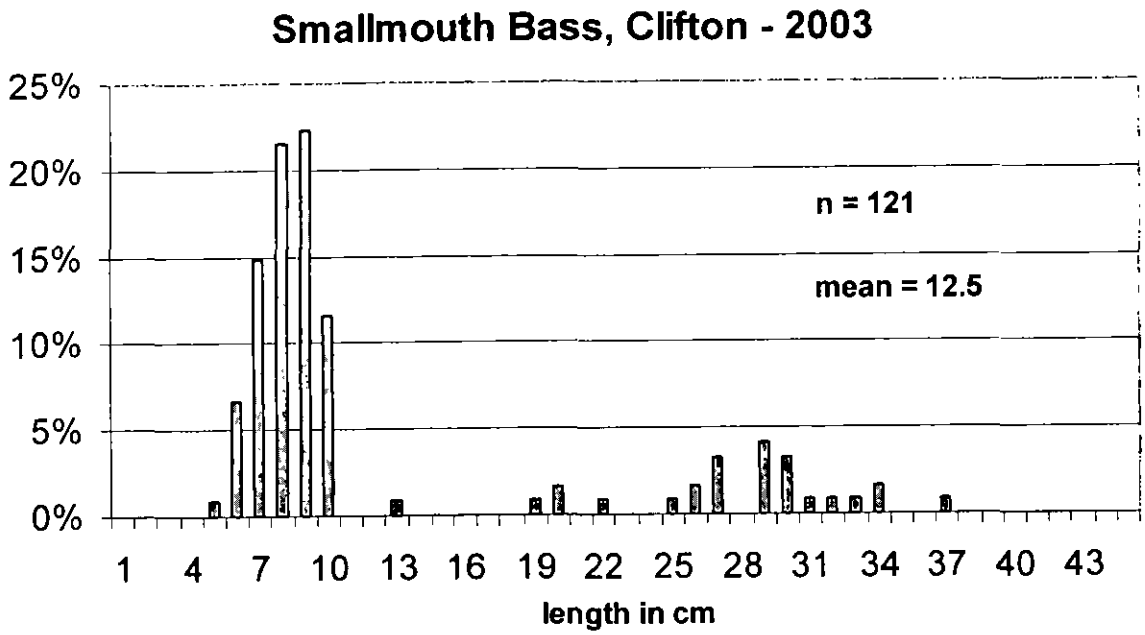

Figure A1-54. Smallmouth bass length frequency at Clifton, September and October 2003, Colorado River.

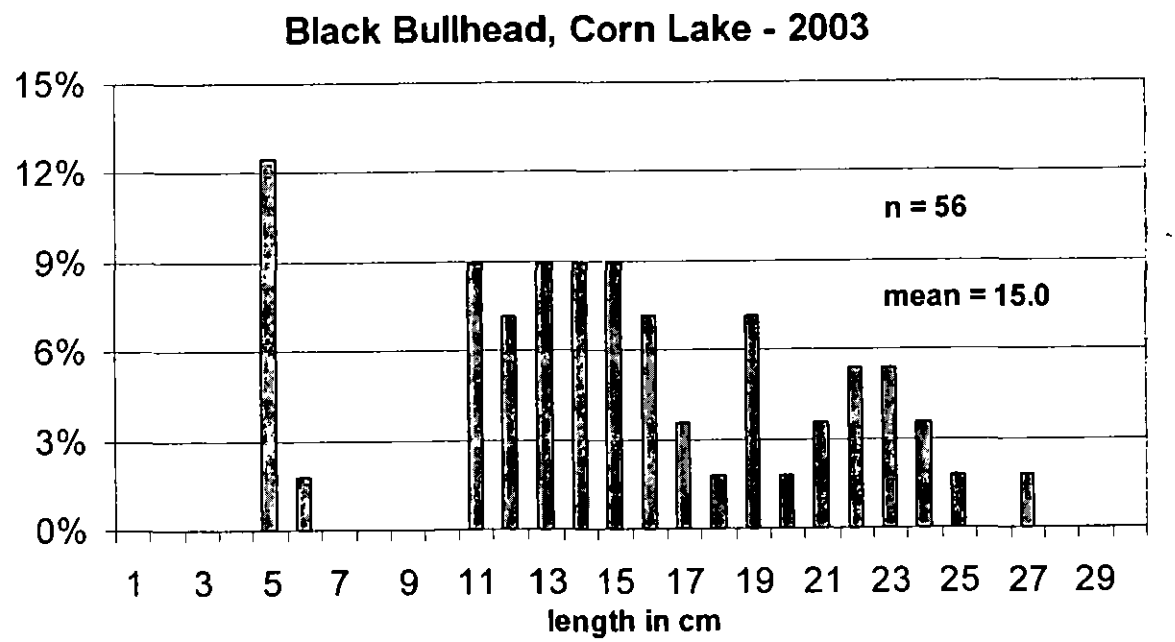

Figure A1-55. Black bullhead length frequency at Corn Lake, September and October 2003, Colorado River.

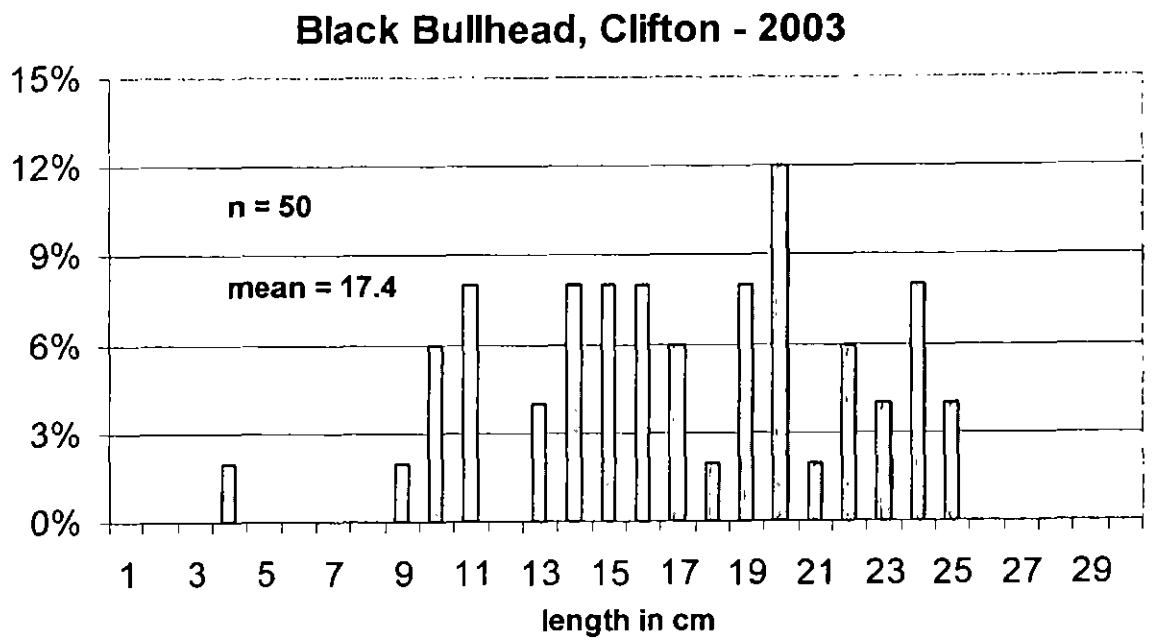

Figure A1-56. Black bullhead length frequency at Clifton, September and October 2003, Colorado River.

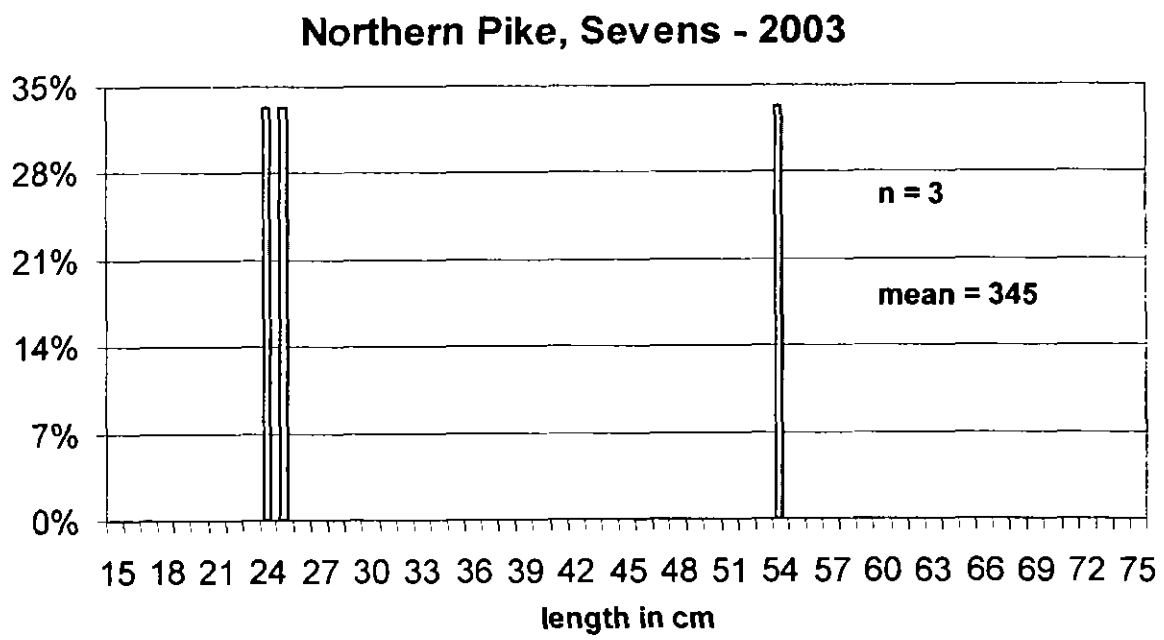

Figure A1-57. Northern pike length frequency at Sevens, July and August 2003, Yampa River.

