Riverine Fish Flow Investigations

Federal Aid Project F-288-R8

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State: Colorado

Title: Riverine Fish Flow Investigations Grant No. F-288-R8

Period Covered: July 1, 2004 - June 30, 2005

Study Objective: Quantification of impacts of the 2002 drought on native fish populations in the Yampa, Colorado, Dolores and Gunnison Rivers.

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 for native species based on density and biomass population estimates. Flows were simulated with a 2-D flow model.

The Yampa, Colorado and Dolores Rivers fish populations were sampled during both ‘wet’ (1995 to 1999) and ‘dry’ periods. A period of severely reduced flows began in the year 2000 and the statewide drought of record occurred in 2002. Drought or altered stream flows directly impacts habitat availability and can thus unbalance normal environmental and biological interactions (Bain et al 1988, Scholsser 1982, Poff et al. 1997). Drought related habitat and temperature alternations could be a direct cause for changes in native invertebrate and fish carrying capacity and species relative abundance. Drought related impacts to native fish would be indirect when predation rates or competitive pressures change in favor of nonnative organisms.

Since fish populations had been 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 pre-drought baseline data set had been established. These data provided the opportunity to empirically demonstrate how apparently stable fish communities would respond to the very low flows observed in 2002. These data would also be useful for validation or calibration of the biomass model developed during the prior instream flow study (Anderson and Stewart 2003).

Available hydrologic and geomorphic data for these rivers were compiled and presented . The objective of this synthesis was to identify relationships between the native fish population characteristics of a river and its hydrologic and geomorphic characteristics. Habitat availability as during pre-drought- and drought- base flow hydrographs would be used to form hypotheses concerning the importance of the base flow hydrograph on native fish abundance. These hypotheses could be refined or tested with future research.

Study Objectives:

1. Sample fish populations in the Yampa River, Colorado River and Dolores River following the 2002 base flows for two years (2003 and 2004).

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

3. Establish a new study site on the Gunnison for the 2D habitat modeling using the same approach as the other study sites. Refine and update the biomass model made by the instream flow study with fish data collected in 2003 and 2004. Compare data from the Gunnison River to the Colorado and Yampa Rivers.

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 Locations

Yampa River

There were three study areas on the Yampa River. The two sites established in 1998 are 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 RM 109, is 4.5 miles in length (Figure 1). Sevens and Duffy were electro-fished in 1998, 1999, 2000, 2001, 2003 and 2004. 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, 2003 and 2004.

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 and Clifton. Corn Lake was from RM 177.5 downstream to RM 175.3 (Figure 2) and was 3.9- km in length and Clifton is just upstream, only a short section (about 300 m) above Corn Lake. Clifton is from RM 177.7 to 180.4 and has a total length of 4.2 km.

Mark-recapture sampling was made at Corn Lake in 1999, 2000, 2001, 2003 and 2004, and at Clifton in 2000, 2001 and 2003. Because the two sites were adjacent, it was possible and desirable to combine mark- recapture data and combined estimates were reported in Anderson (2004).

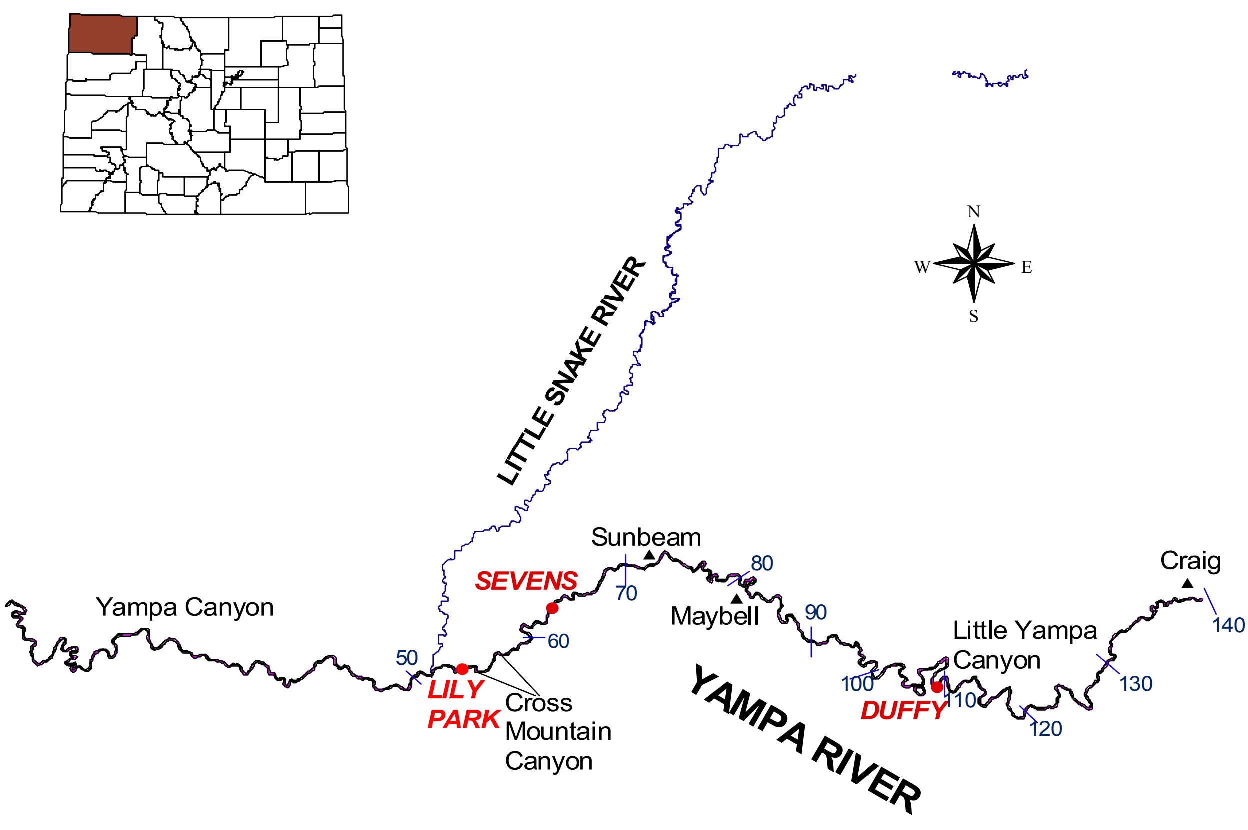

Figure 1. Yampa River study site locations for Lily Park, Sevens and Duffy.

Gunnison River

The Gunnison River was reconnaissance surveyed in 2003 at three sites, Austin, Delta and Escalante. Two electrofishing passes were made at each site in 2003 to determine relative abundance of native fish and for selecting 2D modeling sites.

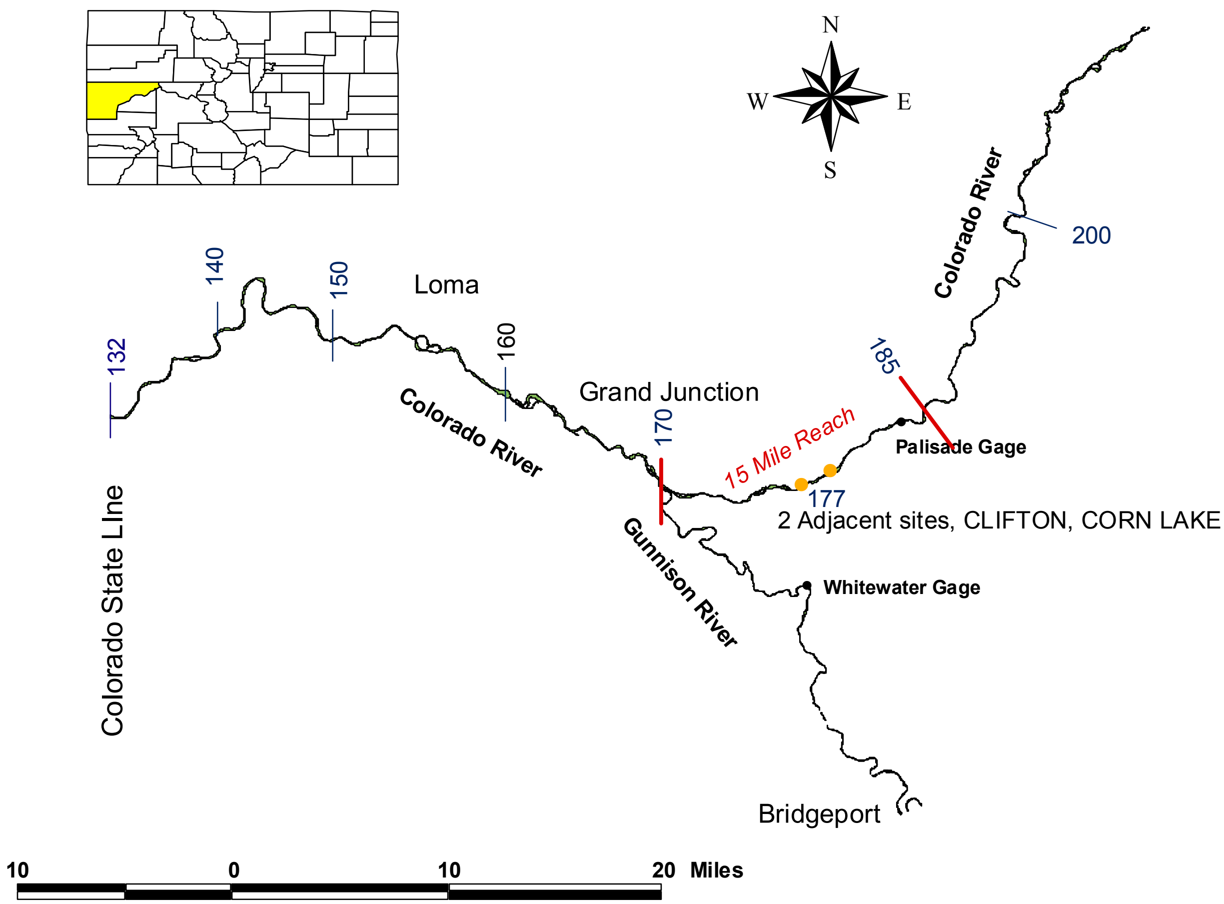

Figure 2. Colorado River study site locations in the 15-Mile Reach for Corn Lake and Clifton.

The two sites selected for channel and fish surveys were Delta and Escalante. Delta extended from the confluence of the Uncompahgre River (RM 56.3) downstream two miles to the county road bridge. Escalante extended from Escalante Bridge (RM 42.7) downstream about 2.5 miles to Hail Mary rapids. The Escalante site was located on private property owned by the Escalante Land and Cattle Ranch. The Austin site is also on private property and located near the town of Austin 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).

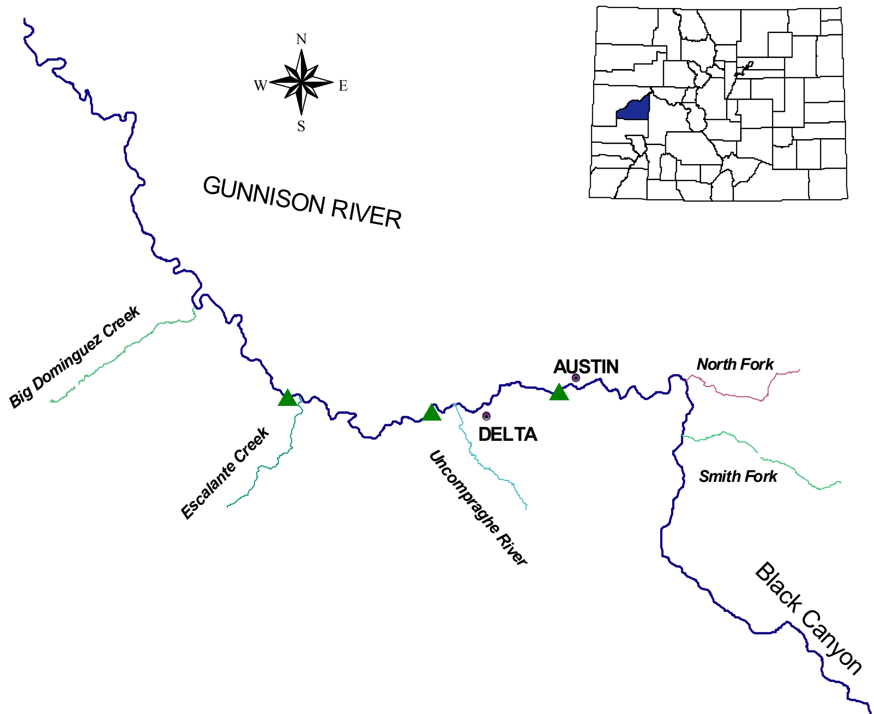

Figure 3. Gunnison River study sites locations near Escalante Creek, Uncompahgre River and Austin.

Dolores River

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 Reservoir has a capacity of 381,000 acre feet, began storing water in 1984 and has resulted in altered spring flows.

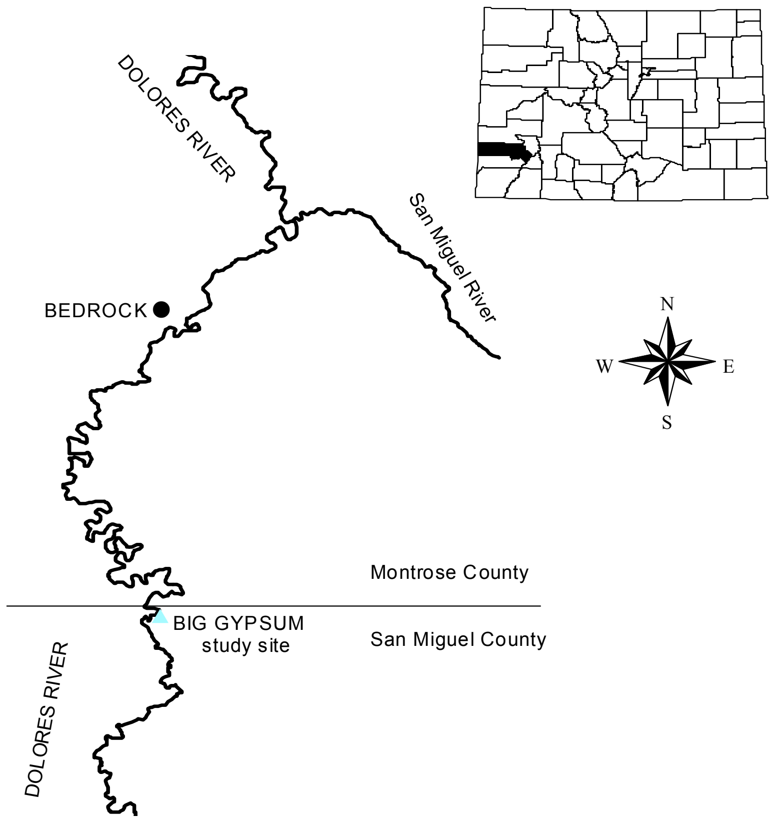

Figure 4. Dolores River study site location in the Big Gypsum Valley.

The study site was located in the Big Gypsum Valley, about 70 river miles downstream from McPhee Reservoir and 12 river miles downstream from the Slick Rock Bridge. The mouth of Disappointment Creek is about 16 river mile upstream of the study site and is a significant source of fine sediment downstream. The Big Gypsum site begins at the BLM boat launch and ends just upstream of the county road bridge, 2.2 miles downstream (Figure 5). The Dolores River fish population was sampled in 2000, 2001 and 2004.

Site Hydrology

Each of the four study rivers had unique hydrographs for runoff and base periods. The Yampa River has 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). The Colorado River runoff flows (Cameo gage) have been moderate-highly reduced by at least 29% (Pitlick et al. 1999). The Gunnison River runoff flows have been heavily reduced by Blue Mesa Dam (Pitlick et al 1999). The Dolores River runoff flows have been dramatically reduced due to the capacity of McPhee Reservoir to capture all main stem runoff flows during below average snow pack years.

The Yampa River has been the most vulnerable to dewatering and experienced the most dramatic reductions in base flows during the drought period. The Dolores River experienced very low base flows during 2002, but typically its base flows have increased compared to flows recorded prior to construction of the McPhee Dam. The 15-Mile Reach in the Colorado River experienced only moderate base flow reductions during the drought period. The Gunnison River did not have base flow reduction during the drought period and can be considered a control site.

Yampa River (Maybell gage)

Andrews (1980) calculated bankfull flow at Maybell Gage to be about 9,000 cfs and peaks flow have exceeded bankfull in 53 out of the last 89 years for a frequency of 1.7. The frequency for the last 30 years was also a frequency of 1.7. The median peak flow for the 89 years of record is 9,930 cfs (Figure A2-1). Peak flows read at the Maybell gage for 1998, 1999 and 2000 were 10,040, 9,980, and 9,830 cfs respectively (Figure A2-1 and A2-3). Below median peaks occurred in 2001, 2002, and 2004 and were 7,650, 3,420 and 5,950 cfs respectively (Figure A2-1). The only year during the study period with an above median peak (12,900 cfs) was 2003.

The 87-year median (50% exceedence flow) summer/fall minimum flow was 119 cfs (Figure A2-2 and Table 1) and flows in August and September can often drop below 200 cfs. Minimum flows for 1997, 1998, and 1999 were 320, 115 and 166 cfs respectively (Figure A2-2). Minimum flow in 2000, 2001, 2002, 2003 and 2004 were 30, 50, 1.8, 43 and 22 cfs respectively.

In 1998 and 1999 the 40-day minimum flow was 248 cfs and 237 cfs respectively and the number of days where flow under 200 was 29 and 6 respectively (Table 1 & Figure A2-4). Degree-days-12 (mean daily temperature C minus 12 then summed) were higher after 2000 than they were in 1998 and 1999 (Table 1). Correlations were found to be highly significant (r-square 0.97) between degree-days and the number of days flow was less than 200 cfs (Table A1-1). Correlations were good between degree-days-12 and the 40-day minimum flow (r-square = 0.76), but not good with the one day minimum (r square = 0.55) (Table A1-1).

Table 1. Flow characteristics (minimum, 40-day minimum, number-of-days flow under 200 cfs) and degree-days-12 for each year of the study period, 1998 to 2004.

	1998	1999	2000	2001	2002	2003	2004
Min flow (cfs)	110	166	30	50	2	43	22
40d Min (cfs)	248	237	113	110	12	141	146
Days <200	29	6	76	105	129	90	48
DegreeDay-12	810	743	867	957	984	897	811

A single year or intermittent year of low flow event may not have lasting ecological impacts as appeared to be the case during 1994. However, five consecutive years of low flows may unbalance normal habitat and thermal regimes and in turn may unbalance competitive interactions among aquatic organisms. In regards to flow recommendations, it appears prudent to consider the impacts of low flow on both habitat availability and thermal alterations.

Colorado River (Palisade Gage)

Pitlick (1999) determined bankfull flow for the 15-Mile Reach to be near 22,000 cfs. Flows have exceeded bankfull three in the last 14 years (Figure A2-5), a 4.7 year frequency. The median annual peak flow for the 14-year Palisade Gage history was 13,250 cfs. The 1999 and 2000 peaks were near the median. The 2002 (2,780) and 2004 (5,510) peaks were the lowest of the gauging record and study period (Figures A2- 5 and A2-7).

Summer/fall minimum flows recorded at the Palisade Gage for 1997, 1998, 1999, 2000, 2001, 2002, 2003 and 2004 were 1,710, 988, 1,240, 543, 477, 58, 342 and 341 cfs respectively. The 13-year median (50% exceedence flow) minimum flow was 543 cfs (Figure A2-6).

For three consecutive years (1997, 1998 and 1999) base flows were very high and rarely dropped below 800 cfs (Figure A2-8). Base flows were moderate in 2000 and 2001, and rarely dropped below 600 cfs (Figure A2-8) These years represented a period when habitat or flows were likely not a limiting factor for native fish in the 15-Mile Reach. In 2002 flows were below 200 cfs for 71 days and base flows were lower than normal in 2003 and 2004 (Figure A2-8). Aberrations in the fish community structure during 2003 and 2004 were assumed attributable to the 2002 drought.

Gunnison River (Delta gage/ Uncompahgre Gage)

Peak flows have declined substantially in the Gunnison since the 1950s (McAda 2003) (Figure A2-9). Pitlick (1999) determined bankfull flow to be 14,350 cfs for the Gunnison River. Prior to completion of the Blue Mesa project in 1965 the median peak flow was 15,800 cfs (57 years of gage data) and peak exceeded bankfull in 27 of 49 years for a 1.8 frequency. From 1966 to 2004 (39 years) the median peak flow was 7,260 cfs and peaks have exceeded bankfull in only five of the last 39 years for a 7.8 frequency. Peaks have not exceeded bankfull in the last nine consecutive years. The recent drought reduced peak flow magnitudes, but base flows were relativity unaffected and higher than the historical median (Figure A2-10).

The USGS Gage at Delta is located about five miles downstream of Austin and below the Hartland Diversion, which removes about 30 to 50 cfs from the river. 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 downstream study sites.

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, 2003 and 2004 were 8,383, 5,676, 4,260, 4,375, 1,451, 5,379 and 2,772 cfs respectively (Figures A2-11 and A2-13). Over the last seven years peaks have not approached bankfull (14,350 cfs).

Summer/fall minimum flows summed for the Delta and Uncompahgre gages for 1998 through 2004 were 1,062, 1,303, 1,026, 832, 543, 622 and 637 cfs respectively (Figure A2-12). Gunnison River summer/fall minimums (Figure A2-14) have been higher than the 15-Mile Reach on the Colorado River and also much higher than the Yampa River. The Gunnison River with its high base flows and heavily impacted peak flows is reverse of the Yampa River situation.

Dolores River

The Bedrock Gage is 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. Since 1984 the spring hydrograph of the Dolores River has been highly modified by McPhee Reservoir. The median annual peak flow for the 32-year Bedrock Gage history was 3,095 cfs (Figure A2-15). The runoff peak for 1998 through 2004 was 3,560, 3,100, 1,170, 522, 54, 323 and 307 cfs. Bankfull flow is under study by this project (Richard and Wilcox 2005). Estimated bankfull flow for the Big Gypsum Valley was 2,200 cfs and 2,500 cfs at the Bedrock gauging station (USDI BLM 1990)

Annual minimum flows recorded at the Bedrock Gage for 1998 through 2004 were 21, 32, 25, 24, 1.4, 6.4 and 20 cfs respectively (Figure A2-16). The 32 year median minimum flow was 24 cfs.

McPhee Reservoir captured the entire spring runoff from 2001 to 2004. In this five-year period peaks were determined by tributary flow, primarily Disappointment Creek. Even though a fish pool was established in McPhee reservoir to improve base flows below the dam, base flows were very poor in 2002 and 2003. The Dolores River at the Big Gypsum site appears to have had geomorphic modifications such as channel narrowing and riparian encroachment, likely related to lack of runoff flows for five consecutive years (Richard and Wilcox 2005).

Site Geomorphology

The Colorado River, upstream of the mouth of the Gunnison River, had the largest drainage area (8,753 mi²) and mean annual flow (2,912 cfs - Palisade gage, 1991 to 2004) of the four rivers under study. The Gunnison River drainage area at the Whitewater gage was 7,928 mi² and the mean annual flow was 2,507 cfs from 1965 to 2003. The Yampa River drainage area at the Maybell gage is 3,410 mi², less than half that of the Colorado and Gunnison River and its mean annual flow was 1,566 cfs from 1917 to 2001 (85 years of record). The Yampa River drainage area at Deerlodge was 7,660 mi² and mean annual flow was 2,100 cfs (1983 to 2003). Deerlodge is located immediately downstream of the Little Snake River confluence and downstream of the three study sites. The Dolores River at

Bedrock has a drainage area of 2,024 mi^2 and had a mean annual flow (1972 to 2001) of 399 cfs.

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 mean bankfull width was 73.4 m and mean slope was 0.12% for the Gunnison River near Whitewater, 73 m and 0.19% at Delta, and 68 m and 0.12% at Escalante (Pitlick et al. 1999). The Gunnison River had a much narrower channel proportionally to the Colorado River given small differences in drainage area and mean annual flow.

The Yampa River channel appears to be proportionately wider than the Colorado and Gunnison Rivers, given the lower drainage area and mean annual flow at Maybell. Bankfull width for the Yampa River is under study (Dr. Richard, Mesa State University), but a survey of bankfull indicators produced a mean channel width of 85 m at Lily Park and 94 m at Sevens.

The Yampa River basin was studied by Andrews (1980, 1984) who determined that bankfull discharge was approximated by effective discharge at 15 gauging stations. Since the 1980's the Yampa River has continued to be impacted by grazing and agricultural diversions. In grazed reaches, there is evidence of channel widening including bank erosion, loss of fences and over-steepened banks.

Anderson and Stewart (2003) reported mean wetted width at 600 cfs was 68 m at Duffy, 60 m at Sevens and 57 m at Lily Park (Yampa River), all wider than Corn Lake (50m) on the Colorado River. The Yampa River therefore had a higher width/depth ratio at low flows. Mean channel width at 600 cfs for the Gunnison River will be determined upon completion of the 2D modeling in 2005. Preliminary data indicates the Gunnison River has a narrow and stable channel, the Colorado River has a wide and stable channel, and the Yampa River has a very wide and perhaps unstable channel.

The Dolores River study site is in a much smaller drainage area. Mean wetted width at the Big Gypsum site was 22 m at 100 cfs and 25 m at 500 cfs. Slope was 0.15% at the Big Gypsum site.

Anderson and Stewart (2003) found meso habitat availability was primarily a function of flow. Peak flow and channel maintenance flow appear to be very important for habitat maintenance. High peak flows on the Yampa River have been maintaining a wide channel given the magnitude of its base flows. Land use practices may be contributing to channel instability and channel widening. This is currently under investigation by Dr. Richard at Mesa State University. In contrast, the Gunnison River with reduced peak flows has the narrowest channel and the highest base flows.

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, 2002 and 2004. 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 15 cm were marked, and therefore used for mark and recapture population estimates.

The Darroch multiple mark method (Everhart and Youngs 1981) with the Chapman (1954) formula was used to make the population estimate with ninety-five percent confidence intervals. A total fish estimate was made for all species combined and for individual species. Recapture rates generally varied between species and size-groups. Larger suckers had the highest recapture probabilities in our samples, 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 (Dr. David Bowden, CSU, pers. communication).

Channel topography was surveyed at Delta and Escalante in May, June and July 2004. The channel surveying technique was the same as described in Anderson and Stewart (2003) for the other rivers in the study. The channel bed was surveyed using a boat mounted RTK GPS and sonar systems. Shallow shoreline areas and water-lines were surveyed by wading shallow areas or walking the bank.

RESULTS and DISCUSSION

This report compares 2004 fish data to prior years. Each annual progress report between 1999 and 2004 presented length distribution data for that year's fish collections. Anderson and Stewart (2000) presented length data for fish sampled in 1998 and 1999. Meso habitat preferences for depths and velocities determined for flannelmouth sucker and bluehead sucker were given in Anderson and Stewart 2003.

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

YAMPA RIVER
RESULTS

Duffy

Native fish species were uncommon to rare at Duffy during all years of sampling, averaging 14% of fish over 15 cm for first three years, and only 9% by 2004 (Table 2). Flannelmouth sucker and bluehead sucker both hybridized with non native white sucker and their hybrids comprised about 50% of the suckers captured during the study period. Pure-appearing bluehead and flannelmouth sucker (native species) represented about 10% of the total catch in the baseline years and only four and 5% in 2003 and 2004, respectively. Roundtail chub were about 3% of the catch and Colorado pikeminnow were 1.5% to 0.6% of the total catch from 1998 and 2001 and less in 2003 and 2004 (Table 2).

White sucker and their hybrids were the dominant taxon from 1998 (72%) to 2003 (66%) for fish over 15 cm (Table 2). In 2004 smallmouth bass was the most common species (>15 cm) at 44% and white sucker/crosses dropped to second at 38%.

Smallmouth bass were 77% of the total fish (includes fish under 15 cm) catch in 2004, whereas its composition was much less (22% and 26%) in 1998 and 1999 (baseline years) (Table A1-2). Two small-bodied native species, the speckled dace and mottled sculpin were common in 1998 and 1999. One dace was found in 2003, but otherwise these species were not found in 2003 and 2004.

Table 2. Species composition (fish >15 cm) at Duffy, Yampa River, 1998 to 2004.

YAMPA –REACH	DUFFY	DUFFY	DUFFY	DUFFY	DUFFY	DUFFY
Species	1998	1999	2000	2001	2003	2004
Flannelmouth sucker	6 – (85)	5 – (54)	5 – (65)	2 – (17)	4 – (23)	3 – (14)
Bluehead sucker	4 – (56)	7 – (80)	4 – (45)	4 – (38)	1 – (8)	0.5 – (2)
Roundtail chub	4 – (52)	3 – (35)	4 – (46)	3 – (27)	2 – (10)	5 – (20)
Colo. Pikeminnow	1.6- (22)	0.9 - (11)	0.8 – (10)	0.6 – (5)	0	0.5 – (2)
White S. + hybrids	71 – (969)	72 – (870)	72 – (938)	50 – (425)	66 – (388)	38 – (162)
Channel catfish	3 – (44)	4 – (52)	3 – (41)	4 – (38)	4 – (26)	6 – (26)
Carp	2 – (27)	1.5 – (18)	0.8 – (10)	2 – (19)	0.3 – (2)	1 – (5)
Smallmouth bass	6 – (80)	6 – (70)	10 – (126)	33 – (278)	18 – (106)	44 – (189)
Northern pike	2.8 – (39)	2.3 – (23)	0.9 – (12)	1.1 – (9)	0.7 – (4)	1.6 – (7)
Black bullhead	0	0			-	0.2 –(1)
Black crappie	0.1 - (1)	0.1 1)	0.1 (1)		3 - (17)	0
Native species	15.6	14.8	12.8	10.2	7.0	8.9
Sample size	1375	1213	1294	856	584	428

Total fish density estimates in baseline years (63 and 66 fish/ha) were higher than in 2003 and 2004 (40 and 28 fish/ha) (Table 3) and significant at 95% confidence (Table 4). The highest total density in 2001 was due to a spike of smallmouth bass that year (Table 3).

Density estimates for flannelmouth sucker, bluehead sucker, Colorado pikeminnow and roundtail chub were highest in the baseline years, but lowest in 2003 and 2004 (Table 3) with differences significant (Table 4). Significantly higher density estimates were also found for the non-native species of white sucker, carp and northern pike in 1998 and 1999 than after 2002 (Table 4). Smallmouth bass was the only species to display increased abundance or density during the dry years of 2001 to 2004 with a significant difference between 1998 and 2004 (Table 4).

Table 3. Density estimates at Duffy, Yampa River, 1998 to 2004.

YAMPA RIVER						
DUFFY	**No/ha**	**no/ha**	**No/ha**	**No/ha**	**no/ha**	**no/ha**
Species	**1998**	**1999**	**2000**	**2001**	**2003**	**2004**
Total fish	62.9	65.6	51.5	69.4	40.0	28.4
Flannelmouth sucker	4.0	2.4	1.8	0.7	0.9	1.0
Bluehead sucker	3.6	3.7	4.0	2.7	0.5	0.1
Colorado pikeminnow	1.3	0.9	0.6	0.5	0.0	0.1
Roundtail chub	2.8	2.9	1.8	2.6	1.1	1.4
White S. + hybrids	39.2	39.4	33.0	29.7	20.8	11.2
Channel catfish	2.6	5.5	2.3	3.9	3.0	1.8
Carp	1.8	1.5	0.5	1.3	0.2	0.3
Smallmouth bass	5.0	6.3	6.7	27.1	13.0	11.9
Northern pike	2.5	3.0	0.6	1.0	0.5	0.5

Table 4. Significant differences (alpha = 0.05) in density estimate between years are denoted when letters (a, b, c, d, e, f) are present in a column.

Duffy	1998-a	1999-b	2000-c	2001-d	2003-e	2004-f
Total fish	c, e, f	c, e, f	a, b, d, e, f	c, e, f	a, b, c, d	a, b, c, d
Flannelmouth S	c, d, e	d, e	a, d, e	a, b, c	a, b, c	
Bluehead S.	e, f	e, f	f	e, f	a, b, d	a, b, c, d
Roundtail Chub	c, f	e, f	a		a, b	a, b
White S. + hybrids	e, f	d, e, f	e, f	b, e	a, b ,c, d	a, b, c
S, Bass	d, f	D	d	a, b, c, f		a, d
N. Pike		c, e	b		b	
Carp		e			b	

Prior to the drought the total fish biomass at Duffy was about 66 kg/ha (1998/99) and fell to about 21 kg/ha in 2003 and 2004 indicating a large drop in fish biomass. Biomass estimates were much lower in 2003 and 2004 for most species compared to the baseline years (Table 5). White sucker and their hybrids were about 40 kg/ha in 1998/99, but about 12 kg/ha in 2003/04. Bluehead sucker was very rare in 2003/04 with a biomass of only 0.1 kg/ha. Although smallmouth bass percentage in the catch and density increased at Duffy in 2003/04, their biomass was fairly stationary over the study period.

Table 5. Biomass estimates at Duffy, Yampa River 1998 to 2004.

YAMPA RIVER						
Duffy	**Kg/ha**	**Kg/ha**	**Kg/ha**	**Kg/ha**	**Kg/ha**	**Kg/ha**
Species	**1998**	**1999**	**2000**	**2001**	**2003**	**2004**
Total fish	66.5	65.9	51.0	47.4	22.6	20.6
Flannelmouth sucker	4.7	2.7	2.2	0.8	1.1	1.2
Bluehead sucker	1.8	1.3	2.2	1.5	0.2	0.1
Roundtail chub	2.5	2.7	1.6	2.2	1.1	0.3
Colorado pikeminnow	2.5	1.6	0.9	0.7	0	1.2
White S. + hybrids	39.9	39.7	35	26.9	12.7	10.7
Channel catfish	4.3	6.5	3.3	4.1	3.9	3.4
Carp	7.3	6.1	2.8	6.1	1.5	1.7
Smallmouth bass	1.9	2.6	2.3	4.8	1.9	1.9
Northern pike	1.5	2.8	0.7	0.2	0.3	0.0

Age-1 white sucker were common in 2003, but rare in 2004 (Figure A2-19). Age-1 fish were rare for all species in the 2004 sample (Figures A3-1, 9, 34, 41, 47, 52, 60, 68 and 74) except for smallmouth bass. In years prior to 2004, age-0 smallmouth bass were abundant at Duffy whereas age-1s were uncommon. Age-1 smallmouth bass abundance was very high in 2004 and may be related to the apparent reduced survival of age-0 smallmouth bass seen that year either by intra-specific predation or competition.

The higher than usual abundance of age-1 smallmouth bass in 2004 indicated improved survival of age-0 bass in 2003. Above normal abundance for an age-1 cohort was not observed for other species in 2004 (Figures A3-1, A3-9, A3-19, A3-27, A3-34, A3-41, A3-47, A3-52, A3-60, & A3-74). Mean lengths were similar to prior years except for white sucker and hybrids and northern pike, which were smaller on average (Table 6).

Table 6. Mean lengths fish at Duffy, Yampa River 1998 to 2004.

YAMPA RIVER						
SEVENS	**1998**	**1999**	**2000**	**2001**	**2003**	**2004**
Species	**cm**	**cm**	**cm**	**cm**	**cm**	**cm**
Flannelmouth Sucker	48.4	47.8	49.8	47.5	49.4	49.9
Bluehead Sucker	35.7	38.0	37.6	36.2	30.9	40.9
Colorado Pikeminnow	60.8	57.4	56.4	55.5	-	61.8
Roundtail Chub	43.5	40.7	44.2	43.4	44.9	45.0
White S. + Crosses	39.7	33.1	40.6	38.2	28.3	29.2
Channel Catfish	52.9	47.6	51.6	46.4	49.7	56.3
Carp	59.8	67.9	48.0	68.0	80.0	70.6
Smallmouth Bass	12.6	16.1	12.2	13.1	9.6	12.5
Northern Pike	43.3	51.7	57.6	32.2	43.2	23.0

Sevens

The native fish component (density and species composition) 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 7). In 2003 native species composition was 42% and dropped to only 30% in 2004.

Flannelmouth sucker relative abundance ranged from 46% to 53% between 1998 and 2001 and it was 37% in 2003 and 24% in 2004. Bluehead sucker abundance for the first three years averaged 21% and it progressively dropped to 2% in 2003/2004. Roundtail chub was consistent at 3% to 4% of the sample in all years at Sevens (Table 7). Colorado pikeminnow were rare or absent at Sevens for all years.

White sucker and their hybrids were 36% of the catch in 2003 and 2004 compared to about 15% of the catch in the four previous years. Smallmouth bass were 23% in 2004 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). Carp were consistent in all five years at near 4% of the catch.

Table 7. Species composition at Sevens, Yampa River, 1998 to 2004.

YAMPA RIVER	Percent composition for **FISH > 15 CM** with number caught					
Sevens	**- (n)**	**- (n)**	**- (n)**	**- (n)**	**- (n)**	**- (n)**
Species	**1998**	**1999**	**2000**	**2001**	**2003**	**2004**
Flannelmouth sucker	48 – (668)	46 – (476)	50 – (404)	53 –(359)	37 - (300)	26 - (187)
Bluehead sucker	23 – (314)	18 – (187)	22 – (180)	13 – (89)	2 - (16)	2 - (11)
Roundtail chub	5 – (73)	4 – (39)	4 – (31)	3 – (23)	4 - (31)	2 - (15)
Colo. Pikeminnow	0.2 – (3)	0.2 – (2)	0.25 – (2)	0	0	0
White S. + hybrids	11 – (158)	15 – (152)	17 – (138)	16 – (106)	36 - (298)	36 - (267)
Channel catfish	7 – (93)	7 – (75)	2 – (15)	5 – (35)	3 – (28)	5.5 - (40)
Carp	4 – (50)	5 – (50)	4 – (31)	4 – (28)	4 – (31)	5.5 - (43)
Smallmouth bass	1 – (14)	2.5 – (26)	0.5 – (4)	5 – (34)	13 – (106)	23 - (165)
Northern pike	1 – (18)	1.8 – (19)	0.2 – (2)	0.3 – (2)	0.4 – (3)	0.3 - (3)
Native species	76.1%	68.6%	76.5%	69.7%	41.7%	29.1%
Sample size	1391	1026	807	676	832	731

Native species comprised about 75% of the total fish (includes fish < 15 cm) caught in all years prior to 2002 (Table A1-3). A radical change in community composition for total fish was observed in 2003, by 2004 smallmouth bass was the dominant (44%) species followed by white sucker (38%). Speckled dace and mottled sculpin were common in 1998 and 1999, but not collected in 2003 and 2004.

Density estimates for native species (flannelmouth sucker, bluehead sucker and roundtail chub) declined after 2002 (Table 8) and differences were significant (alpha = 0.05) from the 1998 and 1999 estimates (Table 9). The highest white sucker and smallmouth bass density was in 2003. Numbers of yearling-sized white sucker were much higher in 2003 than prior years and inflated both white sucker and total fish estimates that year.