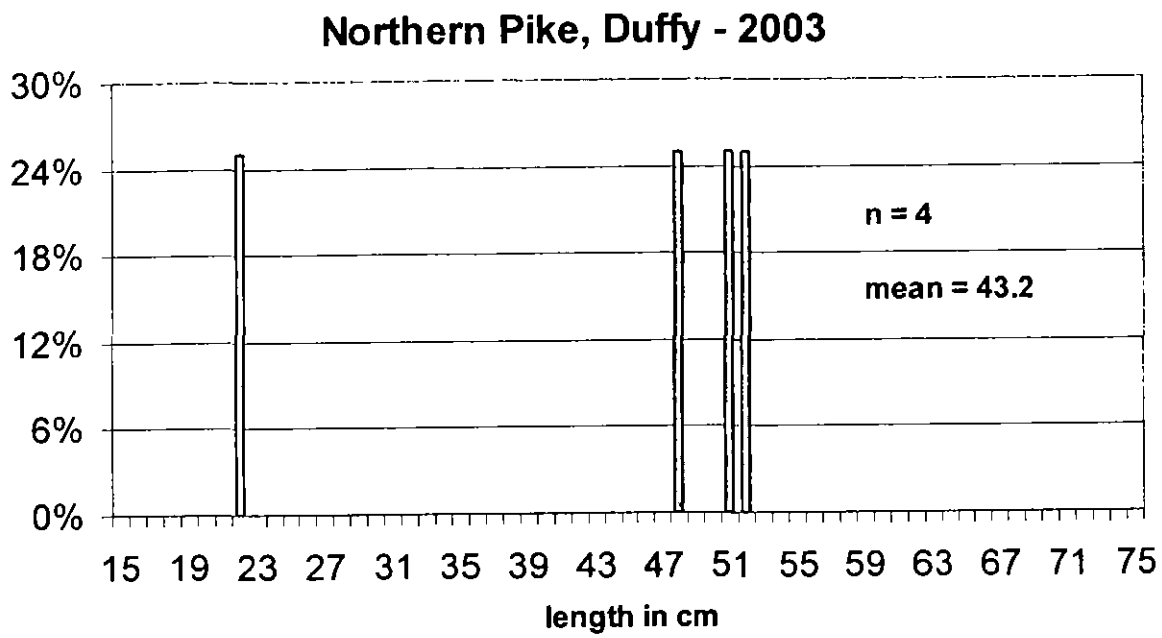

Figure A1-58. Northern pike length frequency at Duffy, July and August 2003, Yampa River.

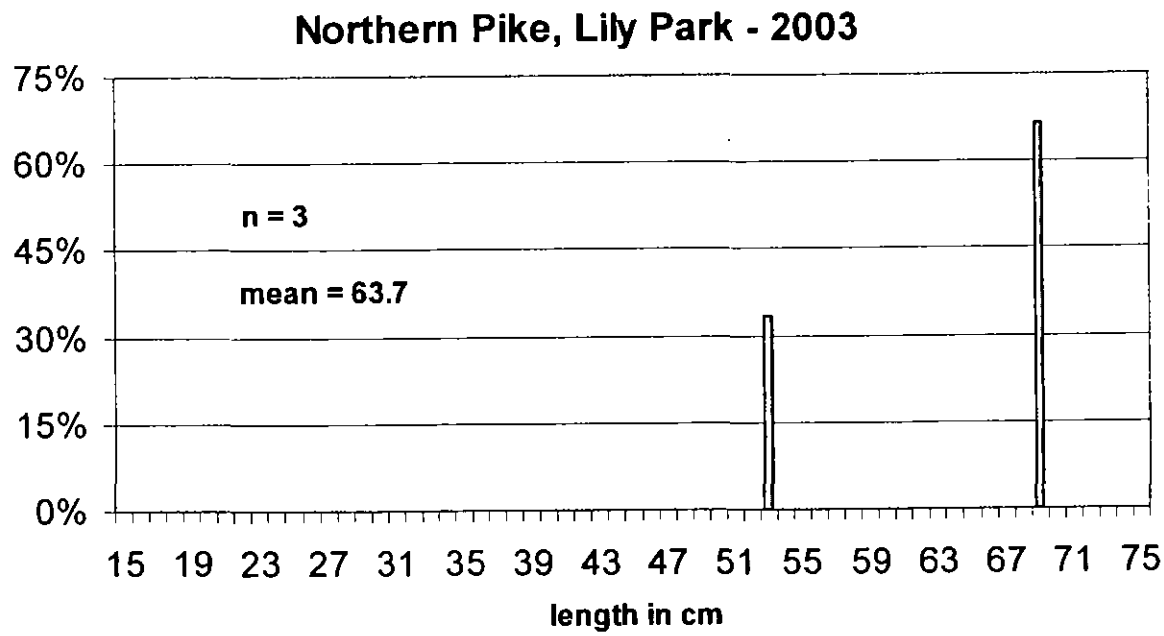

Figure A1-59. Northern pike length frequency at Lily Park, July and August 2003, Yampa River.

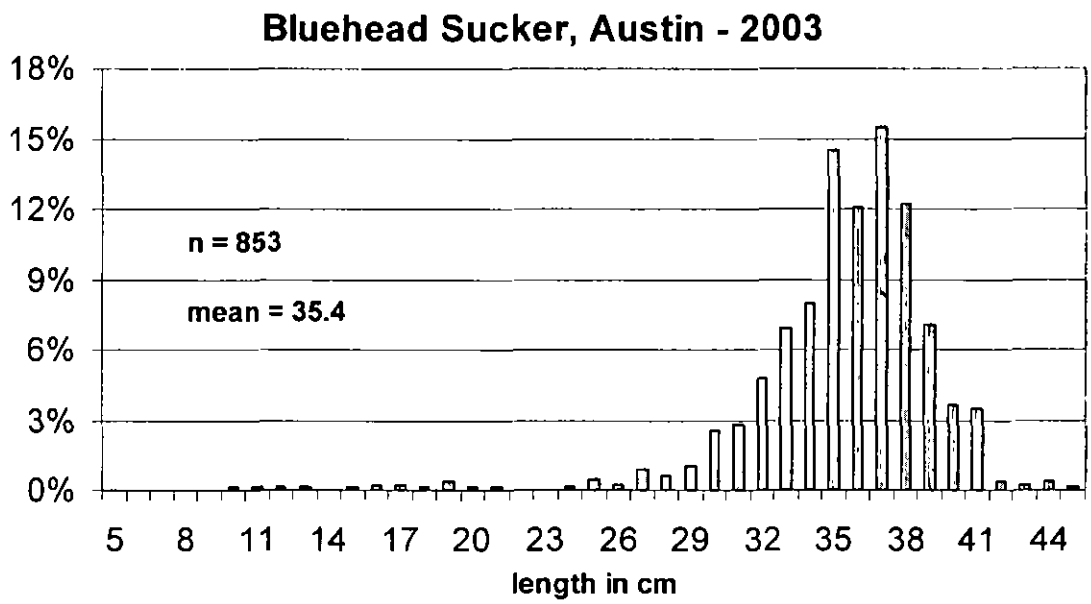

Figure A2-1. Bluehead sucker length frequency at Austin, August 2003, Gunnison River.

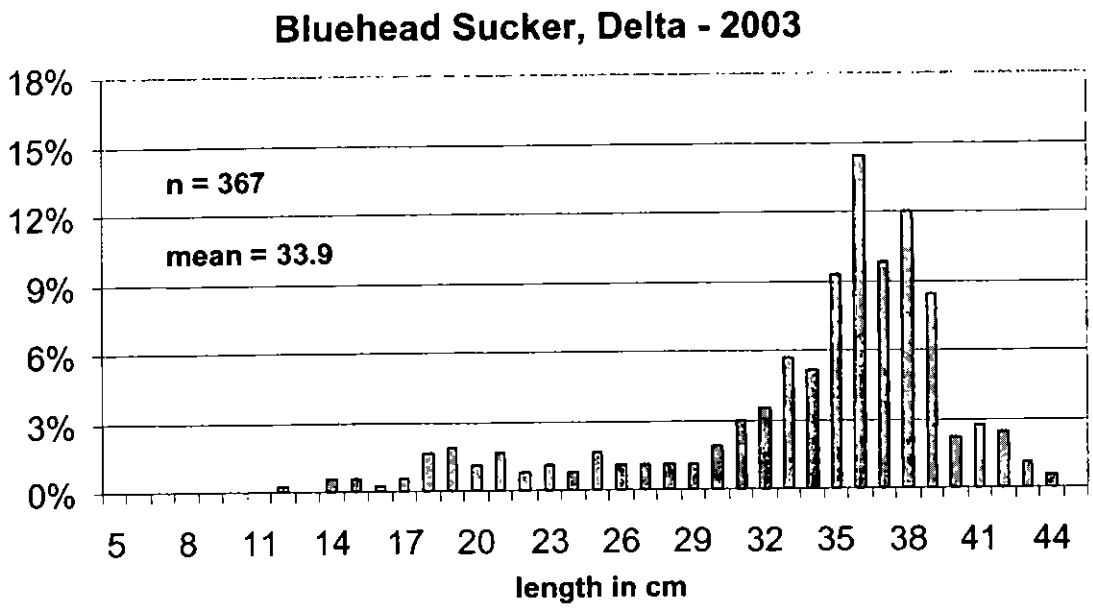

Figure A2-2. Bluehead sucker length frequency at Delta, August 2003, Gunnison River.

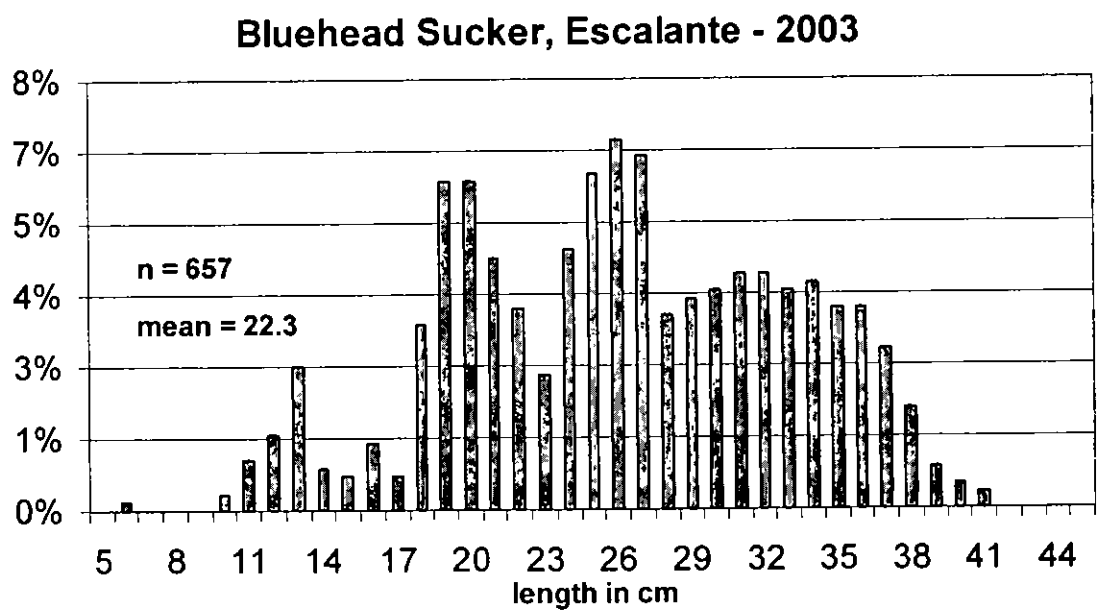

Figure A2-3. Bluehead sucker length frequency at Escalante, August 2003, Gunnison River.

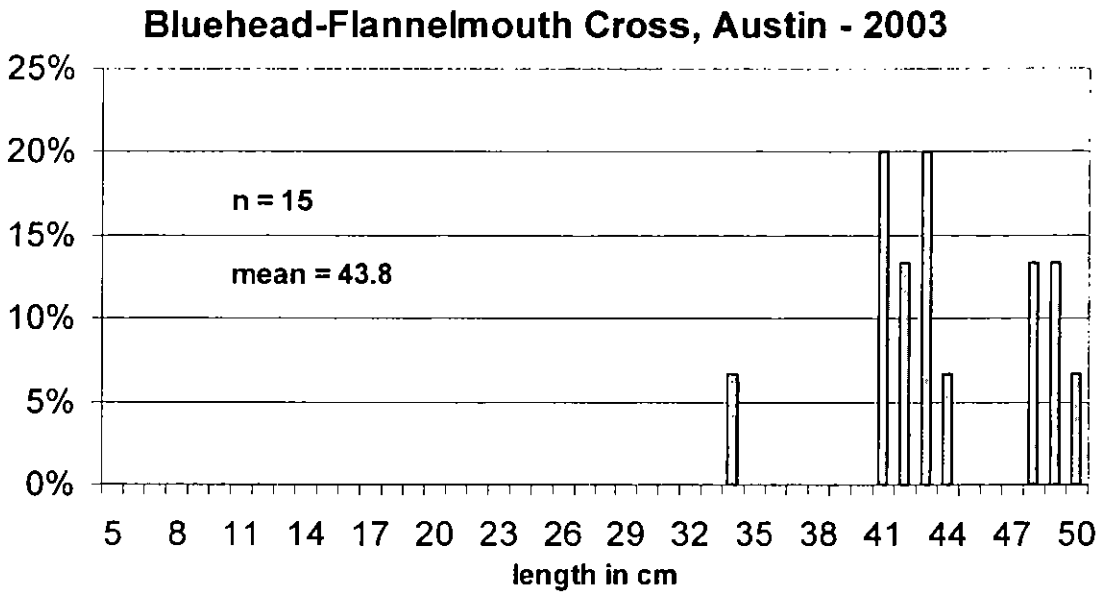

Figure A2-4. Bluehead-Flannelmouth hybrids length frequency at Austin, August 2003, Gunnison River.

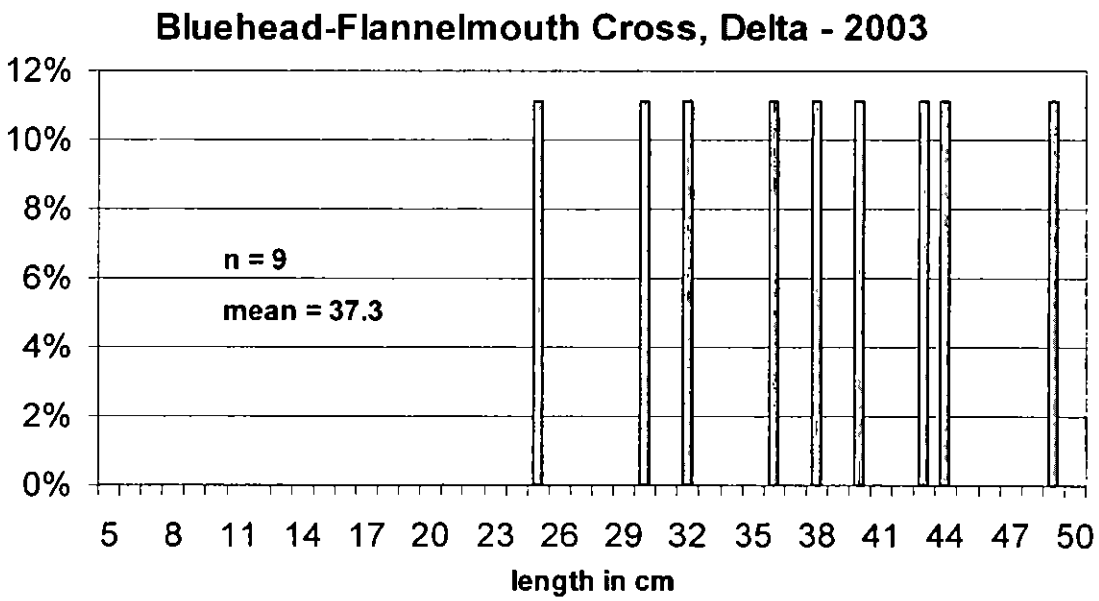

Figure A2-5. Bluehead-Flannelmouth sucker hybrids length frequency at Delta, August 2003, Gunnison River.

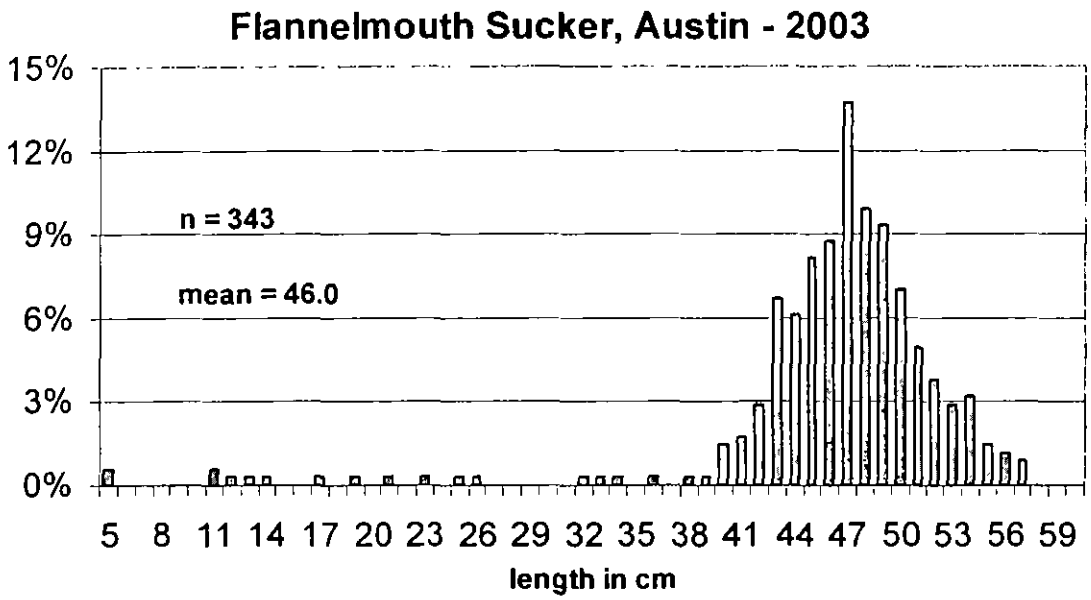

Figure A2-6. Flannelmouth sucker length frequency at Austin, August 2003, Gunnison River.

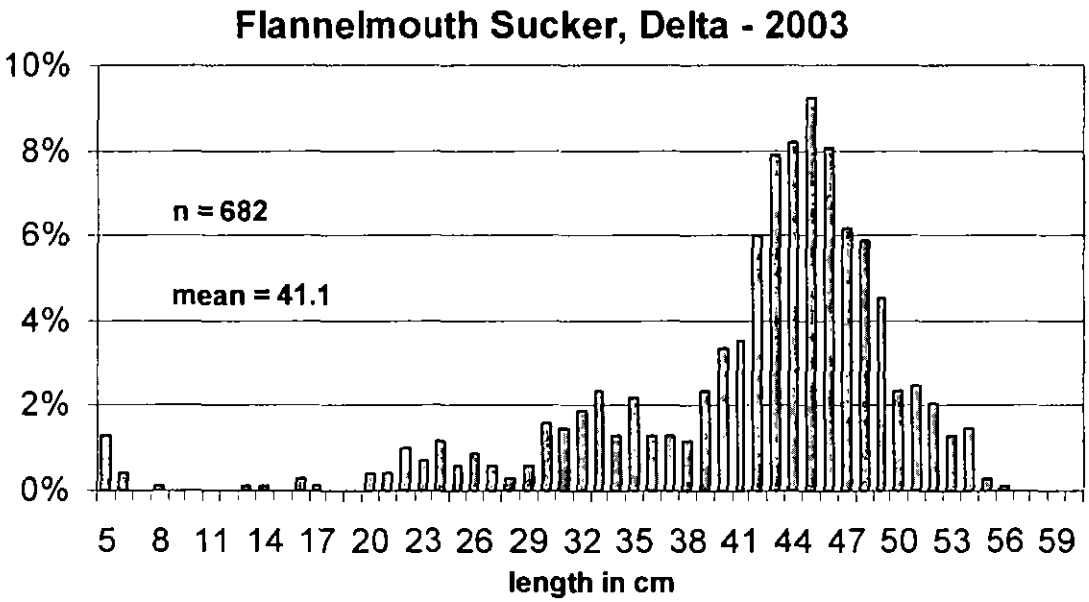

Figure A2-7. Flannelmouth sucker length frequency at Delta, August 2003, Gunnison River.