Smallmouth bass density estimates were higher in 2003 and 2004 than prior years (Tables 8 & 9). The smallmouth bass density estimate was higher in 2003, but capture rates for bass (CPUE) were higher in 2004. The number of smallmouth bass >15 cm caught in 2003 was 106 compared to 156 in 2004, which indicated smallmouth bass abundance continued to increase in 2004. The lower density estimate was a function of a higher recapture proportion in 2004 than 2003, and the estimates were not significantly different for those years (Table 9).

Table 8. Density estimates at Sevens, Yampa River, 1998 to 2004.

YAMPA RIVER	Density estimate in fish per hectare					
SEVENS	**no/ha**	**no/ha**	**no/ha**	**no/ha**	**no/ha**	**no/ha**
Species	**1998**	**1999**	**2000**	**2001**	**2003**	**2004**
Total fish	179.4	179.1	122.1	104.7	173.1	82.5
Flannelmouth sucker	63.2	60.5	47.4	42.3	30.6	19.0
Bluehead sucker	42.8	36.9	46.9	17.9	1.6	2.4
Roundtail chub	10.6	6.0	6.4	3.7	3.5	1.5
White S. + hybrids	30.4	29.2	16.7	20.8	77.8	20.3
Channel catfish	14.8	19.8	2.0	7.5	9.5	6.4
Carp	9.1	12.6	4.1	5.6	10.5	6.9
Smallmouth bass	2.4	5.6	0.5	5.8	32.8	24.5
Northern pike	3.6	4.6	0.3	0.4	1.0	0.2

The pre-drought total fish biomass (165 kg/ha) was nearly double that of 2003 (96 kg/h) and 2004 (74 kg/ha) (Table 10), suggesting pre-drought carrying capacity was much higher.

Table 9. Significant differences (alpha = 0.05) for density estimates between years are denoted when letters (a, b, c, d, e, f) are present in a column.

SEVENS	1998-a	1999-b	2000-c	2001-d	2003-e	2004-f
Total fish	c, d, f	c, d ,f	a, b, e, f	a, b, e	c, d, f	a, b, c, e
Flannelmouth	c, d, e, f	d, e, f	a, e, f	a, b, e, f	a, b, c, d, f	a, b, c, d, e
Bluehead s	d, e, f	d, e ,f	d, e, f	a, b, c, e, f	a, b, c, d	a, b, c, d
Roundtail c	d, e ,f			a	a	A
WS & xs	c, e	E	a, e	e	a, b, c, d, f	E
S. bass	e, f	e, f	e, f	e, f	a, b, c, d	a, b, c, d
N. pike	e, f	e, f			a, b	a, b

In 2003 and 2004 biomass estimates for all native species were lower than in 1998 and 1999. Flannelmouth sucker was about 66kg/ha in 1998 and 1999, but was only about 30 kg/ha in 2003 and 2004 (Table 10). Bluehead sucker was very low in 2003 and 2004 (only 0.1 kg/ha) and roundtail chub biomass also declined, but at a lesser rate.

The total biomass estimate in 2003 was somewhat higher than 2001 and 2004, because white sucker density peaked that year. However, in 2004 white sucker biomass was less than all previous years. Channel catfish biomass was about half in the dry years (2000, 2001 and 2003) compared to 1998 and 1999 and northern pike biomass in 2004 appeared to be about a third of 1998 and 1999 (Table 10).

Table 10. Biomass estimates at Sevens, Yampa River, 1998 to 2004.

YAMPA RIVER						
SEVENS	**Kg/ha**	**Kg/ha**	**Kg/ha**	**Kg/ha**	**Kg/ha**	**Kg/ha**
Species	**1998**	**1999**	**2000**	**2001**	**2003**	**2004**
Total fish	162.2	165.4	98.4	87.5	96.1	73.5
Flannelmouth sucker	66.1	66.1	50.0	39.2	35.4	24.1
Bluehead sucker	17.2	14.5	14.8	5.0	0.6	1.0
Roundtail chub	6.3	3.9	3.9	2.0	1.8	1.1
White S. + hybrids	22.9	23.2	14.4	12.3	24.6	10.0
Channel catfish	21.5	22.4	3.2	10.2	14.7	11.8
Carp	25.4	30.8	11.6	17.0	28.0	20.5
Smallmouth bass	1.2	1.9	0.2	0.9	5.3	4.7
Northern pike	1.4	2.6	0.4	0.8	0.4	0.5

Mean lengths did not reveal changes in size structure between years for native fish (Table 11). Mean lengths at Sevens tended to be less than Duffy. In years prior to 2002 very few individuals less than 20 cm were caught. In 2003 a very large number of age-1 carp, white sucker and smallmouth bass were present or recruited indicating improved survival of age-0s during 2002. High numbers of age-1 carp and white sucker were not observed in 2004, but age-1 smallmouth bass were very numerous. Duffy also had improved recruitment of smallmouth bass age-1 in 2004.

Table 11. Mean lengths of fish at Sevens, Yampa River 1998 to 2004.

YAMPA RIVER	Mean length for all fish collect in cm					
SEVENS	A	B	C	D	E	F
Species	**1998**	**1999**	**2000**	**2001**	**2003**	**2004**
Flannelmouth sucker	45.7	46.5	45.8	43.8	46.0	47.9
Bluehead sucker	33.5	33.6	31.3	30.0	30.8	33.3
Roundtail chub	39.0	40.0,d	39.2	37.9	34.5	40.2
White S. + hybrids	31.1	35.6	25.4	29.7	19.4	24.6
Channel catfish	49.0	44.8	49.4	48.1	49.8	48.4
Carp	56.7	53.3	57.5	58.6	31.3	52.2
Smallmouth bass	29.6	21.0	8.4	13.6	13.2	13.3
Northern pike	37.5	41.1	55.2	64.3	34.5	56.2

Lily Park

Flannelmouth sucker and channel catfish were the two most common species (fish > 15 cm) during the study period (2000 to 2004). Flannelmouth sucker was 52 % of the catch in 2004 and channel catfish was 27% (Table 12). Bluehead sucker was the third most common species in 2000, 2001 and 2003, with smallmouth bass being third most common in 2004. Four species at Lily Park represented less than or near 1% (roundtail chub, Colorado pikeminnow, northern pike and white sucker).

The percent composition of smallmouth bass was higher when computed for total fish, since it was the most common fish <15cm. In 2000, 2001 and 2003 smallmouth bass were only 0.8%, 9% and 9%, respectively, of the total catch and increased to 21% in 2004 (Table A1-4). An increased percentage of smallmouth bass was observed at all Yampa River sites in 2004.

Table 12. Species composition at Lily Park, Yampa River, 2000 to 2004.

YAMPA RIVER	Percent composition for **FISH > 15 CM** with number caught			
Lily Park	**%- (n)**	**% - (n)**	**% - (n)**	**% - (n)**
Species	2000	2001	2003	2004
Flannelmouth sucker	48 - (1940)	68 - (2023)	55 - (1181)	52 - (1166)
Bluehead sucker	9 - (345)	7 - (212)	8 - (163)	6 - (143)
Roundtail chub	0.02 - (1)	0.03 - (1)	0 - (0)	0.3 - (7)
Colo. Pikeminnow	0.1 - (3)	0.03 - (1)	0.1 - (2)	0.5 - (11)
White S. + hybrids	0.2 - (11)	0.2 - (6)	0.6 - (14)	1.3 - (31)
Channel catfish	40 - (1631)	18 - (528)	28 - (602)	27 - (603)
Carp	2 - (87)	2 - (62)	3 - (73)	3 - (77)
Smallmouth bass	0.8 - (32)	5 - (151)	5 - (109)	9 - (205)
Northern pike	0.2 - (8)	0.2 - (5)	0.1 - (3)	0.1 - (3)
Total number in sample	4,058	2989	2159	2244

Density estimates for total fish, flannelmouth sucker, bluehead sucker and channel catfish were highest in 2000 (Table 13) and differences significant for total fish and flannelmouth sucker compared to following years (Table 14). Flannelmouth sucker estimates were significantly lower in 2004 compared to 2000 and 2001, but not 2003 (Table 14). Bluehead sucker estimates were significantly less in 2004 than 2000 (Table 14). Smallmouth bass estimates and catch rates displayed definite increases at Lily Park in each successive year, but estimates were not significant at the 95% C.I. due to low recapture rates.

Table 13. Density estimates at Lily Park, Yampa River, 2000 to 2004.

YAMPA RIVER	Density estimate in fish per hectare			
Lily Park	**No/ha**	**no/ha**	**No/ha**	**No/ha**
Species	**2000**	**2001**	**2003**	**2004**
Total fish	1001.5	528.9	666.6	547.2
Flannelmouth sucker	347.5	277.5	250.5	208.3
Bluehead sucker	96.8	54.8	57.1	47.1
Colorado pikeminnow	0.4	0.3	0	3.6
Roundtail chub	0.4	0.3	0	2.3
White S. + hybrids	0.9	0.3	4.0	2.2
Channel catfish	513.3	137.3	265.6	193.2
Carp	26.0	16.8	31.9	24.6
Smallmouth bass	10.6	39.0	50.0	57.7
Northern pike	2.6	1.4	1.4	1.0

Channel catfish density estimates had high variability between years, but only significant (alpha = 95%) between 2000 and 2001, and between 2001 and 2004 (Table 14). The channel catfish catch rate and density estimate was highest in 2000 and lowest in 2001.

Table 14. Significant differences (alpha = 0.05) for density estimates between years are denoted when letters (a, b, c, d, e, f) are present in a column.

	2000 - a	**2001 - b**	**2003 - c**	**2004 - d**
TOTAL	b, c, d	a, c	a, b	a
Flannelmouth sucker	b , c, d	a, d	a	a, b
Bluehead sucker	d			a
Channel Catfish	b	a, d		b

The abundant channel catfish and flannelmouth sucker population were unique to the Lily Park site and the much higher total fish density indicated a superior carrying capacity at this site relative to upstream locations. Compared to Duffy and Sevens, Lily Park had the lowest relative proportion of smallmouth bass, the lowest catch rates for smallmouth bass <15 cm but the highest smallmouth bass density >15 cm.

Biomass estimates of total fish, flannelmouth sucker and bluehead sucker declined progressively and were lowest in 2004 (Table 15). Channel catfish biomass was also lowest in 2004, but only slightly less than that determined for 2001. In spite of increasing smallmouth bass species composition and density from 2000 to 2004, biomass was consistent between years and was a function of fewer smallmouth bass >29 cm in later years.

Flannelmouth sucker were smaller in 2003 (Table 16) because there were fewer fish > 39 cm observed in the 2003 sample (36%) compared to 2001 (70%). Flannelmouth sucker > 44 cm were 21% in 2000, but only 2% were over 44 cm in 2003. Mean length and number percent of flannelmouth >44 cm increased to 8% in 2004. Bluehead sucker >34 cm was 49% in 2000, 29% in 2003 and 40% in 2004 indicating fish were smaller in 2003.

Table 15. Biomass estimates at Lily Park, Yampa River, 2000 to 2004.

YAMPA RIVER	Biomass estimate in kilograms per hectare			
Lily Park	**Kg/ha**	**Kg/ha**	**Kg/ha**	**Kg/ha**
Species	**2000**	**2001**	**2003**	**2004**
Total fish	521.1	253.0	256.8	240.2
Flannelmouth sucker	218.4	143.3	122.4	120.3
Bluehead sucker	37.2	19.8	18.9	17.1
Roundtail chub	0.2	0.01	0	0.6
Colorado pikeminnow	0.6	0.7	0	5.6
White S. + hybrids	0.4	0.2	2.5	1.1
Channel catfish	224.2	56.8	61.7	53.9
Carp	29.1	21.5	36.9	31.7
Smallmouth bass	6.8	8.0	7.9	8.2
Northern pike	3.8	2.8	2.4	1.7

Table 16. Mean lengths fish at Lily Park, Yampa River 2000 to 2004.

YAMPA RIVER	Mean length for all fish collect in cm			
Lily Park	**2000**	**2001**	**2003**	**2004**
Flannelmouth sucker	41.5	38.3	37.8	40.3
Bluehead sucker	34.2	33.5	32.5	33.8
Colorado pikeminnow	59.4	64.3	52.6	54.6
Roundtail chub	40.3	18.0	6.0	30.0
White S. + hybrids	26.6	28.0	35.8	31.2
Channel catfish	34.7	32.9	27.2	29.0
Carp	42.1	44.6	43.1	44.8
Smallmouth bass	12.0	15.1	16.7	15.0
Northern pike	64.6	66.7	63.7	62.0

Channel catfish mean length was less in 2003 and 2004 than prior years (Table 16) and their length distribution was highly variable between years. In 2000, 72% of the channel catfish were between 30 and 39 cm. This same size group represented 48% in 2001, 13% in 2003 and 17% in 2004. In 2000, 13% of the channel catfish were less than 30 cm. In 2003 and 2004, 78% and 73% were less than 30 cm.

Age-0 smallmouth bass were common in 2000 and 2001, but rare in 2003 and 2004 (Figure A2-52). Age-1 smallmouth bass (9 to 18 cm) abundance was higher in 2004 relative to prior years (Figure A2-52), while bass >29 cm were less abundant in 2004.

Degree-Day Correlation
RESULTS

A very strong correlation (r = 0.985) occurred between degree-days-12 and the number of days flow was less than 200 cfs (Table 1, Table A1-1). There was also a very strong trend for increasing numbers of age-1 smallmouth bass in 2003 and 2004. In 1998, 1999 and 2000 age-1 bass were rare at Duffy and Sevens (Figure 5). The increasing trend in age-1 bass closely follows the degree-days trend. 1998 and 1999 had higher flows, cooler growing seasons and there were few age-1 bass in 1999 and 2000. 2000 had higher degree-days and number of age-1 bass was higher in 2001. It was warmer in 2001, 2002 and 2003 and this may explain high recruitment of age-1 bass in 2003 and 2004.

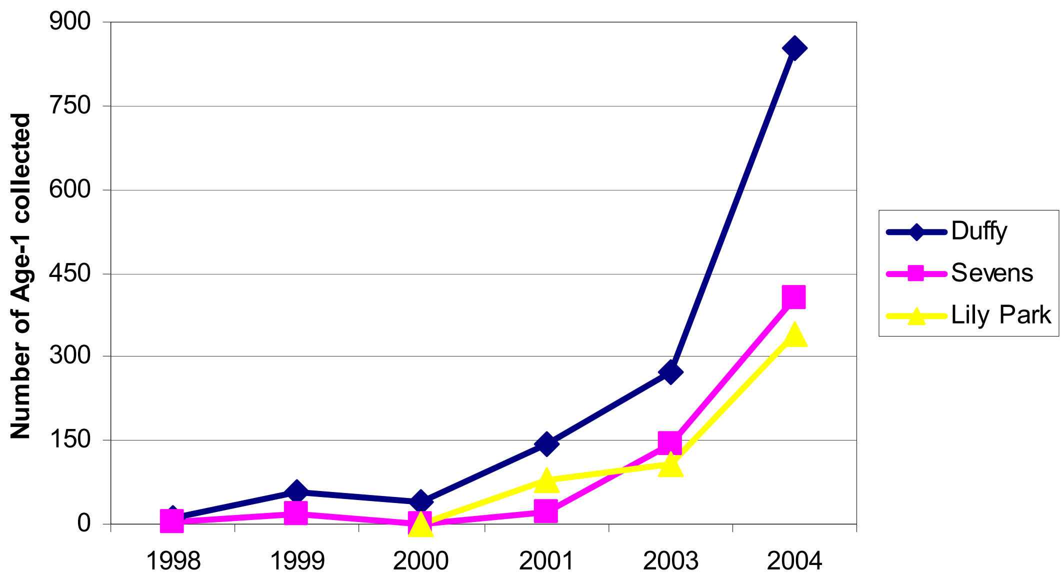

Figure 5. Number of age-1 smallmouth bass (based on length-frequency) collected in the Yampa, 1998 to 2004.

YAMPA RIVER
DISCUSSION

Smallmouth bass were first observed in the Yampa River after Elkhead Reservoir, which is 50 km upstream of the Duffy site, was drained in 1992 (Martinez 2003). At the time sampling began in 1998 smallmouth bass had colonized the Duffy location, but were still rare 90 km downstream at Sevens. In 1998 the northern pike, another exotic predator, was common and widely distributed in the Yampa River and predation impacts from that species were considered highly problematic for native fish management (Nesler 1997).

The first two years of the study (1998 and 1999) were at the end of a five-year-long 'wet' period when flows were above average (1995 to 1999). In 1998 and 1999 the minimum flow was 110 and 166 cfs. The forty-day low flow in 1998 was 248 cfs, it was 237 cfs in 1999. The fish community structure and biomass estimates in 1998 and 1999 were assumed to reflect a carrying capacity that would have continued given similar flow and thermal conditions.

The year 2000 was the first year of the drought and the minimum flow was 30 cfs and flows were below 113 cfs for 40 days. Total fish biomass was somewhat reduced at Sevens and Duffy compared to prior years, but community structure did not appear highly altered. In 1994 base flows were poor, much less than in 2000, but that was a one year event followed by a high-flow year in 1995. Presumably, the low flows in 1994 had not had long term impacts on the native fish community. Likewise it was speculated that if flows had recovered to pre-2000 characteristics the native fish community would have also recovered.

One important impact of the 2000 flows was identified at Lily Park. Flows were about 70 cfs and 110 cfs during the first two sampling trips and large numbers of channel catfish and flannelmouth sucker were caught from four deep pools. On subsequent trips at higher flows (200 and 350) flannelmouth were not found in those pools. They where occupying run habitats in the main channel. These findings indicated that pools were not preferred habitats and were used only when runs were too shallow, < 110 cfs. It was also noted that channel catfish had low recapture rates possibly indicating emigration between sampling trips.

In the second drought year, 2001, the minimum flow was 50 cfs and flows were below 110 cfs for 40 days. Flow and/or habitat conditions were similar to 2000, but thermal properties had changed in 2001 with warmer water in 2001 than preceding years. Numbers of age-0 smallmouth bass were higher in 2001 compared to prior years. At Duffy, numbers of age-0 smallmouth bass were between 700 and 800 from 1998 to 2000, but over 3,500 in 2001. Age-0 smallmouth bass were occupying riffles that speckled dace and mottled sculpin had occupied in prior years. At reduced flows riffles were shallow and apparently suitable habitat for age-0 smallmouth bass, which was also the preferred habitat for native speckled dace and mottled sculpin.

Flows in 2002, the third year of drought were the lowest of the period. The minimum was 2 cfs and flows were less than 12 cfs for 40 days. Degree days were higher in 2002 than all prior years. No fish sampling was done during 2002. Normal pumping and irritation continued in 2002 and in-channel check dams at pumping stations were common.

Spring flows were above average in 2003, but base flows in 2003 were low for the fourth year in a row. The minimum 2003 flow was 43 cfs and flows were below 141 cfs for 40 days. Total fish biomass in 2003 at both Duffy and Sevens was much lower that in 1998 and 1999. Upstream of Maybell, white sucker/hybrids have been the dominant sucker for many years (Pruitt 1977). The drop in white sucker/hybrids biomass and other species including northern pike indicated carrying capacity at Duffy was reduced. There were also large declines in total biomass at Sevens. The lowered biomass in 2003 could be due to less available physical habitat, along with increased mortality rates associated with fish lost to irrigation ditches, and potential increases in avian or terrestrial predation (lack of cover).

Biomass of bluehead sucker was very low at Sevens and Duffy in 2003, and reduced at Lily Park. Anderson and Stewart (2003) quantified habitat availability using 2D modeling at all three sites and identified preferred habitats for flannelmouth and bluehead sucker. They concluded that loss of deep and shallow riffle habitat at flows less than 200 cfs would be problematic for riffle-obligate species, i.e. bluehead sucker (deep riffle) and speckled dace (shallow riffle). Bluehead sucker are likely at a competitive disadvantage when forced to occupy non-preferred habitats.

In 2003 fewer large individuals (>40 cm) were observed at all sites. This could result if adult fish habitat was less available due to lowered mean depths during low flow periods.

Age-1 smallmouth bass had a stronger appearance in 2003 at all sites. Water temperatures during the 2002 summer were much warmer than typical and a longer growing season in 2002 appears to have facilitated recruitment of age-1 smallmouth bass in 2003.

Prior to 2002 only channel catfish >35 cm were collected at Sevens and Duffy and >30 cm at Lily Park. In 2003 an age-0 channel catfish was collected at Lily Park. Age-0 and yearling channel catfish indicated spawning had occurred locally after 2002. Channel catfish 20 to 30 cm increased in abundance at Lily Park in 2003 and 2004, relative to 2000. A high number of small (<25 cm) catfish could be more problematic since adult Colorado Pikeminnow would be more likely to forage on smaller sized catfish.

The U.S. Fish and Wildlife Service have been actively removing channel catfish since 1998 in Dinosaur Canyon, 20 to 80 k downstream of Lily Park (Modde and Fuller 1999). Fuller (2003, 2004 and 2005) described decreased mean length for channel catfish in Dinosaur Canyon in 2003 and 2004. The removal provides a potential explanation for reduction in mean length for channel catfish in Dinosaur Canyon and perhaps Lily Park. However declines in density, biomass and altered size structure were observed for every species, at Lily Park indicating channel catfish were also likely impacted by reduced flows.

By 2004 the Yampa fish community had been strongly modified. The drought provided habitat alterations that were positive for smallmouth bass. A stronger bass presence in turn altered inter-species competitive dynamics. Not only have fish been impacted, but altered physical habitat and thermal conditions are suspected of causing changes within the invertebrate community. Macroinvertebrate productivity may be proportionate to availability of riffle habitat. So when riffles are dewatered for long periods over consecutive years, invertebrate biodiversity and abundance may be reduced. Invertebrate sampling was performed in 1998 and 1999 (Anderson 2000), but was not in later years.

Field observations indicated a change in riffle communities during the study period. In 1998 and 1999 it was observed that dozens of stunned speckled dace and small white sucker would drift down particular riffles in the Duffy station following passage of the shocking boat. In 2001 those same riffles were filled with age-0 smallmouth bass. In 2003 and 2004 those riffles had dozens of small crayfish, with very few fish observed. This shift from fish to crayfish in riffles could be an indication of reduced carrying capacity for fish since crayfish may not be suitable prey for suckers. In contrast crayfish are suitable prey for smallmouth bass.

Anderson and Stewart (2003) calculated habitat diversity for a range of flows and reported that flow less than 200 cfs had reduced habitat diversity. Likewise fish diversity had decreased when smallmouth bass and white sucker increased in relative abundance. The relative increase in smallmouth bass was not due to increased biomass, which was fairly flat at Duffy and Lily Park between years, but due to reductions in abundance of other species.

The greatest difference between the 2003 and 2004 fish community was an even stronger presence of age-1 smallmouth bass, at all three sites. This appeared to be related to the elevated water temperatures during 2003. The fact that age-1 bass were rare during the cooler years (1998 to 2000), increased in the warm years (2001 and 2003) and very abundant after the warmest year (2004) indicates a relationship between temperature and recruitment to age-1. Water temperatures in 2004 were much cooler and bass recruitment to age-1 should naturally be less in 2005. However the total bass population in 2005 is likely to increase if 2004 age-1s have good recruitment to age-2s.

Smallmouth bass was the only species that increased given habitat and thermal conditions that prevailed during the drought period. This increase was concomitant with efforts by the U.S. Fish and Wildlife Service to remove bass from the Yampa River (Hawkins 2004). Smallmouth bass are very efficient predators and appear to have repressed recruitment of most other species. Reduced catch rates of sand shiner and fathead minnow observed in 2001 were attributed to smallmouth bass predation (Anderson 2002).

Without smallmouth bass in the community, a return to normal flows would likely be accompanied by a return to the pre-drought fish community structure. However, the fact that smallmouth bass have become the dominant species in the Yampa River fish community will negatively influence the potential for native fish to recover even during a long period of high flow years.

The potential for native sucker to recover in the short reach from Lily Park to Sevens appears reasonable if high flows return in the next year or two. Flannelmouth sucker and bluehead sucker have been able to persist at Lily Park during the drought period. The higher proportion of flannelmouth sucker at Sevens is suspected to be due to upstream dispersal of excess flannelmouth sucker from Lily Park. Both Lily Park and Sevens had similar drops in density and biomass between 2000 and 2001.

Bluehead sucker appear to be on the verge of being eliminated and flannelmouth sucker are in poor abundance upstream of Sunbeam. Large increases in nonnative white sucker young were observed at Sevens and Duffy in 2003 and 2004, suggesting their survival improved compared to native sucker species. Hybridization with white sucker has been the largest threat to native sucker species in the past and will likely further dilute native sucker abundance in the future. Native sucker had large populations in the Colorado and Gunnison Rivers even given hybridization with white sucker, and the difference appears to be related to differences in base flows and suitable habitat availability (Anderson 2005, this report).

The upper Yampa River has virtually lost its native fish component and will not likely recover as long as smallmouth bass dominate. Higher base flows and cooler temperatures, at least in the range of those in 1998 and 1999, appear to be absolutely necessary to reverse the trend of increasing relative abundance of smallmouth bass. Higher base flows would hamper recruitment to age-1 and restrict age-0 smallmouth to shoreline and backwater habitats, making them easier to control mechanically. Higher base flows would improve habitat diversity and restore a deep riffle niche for bluehead sucker and a swift riffle niche for speckled dace and may also improve macroinvertebrates relative abundance.

COLORADO RIVER
RESULTS

15-Mile Reach (Corn Lake and Clifton)

The 15-Mile Reach experienced a wide range of base flows during the study period. In 1999 base flows were high, about 1,700 cfs for most of the summer. Base flows in 2000, 2001 and 2004 were in the typical range of 900 to 1,200 cfs. Base flows in 2002 were low with mean daily flows less than 300 cfs for 90 days and less than 100 cfs for 40 days. In 2003 base flows were lower than typical, in the range of 300 to 400 cfs.

Percent composition of flannelmouth sucker and roundtail chub were fairly consistent during the study period. Percent composition of bluehead sucker was highest in 1999, the highest flow year and lowest in 2004, the lowest base flow year (Table 17). Endangered fish represented less than 1% of the total catch in all years, except in 2004 when stocked razorback sucker and bonytail were collected.

The percent composition of white sucker, white sucker-hybrids and channel catfish were higher in 2003 and 2004 (lower flow years) (Table 17). Centrarchid composition was highest in 2003 at about 3%, but was similar in 1999, 2000, 2001 and 2004. Composition of carp was highly variable between years.

Anderson (2004) made a combined density estimate (Corn Lake and Clifton). Since Clifton was not surveyed in 2004 all density data for the study period is for the Corn Lake site only.

Density estimates for total fish and flannelmouth sucker in 2003 and 2004 were not dramatically different than prior years (Table 18). The bluehead sucker estimate in 2004 was significantly less than prior years (Table 19). The channel catfish 2004 estimate was significantly higher than years prior to 2002 (Table 19). Carp density was variable between years and it was observed that carp had a propensity to migrate between Corn Lake and Clifton during mark and recapture sampling.

Table 17. Species composition (>15 cm) at the 15-Mile Reach, Colorado River, 1999 to 2004.

COLORADO RIVER	CORN L.	CORN L.	CORN L.	CORN L.	Corn L
Species	1999	2000	2001	2003	2004
Flannelmouth sucker	38	31.0	39.8	32.1	37.6
Bluehead sucker	35	36.3	37.3	30.7	27.6
Roundtail chub	3	4.3	2.9	4.6	4.5
Colo. pikeminnow	0.10	0.04	0.03	0.02	0.03
Razorback sucker	0.20	0.3	0.05	0.2	1.7
White S. + hybrids	6	4.5	5.8	10.4	11.4
Channel catfish	4	6.3	4.7	6.5	8.5
Carp	11	14.1	6.7	11.6	7.4
Sunfish (all species)	0.9	1.5	1.2	2.7	1.4
Trout (all species)	0.0	0.1	0.25	0.1	0.6
Bullhead	1.3	0.6	1.3	0.7	0.6
Blue-flannelmouth hybrid	0.1	0.1	0	0.4	0.5
Bonytail					1.7*
Razorback sucker					1.7*
Sample size	3499	2784	3667	4279	3888*
COLORADO RIVER		CLIFTON	CLIFTON	CLIFTON	
Species		2000	2001	2003	
Flannelmouth sucker		32.5	42.0	32.5	
Bluehead sucker		40.5	26.8	25.2	
Roundtail chub		5.1	5.9	6.0	
Colo. Pikeminnow		0.03	0.09	0.1	
Razorback sucker		0	0.04	0.00	
White S. + hybrids		3.7	4.1	8.0	
Channel catfish		5.1	5.7	10.5	
Carp		11.7	13.8	12.1	
Sunfish (all species)		1.2	1.1	4.0	
Trout (all species)		0.1	0.3	0.3	
Bullhead		0.2	0.4	1.0	
Blue-flannelmouth hybrid		0.2	0	0.5	
Sample size		3276	4485	3558	

* Stocked razorback sucker caught = 67, stocked Bonytail caught = 69 in 2004. These species were subtracted from total catch (4024) since they were stocked in prior years.

Table 18. Density estimates at the 15-Mile Reach, Colorado, 200 - 2004.

Corn Lake	**no/ha**	**no/ha**	**no/ha**	**no/ha**	**no/ha**
Species	**1999**	**2000**	**2001**	**2003**	**2004**
Total fish	843	691	857	967	781
Flannelmouth sucker	311	215	369	379	304
Bluehead sucker	313	232	258	234	163
Roundtail chub	30.9	56.9	29.2	180	59.3
White S. + hybrids	48.3	23.1	105	95.0	74.7
Channel catfish	36.9	54.1	74.4	78.3	271
Carp	88.6	99.0	49.5	147	74.6

Density estimates in the year 2000 were significantly lower than other years for flannelmouth sucker, white sucker, carp and channel catfish (Table 19). Roundtail chub was the only species not significantly different between 2000 and 2003 (Table 19). Anderson (2003) indicated that total fish and flannelmouth sucker estimates in 2000 were likely biased low due to fewer recapture passes and also speculated the true flannelmouth sucker abundance in 2000 was likely similar to prior years.

Total fish biomass was higher in 2003 and 2004 because channel catfish and carp increased after 2002 (Table 20). Flannelmouth sucker biomass was similar over the study period, bluehead sucker biomass declined, and roundtail chub and white sucker biomasses increased in the last two years.

Table 19. Significant differences (alpha = 0.05) in density estimates between years are denoted when letters (a, b, c, d, e, & f) are present in a column.

Corn Lake	1999-a	2000-b	2001-c	2003-d	2004-e
Total fish	b, d, e	a, c, d, e	b, d, e	a, b, c, e	b, c, d
Flannelmouth S	b, d	a, c, d, e	b, e	a, b, e	b, c, d
Bluehead S.	b, d, e	a, e	e	a, e	a,b,c,d
Roundtail Chub	d, e	c	b, d, e	a, c, e	a, c, d
WS & Crosses	c, d, e	c, d, e	a, b	a, b	a, b
Carp	d	c, d	a, b, d	a, b, c, e	d
Channel catfish	b, c, d, e	a, e	a, e	a, e	a, b, c, d

Table 20. Biomass estimates at the 15-Mile Reach, Colorado River, 2000 to 2004.

Colorado River	Biomass estimate in kg per hectare				
Corn Lake	**kg/ha**	**kg/ha**	**kg/ha**	**kg/ha**	**kg/ha**
Species	**1999**	**2000**	**2001**	**2003**	**2004**
Total fish	590	463	548	711	697
Flannelmouth sucker	253	165	284	299	267
Bluehead sucker	160	99	121	103	80
Colorado Pikeminnow	1.4	1.6	0.9	1.0	1.0
Roundtail chub	9	11	7	38	17
White S. + hybrids	20	8	23	31	32
Channel catfish	34	41	60	70	192
Carp	112	136	52	170	109

Mean lengths of fish in 2004 were not different from prior years (Table 21) except for roundtail chub. Very few age-1 roundtail chub were collected in 2004 relative to before 2002 and fewer age-1 fish in the sample resulted in a higher mean length in 2004. In 1999, 2000 and 2001 about half the roundtail chub sampled were less than 20 cm. The percent less than 20 cm was about 20% in 2003 and only 10% in 2004. In contrast the number of carp less than 20 cm sharply increased in 2003 and 2004 compared to prior years.

Mean lengths (Table 21) and length frequency distributions (Figures A3-4 and A3-12) were fairly constant over the study period for flannelmouth and bluehead sucker (Table 21). Roundtail chub and white sucker had higher mean lengths in 2003 and 2004 (Table 21).

Table 21. Mean lengths of fish at Corn Lake, Colorado River, 2000 to 2004.

Corn Lake					
Species	**1999**	**2000**	**2001**	**2003**	**2004**
Flannelmouth sucker	41.2	38.9	40.6	41.7	41.2
Bluehead sucker	36.5	33.3	34.8	34.0	33.4
Colorado Pikeminnow	57.2	87.5	63.1	65.3	65.0
Roundtail chub	23.2	23.5	20.9	27.0	30.7
White S. + hybrids	25.7	24.0	18.7	28.6	28.6
Channel catfish	43.3	40.4	41.2	42.2	39.3
Carp	41.7	42.3	26.2	38.8	35.1
Smallmouth bass	30.9	8.1	11.1	12.8	21.0
Largemouth bass	15.1	12.9	12.5	14.5	12.7

It was rare in the baseline years to capture age-0 roundtail chub, but age-1 (11 to 20 cm) was the most abundant size-group by far in both 2000 and 2001. Age-1 roundtail chub were rare in 2003 and again in 2004 (Figure A2-22), an indication of poor YOY survival in 2002 and 2003. 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 and the size structure in 2004 was similar to 2001 (Figures A2-55).

White sucker size distribution was also variable between years, mainly in the size of the age-0 mode. In 2004 both age-0 and fish >35m were more numerous than in 2003 results with similar mean lengths between years (Figure A2-30).

Prior to 2002, channel catfish less than 24 cm were rarely caught at Corn Lake. In 2004 ten fish from 18 to 24 cm were collected and in 2003 four fish near 15 cm were caught. The incidence of juvenile channel catfish appears increased during lower flow years.

In 2003 there was a large increase in the number of juvenile largemouth and smallmouth bass. In contrast, the number of sunfish collected at Corn Lake in 2004 was lower than all prior years. The number of Corn Lake centrarchids (largemouth bass, smallmouth bass, green sunfish and bluegill) netted in 2003 was 575, but it was only 150 in 2004, given similar sampling efforts.

Because of the low number of centrarchids at Corn Lake a single pass was made at the Clifton site in 2004. Clifton had several backwaters that were suitable sunfish habitat with high abundance in 2003. The mean number of centrarchids per pass at Clifton in 2003 was 247, but in 2004 it was only 71. Centrachids declined at both sites by over 70% between 2003 and 2004.

COLORADO RIVER DISCUSSION

Native fish comprised about 70% of the total fish community (fish > 15 cm) for each year in the study period. Since community structure (fish >15 cm) was not extensively altered in 2003 and 2004, impacts of the 2002 base flows were not long lasting.

There appears to be the start of a decreasing trend in bluehead sucker abundance at Corn Lake. Bluehead sucker biomass was strongly associated with availability of deep-riffle habitat (Anderson and Stewart 2003). The fact that deep-riffle habitats decrease with decreasing flows indicate a likely cause and effect relationship between reduced flow and declining bluehead sucker abundance.

Flannelmouth sucker density and biomass was constant during the study period indicating stability during the low flow years of 2002 and 2003. Flannelmouth sucker prefer run (moderate velocity) habitats, which are generally maintained over a wider flow range.

Roundtail chub density and biomass appeared to be increasing in 2003 and 2004 indicating this species may have had a positive response to habitat and flow conditions found in 2002 and 2003. Roundtail chub is a pool (low velocity) habitat oriented species, which increases in area with reducing flows, which could be a factor for increasing chub abundance.

The observed trends in population abundance for bluehead sucker, flannelmouth sucker and roundtail chub, albeit fairly minor, were consistent with the observed and modeled trends in habitat availability. Another alteration in the native fish community was a lower proportion of age-1 roundtail chub and flannelmouth sucker collected in 2003 and 2004. This could be an indication of reduced survival of either age-0 or age-1 fish during the low flow period, more likely related to predation than habitat availability.

Total fish biomass was higher in 2003 and 2004 due to increases in channel catfish, carp and to a lesser extent white sucker. These data strongly suggests nonnative species had the greater benefit from drought conditions.

The increased channel catfish population could be a result of improved habitat, forage or reduced mortality from angling during later years of the study period. Not only was channel catfish biomass higher in 2003 and 2004 but recruitment of catfish as indicated by increase presence of fish <26 cm was also observed.

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).

Increased white sucker abundance might also indicate better habitat availability for this species during reduced flow years. White sucker were not commonly caught in main channel habitat with faster velocities and most were collected from backwater habitat that tend to increase in area during reduced flow periods.

There was a definite increase in abundance for sunfish species in 2003 and attributed to the lower flow and a warmer growing season in 2002. There was a definite decrease in sunfish abundance in 2004, indicating a return to the pre-2002 situation for sunfish. The U.S. Fish and Wildlife Service removed sunfish from the 15-Mile Reach in the 2004 summer, prior to our sampling in October. Bob Burdick (U.S.F.W.S. Grand Junction) stated there were 223 green sunfish, 47 bluegill, 422 smallmouth bass and 87 largemouth bass removed from the entire 15 miles. Our study sites represent 4 miles of the total reach. The removal efforts could help explain the fewer sunfish we collected in 2004.

GUNNISON RIVER
RESULTS

There were acute differences in species composition (fish >15 cm) between Delta and Escalante in 2004 and both sites were consistent with 2003 surveys. At Delta the composition of native species were flannelmouth sucker 40%, bluehead sucker 23% and roundtail chub 4% (Table 22). At Escalante bluehead sucker were 45%, flannelmouth sucker 24% and roundtail chub 13%. Native species (fish > 15 cm) comprised 66% at Delta and 88% at Escalante (Table 22).

White sucker were 24% of the catch at Delta, but only 13% at Escalante and carp were 8% at Delta versus 3% at Escalante in 2004 (Table 22). Hybridization rates for the percentages of pure, white sucker-X-bluehead sucker and white sucker-X-flannelmouth sucker were fairly similar between Delta and Escalante in 2004, but different than Austin.

Table 22. Species composition (fish >15 cm), Gunnison River, 2003 and 2004.