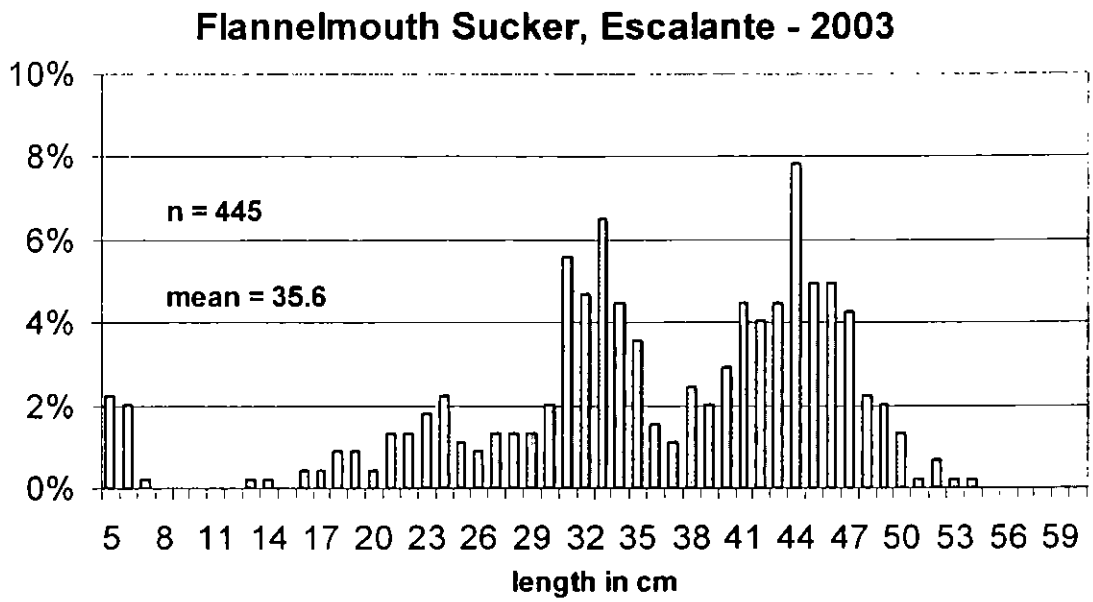

Figure A2-8. Flannelmouth sucker length frequency at Escalante, August 2003, Gunnison River.

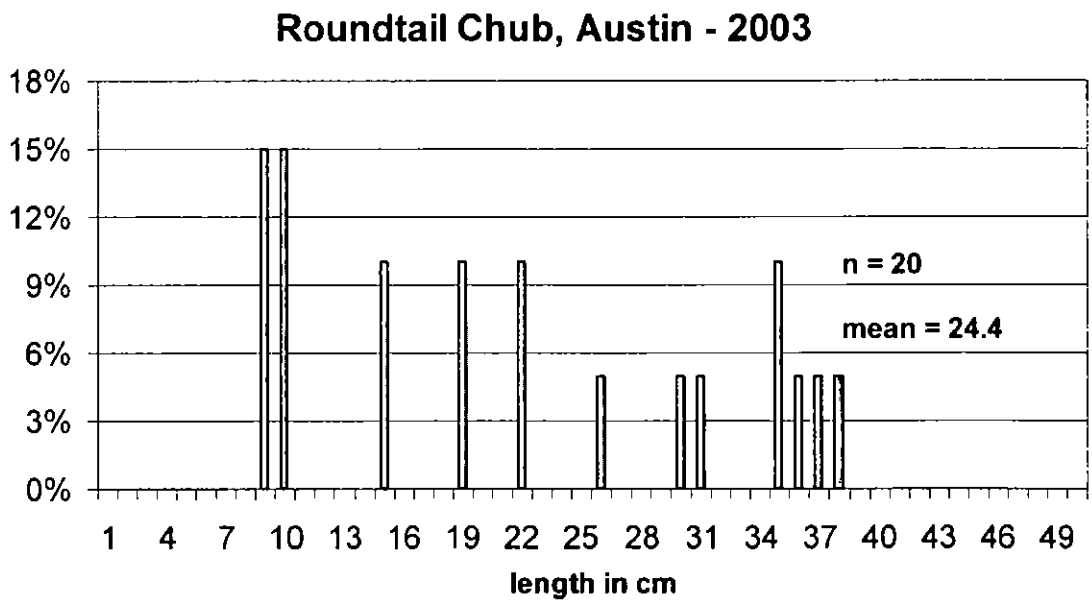

Figure A2-9. Roundtail chub length frequency at Austin, August 2003, Gunnison River.

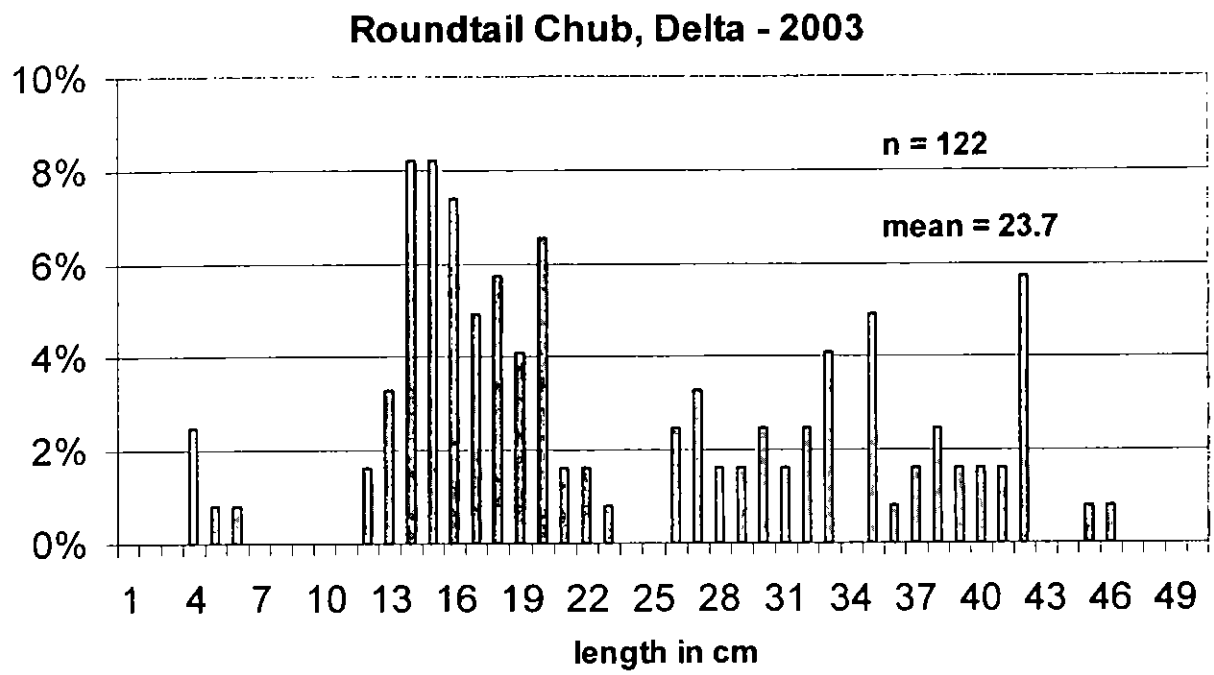

Figure A2-10. Roundtail chub length frequency at Delta, August 2003, Gunnison River.

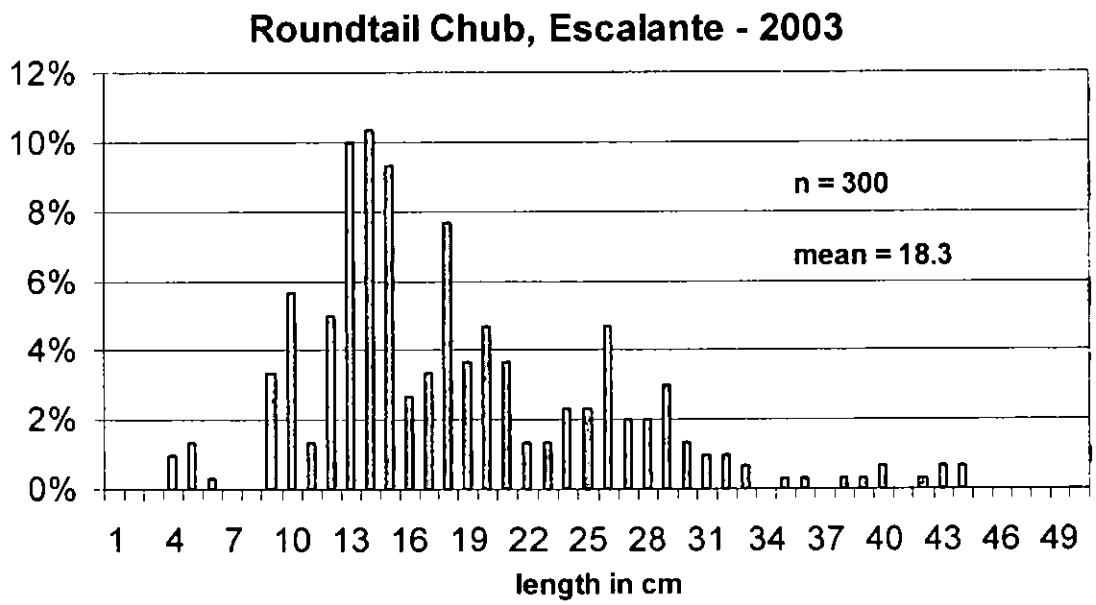

Figure A2-11. Roundtail chub length frequency at Escalante, August 2003, Gunnison River.

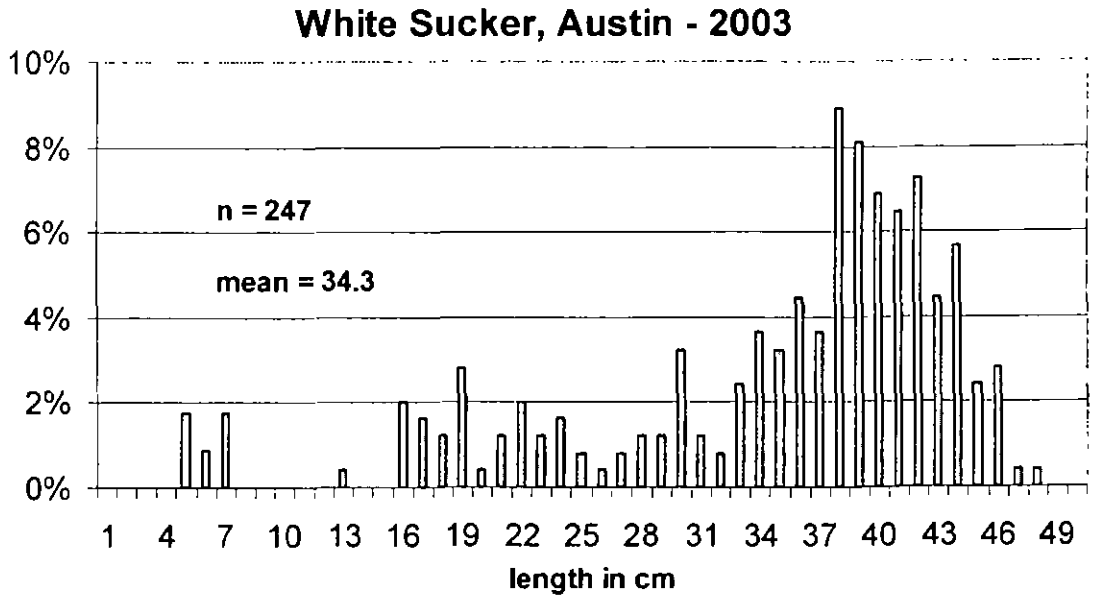

Figure A2-12. White sucker length frequency at Austin, August 2003, Gunnison River.