Gunnison River	Austin	Delta	Delta	Escalante	Escalante
Species	2003	2003	**2004**	2003	**2004**
Flannelmouth sucker	17.6%	41.2%	**39.4%**	28.7%	**20.6%**
Bluehead sucker	44.4%	22.7%	**23.3%**	41.8%	**48.5%**
Roundtail chub	0.7%	6.2	**3.4%**	12.5%	**13.4%**
White S. + hybrids	28%	22.7%	**23.6%**	9.6%	**12.8%**
Carp	1.8%	6.5%	**8.3%**	6.2%	**3.0%**
Brown trout	6.7%	0.6%	**1.0%**	1.1%	**1.1%**
Rainbow trout	0.8%	0.1%	**0.0%**	0%	**0.0%**
Native species			**66.3%**		**82.8%**
Sample size	1934	1622	**3378**	1475	**4381**
	Austin	Delta	Delta	Escalante	
White sucker	43.4%	67.9%	**62.7%**	67.6%	**68.3%**
White X flannelmouth	31.9%	23.6%	**27.6%**	18.3%	**19.8%**
White x bluehead sucker	24.7%	8.4%	**9.7%**	14.1%	**11.9%**

Channel catfish, northern pike, and smallmouth bass were not captured in the Gunnison River in 2003 or 2004 (Table 22). Sand shiners, red shiners, black bullhead, largemouth bass, mottled sculpin and plains killifish were incidental in the catch.

Species composition for total and small fish (<15 cm) were also different between Delta and Escalante. The top five most numerous species for total fish at Delta were flannelmouth sucker, white sucker, bluehead sucker and fathead minnow and carp, respectively. The top five species at Escalante were bluehead sucker, flannelmouth sucker, fathead minnow, roundtail chub and white sucker (Table A1-5).

Size structure in the 2003 and 2004 samples were strongly different between Delta and Escalante. Delta had higher mean lengths for flannelmouth sucker, bluehead sucker and roundtail chub than Escalante whereas mean lengths for white sucker and carp were similar (Table 23). Mean lengths were higher in 2004 for all species compared to 2003 (Table 23).

Escalante had a large abundance of smaller/juvenile-sized fish. The percent of fish less than 21 cm at Escalante for flannelmouth sucker, bluehead sucker, roundtail chub, white sucker & crosses and carp were 8%, 17%, 59%, 22% and 36%, respectively, and at Delta they were 2%, 5%, 36%, 27% and 27%, respectively. Flannelmouth sucker over 45 cm, bluehead sucker > 37cm and roundtail chub >30 were more abundant at Delta (Figures A3-14, A3-6, A3-24) than Escalante (Figures A3-15, A3-7, A3-25). White sucker and carp (age-0 and age-1) size structures were fairly similar for the two sites (Figures A3-31, A3-32, A3-57, A3-58).

Mark-recapture estimates were not available in 2003 (2 passes) and the 2004 abundance estimates were made from six passes. Escalante had the higher total fish density estimate (1052/ha), but Delta had the higher total fish biomass (586 kg/ha) (Table 24). Density estimates for flannelmouth sucker, bluehead sucker and roundtail chub were all significantly different (alpha = 0.05) between these two sites.

Table 23. Fish mean lengths, Gunnison River, 2003 and 2004.

Species	Austin	Delta	Delta	Escalante	Escalante
	2003	2003	**2004**	2003	**2004**
Flannelmouth sucker	46.0	41.1	**44.4**	35.6	**37.5**
Bluehead sucker	35.4	33.9	**34.8**	26.1	**27.9**
Roundtail chub	24.4	23.7	**27.2**	18.3	**21.0**
White S. + Hybrids	38.6	33.0	**30.4**	32.2	**29.9**
Carp	56.6	37.6	**42.5**	39.5	**39.9**

At Delta, flannelmouth sucker was the species with highest biomass (301 kg/ha) and density (318/ha). At Escalante flannelmouth sucker was the highest biomass species (154 kg/ha), but was third in density (236/ha) (Table 24). The flannelmouth sucker density and biomass estimate at Delta was very similar to Corn Lake (Colorado River) in 2004.

Bluehead sucker was the most abundant species at Escalante (431/ha), and biomass (117kg/ha) was about double Delta's (54 kg/ha). Roundtail chub had very high abundance at Escalante (259/ha), and biomass (34kg/ha) was about five times greater than Delta (7kg/ha) (Table 24). Density estimates for carp and white sucker were not very (0.05 alpha) different between Delta and Escalante (Table 24).

Table 24. Density and biomass estimates for Delta and Escalante Gunnison River, 2004.

	DELTA		ESCALANTE	
	2004	**2004**	**2004**	**2004**
Species	**no/ha**	**kg/ha**	**no/ha**	**kg/ha**
Total fish	656	585.6	1052	482.1
Flannelmouth sucker	318	300.8	236	153.7
Bluehead sucker	112	53.5	431	116.9
Roundtail chub	22	7.0	259	34.2
White S. + hybrids	132	69.2	128	55.8
Carp	82	155.1	64	121.4

The differences in the Delta and Escalante density and biomass estimates were in large part due to the different size or age-structure of each site. Escalante was characterized by higher abundance of smaller fish and Delta was characterized by fewer but larger fish.

Gunnison River Channel Topography
RESULTS

Channel bathymetry was surveyed in 2004. The coordinates were sent to Utah State University for 2D modeling, for the same modeling process used in 2001 and 2002. Results are expected in June 2005. Habitat modeling is scheduled for completion by December 2005 and will be presented in the annual progress report due in June 2006.

GUNNISON RIVER
DISCUSSION

The native fish community (species composition, size/age structure, density and biomass) at Delta and Escalante were much different and it is strongly suspected this indicates different habitat characteristics between sites. Bluehead and flannelmouth sucker biomass were correlated to habitat availability on the Colorado and Yampa River (Anderson and Stewart 2003) and these correlations will be also be examined on the Gunnison River.

Escalante with its high density juvenile bluehead sucker and roundtail chub was unique to all others study sites, indicating Escalante had more much rearing habitat availability than any other study location. Juvenile bluehead and roundtail chub habitat suitability criteria will be developed based on relationships identified at Escalante.

Roundtail chub were not found to be highly correlated to a single meso habitat type on the Yampa and Colorado Rivers (Anderson and Stewart 2003). The Gunnison appears more suitable for describing roundtail chub habitat since young fish were abundant at Escalante and adult fish were common at Delta. The lack of nonnative predators (e.g. channel catfish) factors out predation for regulating roundtail chub density.

White sucker and carp had similar size structures and abundance estimates between Delta and Escalante. This suggests habitat or other limiting factors were somewhat equal between sites for these species. This also indicates that juvenile life stages of white sucker and carp had less habitat specialization than native sucker and chub.

The Gunnison community did not have nonnative predators so native fish biomass is likely controlled mostly by physical habitat carrying capacity. This makes the Gunnison River an excellent control site for hypothesis testing about impacts of predators (pike, bass, and catfish) on native fish.

2005 will be the final year for fish sampling. The 2005 sampling effort is planned to be more intense than the 2004 survey. The extra effort is designed to provide more precise habitat use information by PIT tagging individual fish. This should help clarify emigration from the study site. Seven passes were found to produce tighter confidence intervals on the Colorado River so seven passes are planned for 2005.

Species composition for native sucker and roundtail chub observed in 2003 (Anderson 2004) and in the 2004 survey were fairly similar to that reported for collections in 1992 and 1993 (Burdick 1995). It appeared that white sucker composition has increased in the Gunnison River during the past ten years.

DOLORES RIVER
RESULTS

Big Gypsum - Results

In 2000 and 2001 native species composition for fish over 15 cm was 73% and 88%, and it was 80% and 65%, respectively, for total fish. Native species compositions fell to 43% (>15 cm) and 53% (total fish) in 2004 (Table 25). Roundtail chub and speckled dace were still common in 2004, but flannelmouth and bluehead sucker were rare.

Species composition was highly variable between years for flannelmouth sucker, bluehead sucker and roundtail chub. In 2000 and 2001 black bullhead were uncommon (fish >15 cm), but this was the most common species in 2004 (Table 25). Very high numbers of red shiner were collected in 2001 compared to the other years.

Table 25. Species composition for fish over 15 cm and total fish at Big Gypsum.

Gunnison River	Big Gypsum fish > 15 cm			Big Gypsum total fish		
Species	**2000**	**2001**	**2004**	**2000**	**2001**	**2004**
Flannelmouth sucker	**16.0%**	**57.5%**	**2.4%**	**10.2%**	**20.8%**	**3.3%**
Bluehead sucker	**2.2%**	**5.8%**	**1.2%**	**1.0%**	**12.3%**	**0.7%**
Roundtail chub	**54.9%**	**24.5%**	**39.2%**	**51.2%**	**18.3%**	**30.2%**
Channel catfish	**15.8%**	**8.3%**	**5.3%**	**8.1%**	**2.2%**	**3.0%**
Black bullhead	**5.2%**	**0.6%**	**44.7%**	**2.5%**	**0.5%**	**25.8%**
Carp	**3.4%**	**1.7%**	**7.2%**	**1.7%**	**0.4%**	**4.1%**
Green sunfish	**2.0%**	**1.4%**	**0**	**4.0%**	**1.5%**	**3.8%**
Pumpkinseed		**0**			**0.4%**	
Speckled dace				**18.1%**	**13.5%**	**18.3%**
Red shiner				**2.8%**	**28.1%**	**8.2%**
Sand shiner				**0.1%**	**1.8%**	**1.2%**
Fathead minnow		**16.0%**	**57.5%**	2.4%	**0.4%**	**1.4%**
Brown trout	**0.6%**			**0.3%**		
Native species	73.1%	87.9%	42.8%	**80.5%**	**64.9%**	**52.5%**
Sample size	501	**636**	**418**	1078	2795	755

Total fish density estimates were not significantly different between years (Table 26). Flannelmouth and bluehead sucker density were significantly different for all years (Table 26). In 2000 and 2001 roundtail chub, channel catfish and flannelmouth sucker were the dominant species in the community. In 2004 black bullhead and roundtail chub were most numerous.

Table 26. Big Gypsum density estimates for 2000, 2001 and 2004. Significant differences (alpha = 0.05) between years included.

Gunnison River	Big Gypsum density fish/ha			sd (significant difference)		
Species	**2000**	**2001**	**2004**	**2000/2001**	**2000/2004**	**2001/2004**
Total fish	112.8	131.2	118.4			
Flannelmouth sucker	20.0	62.2	2.6	sd	sd	sd
Bluehead sucker	1.6	5.9	0.7	sd	sd	sd
Roundtail chub	48.4	37.5	35.2		sd	
Channel catfish	39.9	30.0	8.7		sd	
Black bullhead	7.5	0.9	63.3	sd	sd	sd
Carp	8.7	3.2	8.3			

Total fish biomass (>15 cm) in kg/ha was very poor in all years. Total fish biomass was about double in 2000 than in 2001 and 2004, suggesting a drop in carrying capacity for channel catfish during the study period (Table 27). Flannelmouth sucker, bluehead sucker, roundtail chub also had declines in biomass. Black bullhead was the only species with a 2004 biomass increase.

Table 27. Big Gypsum biomass estimates for 2000, 2001 and 2004

Gunnison River	Big Gypsum biomass kg/ha		
Species	**2000**	**2001**	**2004**
Total fish	41.2	17.8	21.4
Flannelmouth sucker	4.2	2.6	0.3
Bluehead sucker	0.2	0.6	0.1
Roundtail chub	2.8	2.1	1.6
Channel catfish	15.9	9.9	3.1
Black bullhead	0.6	0.1	2.8
Carp	17.5	2.6	13.6

The size structure of the fish community was extremely skewed with small fish. The only species with fish >30 cm in the 2004 sample were carp (30) and channel catfish (11) (Figures A3-59 and A3-65). The low number of fish over 20 cm explains the poor biomass at this site. In 2004 the mean length was only 13.4 cm for flannelmouth sucker and only 15.6 cm for roundtail chub (Table 28). The lack of flannelmouth, bluehead, and roundtail chub over 20 cm (Figures A3-16, A3-18, A3-26) was not found for any other study site. Mean lengths were highest in 2000 for all species except channel catfish.

Table 28. Mean lengths for Big Gypsum study sites for 2001, 2002, 2004, Dolores River.

	Mean length in cm			Sample size (n)		
Species	**2000**	**2001**	**2004**	**2000**	**2001**	**2004**
Flannelmouth sucker	23.9	14.2	13.4	110	580	21
Bluehead sucker	23.6	12.1	22.5	11	343	5
Roundtail chub	19.5	10.9	15.8	552	512	228
Carp	53.0	35.2	49.6	18	11	31
Channel Catfish	30.3	25.8	32.1	87	62	22
Black Bullhead	21.5	13.6	17.6	27	14	196
Green Sunfish	16.8	9.6	9.4	43	42	26

DOLORES RIVER
DISCUSSION

The pre- and post-McPhee dam annual hydrographs where much different, with the pre- having high natural peak flows (3,000 to 5,000 cfs) and very low base flows (two to five cfs) and the post- with much reduced runoff flows but increased based flows. During the drought period of 2001 to 2004 runoff flows were completely captured by the reservoir and base flows were also severely downsized. The Big Gypsum study site was unique to all other sites in that poor runoff flows appears to be a primary limiting factor for native fish biomass. It was hypothesized that fine sediments had accumulated beyond the threshold necessary to impact invertebrate and fish productivity.

Habitat analysis was completed at the Big Gypsum site in 2001 and results presented in Anderson and Stewart (2003). In 2003 an effort was made to survey the floodplain and use the HEC-RAS model reference to determine bankfull flows. This survey is expected to facilitate understanding the consequences of the lack of channel maintenance flows on habitat quality. These geomorphic results will be available in the 2006 report.

The number of age-1 flannelmouth and bluehead were observed to vary greatly between 2000 and 2001, suggesting these juvenile fish could have migrated from upstream locations. Total fish biomass at Big Gypsum was very poor compared to other rivers and indicates poor fish productivity. The fact that Big Gypsum had a relatively high percent of native species should not be mistaken as evidence that the native fish community was in fairly good shape. The entire biological data indicates the status of the native fish community is highly precarious.

Black bullhead is a species that is strongly associated with backwater habitat types. Black bullhead could not dominate a community (density) unless habitat conditions were highly skewed for backwater, a relative minor habitat in most riverine environments.

Black bullhead may not be a highly efficient predator, i.e. smallmouth bass, but their increase in abundance corresponds with declines in flannelmouth sucker and roundtail chub. A prodigious black bullhead population jeopardizes native species, except perhaps speckled dace.

The trend in bullhead abundance may reverse during an extended period of years of high runoff flows. Monitoring Big Gypsum for several years is strongly recommended and will be necessary to understand relationships between runoff flows and habitat, habitat and black bullhead abundance, and black bullhead and native fish abundance.

Valdez et al (1992) reported no significant changes in species composition between the sampling in 1990 and 1991 to a similar survey done in 1981. Therefore, concluding the ichthyofaunal community remained relatively stable over that ten year period.

The Big Gypsum site is located in Reach 5 of the Valdez et al. (1992) investigation. The Valdez 1991 and 1992 surveys found flannelmouth sucker were most prevalent downstream of Big Gypsum (Reaches 3 and 4) at about 52 to 56 %, about 40 to 45% in Reaches 2 and 5, about 20% upstream in Reach 6 and lowest about 15% in Reach 1, near the state line. Roundtail chub were common in the two upper Reaches (5 & 6) at about 30% of the netting and electrofishing catch. Roundtail chub were uncommon in lower Reaches comprising about 8% in Reach 4 and less than 5% in reaches 1, 2 and 3. Bluehead sucker were more common in lower Reaches 1, 2 and 3 comprising from 11% to 18%, but were about 5% to 8% in upper Reaches 4, 5 and 6. Speckled dace were rare in lower Reaches 1, 2, 3, 4 and 5 with only 1 to 3% of the catch, but were common in reach 6 (23%). These prior samples also indicate a strong decline in native fish, given Big Gypsum is representative of Reach 5.

Mike Japhet (CDOW biologist in Durango, Colorado) has sampled a 1,000 ft reach below the Dove Creek power plant beginning in 1986 and has accumulated 15 years of data over the last 18 year period. The Dove Creek site was sampled by wade electrofishing using a stationary shore shocker. At least one pass was made, but in most years there were two passes at the site.

The three most common species collected at the Dove Creek site over the 18 year period were roundtail chub, speckled dace and mottled sculpin. Mottled sculpin was the most common species in 1986, 1987 and 1989, but ranked fourth in 2002 and 2003 and averaged 24% of the catch for the entire period. Flannelmouth sucker were rare at Dove Creek (1.4%).

Fish community composition was fairly stable at the Dove Creek site from 1986 to 2000. The nonnative fish with the greatest influence were brown and rainbow trout. When trout were excluded, native species comprised between 95 to 100% of the remaining catch at Dove Creek site. In 2002 and 2003 native composition dropped to 79 and 76% (trout excluded). In 2002 and 2003 a large increase in fathead minnow and green sunfish were observed. The long term trend data at Dove Creek indicate that habitat conditions were more favorable for nonnative species after 2002 than in earlier years.

COMBINED SITES
RESULTS and DISCUSSION

Each study site had unique species composition, fish biomass (Table 29 and 30) and hydrology characteristics. A rather compelling trend was that rivers with high base flows (Colorado and Gunnison) had greater overall fish biomass, native fish biomass and a higher percent and diversity of native fish in their communities (Table 30). Habitat diversity was significantly correlated to magnitude of the base flow (Anderson and Stewart 2003) and may explain why higher base flows are positive for native fish. Further hypotheses testing can be accomplished when 2D modeling and habitat availability results for the Gunnison River are available.

The two Gunnison River sites were a valuable addition to the 2D site data base. The fact that Escalante had very high roundtail chub and bluehead sucker biomass indicates habitat availability for these species may be near ideal. Flannelmouth biomass was found to be highest at Delta indicating ideal habitat for this species. These sites appear to provide optimal habitat conditions for these three native species. Escalante also had a greater abundance of juvenile fish than any site in the study, providing empirical data for developing optimal juvenile habitat suitability criteria.

Table 29. Species composition (%) for fish >15 cm for pre- and post 2002, all study sites surveyed during the study period.

Native >15cm	Escalan	Corn L.	Delta	Clifton	Austin	Lily Park	Big Gyp	Sevens	Duffy
pre- 2002	*	79	*	78	*	57	73	72	13
post- 2002	80	70.5	67	64	62.7	58	42	31	7.5
Flannelmouth S.	Lily P	Delta	Corn L.	Clifton	Sevens	Escalante	Austin	Duffy	Big Gyp
pre- 2002	48	*	39	33	47	*	*	5	16
post- 2002	52	40	38	33	26	22	18	3	2
Bluehead S.	Escalan	Austin	Corn L.	Clifton	Delta	Lily Park	Sevens	Big Gyp	Duffy
pre- 2002	*	*	36	41	*	9	20	2	4
post- 2002	45	44	28	25	23	6	2	1	0.5
Roundtail Chub	Big Gyp	Escalante	Clifton	Corn L.	Delta	Duffy	Sevens	Austin	Lily P.
pre- 2002	55	*	5	4	*	4	5	*	0.02
post- 2002	39	13	6	4.5	4	4	3	0.7	0.3
White sucker	Duffy	Sevens	Austin	Delta	Escalan	Corn L.	Clifton	Lily Park	Big Gyp
pre- 2002	72	13	*	*	*	6	4	0.02	0
post- 2002	38	36	28	23	11	11	8	1.3	0
Carp	Clifton	Corn L.	Delta	Big Gyp	Escalan	Sevens	Lily Park	Austin	Duffy
pre- 2002	12	10	*	3	*	5	2	*	2
post- 2002	12	7	7	7	5	5	3	2	1
Channel catfish	Lily P.	Clifton	Corn L.	Big Gyp	Duffy	Sevens	Escalante	Delta	Austin
pre- 2002	40	5	5	16	4	7	0	0	0
post- 2002	27	11	8.5	5	5	4	0	0	0
NN predator *	Duffy	Big Gyp	Sevens	Lily P.	Clifton	Corn L.	Escalante	Delta	Austin
pre- 2002	8	5	2	0.8	1	1	0	0	0
post- 2002	44*a	26*c	23*a	9*a	4*b	3*b	0	0	0

*a is smallmouth bass, b is all sunfish and c is black bullhead

Table 30. Biomass estimates for fish >15 cm for pre- and post 2002 for all study sites survey during the study period.

Total fish >15cm	Corn L.	Delta	Clifton	Escalante	Lily Park	Sevens	Duffy	Big Gyp
pre- 2002	550	*	522	*	521	164	66	41
post- 2002	700	586	519	482	240	74	21	21
Flannelmouth S.	Delta	Corn L.	Clifton	Escalante	Lily P.	Sevens	Duffy	Big Gyp
pre- 2002	*	270	200	*	218	66	3.7	4
post- 2002	300	270	164	154	120	24	1.1	0.3
Bluehead S.	Escalante	Corn L.	Clifton	Delta	Lily P.	Sevens	Duffy	Big Gyp
pre- 2002	*	140	78	*	37	16	1.6	0.2
post- 2002	117	80	56	54	17	1	0.1	0.1
Roundtail Chub	Escalante	Corn L.	Clifton	Delta	Big Gyp	Sevens	Lily Park	Duffy
pre- 2002	*	9	14	*	2.8	5	0.2	2.6
post- 2002	34	17	12	7	1.6	1.5	0.6	0.3
White sucker	Delta	Escalante	Corn L.	Clifton	Duffy	Sevens	Lily Park	Big Gyp
pre- 2002	*	*	21	15	40	23	0.4	0
post- 2002	69	56	32	13	10.7	10	1.1	0
Carp	Clifton	Delta	Escalante	Corn L.	Lily P.	Sevens	Big Gyp	Duffy
pre- 2002	180	*		100	29	28	18	7
post- 2002	165	155	121	110	32	21	13	1.6
Channel catfish	Corn L.	Clifton	Lily Park	Sevens	Duffy	Big Gyp	Delta	Escalante
pre- 2002	50	92	224	22	4.9	16	0	0
post- 2002	190	107	54	12	3.4	3	0	0
NN predator **	Lily Park	Sevens	Big Gyp	Duffy	Corn L.	Clifton	Escalante	Delta
pre- 2002	6.8	1.6	0.6	2.3	0.5	0.5	0	0
post- 2002	8.2*a	5*a	2.8*c	1.9*a	0.5*b	0.5*b	0	0

*a is smallmouth bass, b is all sunfish and c is black bullhead

The rivers with the most extreme drought related flow reductions had the largest drops in native species composition and biomass, i.e. Big Gypsum and Sevens (Tables 29 and 30). The Gunnison River did not experience a drop in base flows during the drought and Escalante had the highest native fish relative abundance, Duffy the lowest. Lily Park post 2002 had only a single common native fish (flannelmouth sucker). At Big Gypsum roundtail chub and speckled dace were the only common native fish in 2004.

Nonnative predator relative abundance increased on the Yampa and Dolores rivers during the drought period, but not on the Colorado River.

The Gunnison River did not experience severe low flows during 2002 or prior years, but had base flows in the natural range for the past several years. Data collected in 2003 and 2004 was similar to Osmundson (1999) and Burdick (1995) who reported high abundance of adult flannelmouth sucker, bluehead sucker and roundtail chub in the Gunnison River 1995 and 1996.

The Gunnison River appears to be an example of the critical importance of maintaining base flows capable of providing habitat stability and therefore native fish stability. This stability refers to maintenance of the natural variability of base flows. Variability of the flow regime is believed to be critical to ecosystem function and native species biodiversity Poff et al. (1997). The Yampa River is a negative example of the critical importance of maintaining natural base flow variability. Loss of natural base flow variability on the Yampa is the primary cause of destabilized habitats and displacement of native fish relative abundance.

Peak flows did not appear to be important for determining biomass or carrying capacity. The Yampa River with its near natural spring runoff flows (runoff variability intact) was a low biomass river and the Gunnison River with a highly reduced spring runoff (runoff variability destabilized) was a high biomass river.

Channel geometry may be a factor determining habitat quality and biomass. At moderate and low flows the Yampa River had a proportionally wider channel than the much larger volume Colorado and Gunnison Rivers. Some evidence was available that the Yampa River channel is unstable and actively cutting.

The Dolores River is an apparent example of reduced fish productivity due to poor runoff flows. The Big Gypsum site appears to be a suitable location for forming and testing hypothesis concerning geomorphic processes such as flushing flows, sedimentation and channel maintenance as limiting factors for native species.

The Gunnison River fish community did not include the nonnative predators, such as northern pike, channel catfish or smallmouth bass. Therefore the Gunnison River could be a control area for testing hypotheses regarding predation impacts in rivers where predation is perceived to be problematic for native species.

The two Gunnison River sites had much higher white sucker and hybrid biomasses suggesting superior habitat or thermal regimes for this species. Inclusion of a thermal component could improve the predictive abilities of habitat or biomass modeling for white sucker. It is likely that altering reservoir releases for thermal management from the Aspinal Unit would have a direct impact on white sucker abundance.

Burdick (1995) reported white sucker catch rates for the Gunnison River 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.

Channel catfish have been identified as negatively impacting native fish populations in the Colorado basin (Tyus and Nikirk 1990), particularly roundtail chub. Channel catfish biomass was highest in the Colorado River and composed 27% of the total biomass. Channel catfish were stocked in the Gunnison River many years ago (DOW stocking records). Burdick speculated the Gunnison was too cool for channel catfish spawning and they had to migrate downstream to warmer reaches below Redlands Diversion dam for suitable spawning areas. The dam blocked juvenile and young adult fish from upstream colonization.

Construction of temporary low-head fish traps could be an effective way of inexpensive long term control for unwanted species like channel catfish in the Colorado River. For example a trap at Loma might be effective at reducing channel catfish in the 15 and 18 Mile Reaches. A trap just below Cross Mountain Canyon appears to be a good site to reduce channel catfish on the Yampa River.

Carp were over 25% of the total biomass on the Gunnison and Colorado rivers and at Sevens. Carp were over 60% of the total biomass at Big Gypsum. Presently this project has not identified suitability criteria for carp habitat, but that exercise might provide useful information for understanding of carp habitat and may assist in control of this species.

Upstream of the Roller Dam (Highline), the Colorado River did not experience severe drought flows during the study period because of water deliveries to the Highline Canal. Prior surveys (Anderson 1999) indicated native fish composition and biomass at Parachute were similar to the 15-Mile Reach. The 1994, 1995 and 1996 surveys in Debeque Canyon found juvenile roundtail chub, flannelmouth sucker and bluehead sucker Anderson (1999). Anderson (1999) proposed that habitat in Debeque Canyon was highly suitable for juvenile fish. Juvenile habitat availability may be similar at Debeque and Escalante Canyons and important reaches for recruitment of native fish.

Anderson and Stewart (2003) found the mean velocity of a habitat type was strongly correlated with bluehead sucker biomass. Other hydraulic metrics could be tested against native fish biomass, e.g. maximum depth, maximum velocity and width/depth ratios for habitat diversity values. Some of these metrics will be examined with the Gunnison River data.

A much simpler approach than 2D modeling could be investigated for instream flow recommendations. Mean riffle depth and velocity are used in the R2Cross instream flow method used for cold water stream and rivers. Mean riffle depths and velocities from the Colorado and Gunnison Rivers, at typical base flows, can be determined and serve as empirical criteria for rivers with high native fish biomass. In contrast mean riffle depths and velocities at typical base flow in the Yampa and Dolores rivers are representative of mean depths and velocities that would be below acceptable criteria.

SUMMARY

The Yampa River had the most severely reduced flows during the drought period (2000 - 2004) and experienced the most negative impacts to native fish. Total fish biomass and native fish biomass were much less in 2004 and baseline years. It was concluded that native fish in the Yampa River will not likely recover without increased base flows and/or decreased summer water temperatures. It was also concluded that channel widening may be impacting habitat availability. Evidence was presented that somewhat reduced runoff flows would not be problematic for most native species in the Yampa River.

Speckled dace, mottled sculpin and bluehead sucker were very rare at the study sites in 2003 and 2004 and these species may be very close to elimination from the river. Flannelmouth sucker and roundtail chub were found to be uncommon and declining upstream of Cross Mountain.

Smallmouth bass composition increased in 2003 and 2004 at Sevens and Duffy and white sucker increased at Sevens in 2004. The increase in smallmouth bass appeared related to elevated summer water temperatures during the low flow period of 2001 to 2003.

Four years of fish population data were presented for the Lily Park site on the Yampa River. This site was unique in that flannelmouth sucker and channel catfish were abundant. Smallmouth bass were common in 2004. All other native fish and white sucker were rare to very rare at this site.

The Colorado River had a single low flow year (2002), and flows in 2003 and 2004 were below normal. The fish data did not indicate a noticeable and lasting impact from the drought of 2002. There appeared to be the start of a decline in bluehead sucker abundance, but it could recover quickly given a return to normal (800 cfs) base flows for a few years. There appeared to be a surge in smallmouth bass abundance in 2003, likely as a consequence of the 2002 flows. Sunfish and bass numbers declined in 2004 to pre 2002 levels.

The Gunnison River had the highest native fish biomass and diversity. Prior surveys by the Fish and Wildlife Service also found higher catch rates of native species on the Gunnison River than in the Colorado River. The Gunnison River did not experience reduced flow during the drought period. Senior water calls meant water was delivered to the Redland Diversion in each year of the drought. The Gunnison River native fish population could be vulnerable if water rights are sold or transferred to upstream users.

Long term stability (natural variability) in Gunnison River base flows and native fish abundance is compelling evidence for the need for maintaining base flows for native fish. It was also observed that reduced peak flows in the Gunnison River have not been problematic for bluehead sucker, flannelmouth sucker and roundtail chub.

The Dolores River experienced extreme runoff reductions during the drought period due to no spills from McPhee dam. Disappointment Creek continued to input sediment and fines that were not diluted or flushed by Dolores River water. Sedimentation from lack of flushing flows appears to be a major cause for poor fish productivity, and the observed increase in black bullhead abundance. A geomorphic study of the site is ongoing.

Minimal base flows (2 to 10 cfs) were normal prior to McPhee Dam (1985) and were also seen in 2002 and 2003. The dominance of small-bodied fish (> 20 cm) was believed related to the regime of long term low base flows.

RECOMMENDATIONS FOR FUTURE RESEARCH

1. Expand mark and recapture effort for the Delta and Escalante sites in 2005. Make seven passes and evaluate the use of pit tags for investigating emigration from study site and habitat use.

2. The Dolores River has been reinstated in the study narrative and will be sampled for fish in 2005. This is an excellent site to perform geomorphic studies to establish recommendations for magnitude and duration of a bankfull flow.

3. Perform a preliminary or reconnaissance survey on the White River to locate at least one site suitable for future fish sampling and a bed topography survey 2D modeling. The White River survey would provide recent fish information, add to the native fish/ habitat data base for refining flow and habitat relationships, and provide an instream flow recommendation.

4. Complete habitat suitability criteria for all endangered species and for problematic nonnative species.

5. Plan to add GIS habitat mapping for larger reaches of the Colorado River (Debeque Canyon, Parachute, 18 Mile Reach and Black Rocks).

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APPENDIX ONE

Tables

Table A1-1. Correlations between minimum flow, 40th lowest flow, and number of days flow was less than 200 cfs and degree days. Degree days are the sums of mean daily water temperature minus, 12, 14, 16, 18 and 20.

Minimum	cfs	DD-12	DD-14	DD-16	DD-18	DD-20
1998	**110**	809.5	590.8	399.3	235.3	98.2
1999	**166**	743.1	527.3	341.5	192.2	76.5
2000	**30**	866.7	617.2	406.4	236.2	107.3
2001	**50**	956.8	697.6	472.1	289.3	136.1
2002	**2**	983.8	706.8	476.7	279.4	111.9
2003	**43**	897.2	637.6	446	297.2	159.4
2004	**22**	811.2	561.1	346.6	178.2	68.3
	Multiple R	0.744	0.654	0.544	0.407	0.334
	R Square	0.553	0.428	0.296	0.165	0.112
40DAY	cfs	DD-12	DD-14	DD-16	DD-18	DD-20
1998	**248**	809.5	590.8	399.3	235.3	98.2
1999	**237**	743.1	527.3	341.5	192.2	76.5
2000	**113**	866.7	617.2	406.4	236.2	107.3
2001	**110**	956.8	697.6	472.1	289.3	136.1
2002	**12**	983.8	706.8	476.7	279.4	111.9
2003	**141**	897.2	637.6	446	297.2	159.4
2004	**146**	811.2	561.1	346.6	178.2	68.3
	Multiple R	0.869	0.799	0.691	0.526	0.365
	R Square	0.755	0.639	0.478	0.277	0.133
<200 cfs	days	DD-12	DD-14	DD-16	DD-18	DD-20
1998	**29**	809.5	590.8	399.3	235.3	98.2
1999	**6**	743.1	527.3	341.5	192.2	76.5
2000	**76**	866.7	617.2	406.4	236.2	107.3
2001	**105**	956.8	697.6	472.1	289.3	136.1
2002	**129**	983.8	706.8	476.7	279.4	111.9
2003	**90**	897.2	637.6	446	297.2	159.4
2004	**48**	811.2	561.1	346.6	178.2	68.3
	Multiple R	0.985	0.950	0.901	0.797	0.663
	R Square	0.970	0.902	0.812	0.636	0.439

Table A1-2. Species composition (total fish) at Duffy, Yampa River, 1998 -2004.

YAMPA RIVER	Percent composition for **total fish** with number caught					
Sevens	**- (n)**	**- (n)**	**- (n)**	**- (n)**	**- (n)**	**- (n)**
Species	**1998**	**1999***	**2000**	**2001**	**2003**	**2004**
Flannelmouth sucker	3 – (86)	2 – (56)	3 – (65)	0.4 – (17)	2 – (23)	1 - (14)
Bluehead sucker	2 – (56)	3 – (80)	2 – (45)	0.9 – (41)	0.6 – (8)	0.1 - (2)
Roundtail chub	2– (53)	3 – (78)	2 – (46)	0.6 – (27)	0.8 – (10)	1.4 - (20)
Colo. Pikeminnow	0.8 – (22)	0.5 – (11)	0.4 – (10)	0.1 (5)	0 – (0)	0.1 (1)
White S. + hybrids	39– (1114)	44- (1035)	44 – (992)	10 – (454)	38 – (483)	17 – (243)
Channel catfish	1.6 – (45)	2 – (51)	1.8 – (41)	0.8 – (38)	2 – (26)	1.8 - (26)
Carp	1.2 – (33)	0.8 – (18)	0.7 – (16)	0.4 – (20)	0.2 – (2)	0.3 - (5)
Smallmouth bass	26 – (745)	22 – (523)	41 – (906)	86 – (4054)	54 – (677)	77 - (1109)
Northern pike	1.4 – (39)	1 – (23)	0.5 – (12)	0.2 – (9)	0.3 – (4)	0.5 - (7)
Speckled Dace	6 (155)	4 - (97)	0.5 (11)	0.1 – (7)	0.1 (1)	0
Mottled Sculpin	9 (257)	14 - (324)	2 –(44)	0.5 – (25)	0	0
B. Crappie	8 – (219)	2 – (41)			1 – (14)	0
B. Bullhead					1 - (10)	1
Native species			10 – (221)	3 – (122)	3 - (42)	3 - (38)
Sample size	2,824	2,337	2,231	776	1,195	1,360

Table A1-3. Species composition (total fish) at Sevens, Yampa River, 1998 -2004.

YAMPA RIVER	Percent composition for **total fish** with number caught					
Sevens	**- (n)**	**- (n)**	**- (n)**	**- (n)**	**- (n)**	**- (n)**
Species	**1998**	**1999**	**2000**	**2001**	**2003**	**2004**
Flannelmouth sucker	42 – (674)	45 – (476)	41 – (405)	46 – (359)	25 – (303)	14 - (187)
Bluehead sucker	20 – (314)	18 – (187)	18 – (180)	12 – (89)	1 – (16)	0.8 - (11)
Roundtail chub	6 – (94)	4 – (39)	3 – (31)	3 – (23)	3 – (32)	1.2 - (16)
Colo. Pikeminnow	0.2 – (3)	0.2 – (2)	0.2 – (2)	0	0	0
White S. + hybrids	13 – (199)	16 – (166)	26 – (256)	15 – (115)	38 – (458)	33 – (453)
Channel catfish	7 – (93)	7 – (75)	1.5 – (15)	5 – (35)	2 – (28)	3 - (42)
Carp	4 – (50)	5 – (50)	3 – (31)	4 – (28)	5 – (58)	3.5 - (48)
Smallmouth bass	0.9 – (15)	4 – (46)	7 – (69)	5 – (122)	25 – (297)	44 - (600)
Northern pike	1.3 – (18)	2 – (19)	0.2 – (2)	0.3 – (2)	0.4 – (3)	0.2 - (3)
Speckled Dace	8 (121)	0.7 (8)	0.7 (7)	0.4 – (3)	0	0
Mottled Sculpin	1 (16)	0	0	0	0	0
Native species						16 - (214)
Sample size	1,597	1,068	998	776	1,195	1,360

Table A1-4. Species composition (total fish) at Lily Park, Yampa River, 2000 to 2004.

YAMPA RIVER	Percent composition for **TOTAL CATCH** with number caught			
Lily Park	**- (n)**	**- (n)**	**- (n)**	**- (n)**
Species	**2000**	**2001**	**2003**	**2004**
Flannelmouth sucker	46 - (1940)	64 - (2023)	52 - (1182)	45 - (1166)
Bluehead sucker	8 - (348)	7 - (212)	7 - (163)	6 - (143)
Roundtail chub	0.02 - (1)	0.03 - (1)	0.04 - (1)	0.3 - (7)
Colo. Pikeminnow	0.1 - (3)	0.03 - (1)	0.1 - (2)	0.4 - (11)
White S. + hybrids	0.3 - (12)	0.2 - (8)	0.6 - (14)	1.2 - (31)
Channel catfish	40 - (1631)	17 - (528)	27 - (602)	23 - (604)
Carp	2 - (88)	2 - (62)	3 - (73)	3 - (77)
Smallmouth bass	0.8 - (171)	9 - (282)	9 - (197)	21 - (540)
Northern pike	0.2 - (8)	0.2 - (5)	0.1 - (3)	0.1 - (3)
Speckled Dace	0.1 - (3)	0	0	0
Mottled Sculpin	0.4 - (18)	0.2 - (6)	0	0
Total number in sample	4,223	3,145	2,254	2,613

Table A1-5. Species composition (total fish and fish <15 cm), Gunnison River, 2004.

Gunnison River	Delta- total	Escalante -total	Delta - <15cm	Escalante - <15cm
Species	**2004**	**2004**	**2004**	**2004**
Flannelmouth sucker	29.9%	16.4%	1.8%	3.6%
Bluehead sucker	17.9%	39.0%	1.9%	10.0%
Roundtail chub	3.1%	11.9%	2.4%	7.4%
Colorado pikeminnow	0.2%	0.1%	0	0
Razorback sucker	0	0.1%	0	0
Bluehead X Flannelmouth	0.6%	0.2%	0	0
Speckled dace	4.3%	1.6%	17.1%	6.6%
Mottled sculpin	0.02%	0	0.1%	0
White S. + hybrids	21.7%	11.2%	16.1%	6.2%
Carp	8.4%	3.5%	8.6%	4.8%
Brown trout	0.8%	0.9%	0.3%	0
Fathead minnow	12.1%	12.9%	47.8%	52.7%
Green sunfish	0.7%	1.0%	2.8%	3.9%
Black bullhead	0.02%	0.1%	0	0
Shiner species	0.1%	1.2%	0.3%	4.7%
Plains killifish	0.2%	0	0.7%	0
Largemouth bass	0	0.02%	0	0.07%
Native species	55.4%	67.6%	23.4%	27.5%
Sample size	4524	5808	1146	1427

APPENDIX TWO

Hydrographic Records

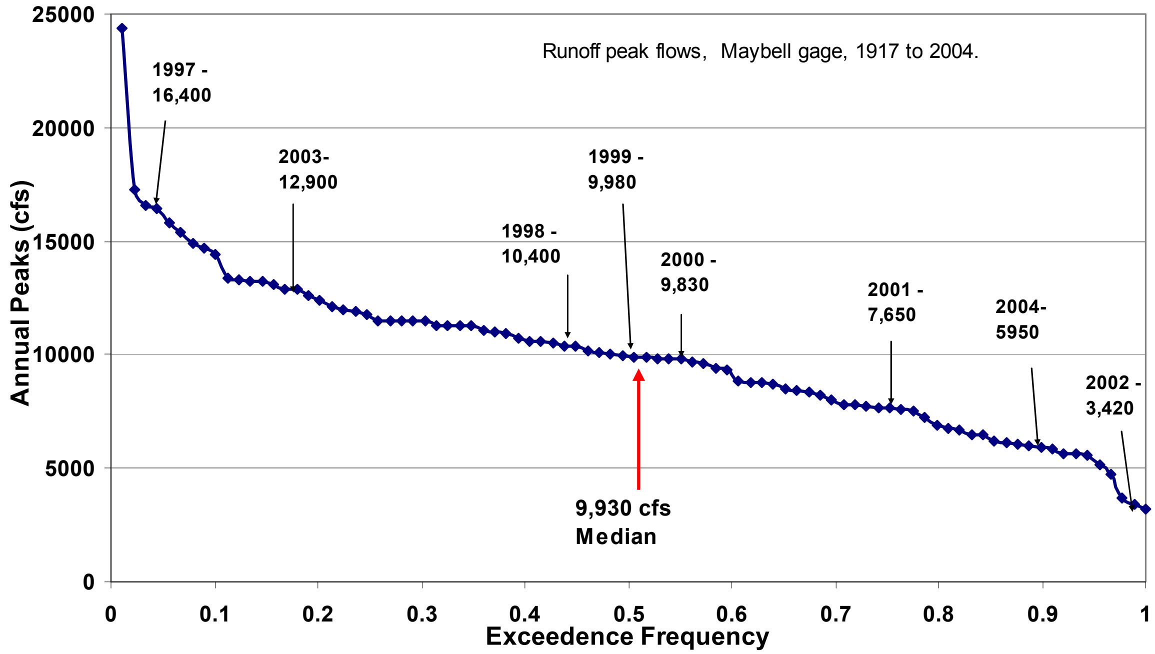


Figure A2-1. Exceedence probability values for annual peak flows at the Maybell Gage, Yampa River for the period of record (1917-2004).

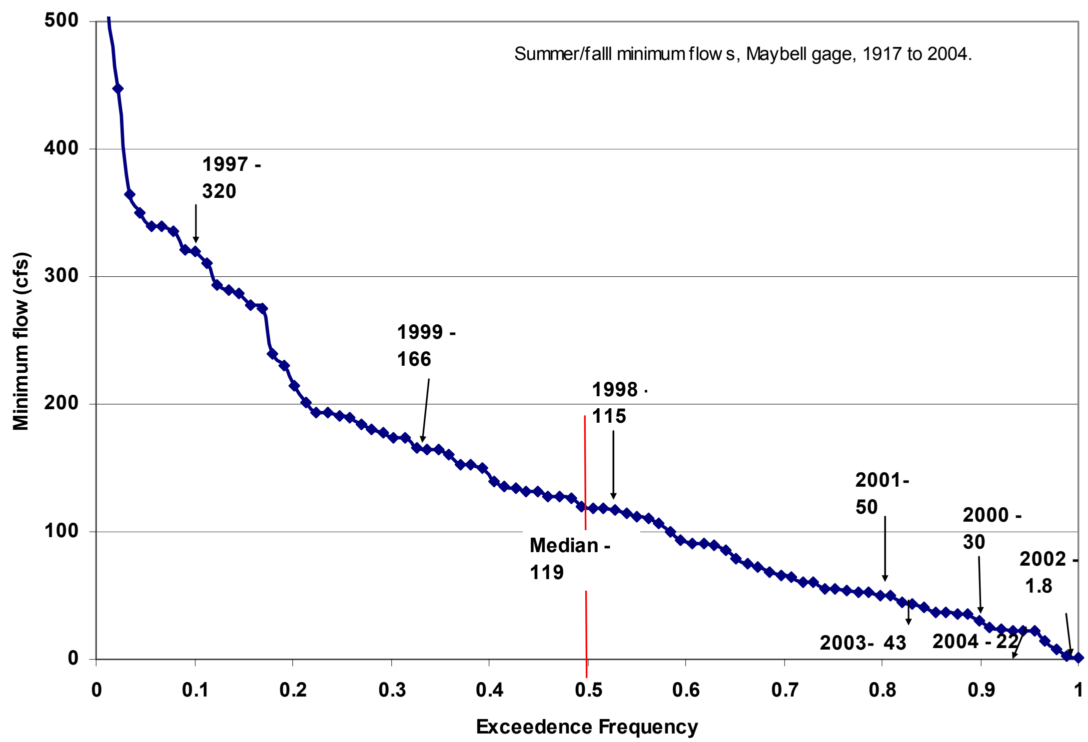


Figure A2-2. Exceedence probability values for summer/fall minimum flows, Maybell Gage, Yampa River for the period of record (1917-2004).

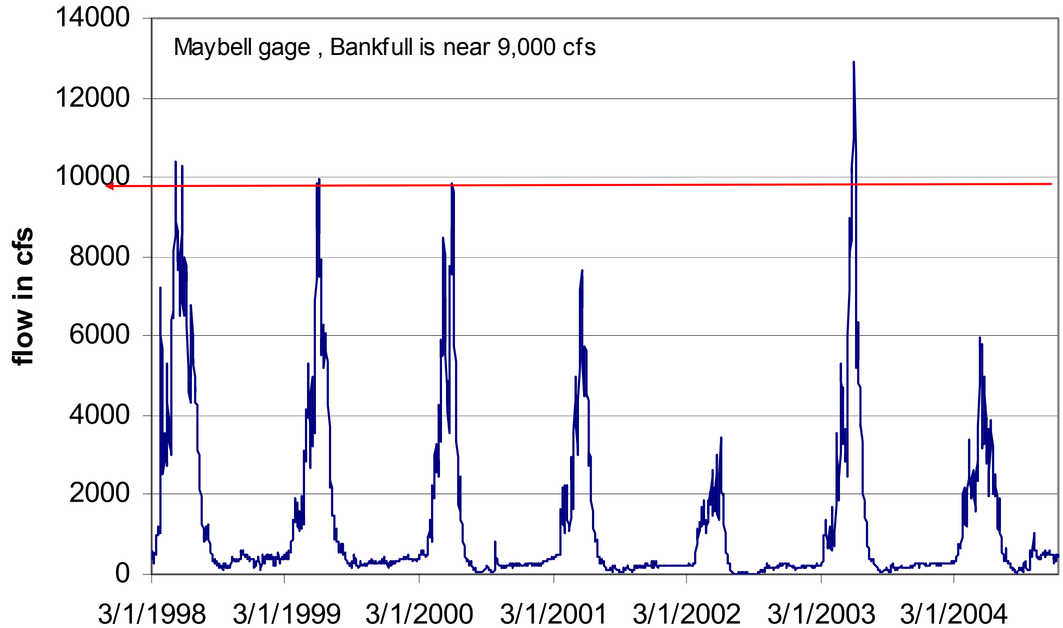


Figure A2-3. Annual hydrograph from 1998 to 2004, Maybell Gage, Yampa River

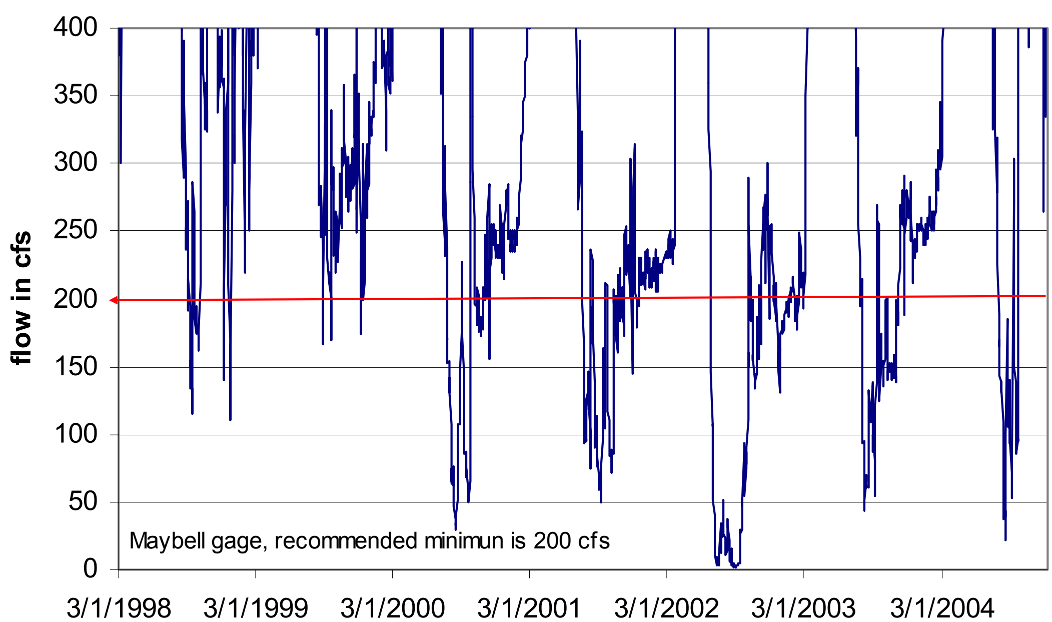


Figure A2-4. Wide-scale annual hydrograph from 1998 to 2004, Maybell Gage, Yampa River.

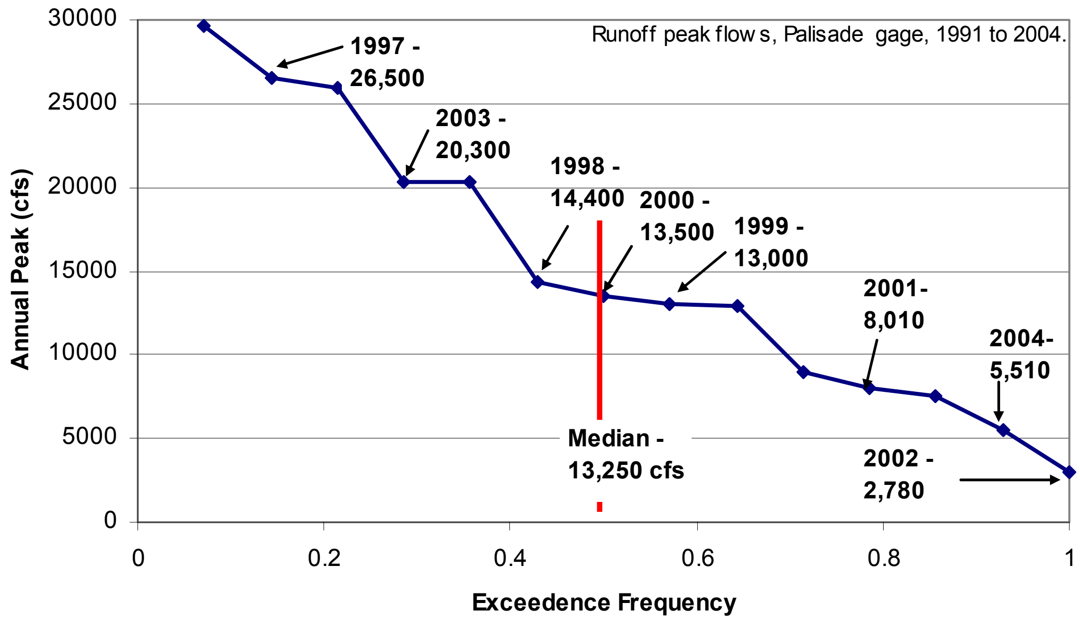


Figure A2-5. Exceedence probability values for annual peak flows at the Palisade gage, Colorado River for the period of record (1991-2004).

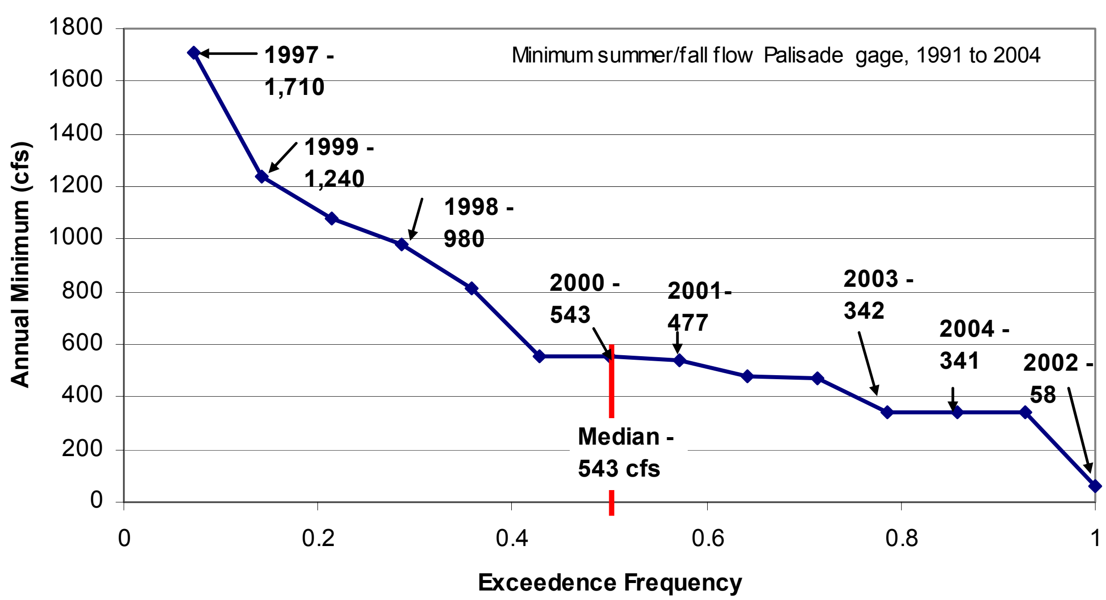


Figure A2-6. Exceedence probability values for summer/fall minimum flows at the Palisade Gage, Colorado River for the period of record (1991-2004).

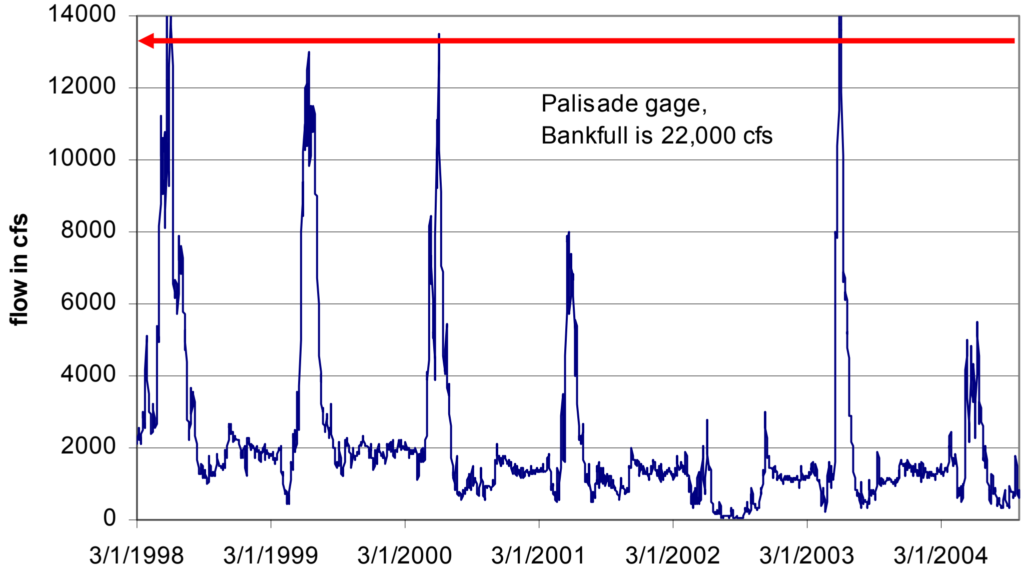


Figure A2-7. Annual hydrograph from 1998 to 2004, Palisade Gage, Colorado River.

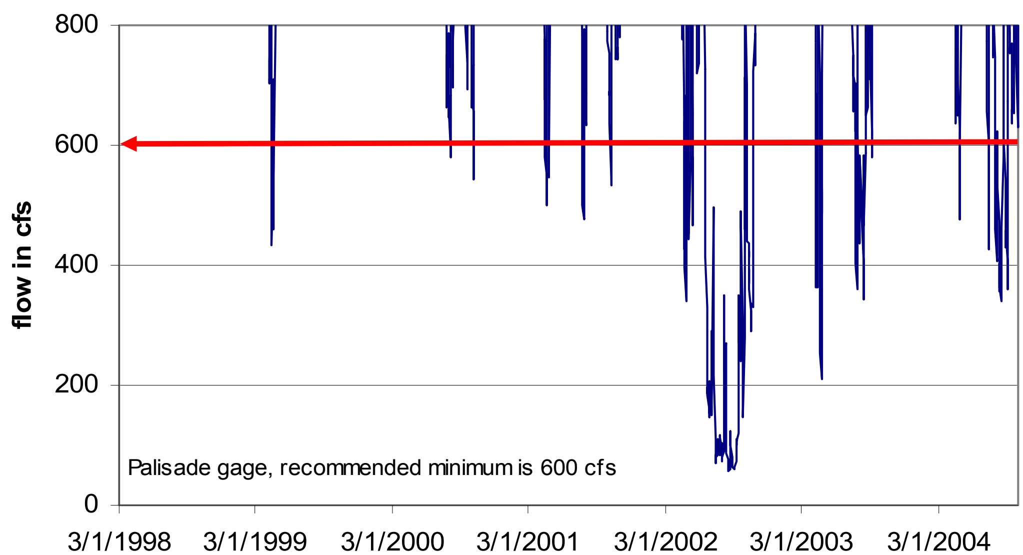


Figure A2-8. Wide-scale annual hydrograph from 1998 to 2004, Palisade Gage, Colorado River.

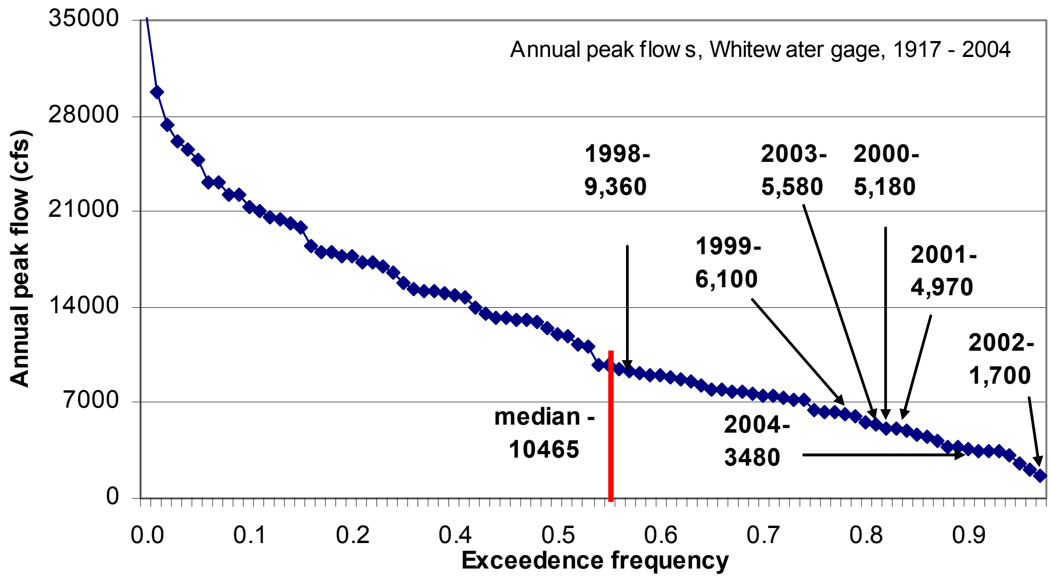


Figure A2-9. Exceedence probability values for annual peak flows at the Whitewater Gage, Gunnison River for the period of record (1917-2004).

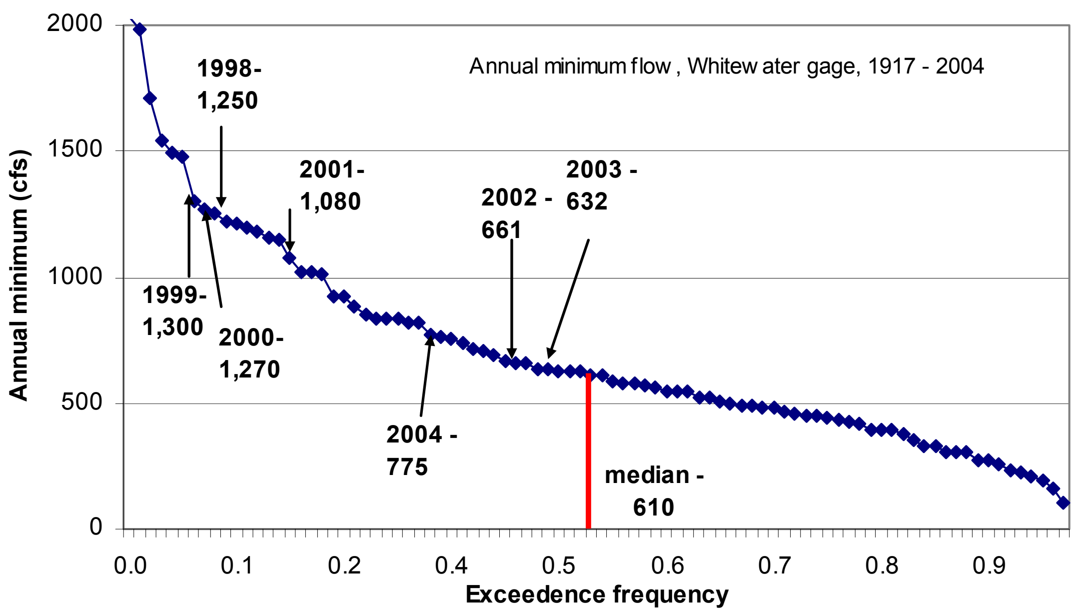


Figure A2-10. Exceedence probability values for annual minimum flows at the Whitewater Gage, Gunnison River for the period of record (1917-2004).

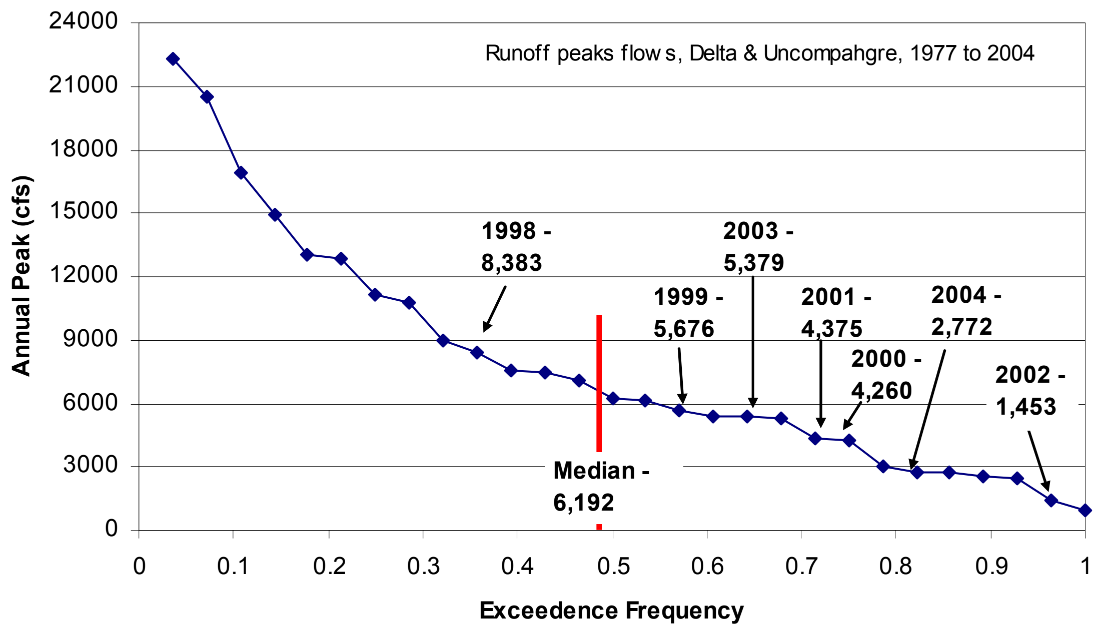


Figure A2-11. Exceedence probability values for annual minimum flows at the Delta and Uncompahgre Gages, Colorado River for the period of record (1991-2003).

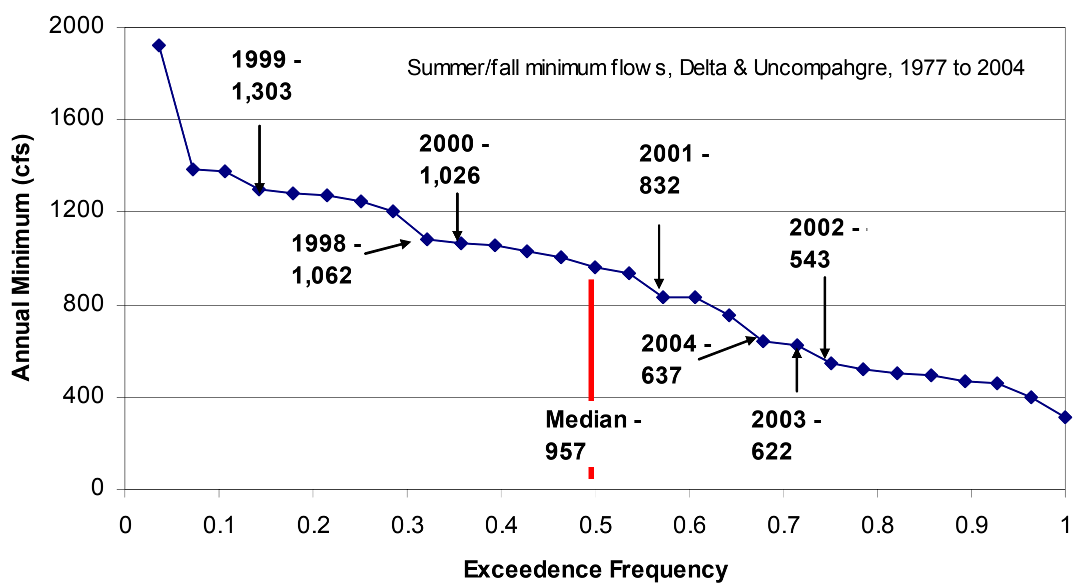


Figure A2-12. Exceedence probability values for summer/fall minimum flows for the Gunnison River (Delta and Uncompahgre gages summed) for the period of record (1977 to 2004).

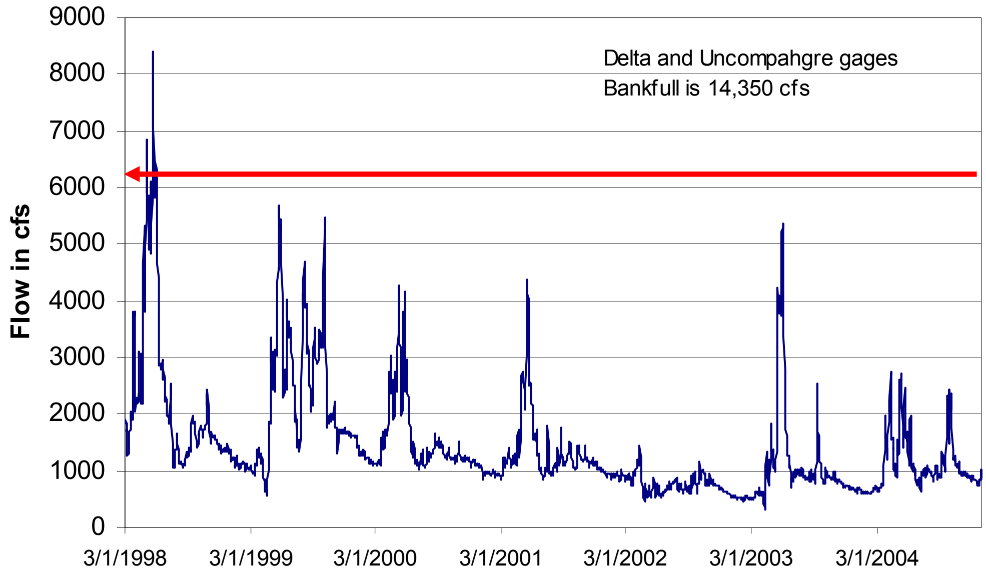


Figure A2-13. Annual hydrograph from 1998-2004, Delta and Uncompahgre Gages, Gunnison River.

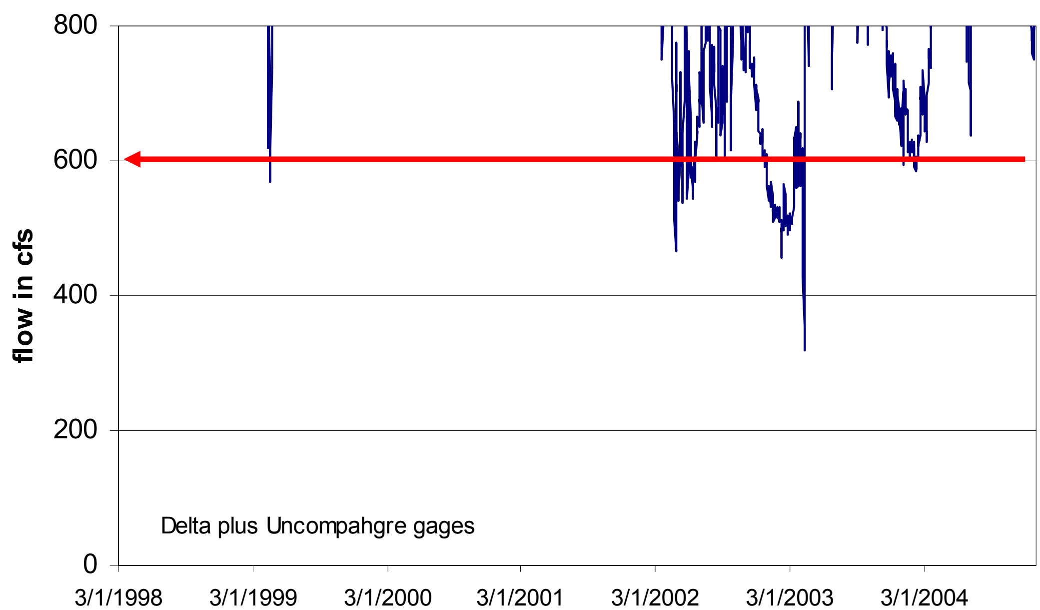


Figure A2-14. Wide-scale annual hydrograph from 1998-2004, Delta and Uncompahgre Gages, Gunnison River.

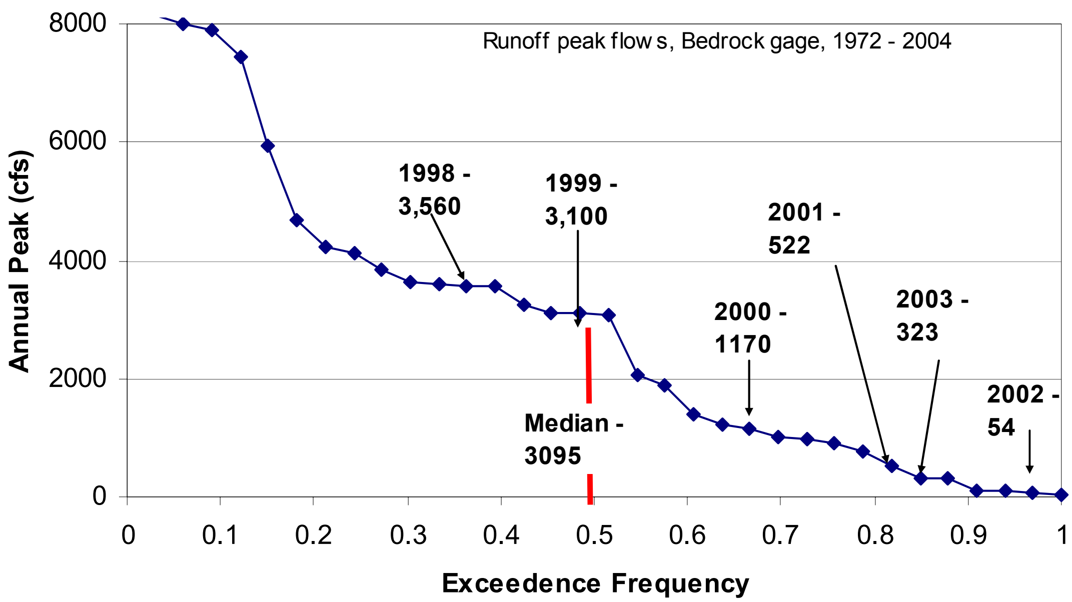


Figure A2-15. Exceedence probability values for annual peak flows at the Bedrock Gage, Dolores River for the period of record (1972-2004).

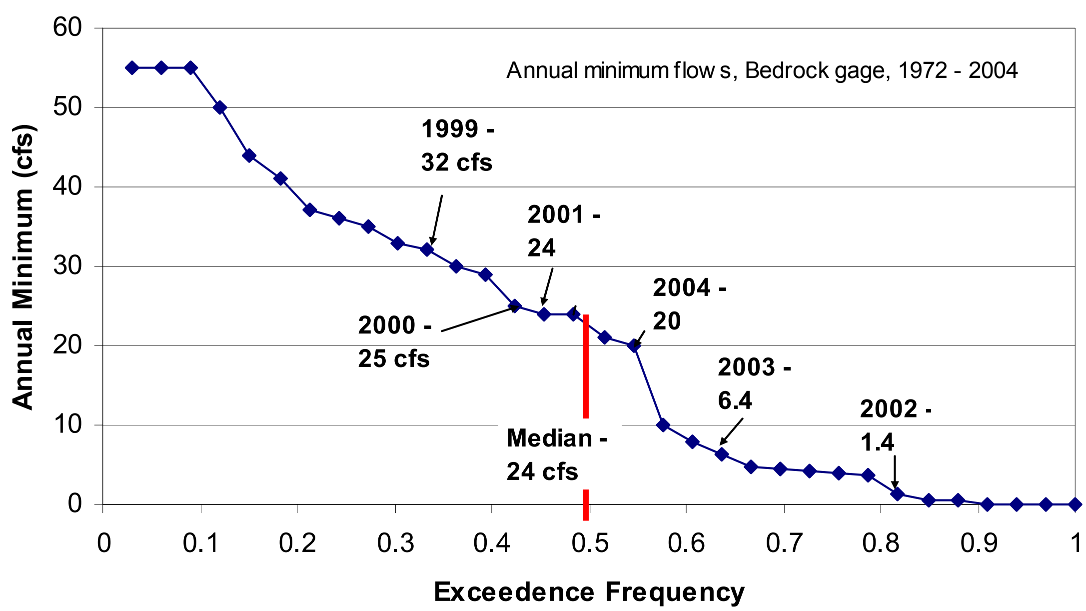


Figure A2-16. Exceedence probability values for annual minimum flows at the Bedrock Gage, Dolores River for the period of record (1972 to 2004).

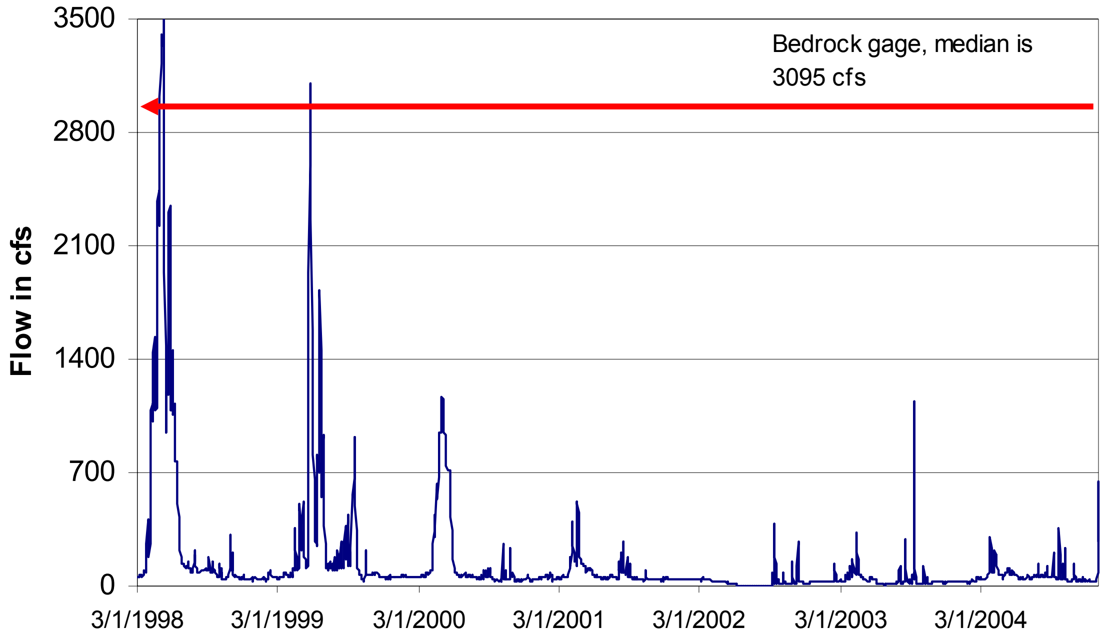


Figure A2-17. Annual hydrograph from 1998 – 2004, Bedrock Gage, Dolores River.