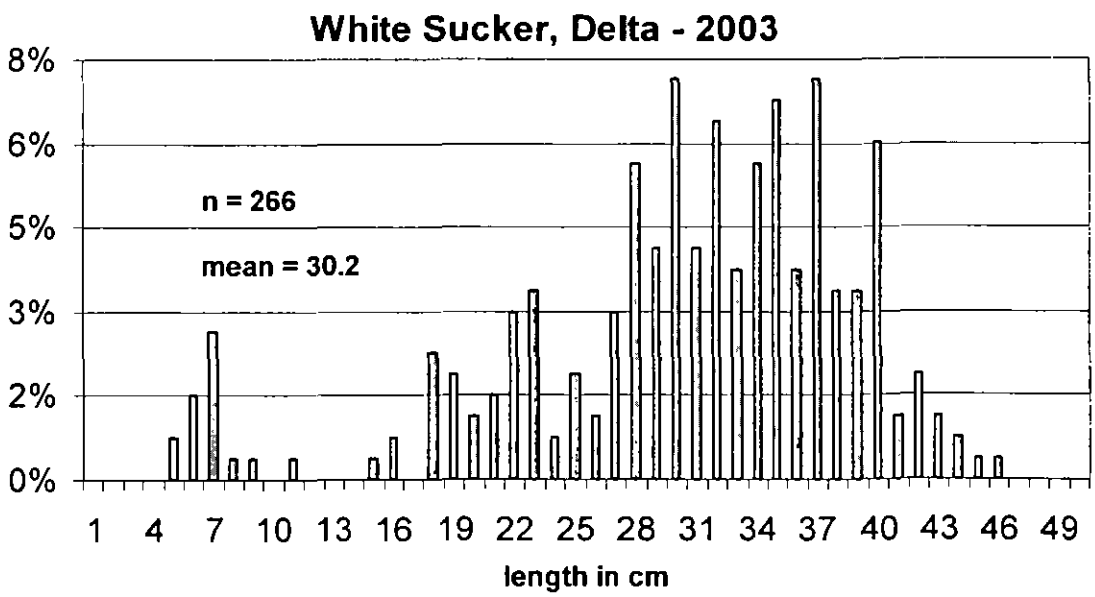

Figure A2-13. White sucker length frequency at Delta, August 2003, Gunnison River.

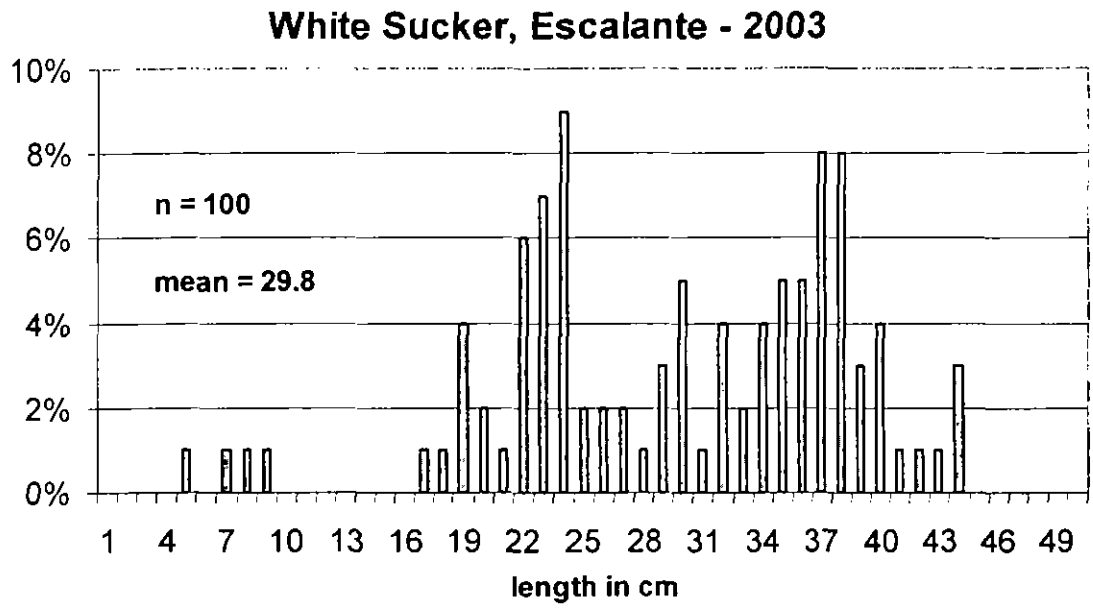

Figure A2-14. White sucker length frequency at Escalante, August 2003, Gunnison River.

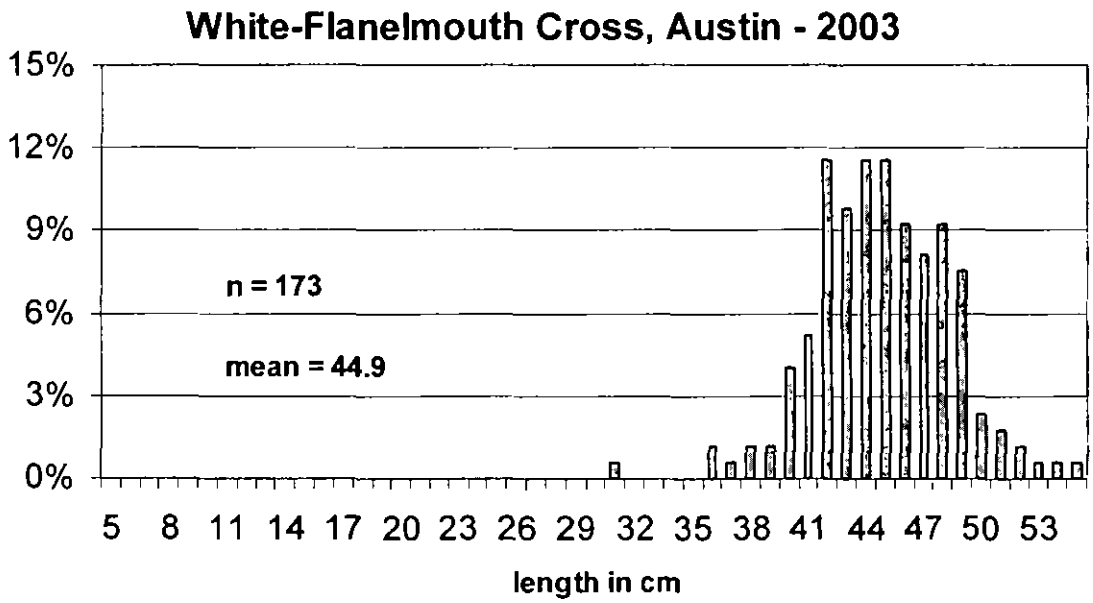

Figure A2-15. White-Flannelmouth sucker hybrids length frequency at Austin, August 2003, Gunnison River.

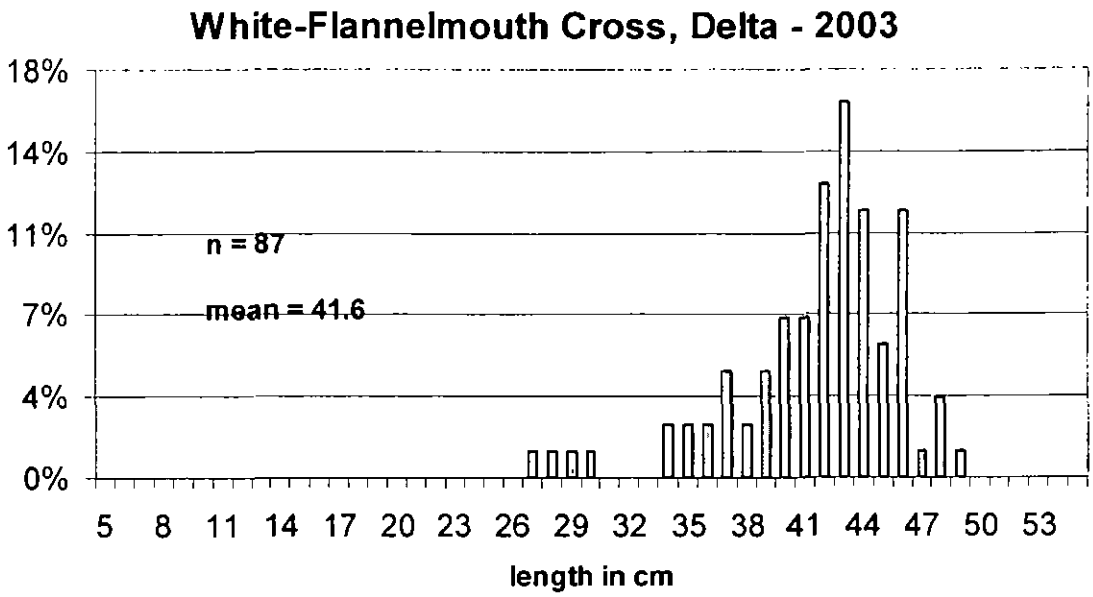

Figure A2-16. White-Flannelmouth sucker hybrids length frequency at Delta, August 2003, Gunnison River.