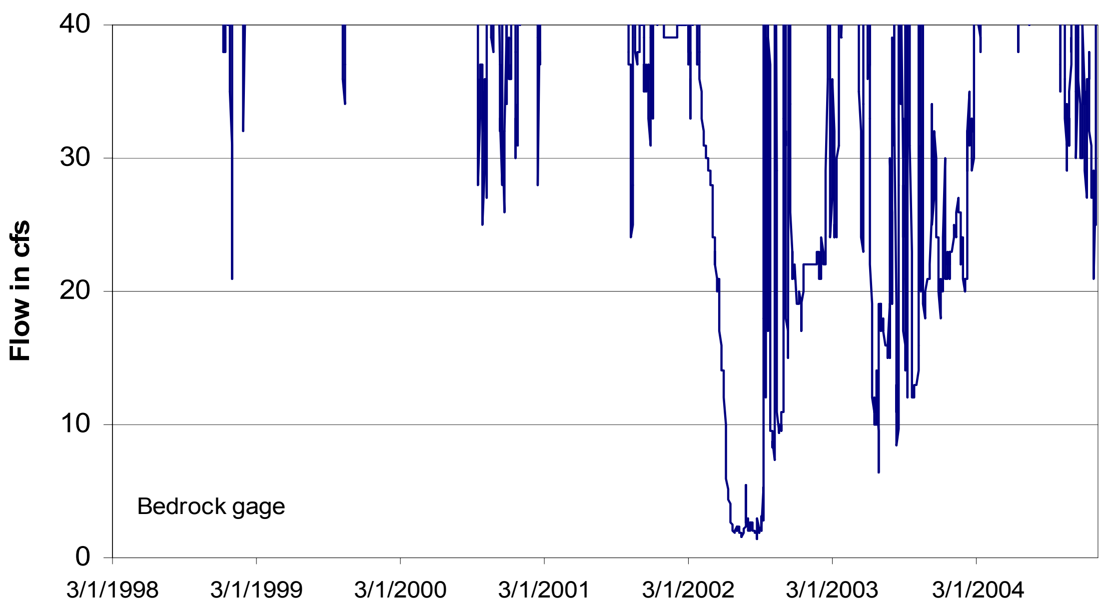


Figure A2-18. Wide-scale annual hydrograph from 1998-2004, Bedrock Gage, Dolores River.

APPENDIX THREE

Length Frequency Histograms

LIST OF TABLES AND FIGURES

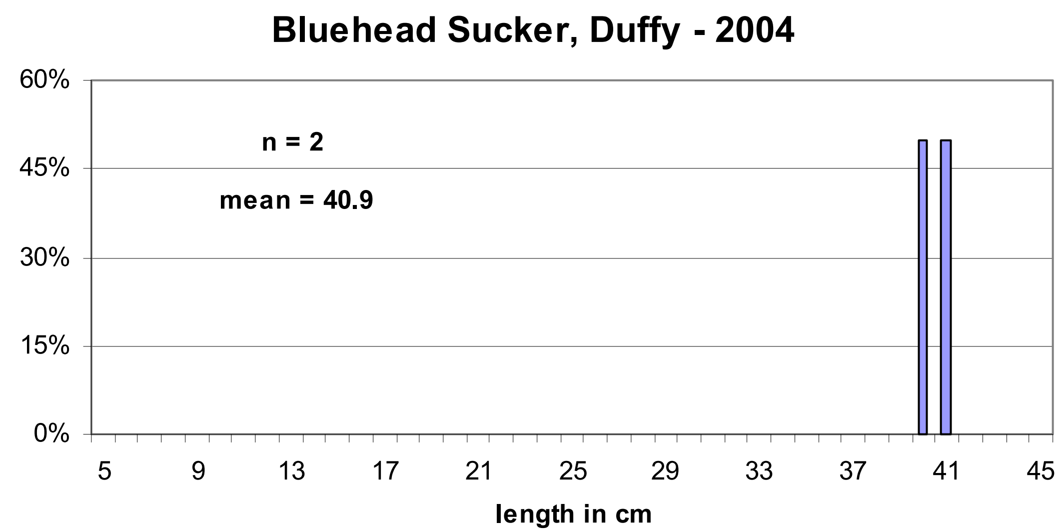


Figure A3-1. Bluehead Sucker - Duffy, Yampa River, July-August 2004.

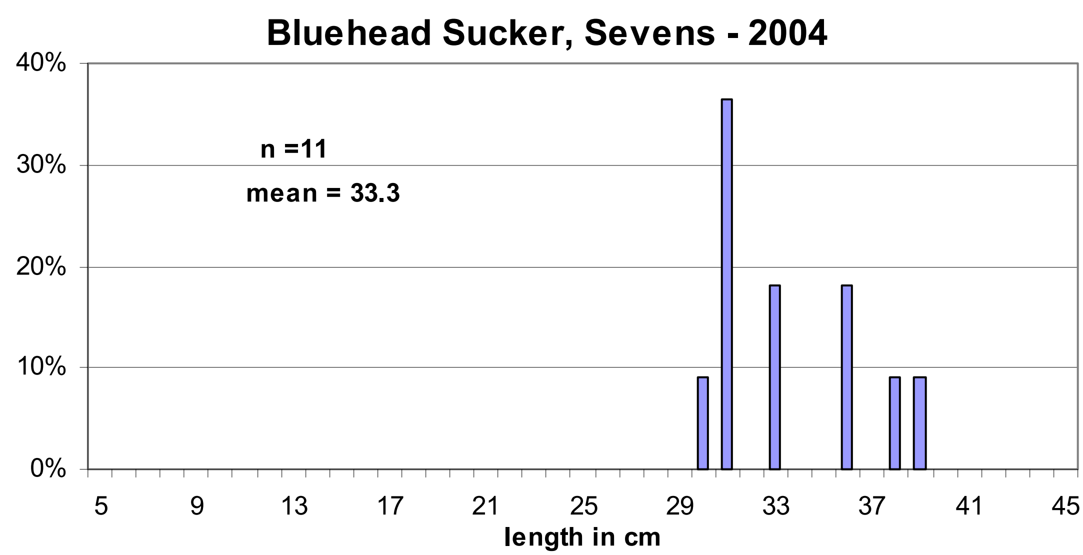


Figure A3-2. Bluehead Sucker - Sevens, Yampa River, July-August 2004.

2004

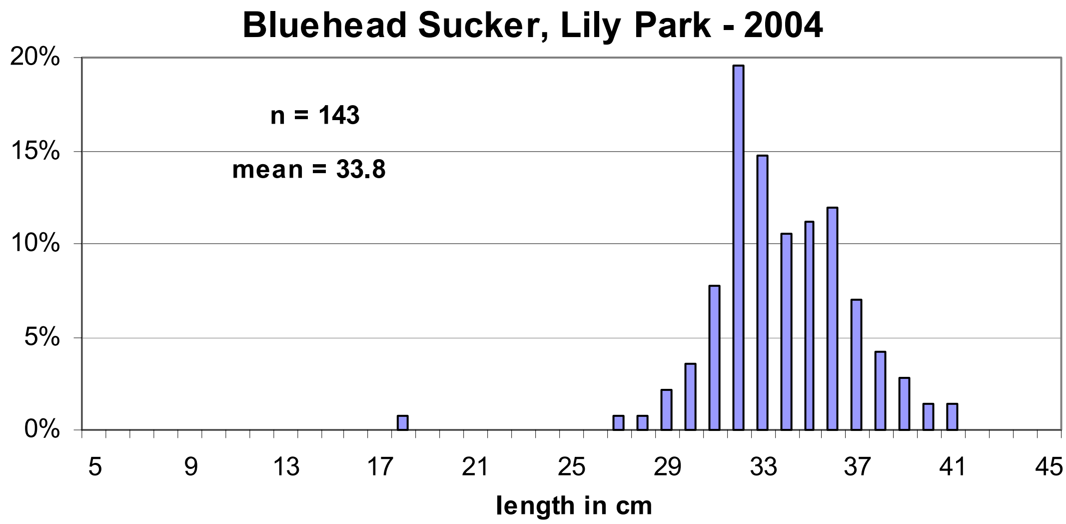


Figure A3-3. Bluehead Sucker - Lily Park, Yampa River, July-August 2004.

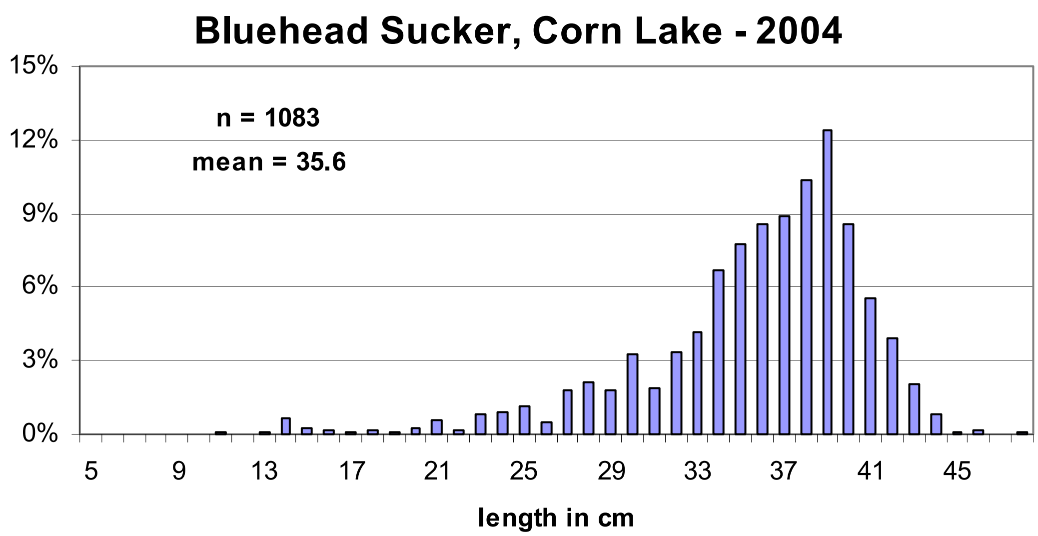


Figure A3-4. Bluehead Sucker - Corn Lake, Colorado River, September-October 2004.

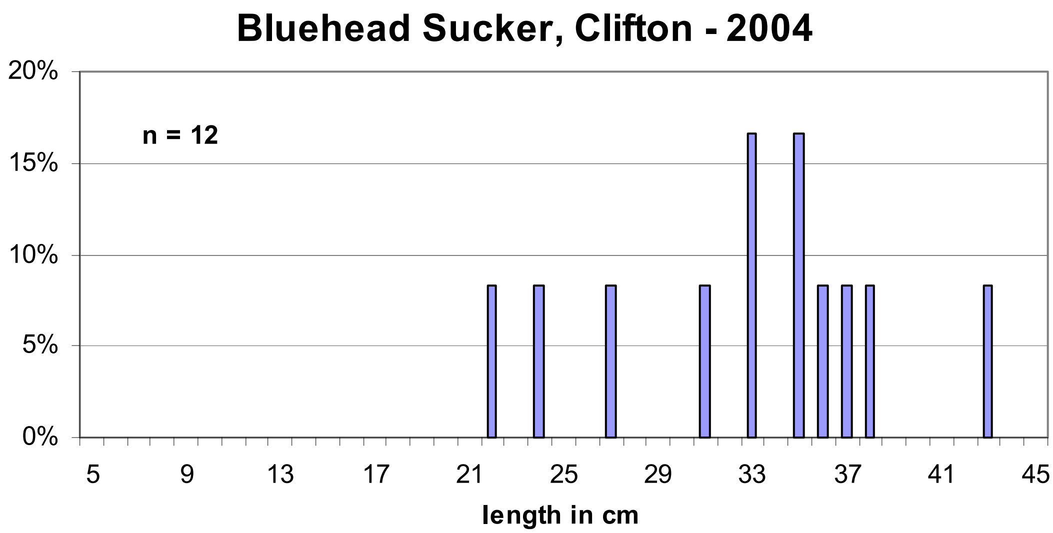


Figure A3-5. Bluehead Sucker - Clifton, Colorado River, October 2004.

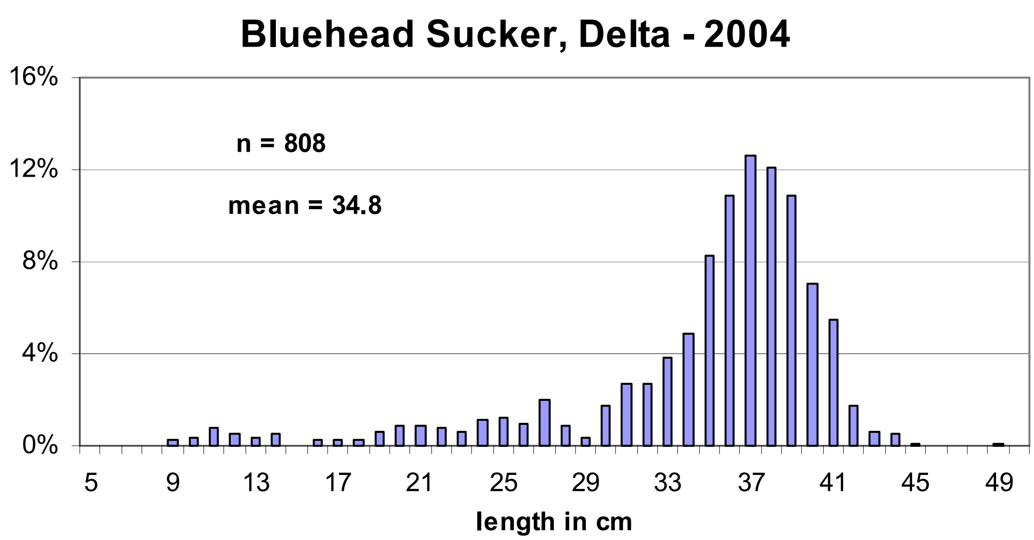


Figure A3-6. Bluehead Sucker - Delta, Gunnison River, August-September 2004.

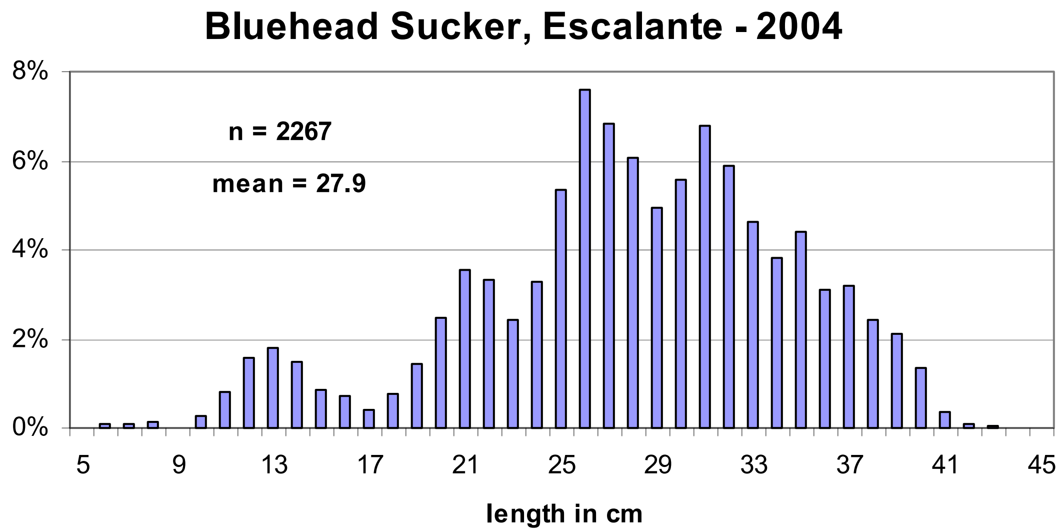


Figure A3-7. Bluehead Sucker - Escalante, Gunnison River, August-September 2004.

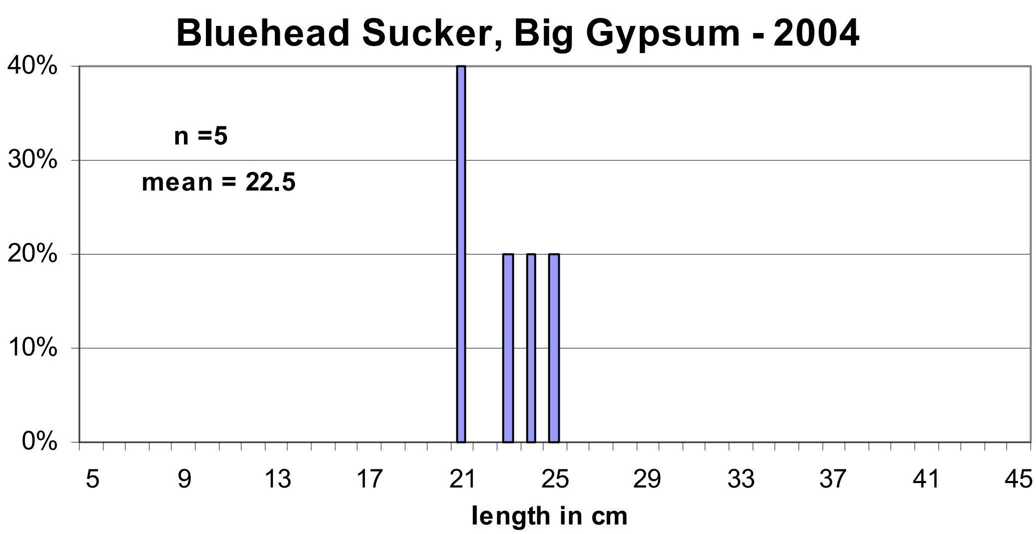


Figure A3-8. Bluehead Sucker - Big Gypsum, Dolores River, July 2004.

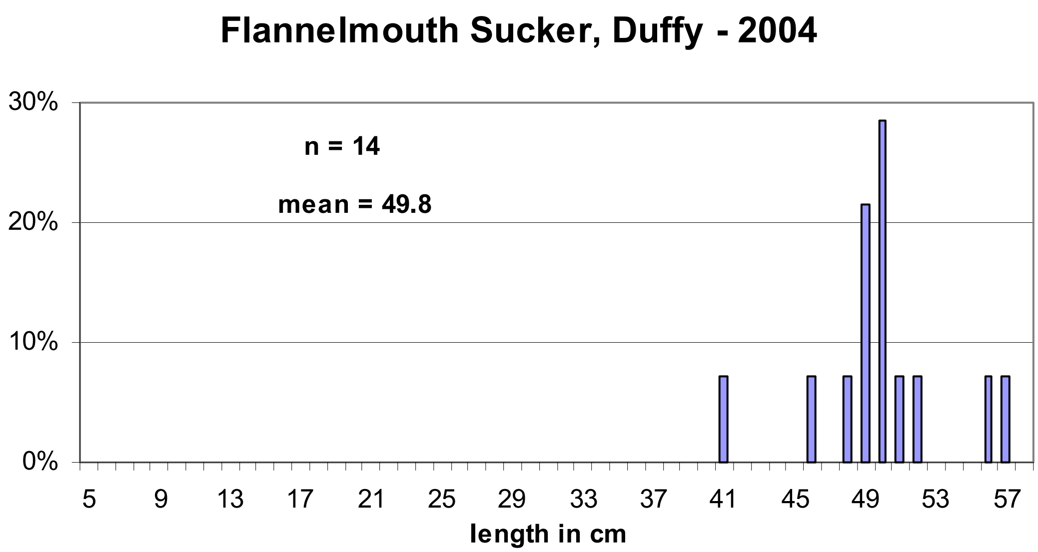


Figure A3-9. Flannelmouth Sucker - Duffy, Yampa River, July-August 2004.

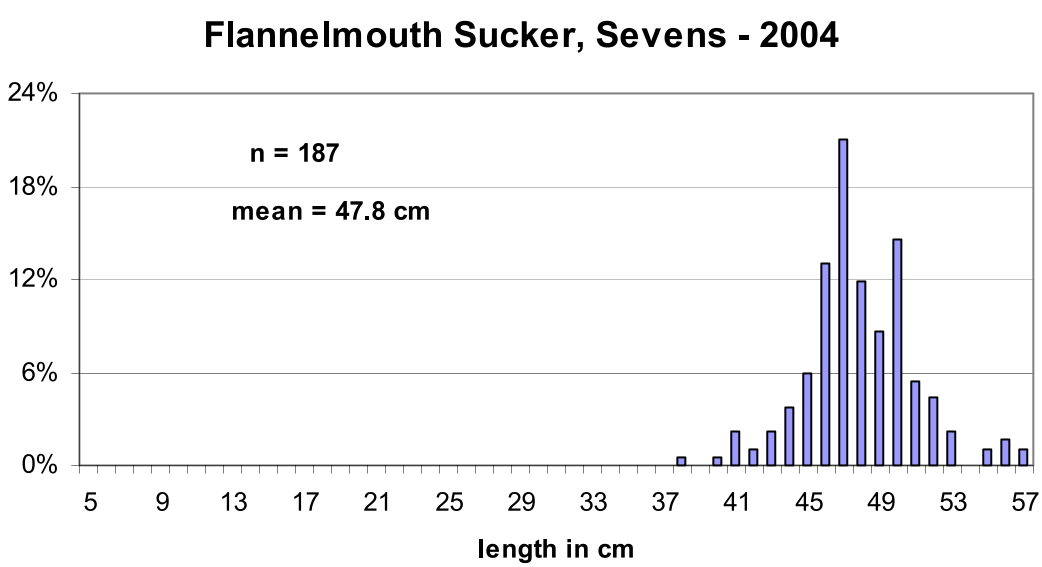


Figure A3-10. Flannelmouth Sucker - Sevens, Yampa River, July-August 2004.

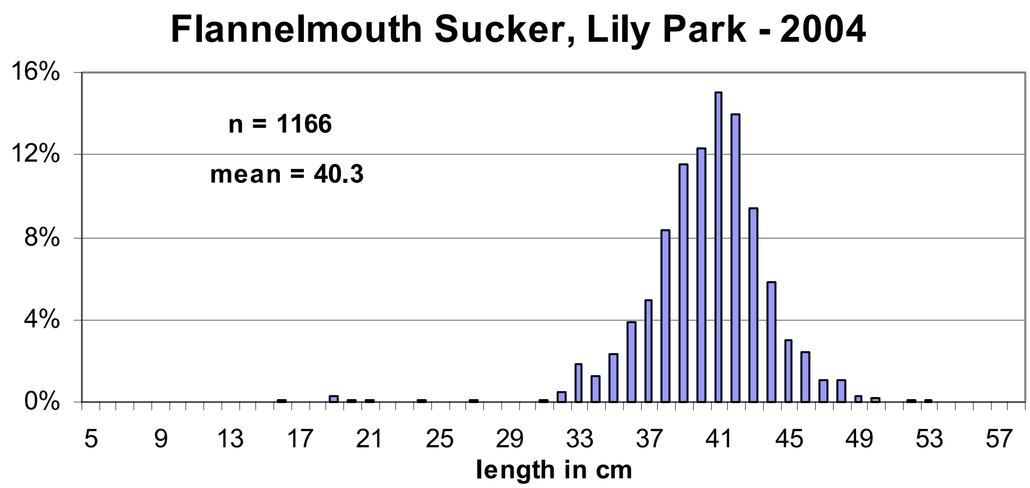


Figure A3-11. Flannelmouth Sucker - Lily Park, Yampa River, July-August 2004.

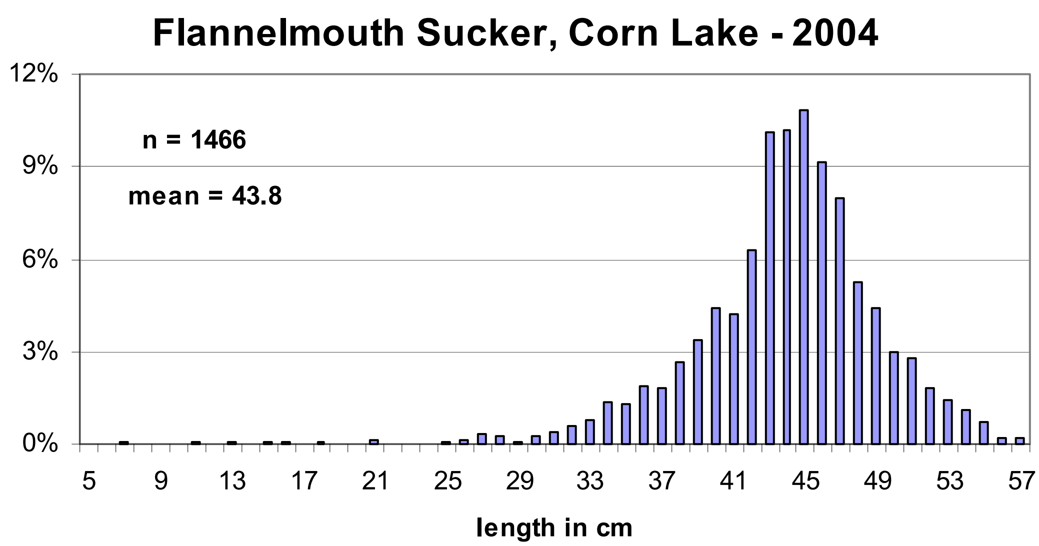


Figure A3-12. Flannelmouth Sucker - Corn Lake, Colorado River, September - October 2004.

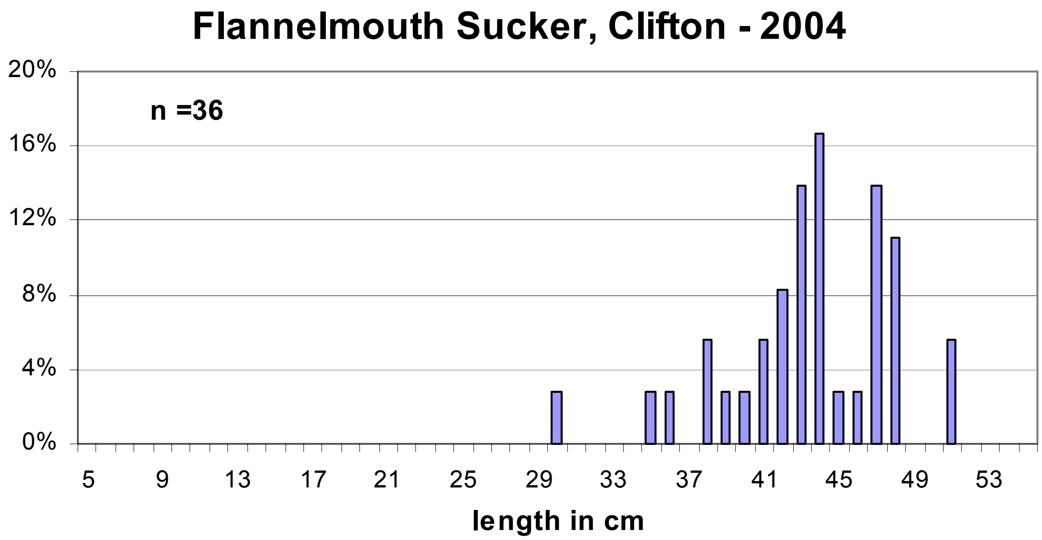


Figure A3-13. Flannelmouth Sucker - Clifton, Colorado River, October 2004.

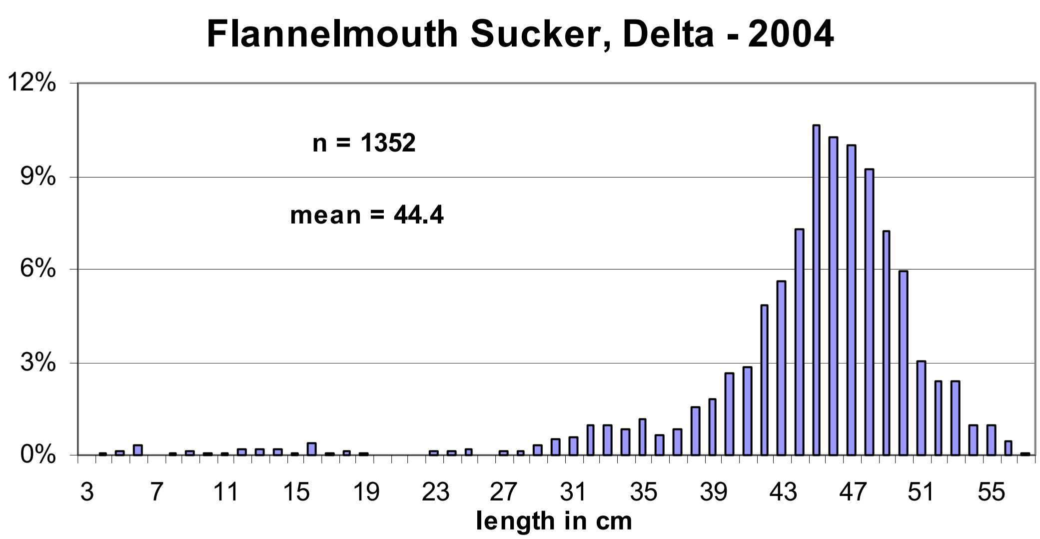


Figure A3-14. Flannelmouth Sucker - Delta, Gunnison River, August-September 2004.

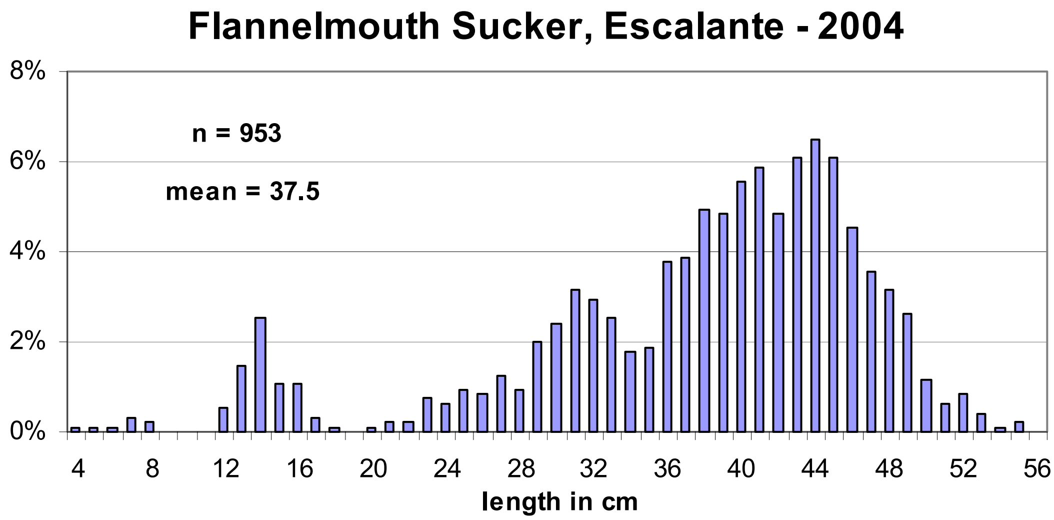


Figure A3-15. Flannelmouth Sucker - Escalante, Gunnison River, August-September 2004.

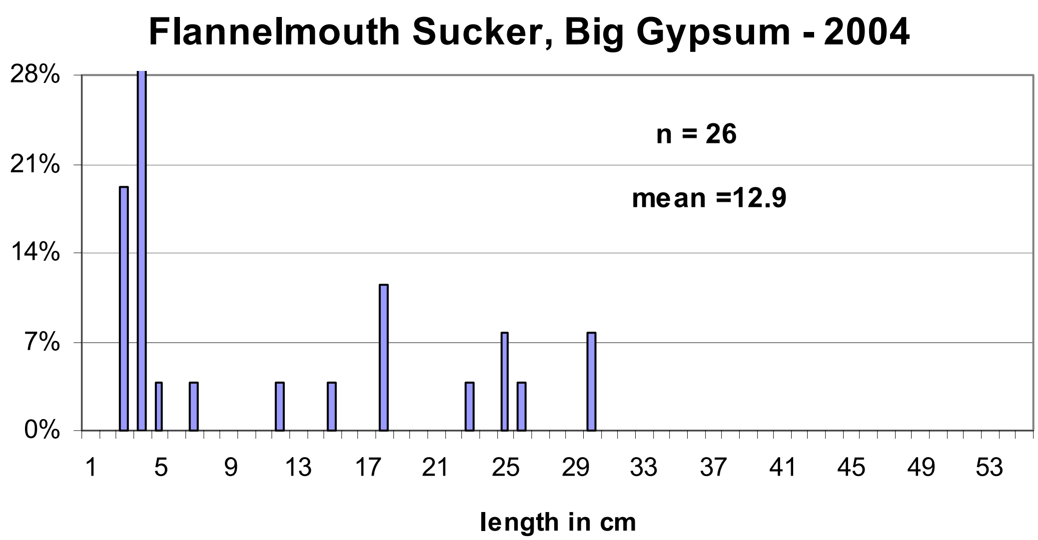


Figure A3-16. Flannelmouth Sucker - Big Gypsum, Dolores River, July 2004.

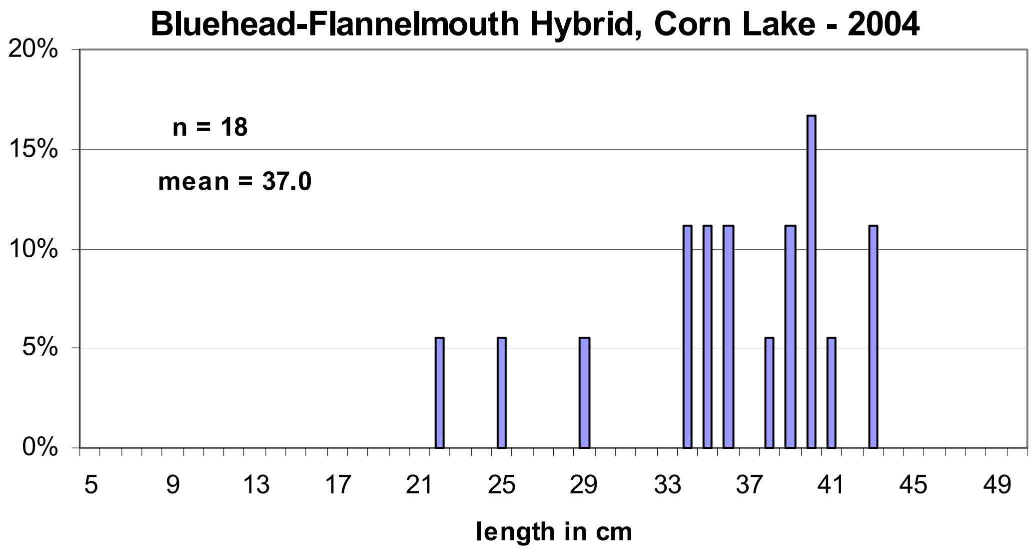


Figure A3-17. Bluehead-Flannelmouth Hybrid - Corn Lake, Colorado River, September - October 2004.

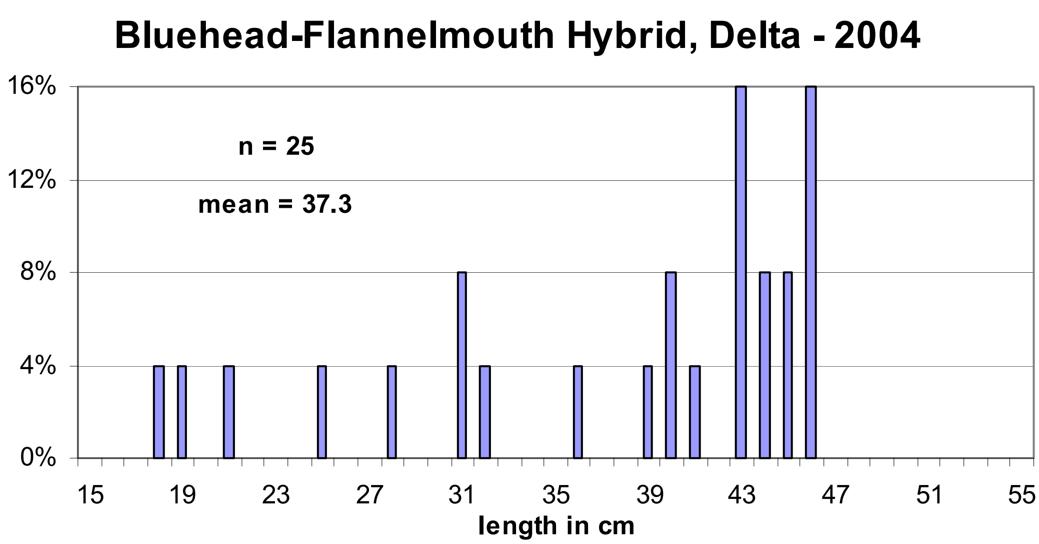


Figure A3-18. Bluehead-Flannelmouth Hybrid - Delta, Gunnison River, August-September 2004.

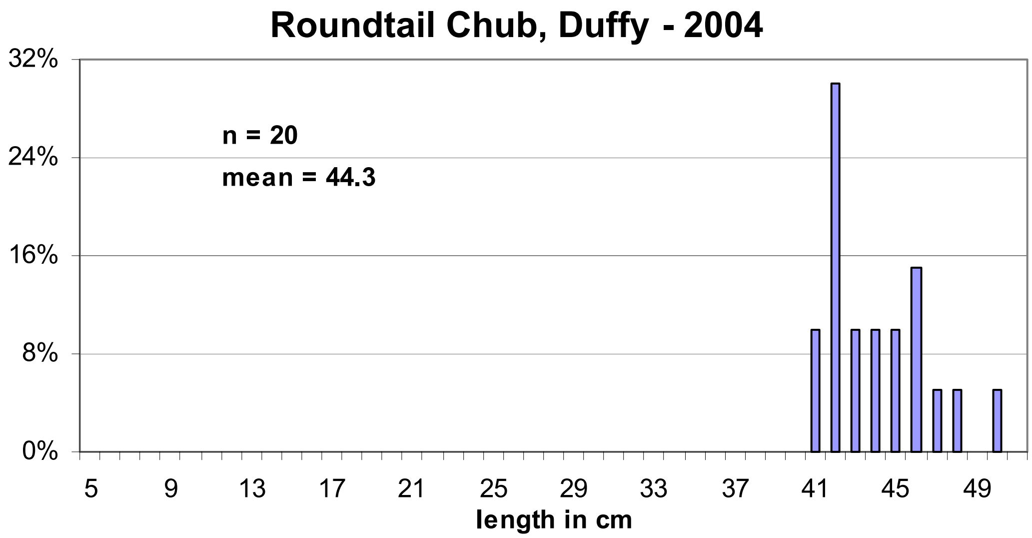


Figure A3-19. Roundtail Chub - Duffy, Yampa River, July-August 2004.

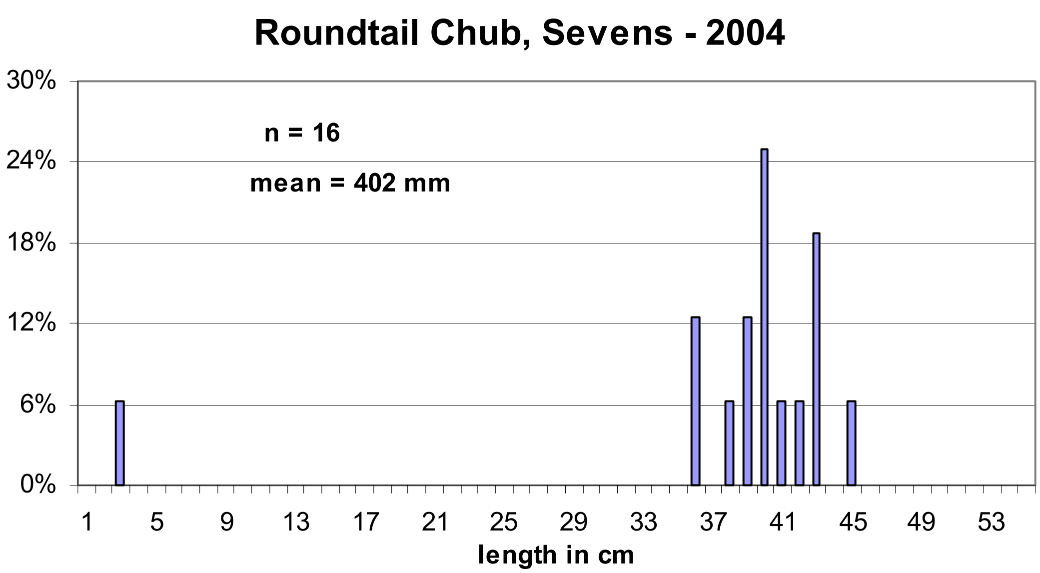


Figure A3-20. Roundtail Chub - Sevens, Yampa River, July-August 2004.

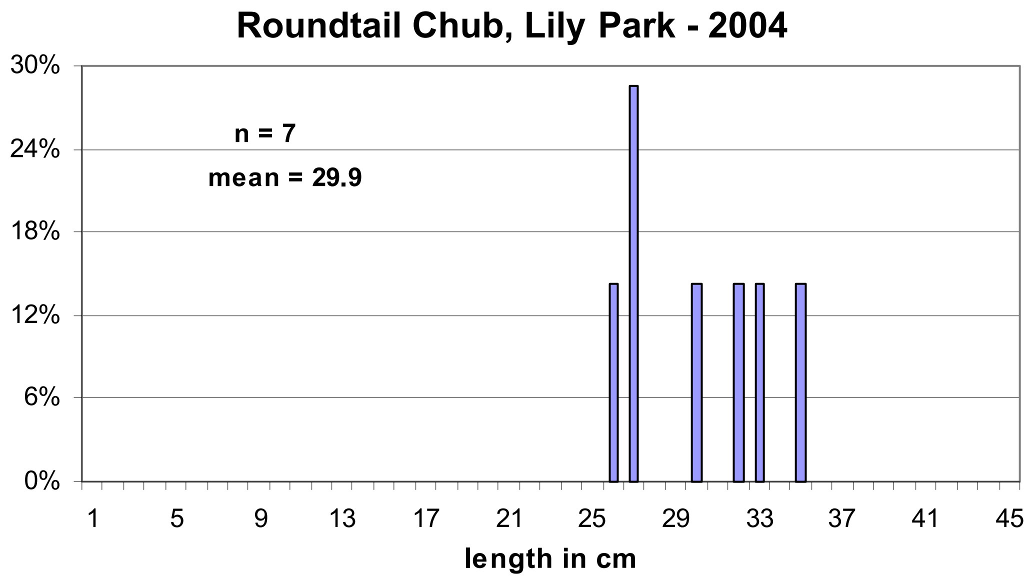


Figure A3-21. Roundtail Chub - Lily Park, Yampa River, July-August 2004.

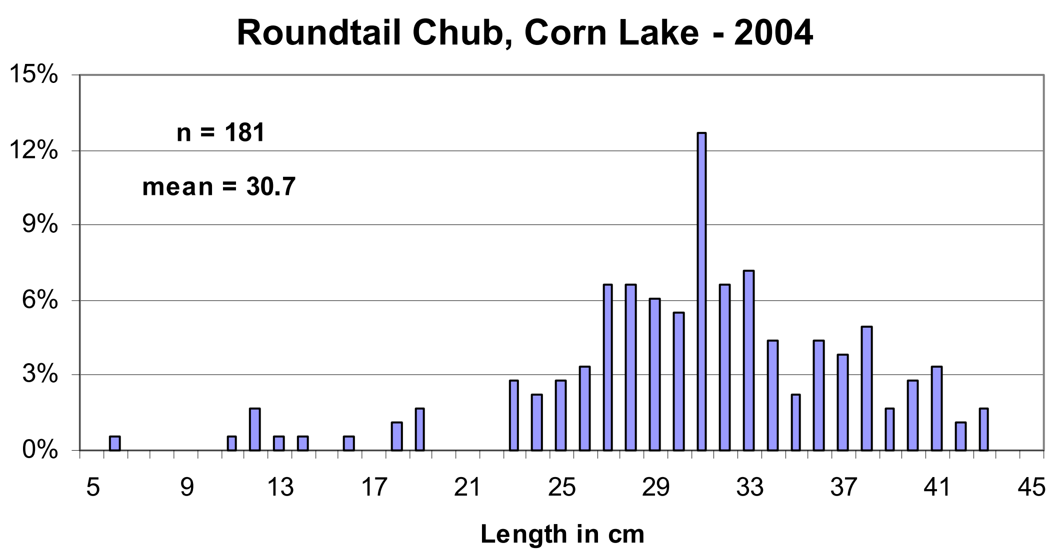


Figure A3-22. Roundtail Chub - Corn Lake, Colorado River, September - October 2004.

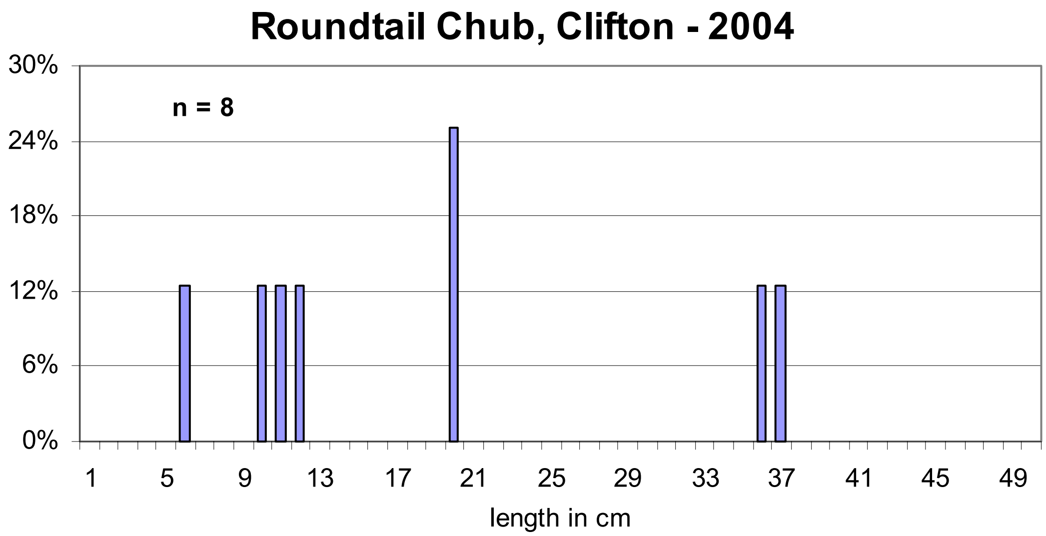


Figure A3-23. Roundtail Chub - Clifton, Colorado River, October 2004.

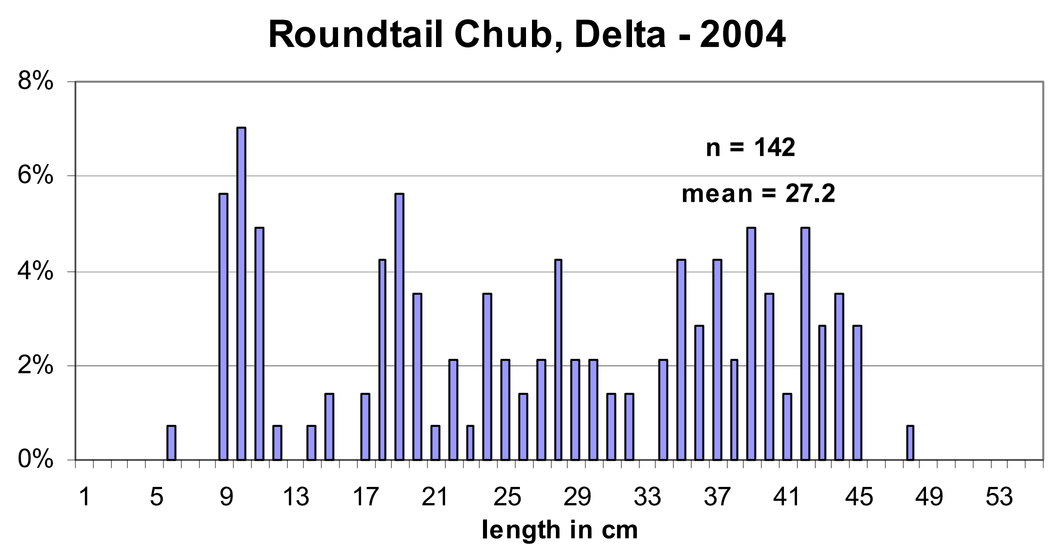


Figure A3-24. Roundtail Chub - Delta, Gunnison River, August-September 2004.

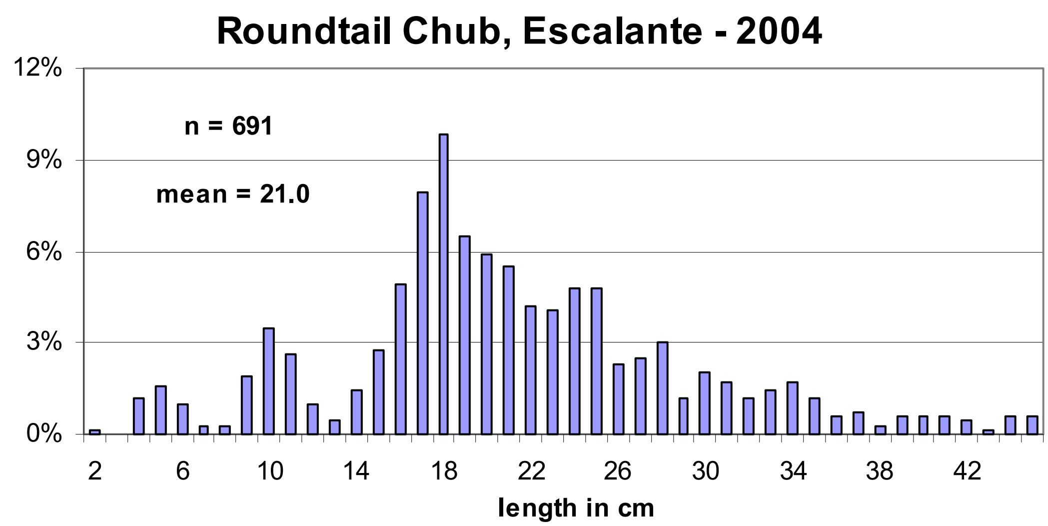


Figure A3-25. Roundtail Chub - Escalante, Gunnison River, August-September 2004.

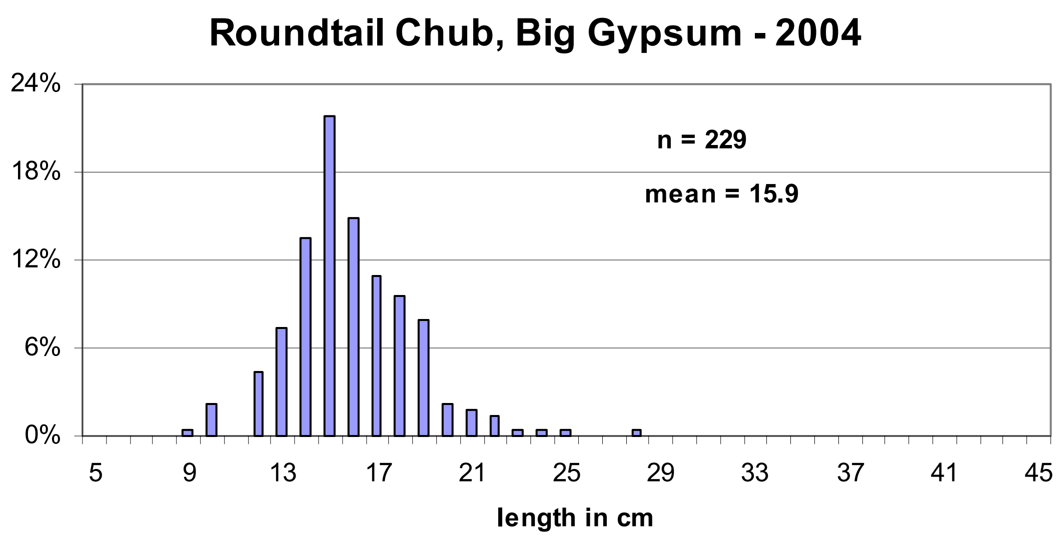


Figure A3-26. Roundtail Chub - Big Gypsum, Dolores River, July 2004.

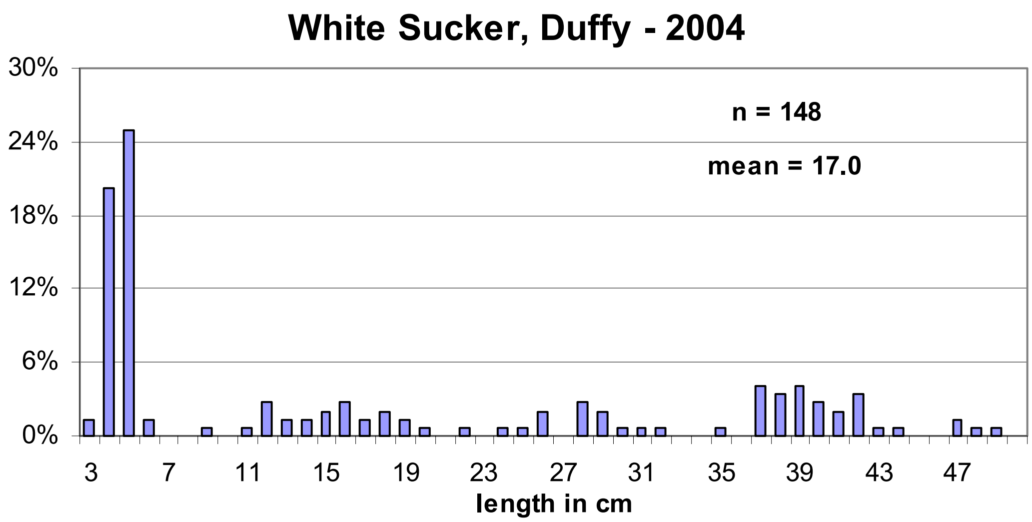


Figure A3-27. White Sucker - Duffy, Yampa River, July-August 2004.

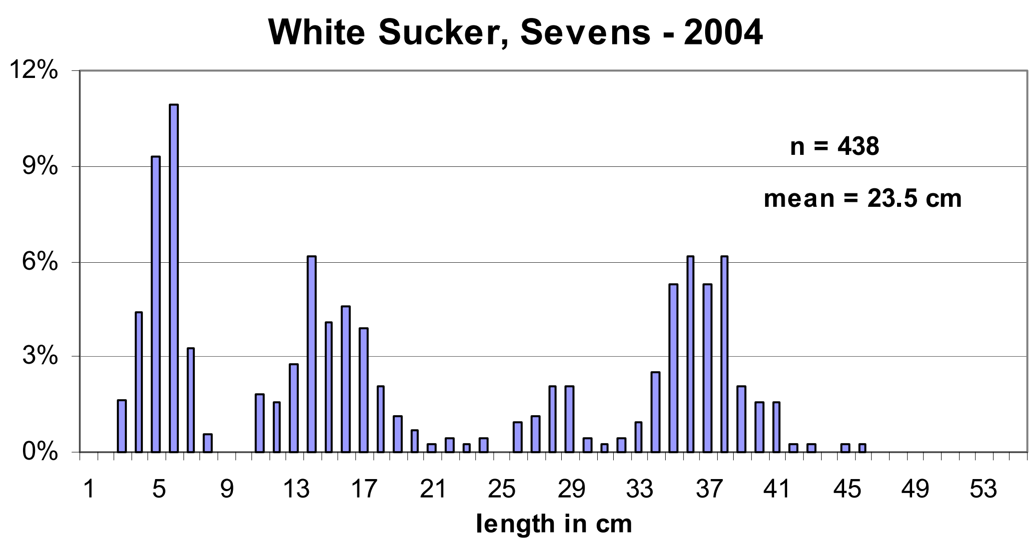


Figure A3-28. White Sucker - Sevens, Yampa River, July-August 2004.

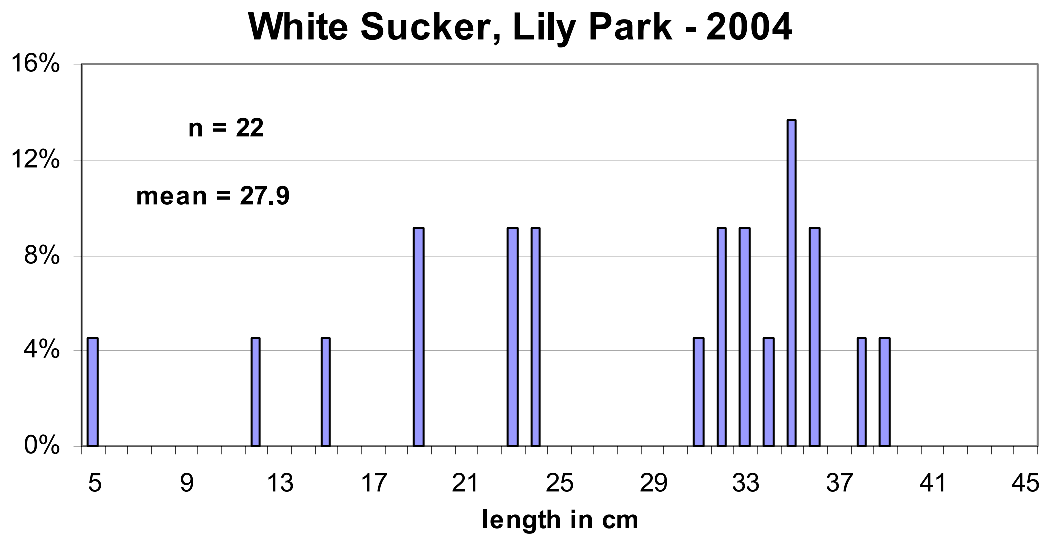


Figure A3-29. White Sucker - Lily Park, Yampa River, July-August 2004.

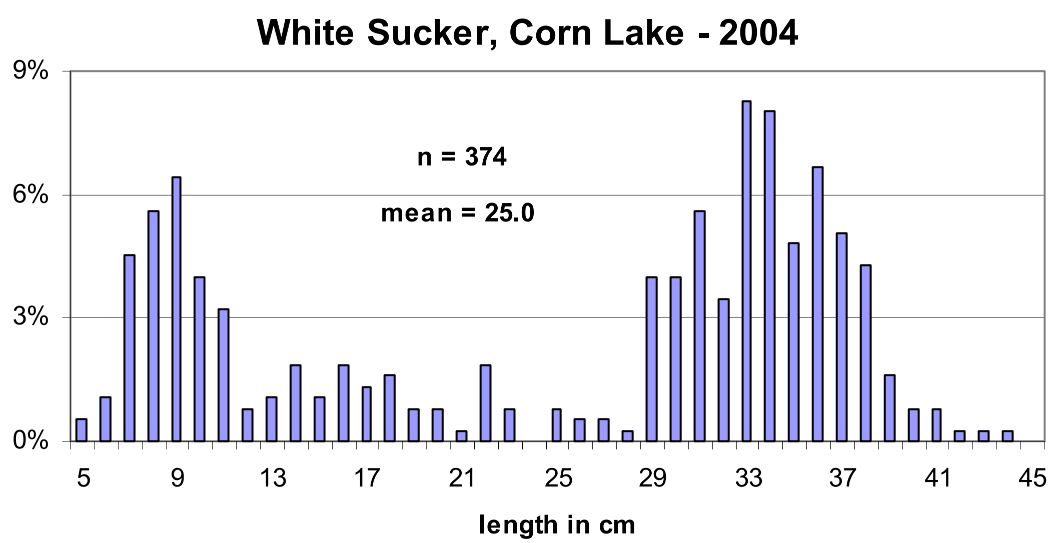


Figure A3-30. White Sucker - Corn Lake, Colorado River, September - October 2004.

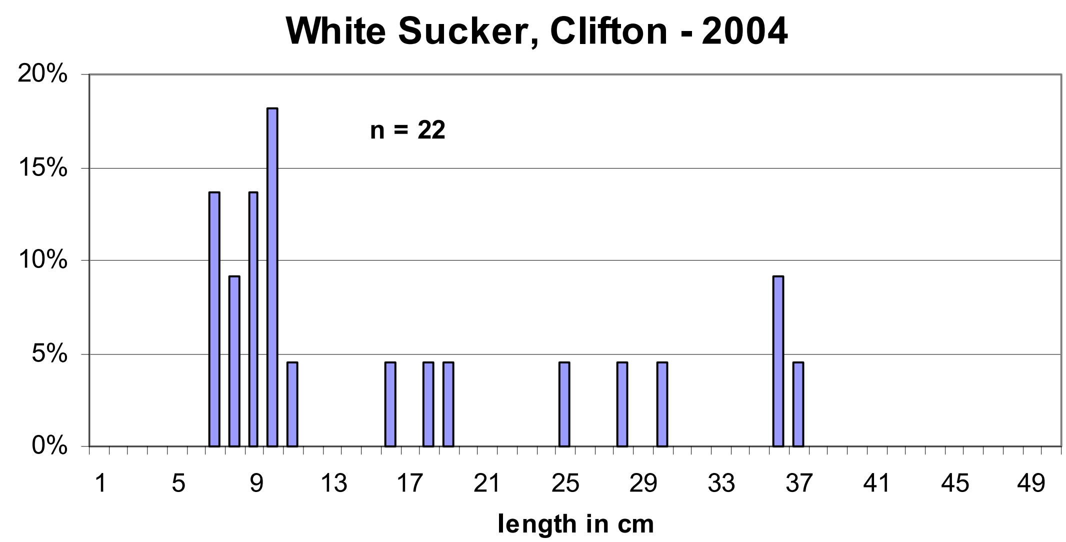


Figure A3-31. White Sucker - Clifton, Colorado River, October 2004.

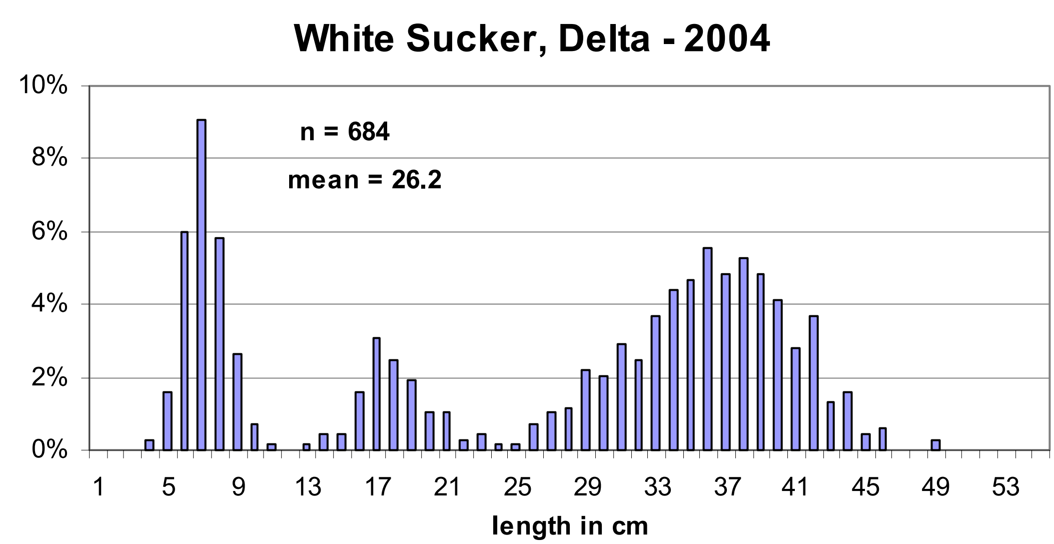


Figure A3-32. White Sucker - Delta, Gunnison River, August-September 2004.

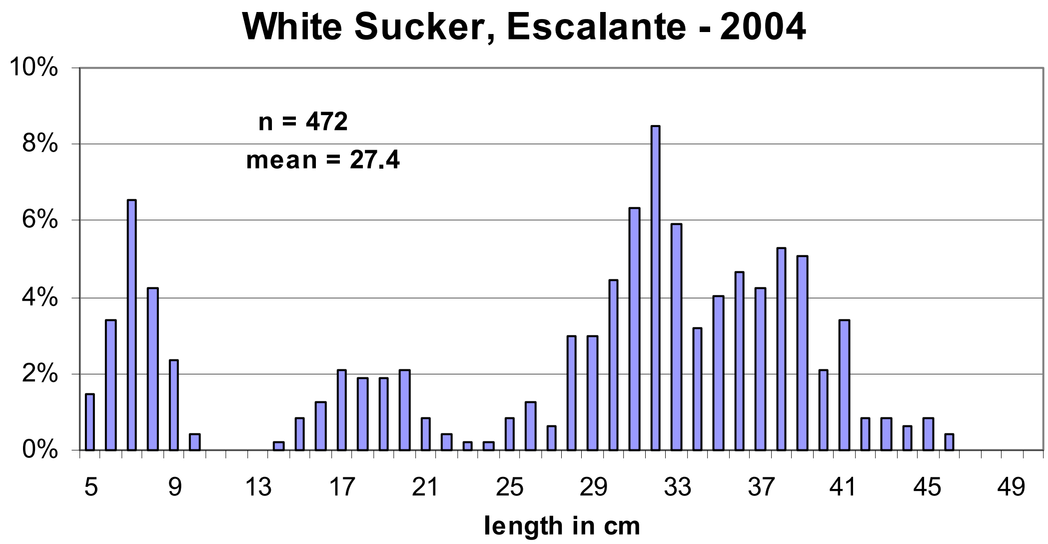


Figure A3-33. White Sucker - Escalante, Gunnison River, August-September 2004.

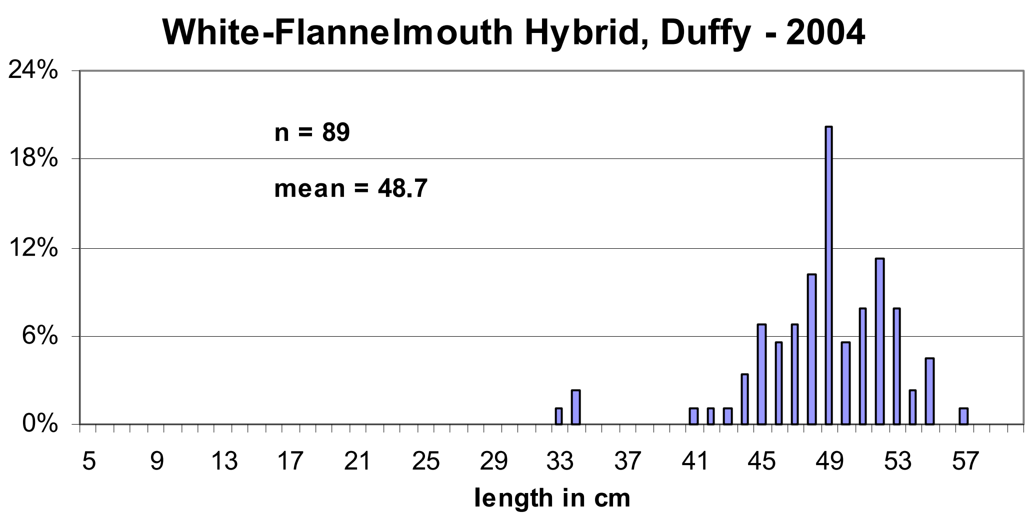


Figure A3-34. White-Flannelmouth Hybrid - Duffy, Yampa River, July-August 2004.

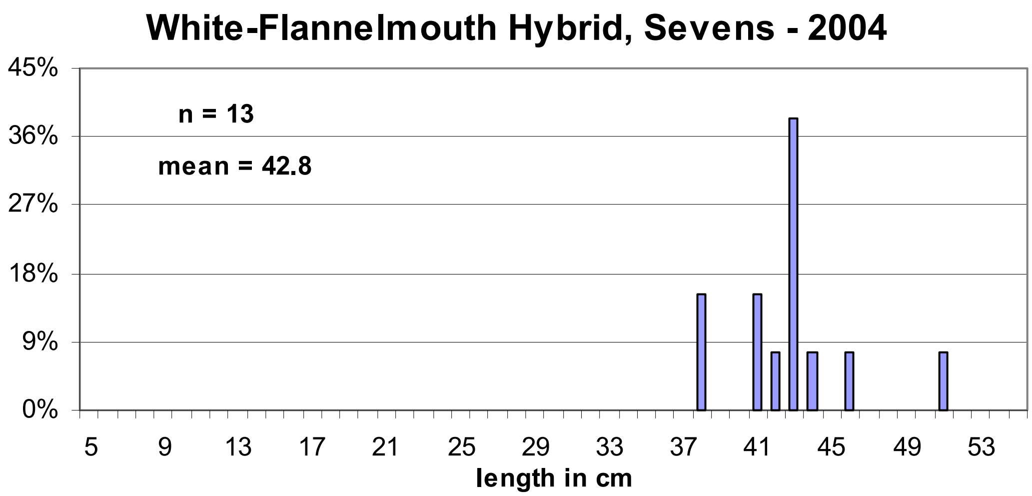


Figure A3-35. White-Flannelmouth Hybrid - Sevens, Yampa River, July-August 2004.

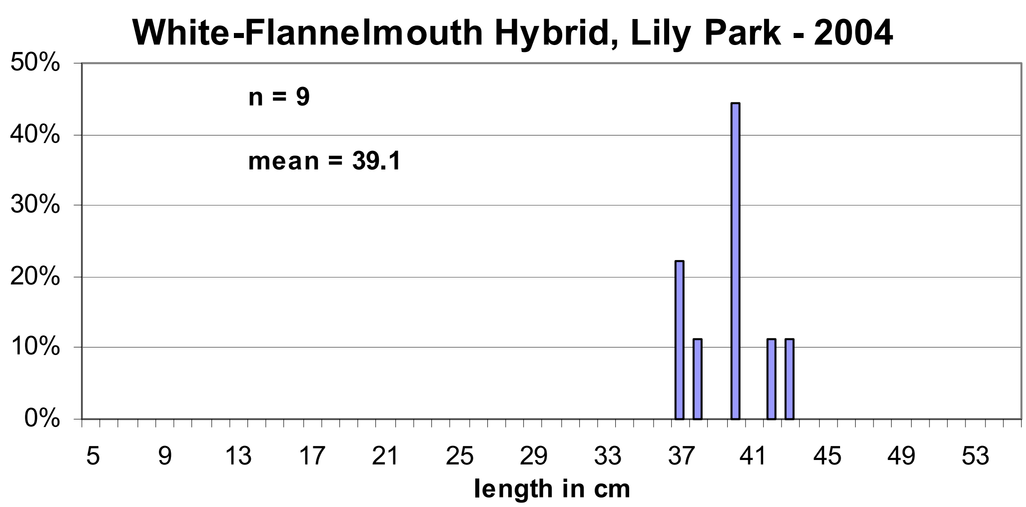


Figure A3-36. White-Flannelmouth Hybrid - Lily Park, Yampa River, July-August 2004.

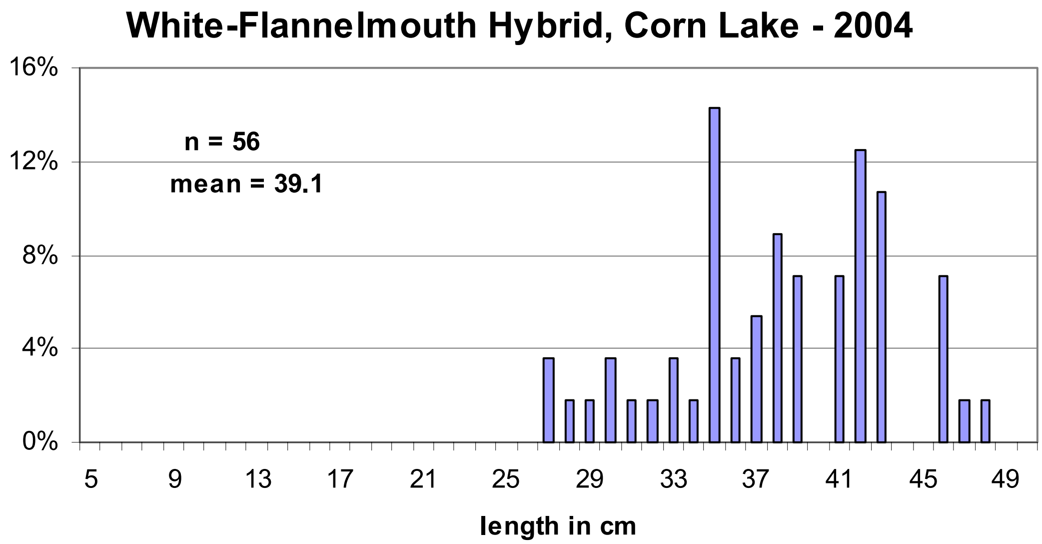


Figure A3-37. White-Flannelmouth Hybrid - Corn Lake, Colorado River, September - October 2004.

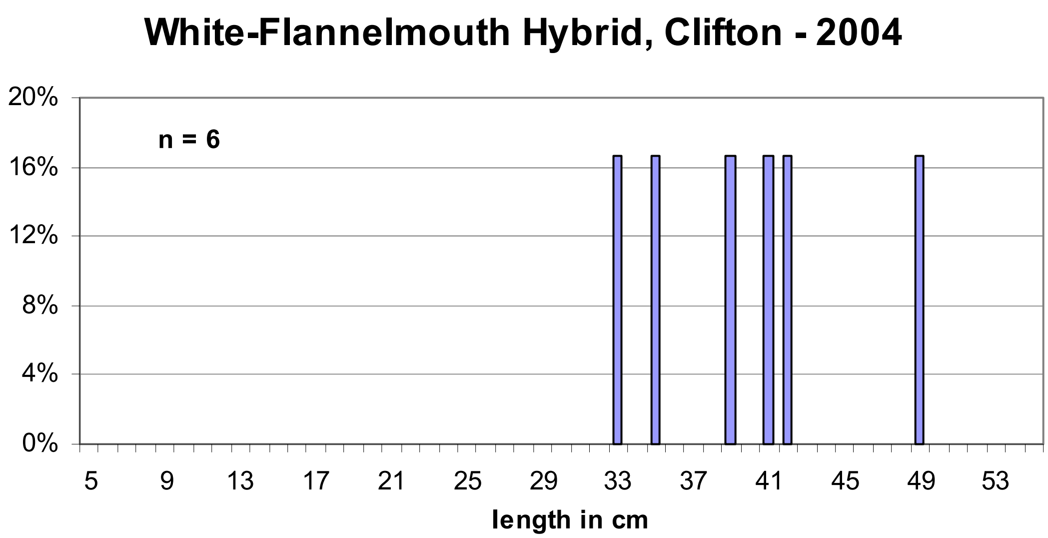


Figure A3-38. White Flannelmouth Hybrid - Clifton, Colorado River, October 2004.

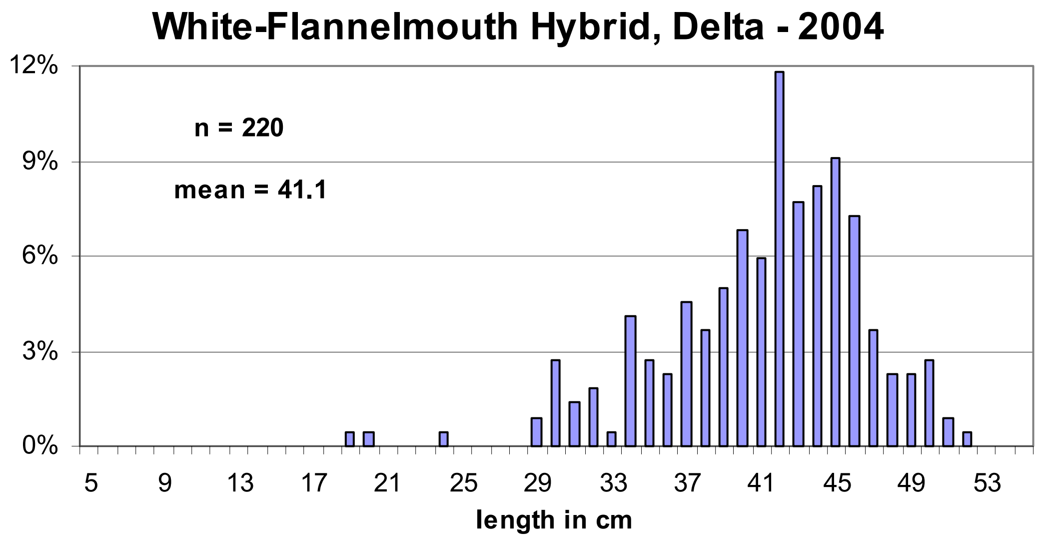


Figure A3-39. White Flannelmouth Hybrid - Delta, Gunnison River, August-September 2004.

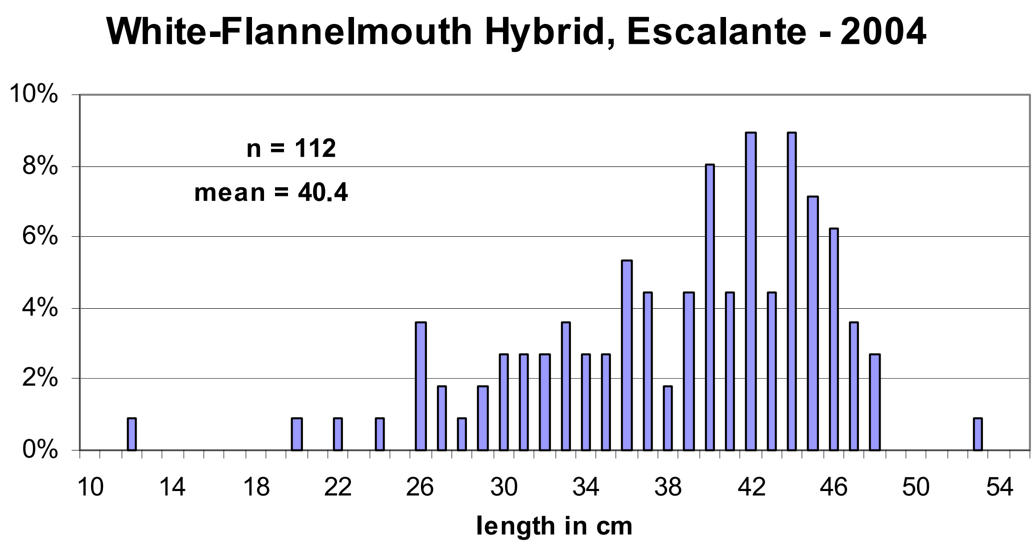


Figure A3-40. White Flannelmouth Hybrid - Escalante, Gunnison River, August-September 2004.