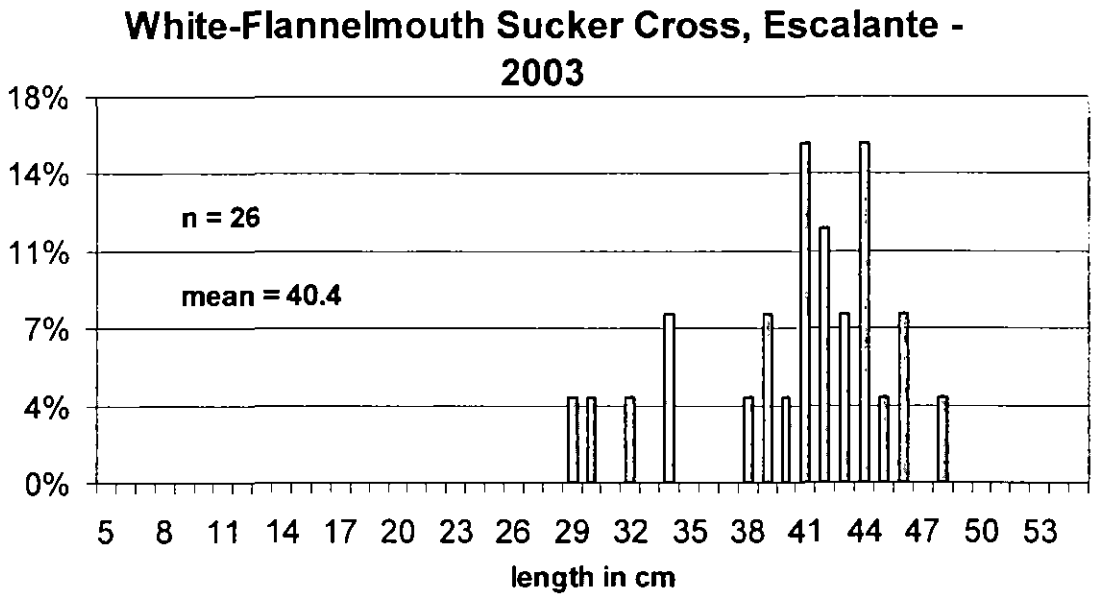

Figure A2-17. White-Flannelmouth sucker hybrids length frequency at Escalante, August 2003, Gunnison River.

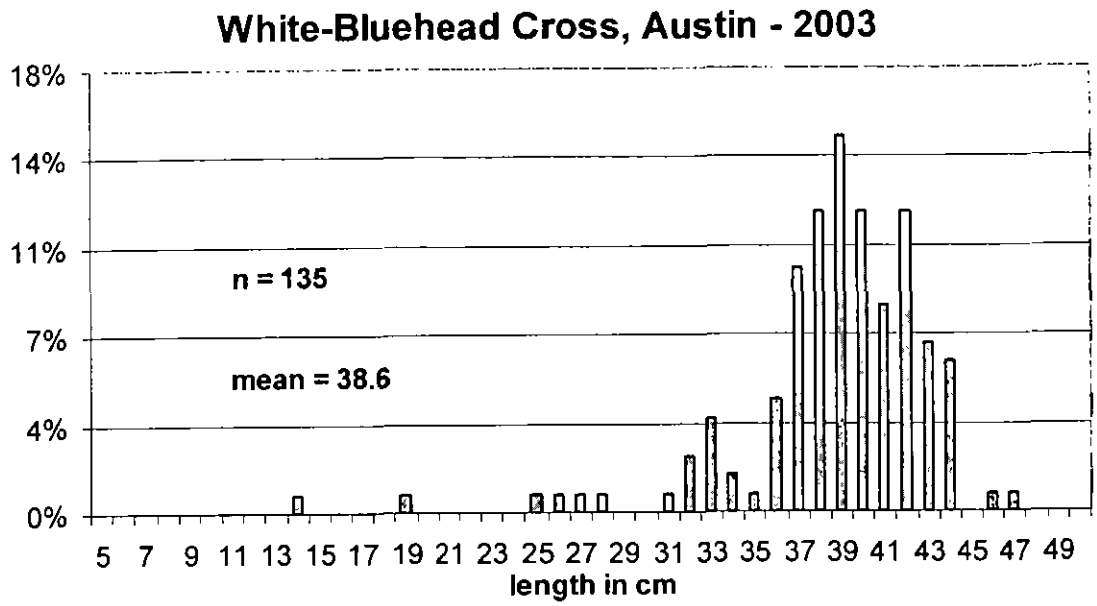

Figure A2-18. White-Bluehead sucker hybrids length frequency at Austin, August 2003, Gunnison River.

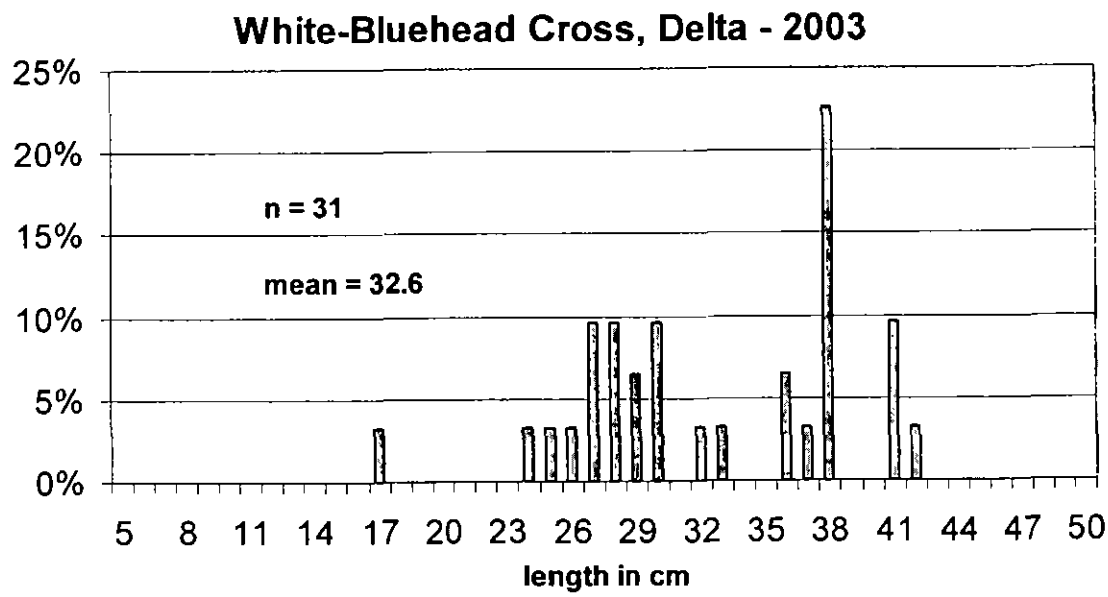

Figure A2-19. White-Bluehead sucker hybrids length frequency at Delta, August 2003, Gunnison River.

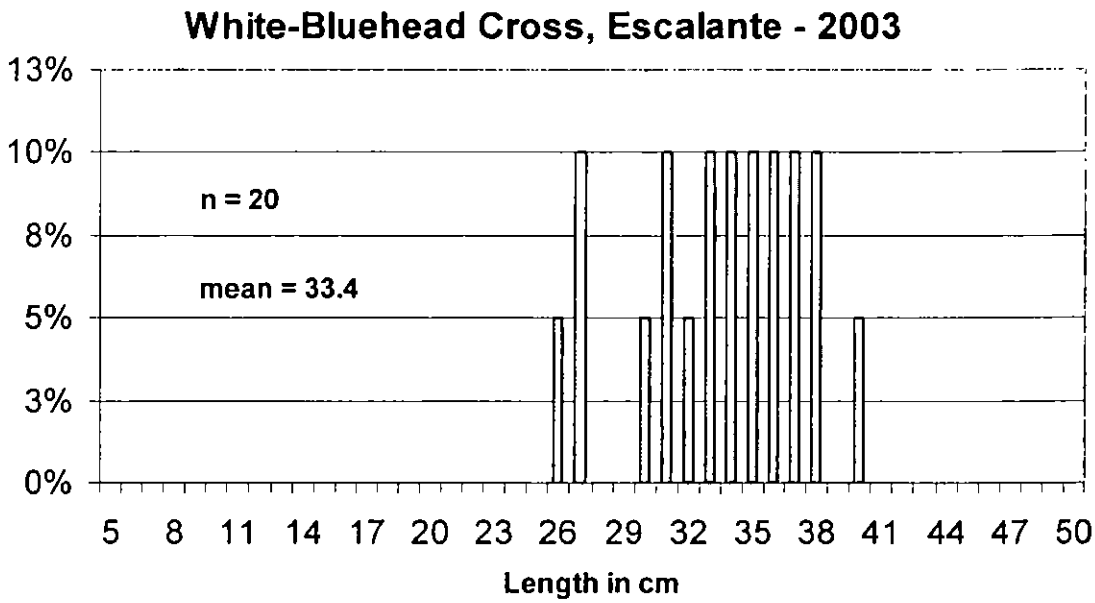

Figure A2-20. White-Bluehead sucker hybrids length frequency at Escalante, August 2003, Gunnison River.

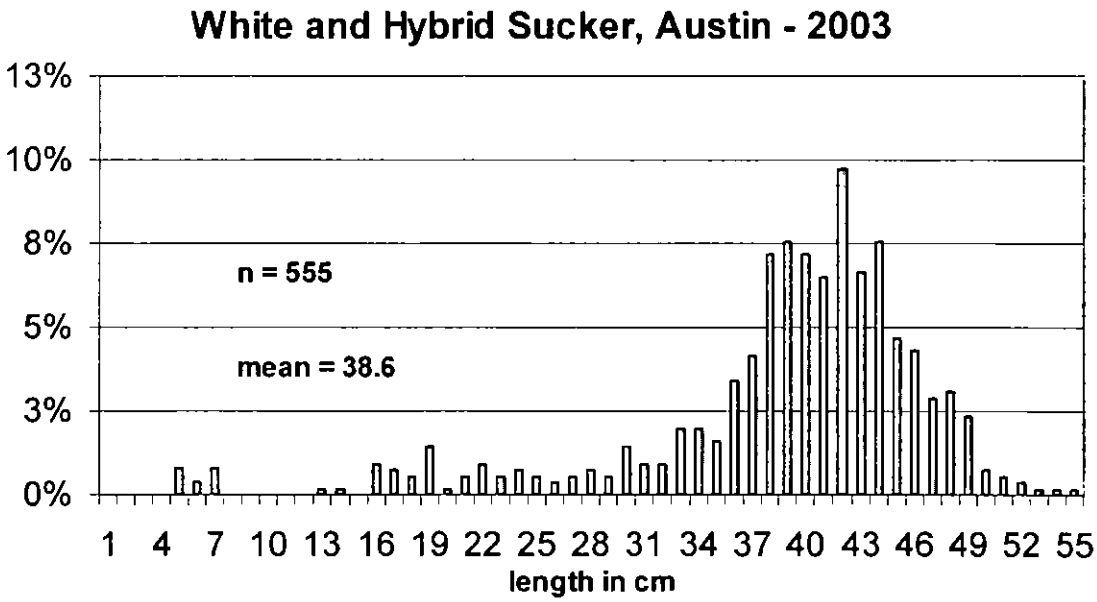

Figure A2-21. White and Hybrid sucker length frequency at Austin, August 2003, Gunnison River.