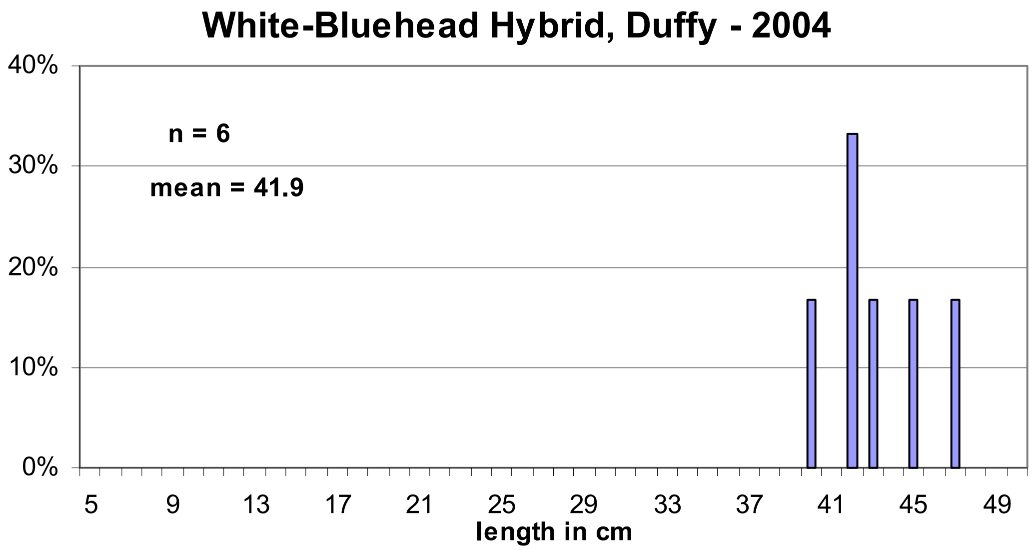


Figure A3-41. White-Bluehead Hybrid - Duffy, Yampa River, July-August 2004.

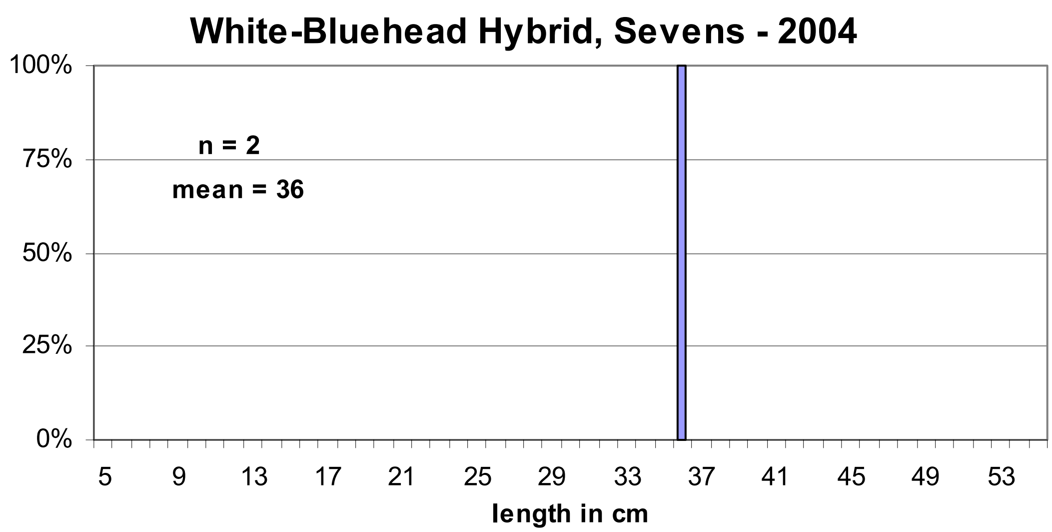


Figure A3-42. White-Bluehead Hybrid - Sevens, Yampa River, July-August 2004.

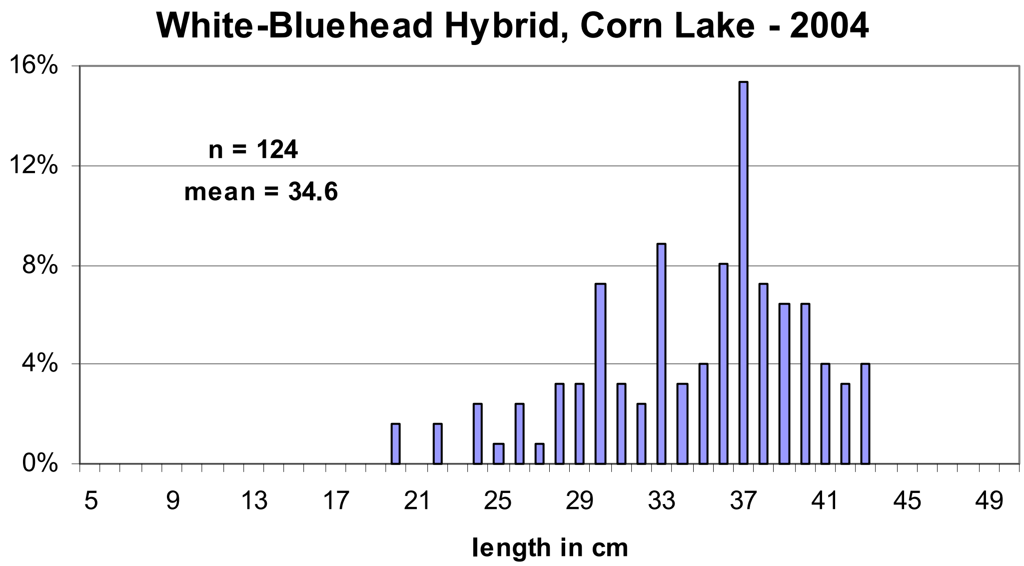


Figure A3-43. White-Bluehead Hybrid - Corn Lake, Colorado River, September - October 2004.

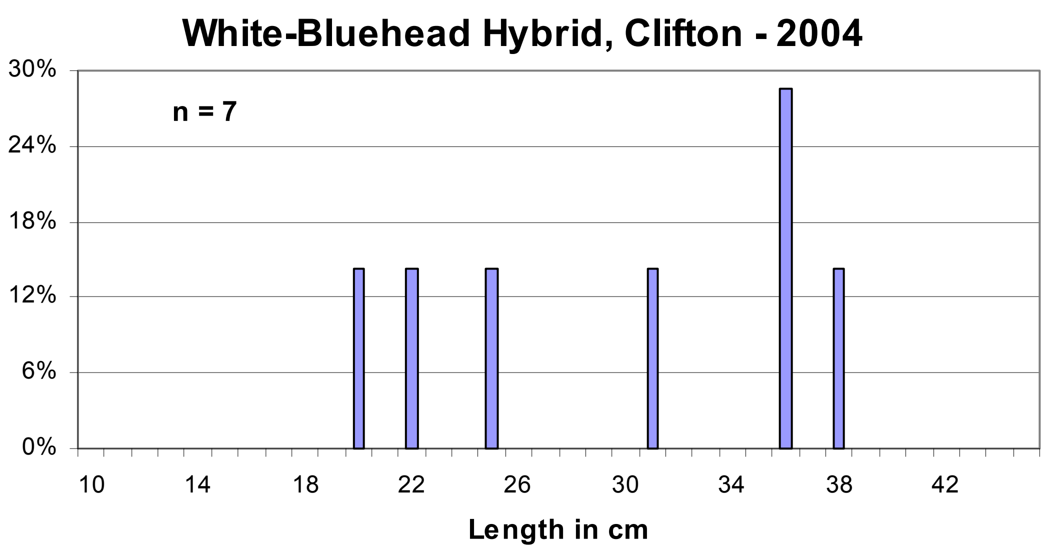
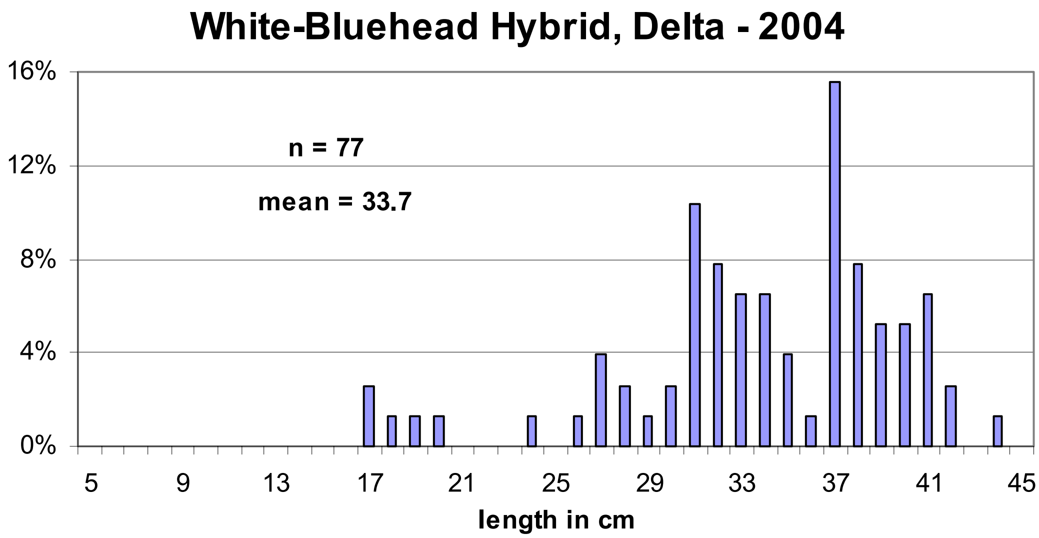


Figure A3-44. White-Bluehead Hybrid - Clifton, Colorado River, October 2004.



A Figure 1-45. White-Bluehead Hybrid - Delta, Gunnison River, August-September 2004.

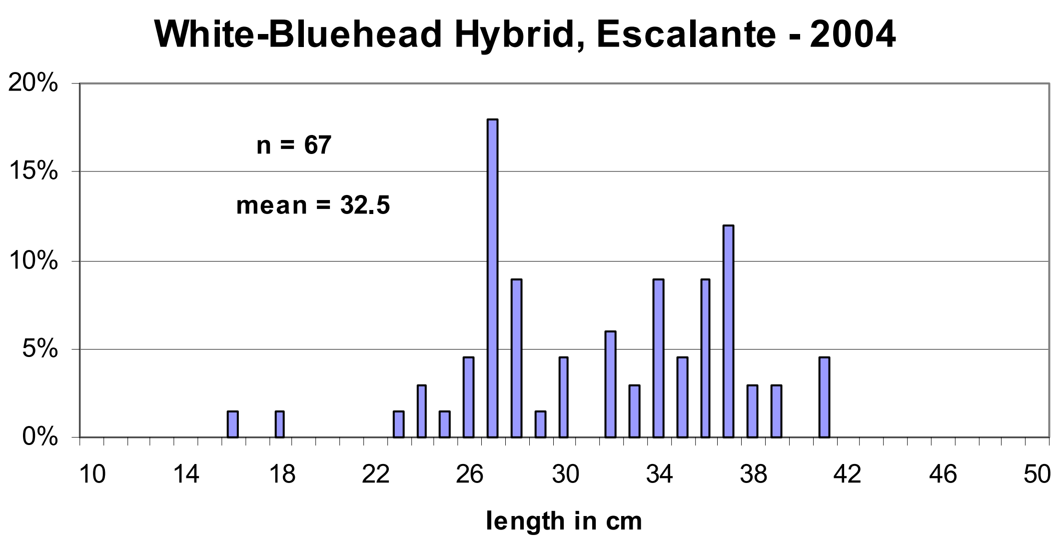


Figure A3-46. White-Bluehead Hybrid - Escalante, Gunnison River, August-September 2004.

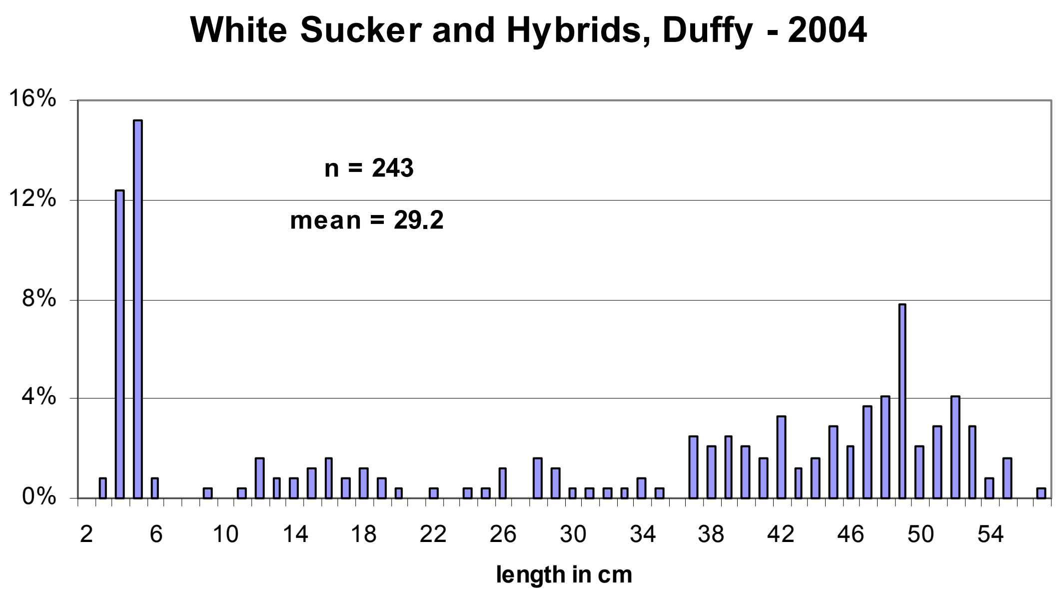


Figure A3-47. White Sucker and Hybrids – Duffy, Yampa River, July – August 2004.

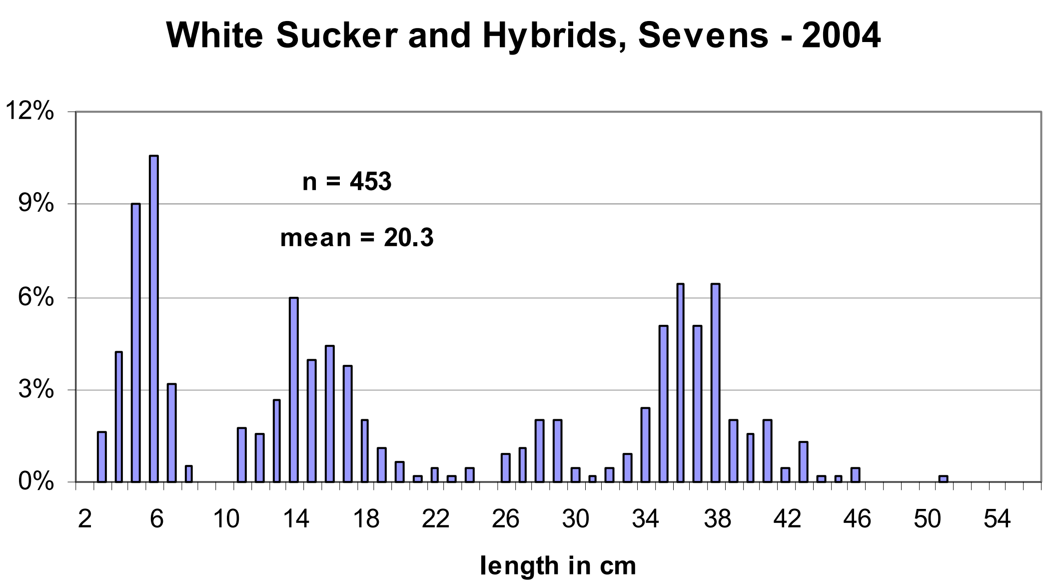


Figure A3-48. White Sucker and Hybrids, Sevens, Yampa River, July – August 2004.

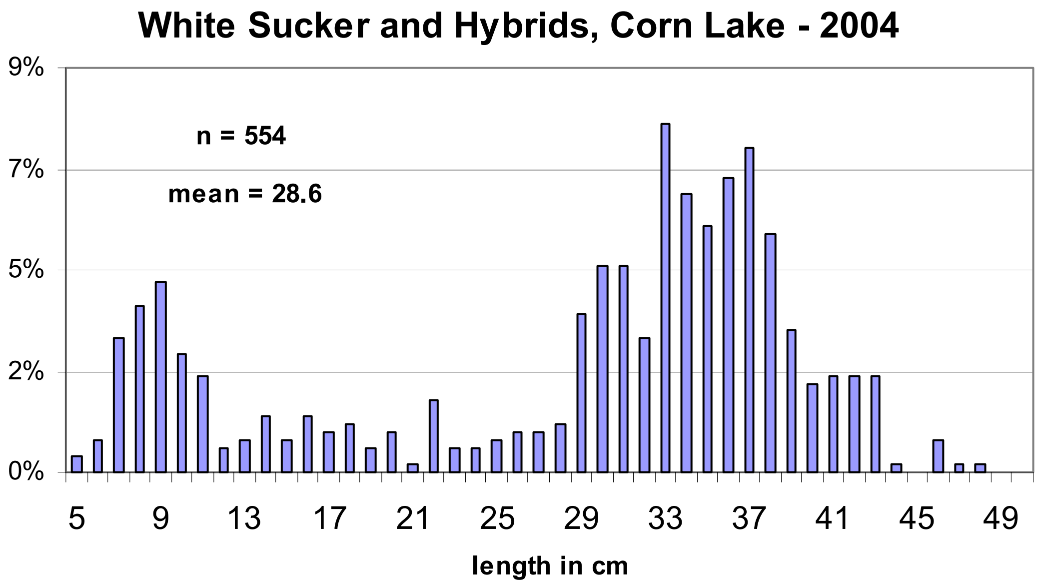


Figure A3-49. White Sucker and Hybrids, Corn Lake, Colorado River, September – October 2004.

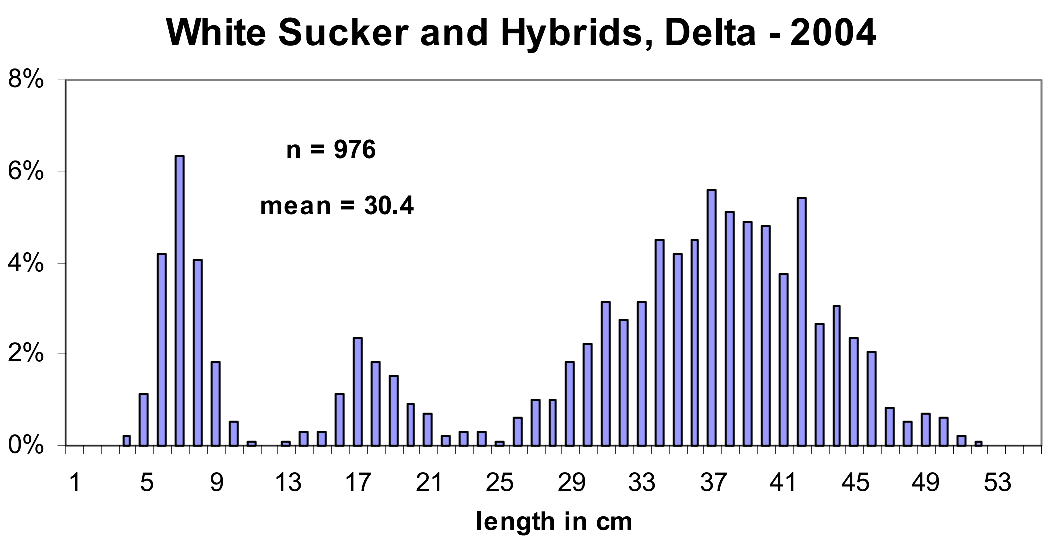


Figure A3- 50. White Sucker and Hybrids - Delta, Gunnison River, August – September 2004.

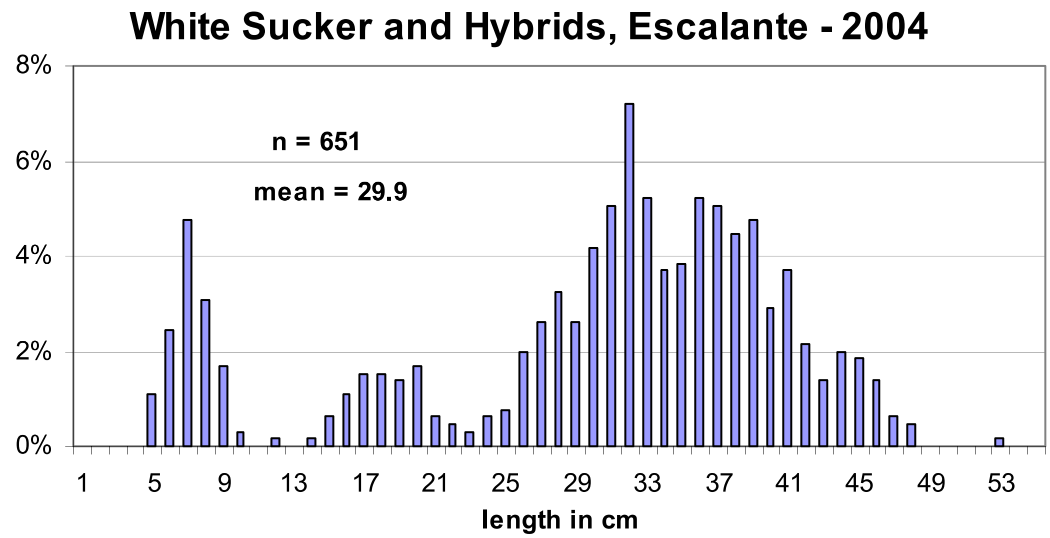


Figure A3-51. White Sucker and Hybrids – Escalante, Gunnison River, August – September 2004.

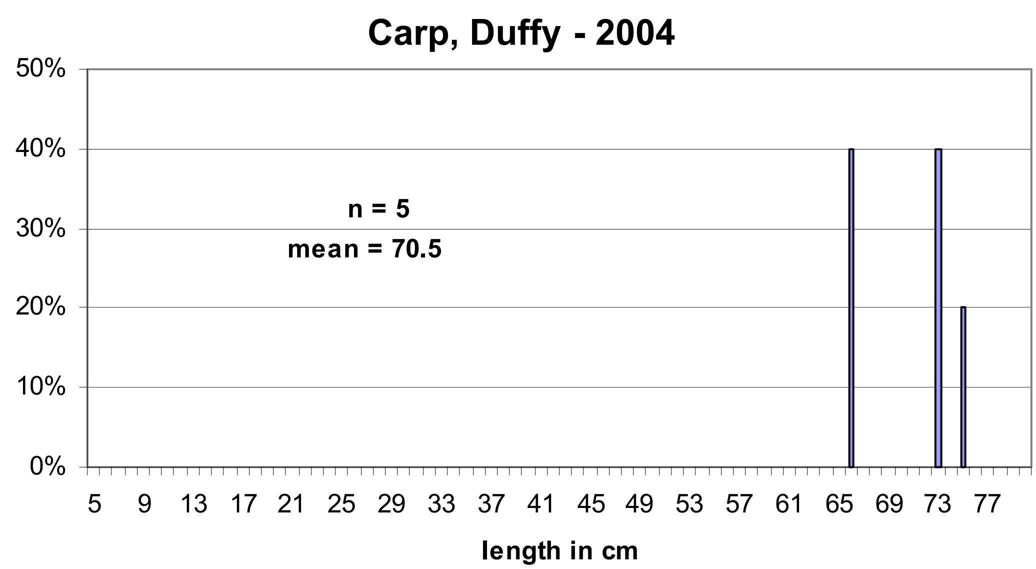


Figure A3-52. Carp - Duffy, Yampa River, July-August 2004.

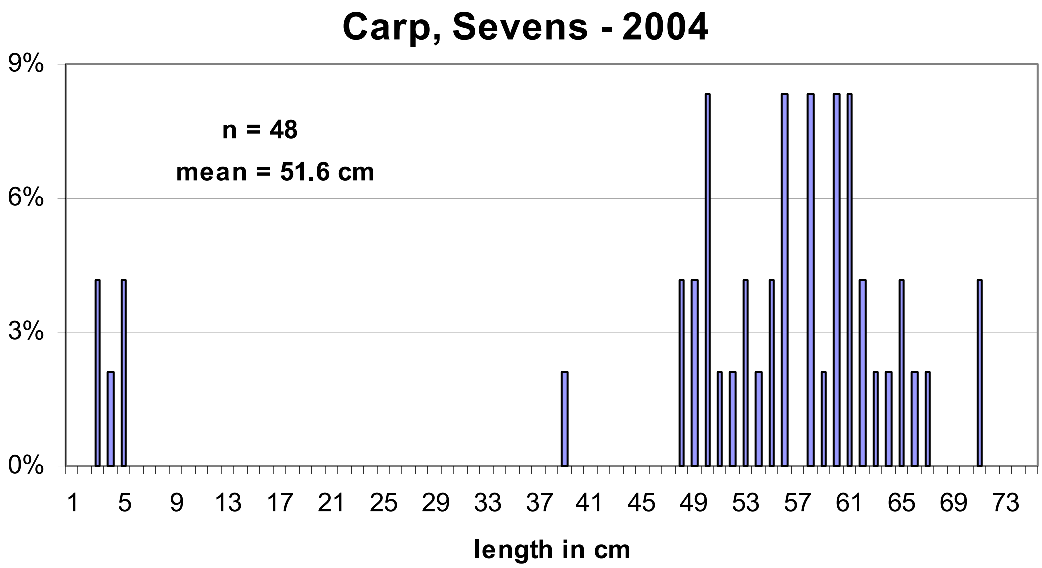


Figure A3-53. Carp - Sevens, Yampa River, July-August 2004.

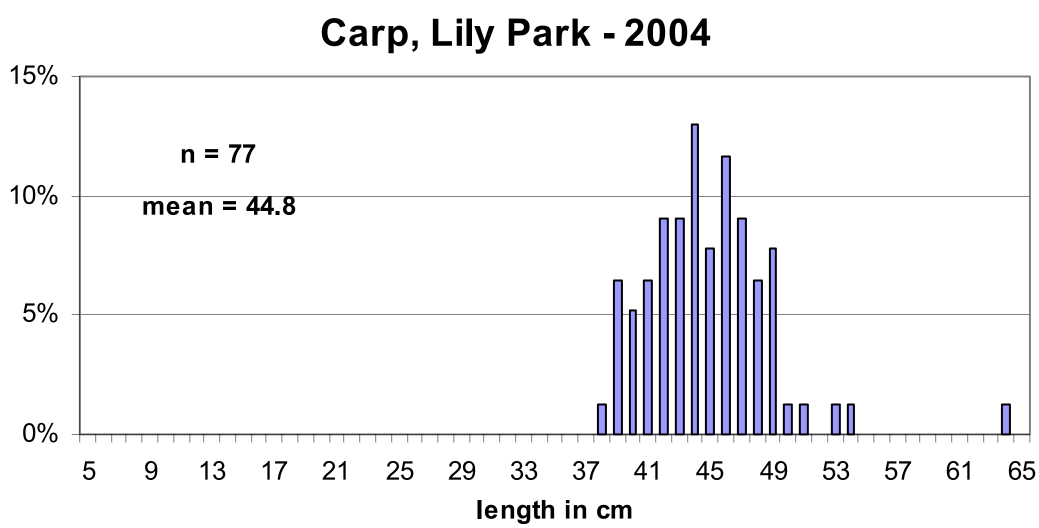


Figure A3-54. Carp - Lily Park, Yampa River, July-August 2004.

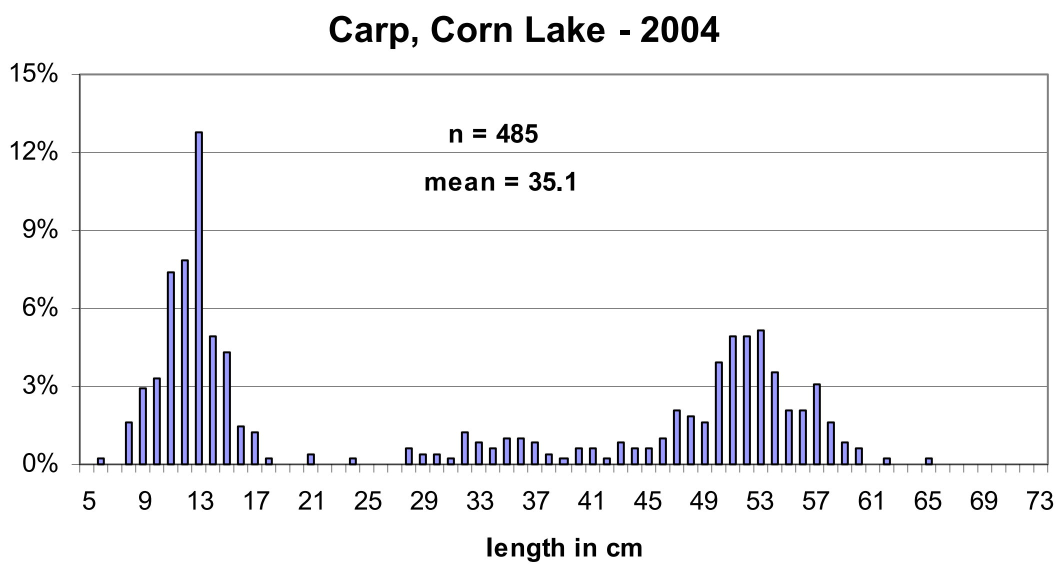


Figure A3-55. Carp - Corn Lake, Colorado River, September - October 2004.

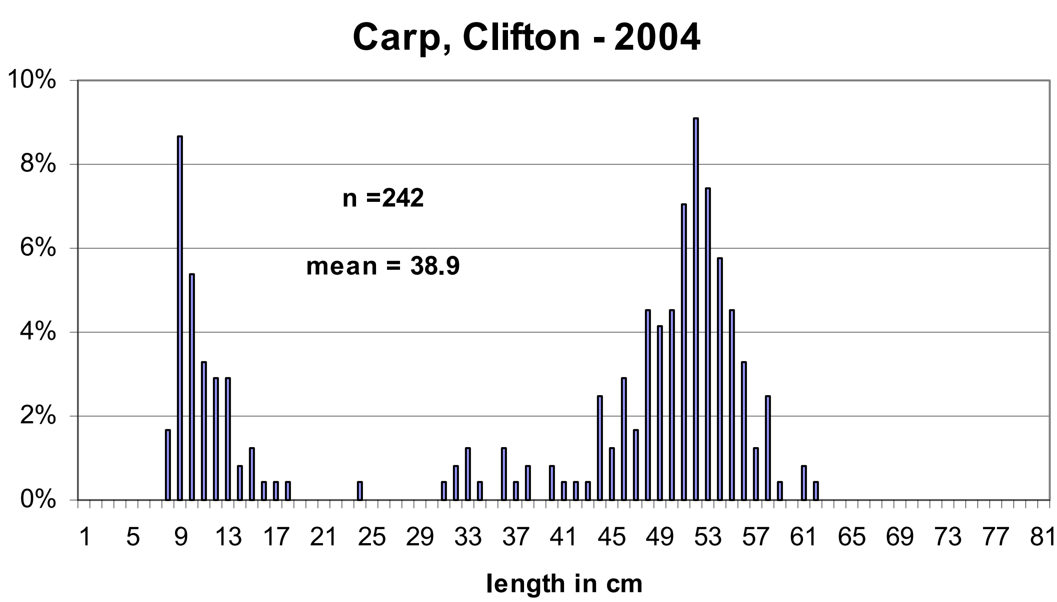


Figure A3-56. Carp - Clifton, Colorado River, October 2004.

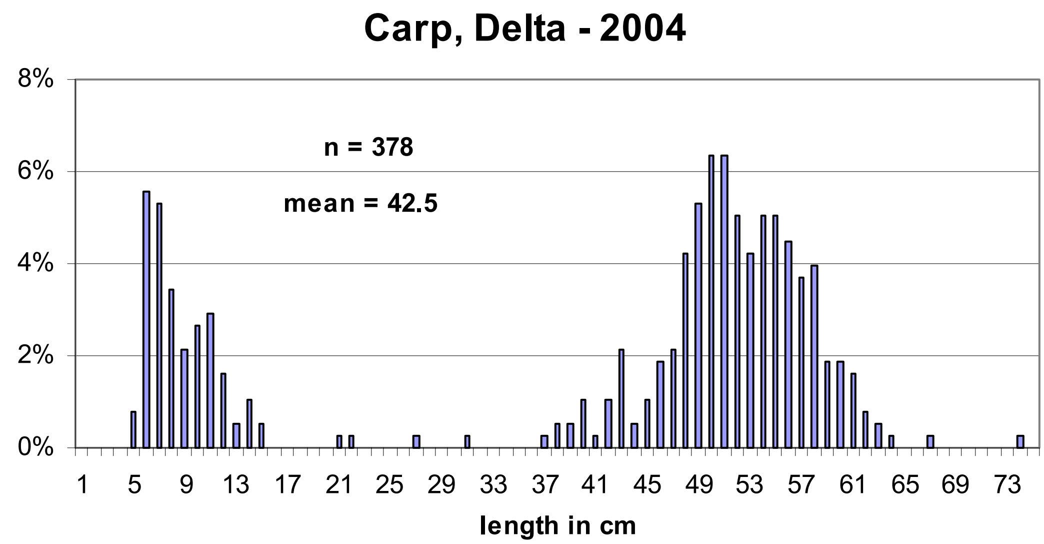


Figure A3-57. Carp - Delta, Gunnison River, August-September 2004.

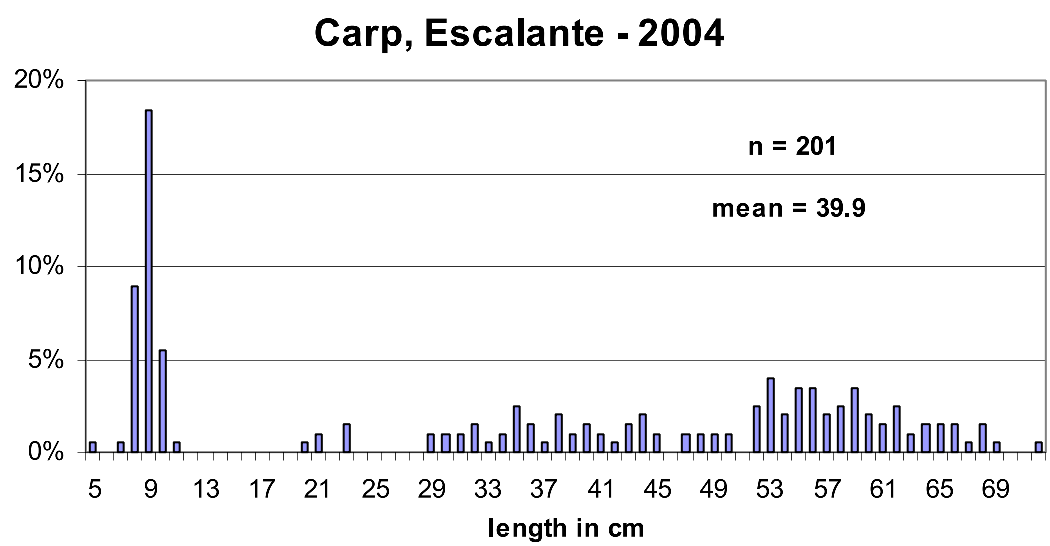


Figure A3-58. Carp - Escalante, Gunnison River, August-September 2004.

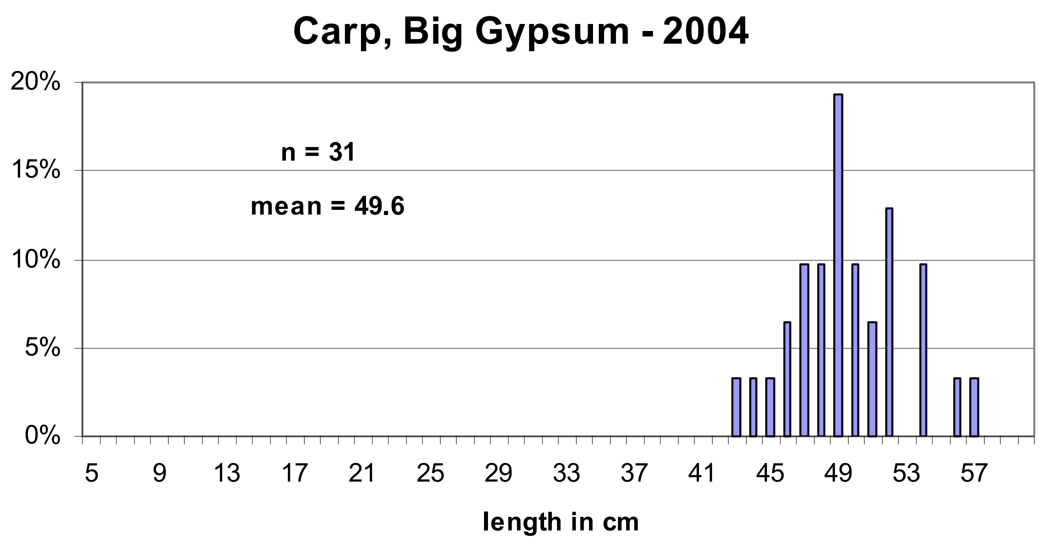


Figure A3-59. Carp - Big Gypsum, Dolores River, July 2004.

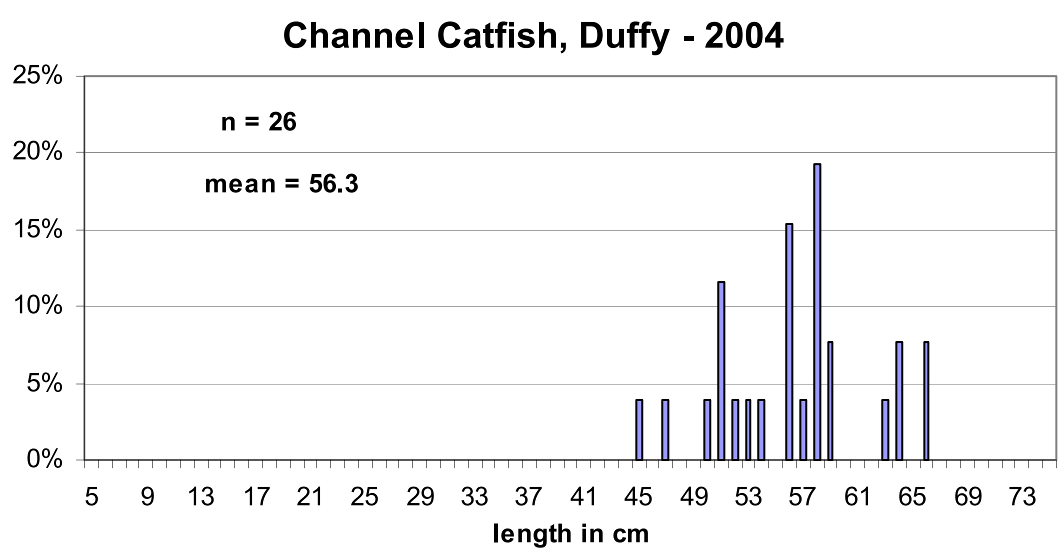


Figure A3-60. Channel Catfish - Duffy, Yampa River, July-August 2004.

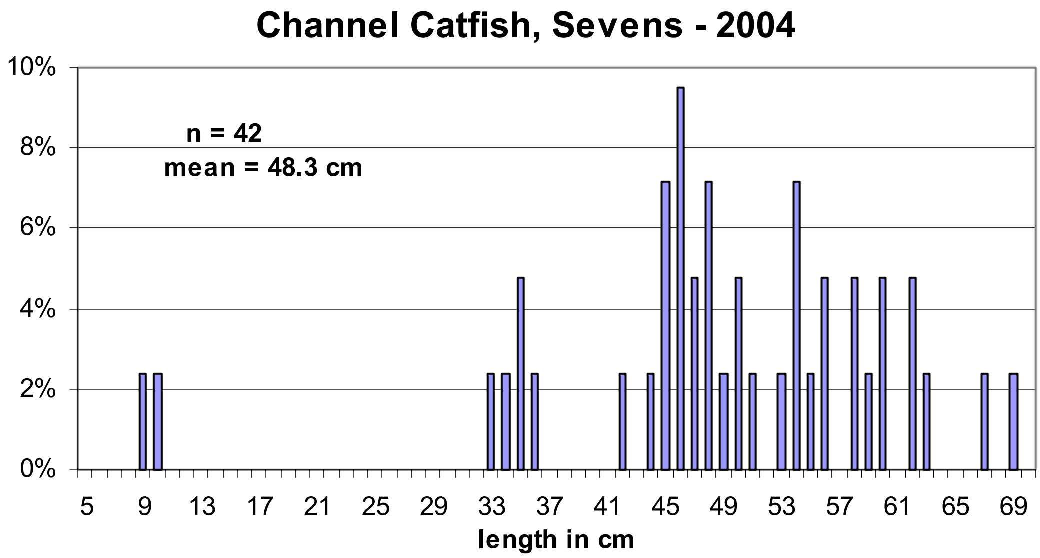


Figure A3-61. Channel Catfish - Sevens, Yampa River, July-August 2004.

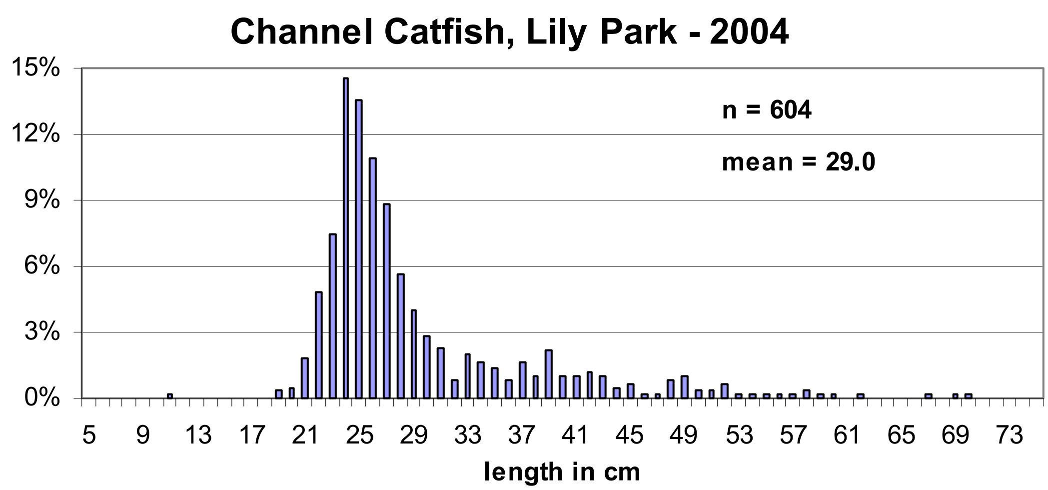


Figure A3-62. Channel Catfish - Lily Park, Yampa River, July-August 2004.

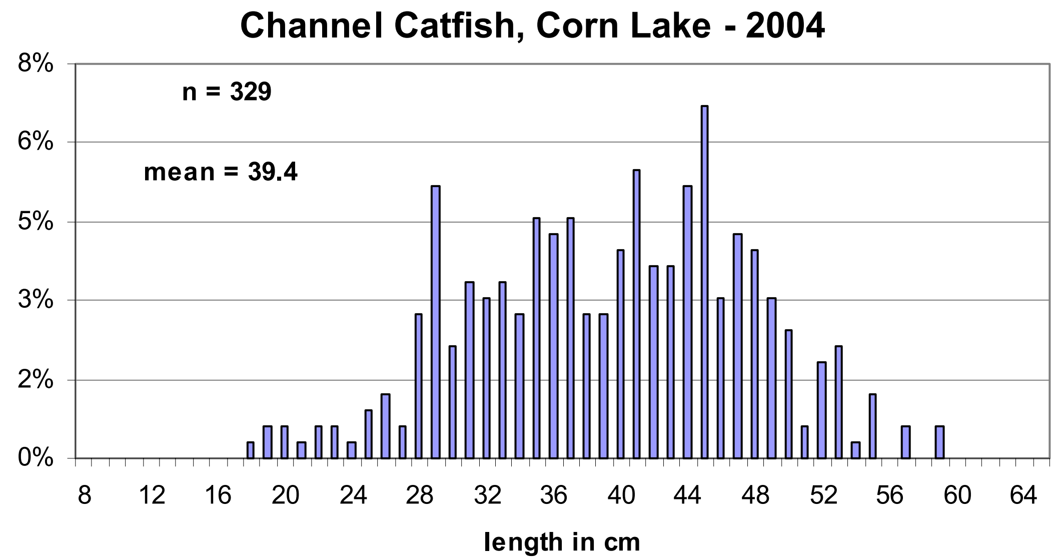


Figure A3-63. Channel Catfish - Corn Lake, Colorado River, September - October 2004.

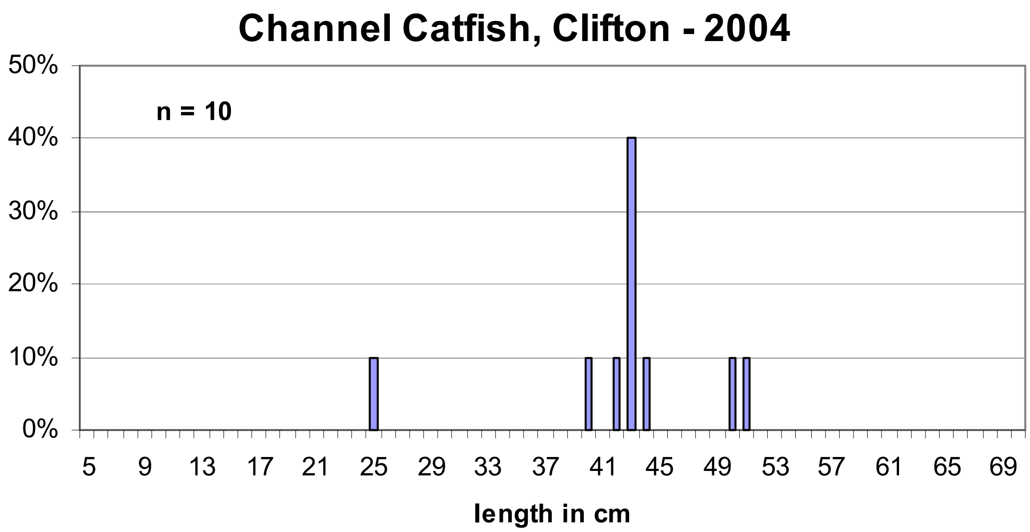


Figure A3-64. Channel Catfish - Clifton, Colorado River, October 2004.

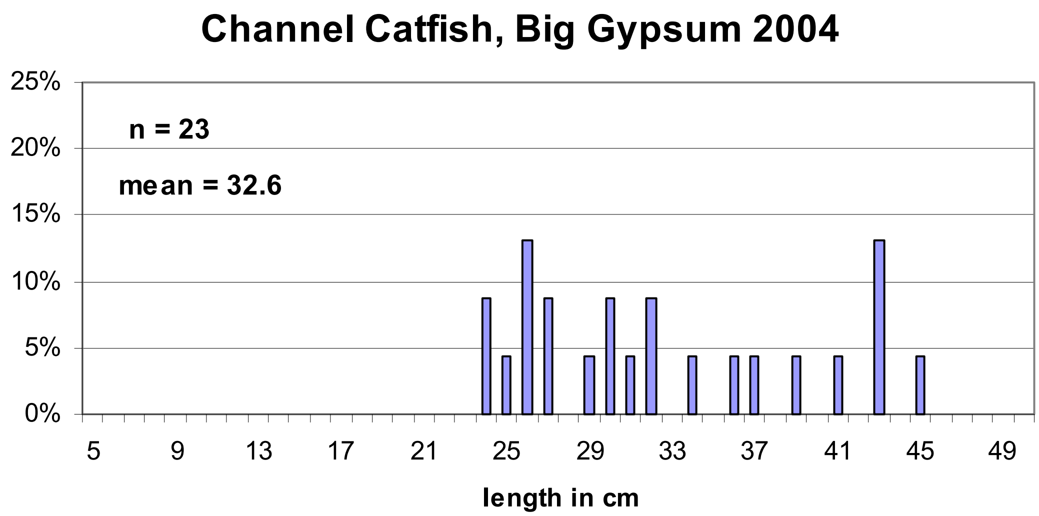


Figure A3-65. Channel Catfish – Big Gypsum, Dolores River, July 2004.

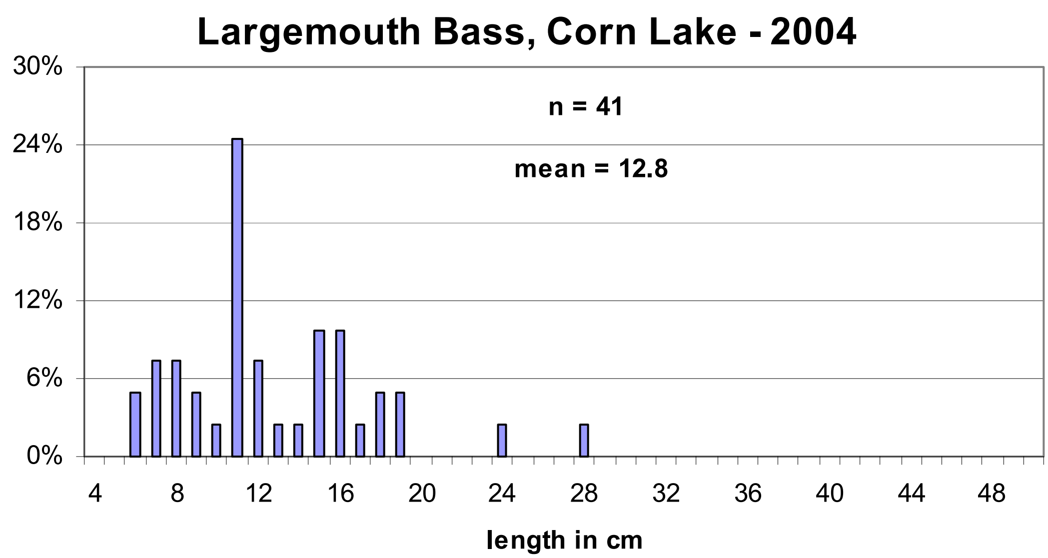


Figure A3-66. Largemouth Bass - Corn Lake, Colorado River, September - October 2004.

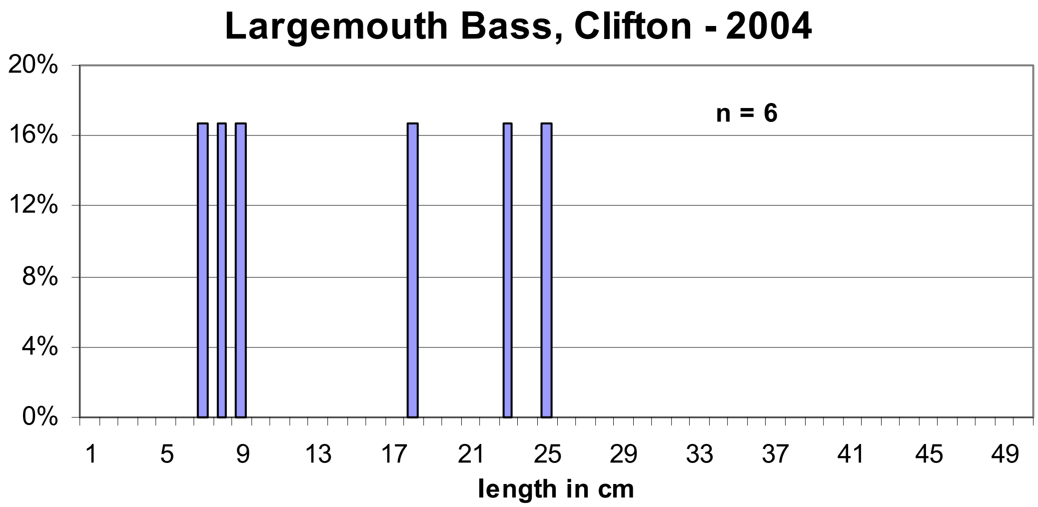


Figure A3-67. Largemouth Bass - Clifton, Colorado River, October 2004.

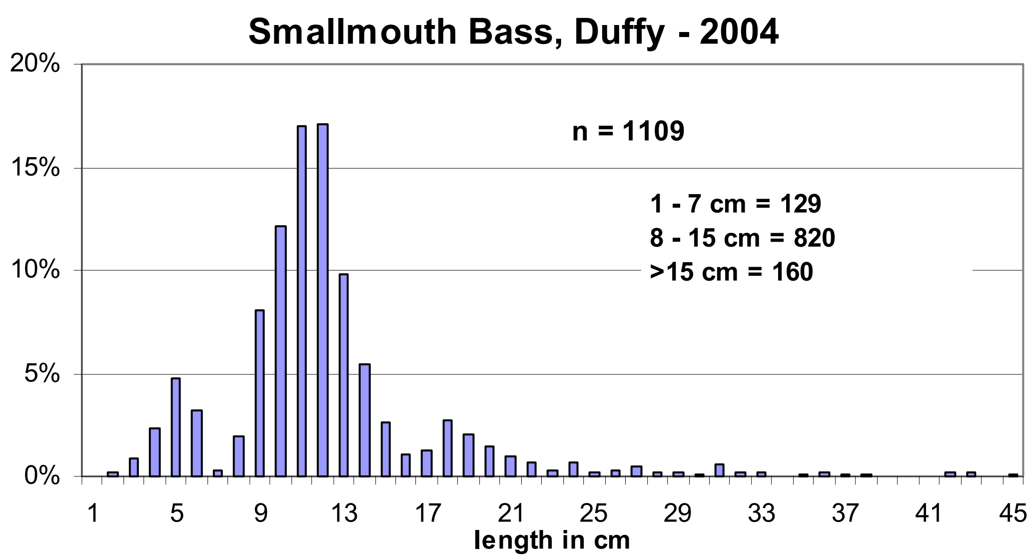


Figure A3-68. Smallmouth Bass - Duffy, Yampa River, July-August 2004.

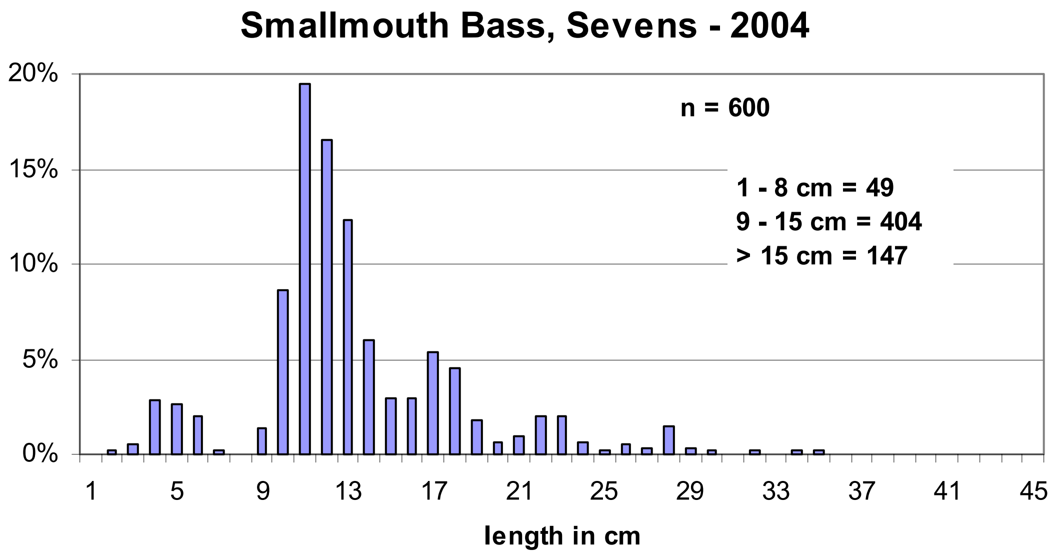


Figure A3-69. Smallmouth Bass - Sevens, Yampa River, July-August 2004.

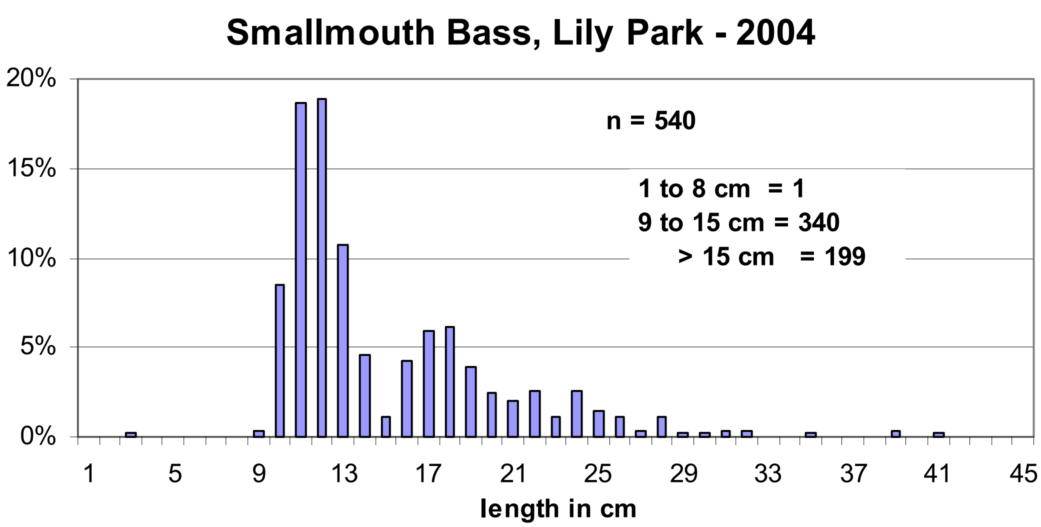


Figure A3-70. Smallmouth Bass - Lily Park, Yampa River, July-August 2004.

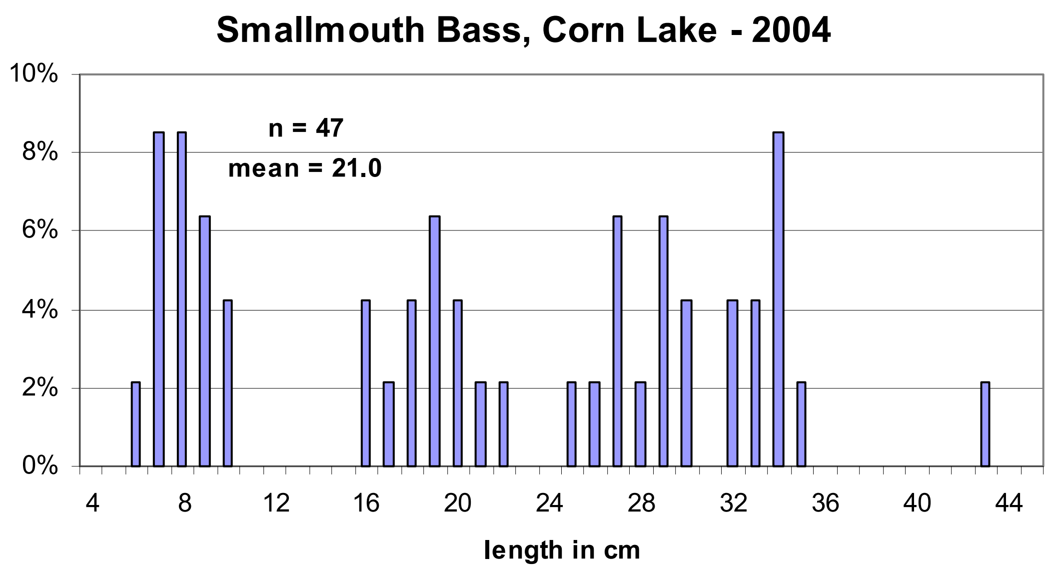


Figure A3-71. Smallmouth Bass - Corn Lake, Colorado River, September - October 2004.

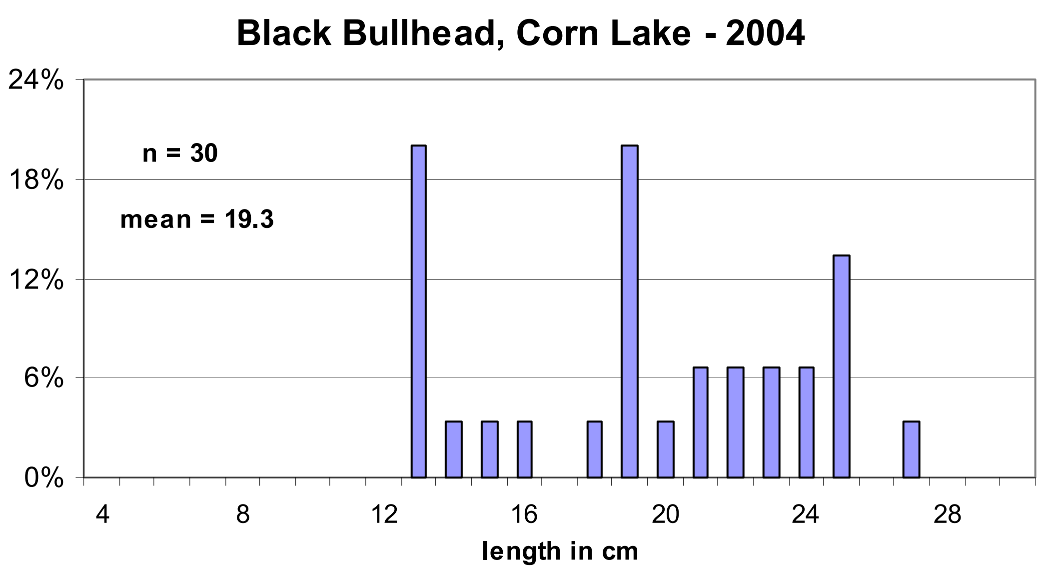


Figure A3-72. Black Bullhead - Corn Lake, Colorado River, September - October 2004.

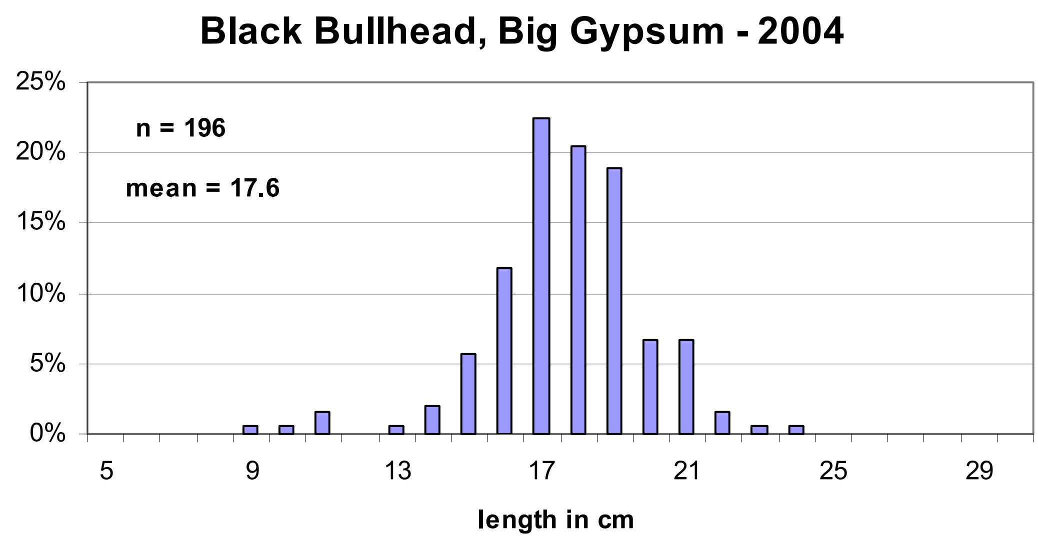


Figure A3-73. Black Bullhead - Big Gypsum, Dolores River, July 2004.

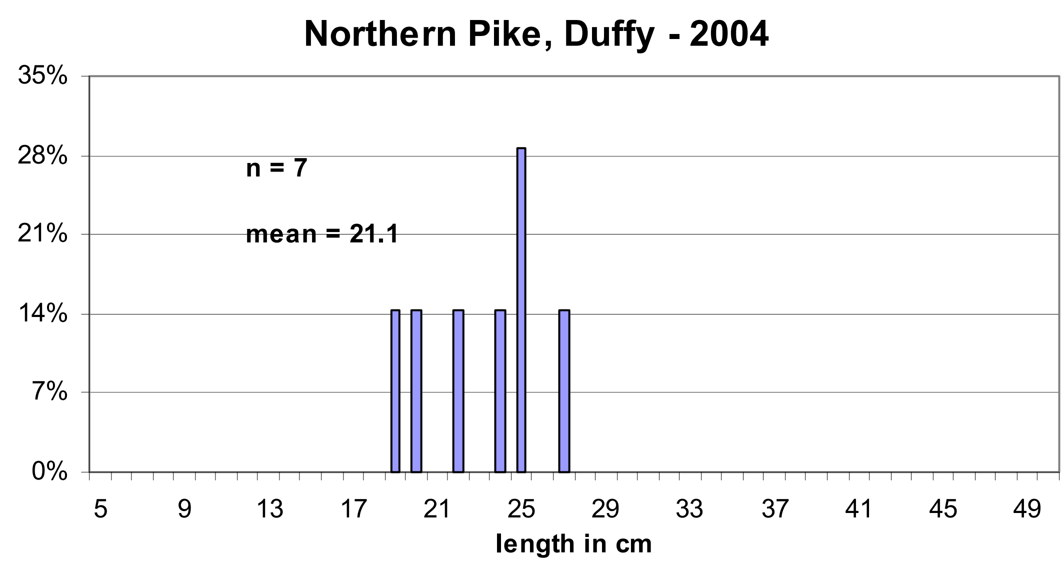


Figure A3-74. Northern Pike - Duffy, Yampa River, July-August 2004.

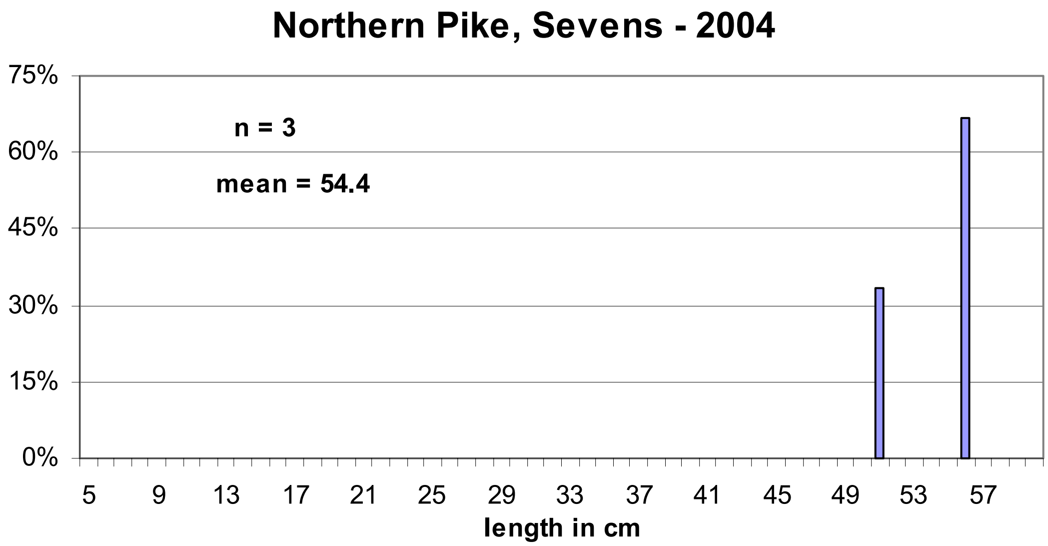


Figure A3-75. Northern Pike - Sevens, Yampa River, July-August 2004.

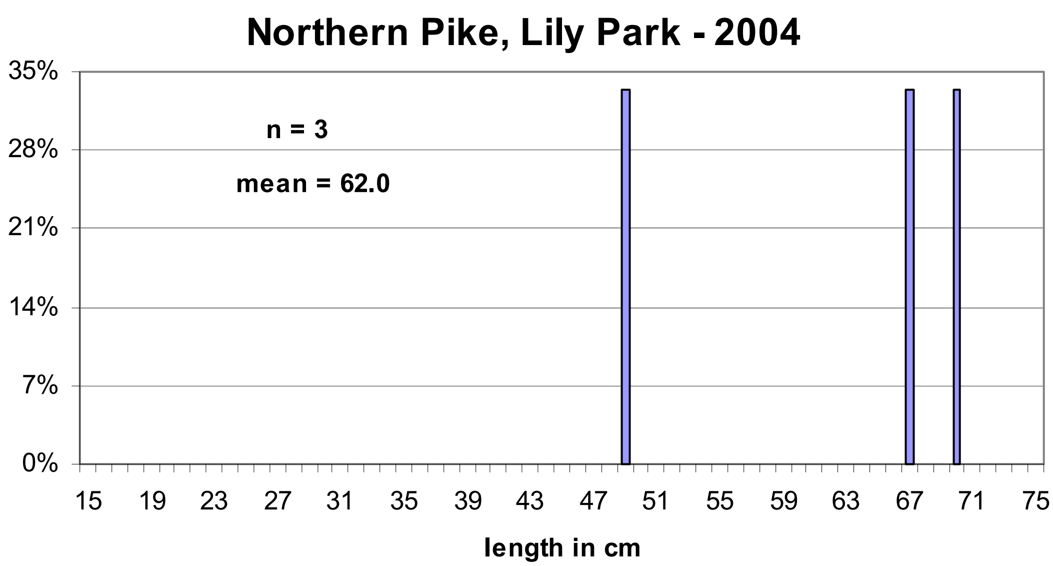


Figure A3-76. Northern Pike - Lily Park, Yampa River, July-August 2004.

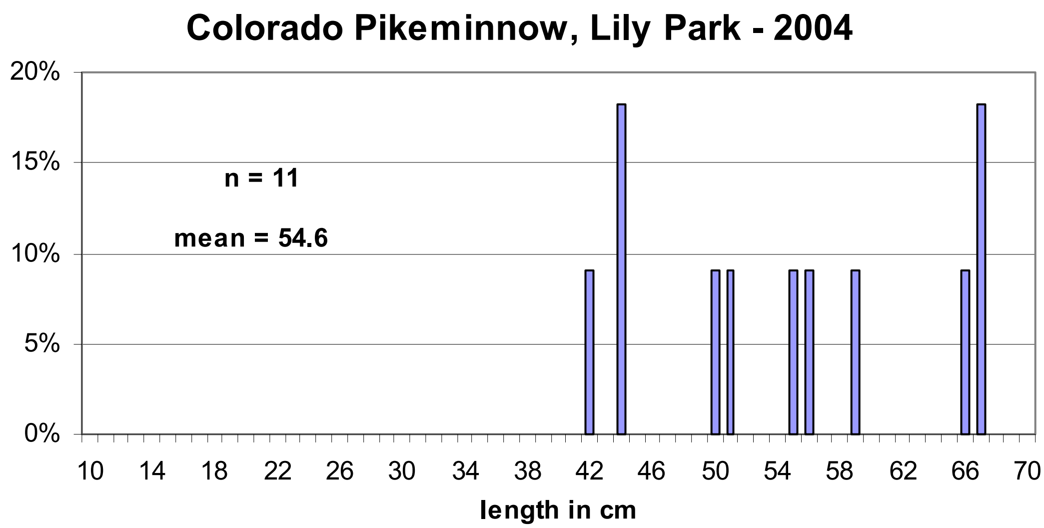


Figure A3-77. Colorado Pikeminnow –Lily Park, Yampa River, July – August 2004.

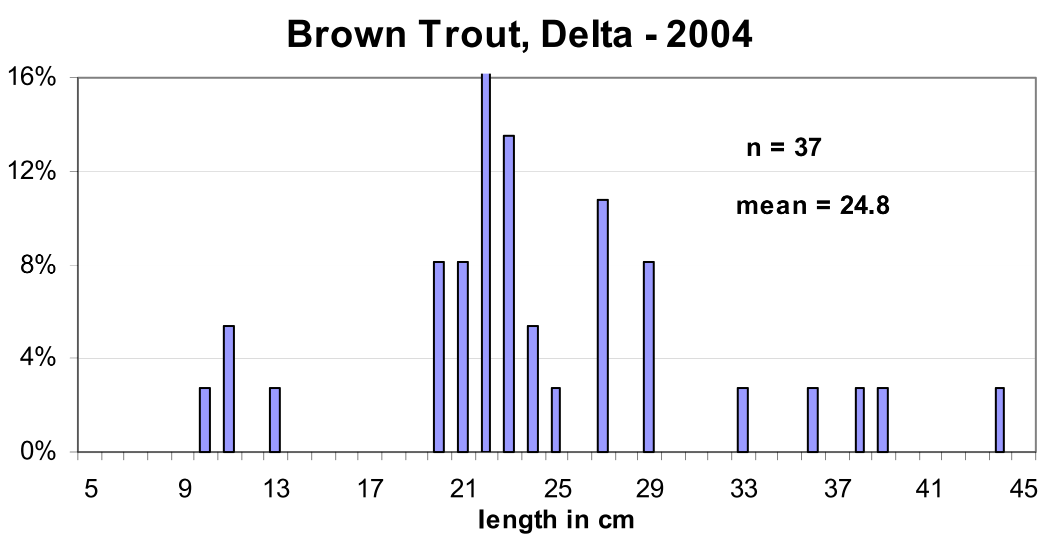


Figure A3-78. Brown Trout – Delta, Gunnison River, August – September 2004.

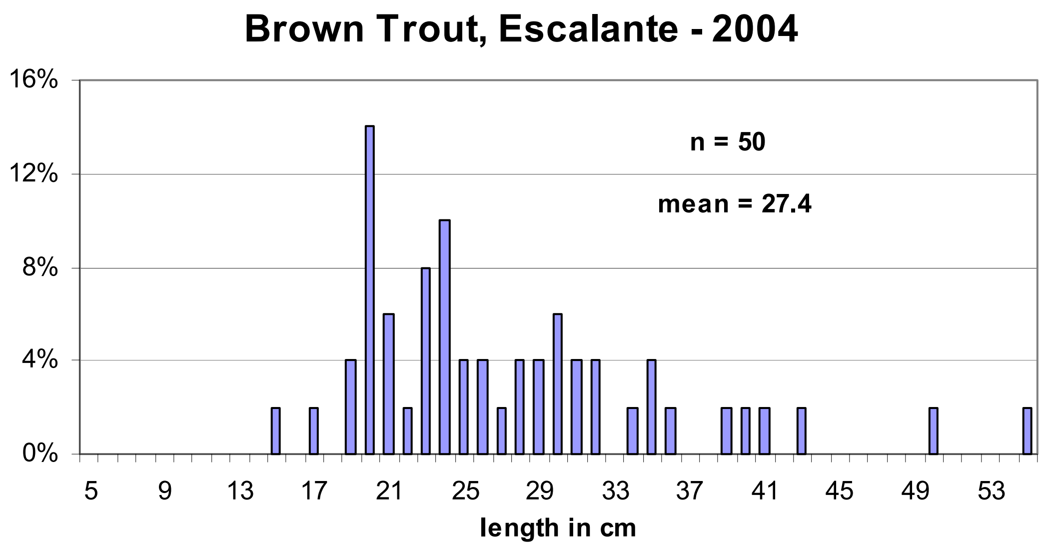


Figure A3-79. Brown Trout – Escalante, Gunnison River, July – August 2004.

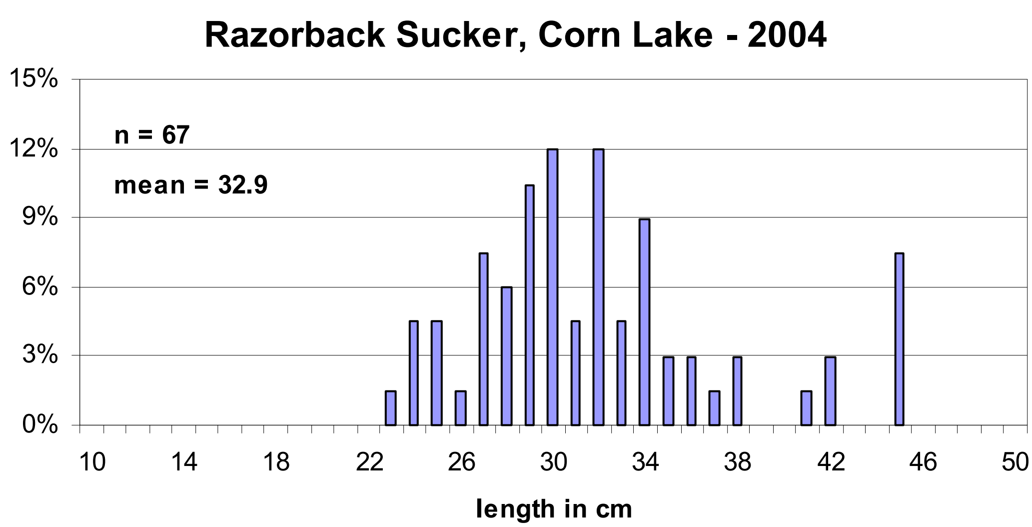


Figure A3-80. Razorback Sucker – Corn Lake, Colorado River, October 2004.