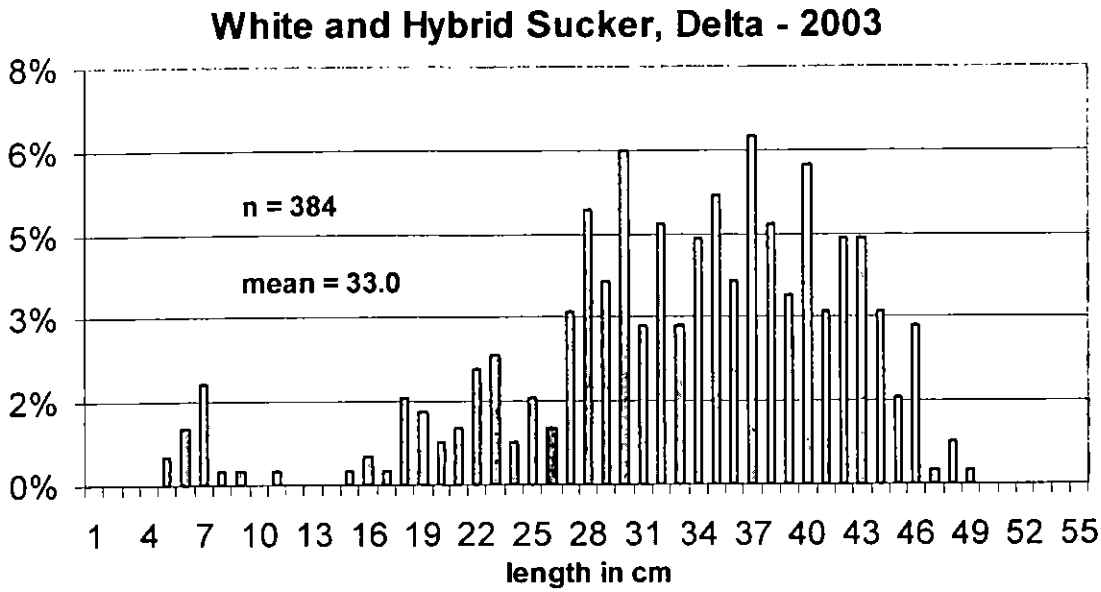

Figure A2-22. White and Hybrid sucker length frequency at Delta, August 2003, Gunnison River.

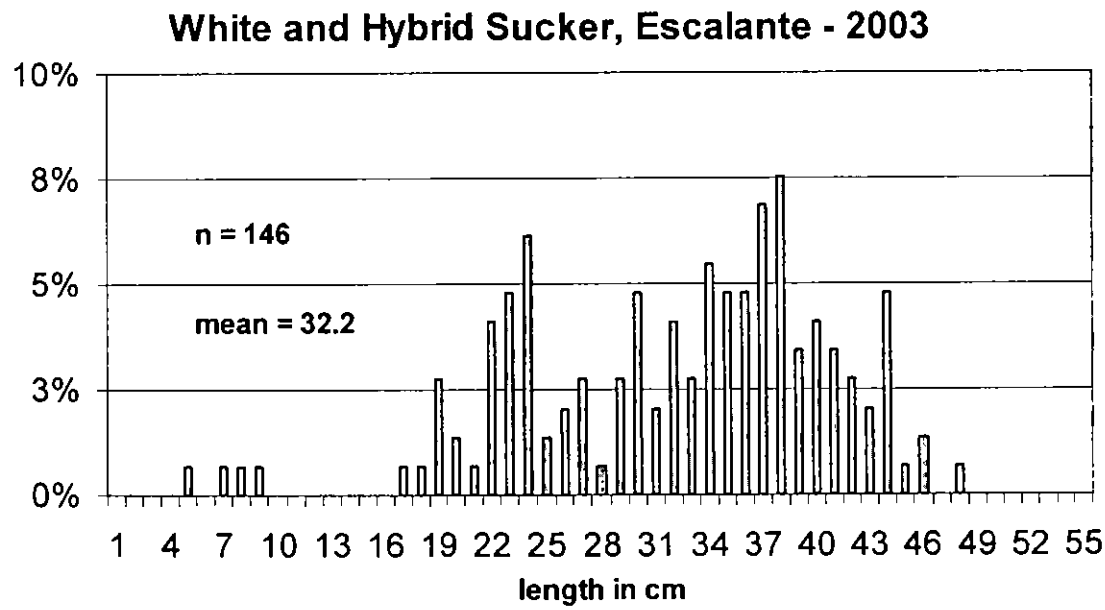

Figure A2-23. White and Hybrid sucker length frequency at Escalante, August 2003, Gunnison River.

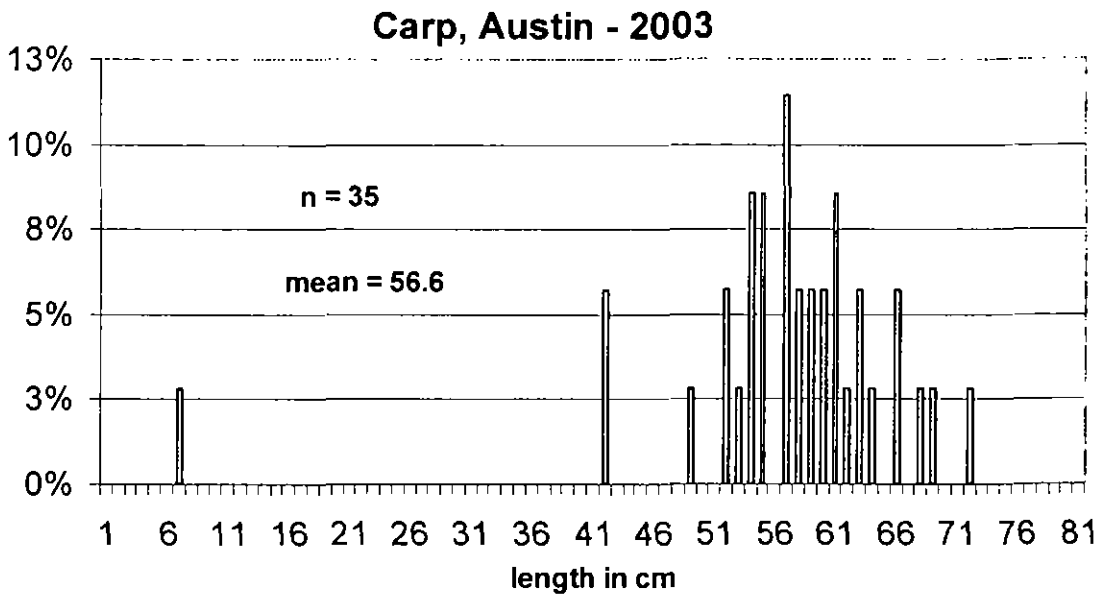

Figure A2-24. Carp length frequency at Austin, August 2003, Gunnison River.

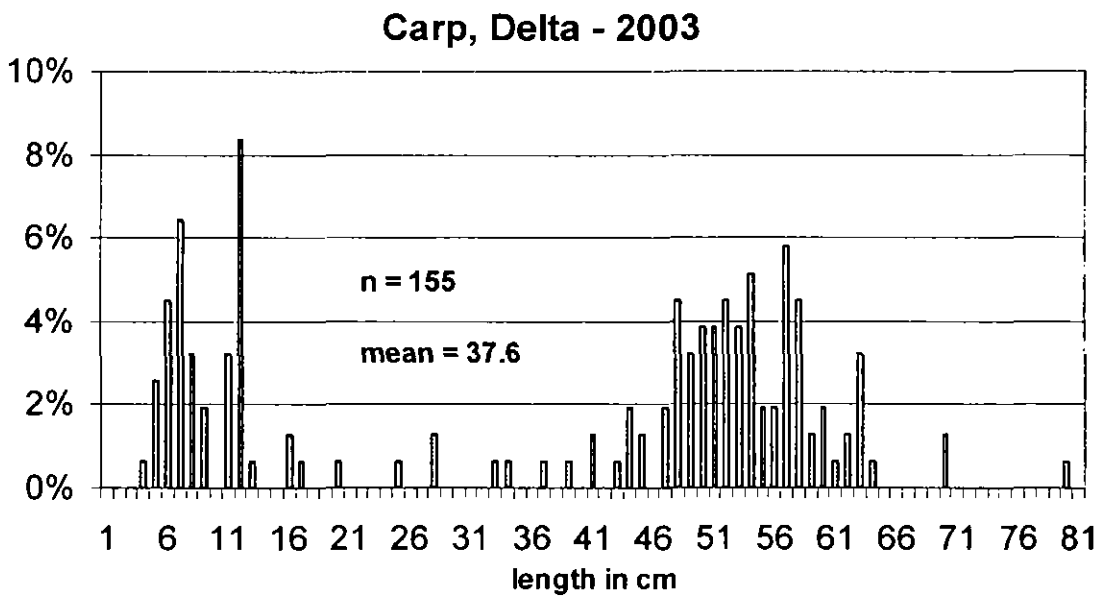

Figure A2-25. Carp length frequency at Delta, August 2003, Gunnison River.

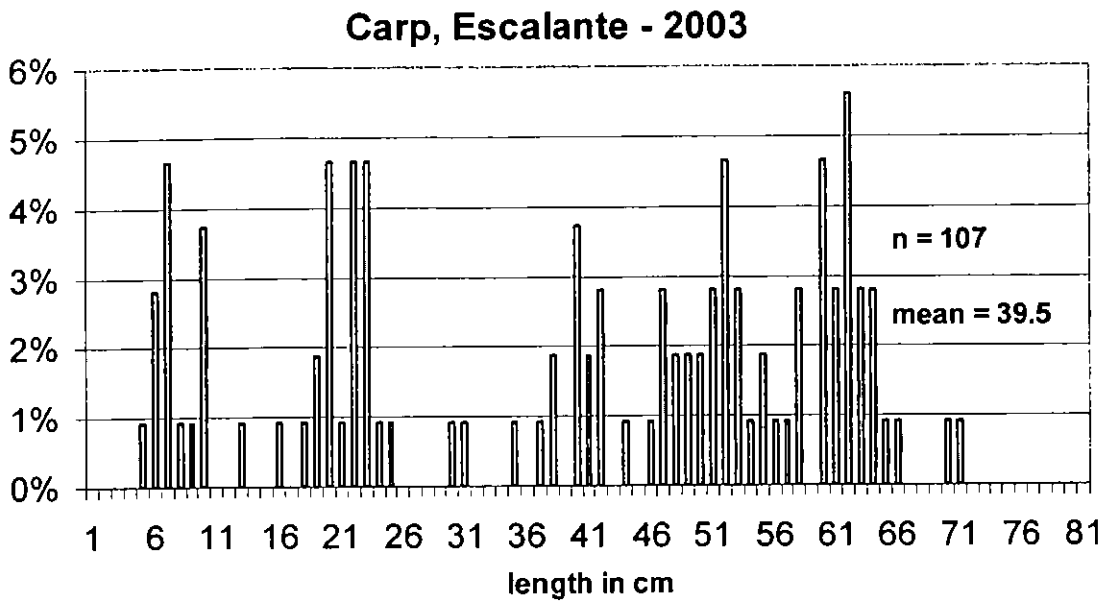

Figure A2-26. Carp length frequency at Escalante, August 2003, Gunnison River.

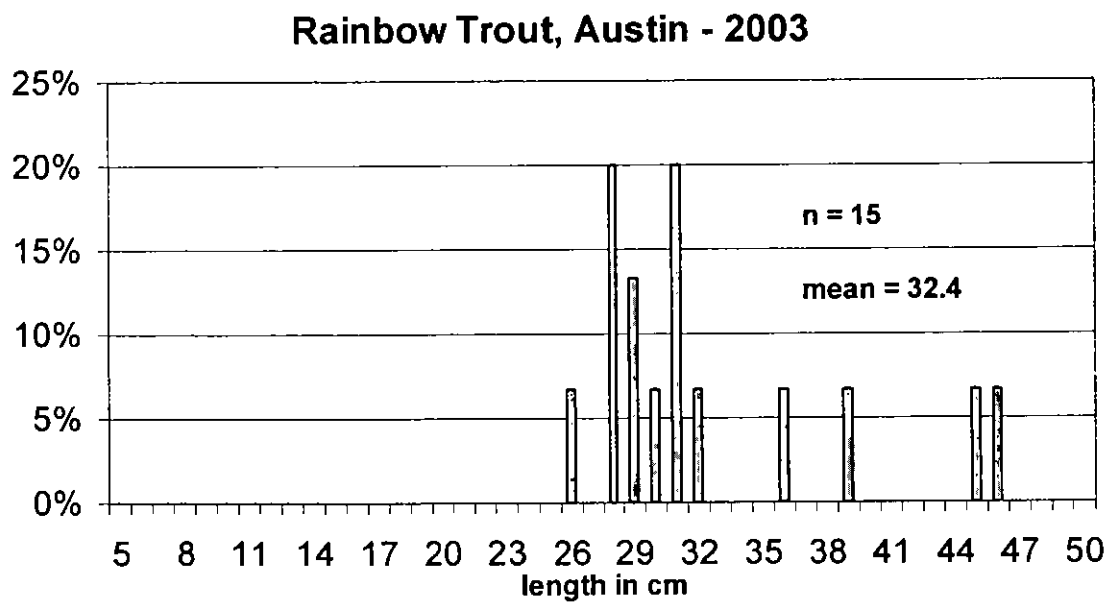

Figure A2-27. Rainbow trout length frequency at Austin, August 2003, Gunnison River.

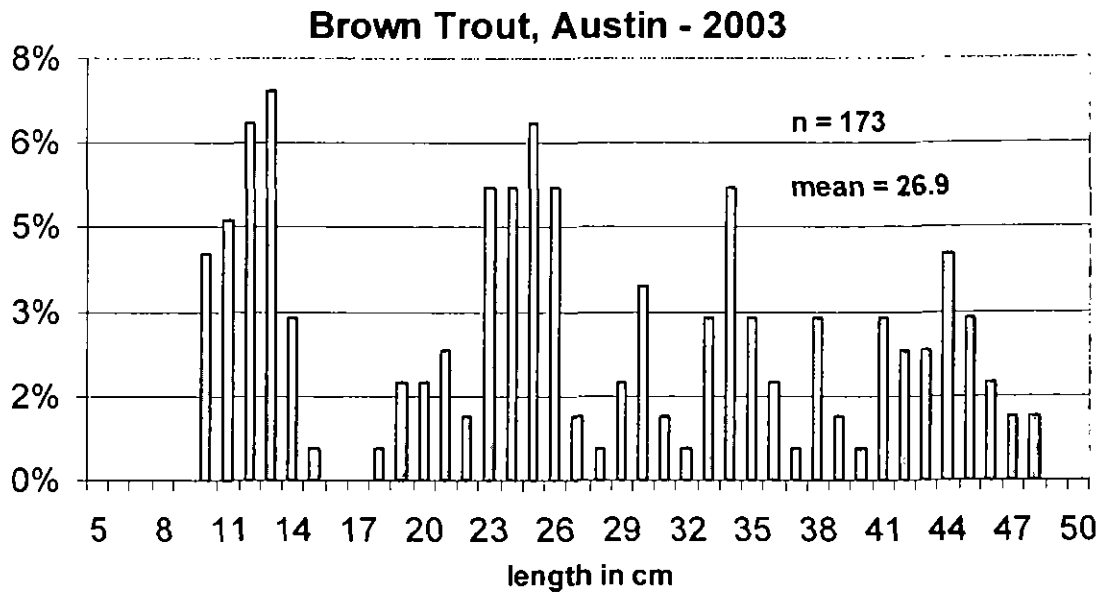

Figure A2-28. Brown trout length frequency at Austin, August 2003, Gunnison River.

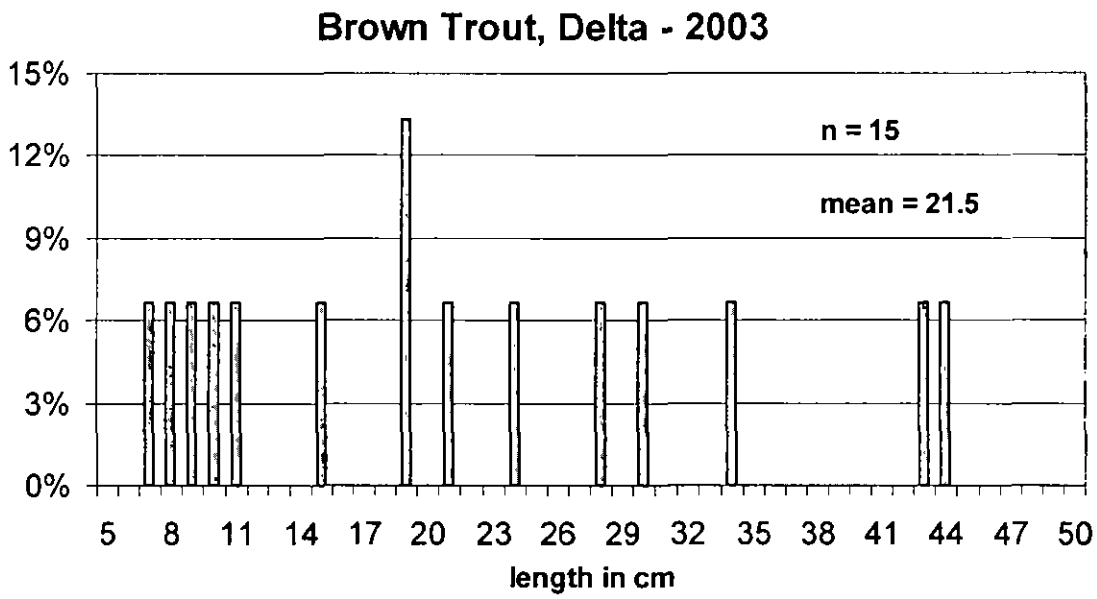

Figure A2-29. Brown trout length frequency at Delta, August 2003, Gunnison River.

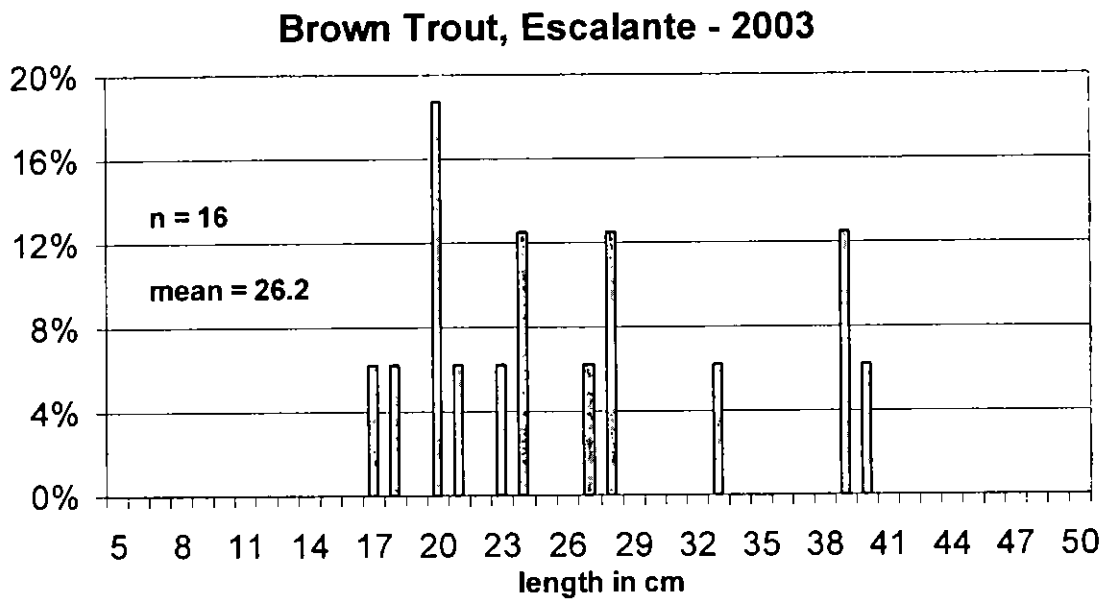

Figure A2-29. Brown trout length frequency at Escalante, August 2003, Gunnison River.