Riverine Fish Flow Investigations

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Job Progress Report

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Study Objective: To determine relationships between flow and habitat availability for warm-water riverine fish communities of Colorado.

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INTRODUCTION

Habitat loss is one of the single greatest causes of declines in populations of native fishes in North America (Williams et al. 1989). The need to preserve minimum stream flows was recognized by the state of Colorado with the passage of Senate Bill 97 in 1973. Espegren (1998) states that most instream flow water right filings in Colorado have been for protecting minimum flow for cold water (headwater) habitats. The most common methodologies used in Colorado are the R2Cross method (Nehring 1979) and Instream Flow Incremental Methodology (IFIM) (Bovee 1982). IFIM estimates the amount of usable habitat for fish as a function of discharge by combining habitat suitability curves with the hydraulic equation. The habitat component of the model has received much criticism because of assumptions implicit with using suitability curves and assumptions of positive relationships between habitat availability and fish abundance. Validation of these assumptions have been obstacles for successfully using IFIM to model minimum flow impacts on large warm water rivers of the west slope (Rose and Hahn 1989).

Currently there is no standardized approach to establish minimum flow needs on warm water river sections, and the use of sophisticated models appear to be required in high profile situations (Espegren 1998). Warm water fish assemblages appear to require a more intensive approach to instream flow modeling compared to cold water fish communities. Warm water river reaches tend to be lower gradient and have higher channel complexity and sediment loads. Warm water fish populations tend to have higher species diversity. Also, habitat suitability curves derived from microhabitat observations do not adequately describe habitat use for many warm water species. A broader community-level perspective, as opposed to an indicator species approach, may be required to protect all habitats of a functioning warm water stream ecosystem.

Instream flow techniques require integration of two processes that combine detailed knowledge of habitat requirements (by species and life stage), and the availability of necessary habitats. Both the collection and analysis of these data bases have been very labor intensive. Recent advances in surveying technique (e.g. G.P.S.) and computer capabilities (G.I.S.) allow for collection and processing of much larger databases. Also, two-dimensional (2-D) flow models may have potential for application in instream flow studies (Leclerc *et al.*, 1995; Bovee, 1996). In theory, 2-D models offer a significant improvement over one-dimensional (1-D) modeling by increasing spatial resolution, allowing for highly accurate quantification of physical habitat availability. A spatially explicit flow model may eliminate the need for micro-habitat suitability curves used by IFIM, and also improve biological resolution of the method. Presently, 2d modeling is not widely used for fishery applications and is still an unknown commodity as far as its practicality for instream flow assessment.

The intent of this study is to develop and validate a methodology for determining instream flow recommendations for warm water fish communities in Colorado (Anderson and Stewart 1999). This is to be accomplished by determining relationships between habitat availability and flow using a 2-D flow model to simulate meso-habitat diversity and abundance over a range of low flows on several sections of three different rivers. Also, fish population and species' life history data will be collected within each of the study sites to provide habitat use and preference data to determine relationships between base flows and habitat availability for native fish species of warm water riverine fish communities.

The study goal was amended in 1999 to submit instream flow recommendations to the Colorado Water Conservation Board (CWCB) for the Yampa River and Colorado River in the 15-Mile Reach. This assignment was made following a decision by the CWCB to withdraw the 1995 water rights filings for the two rivers instead of defending the filings in water court. The 1995 filings were based on recommendations made by the U. S. Fish and Wildlife Service (USFWS) in regard to recovery of endangered fish species [Modde and Smith (1995) and Osmundson et al. (1995)]. The CWCB at that time felt the 1995 recommendations had become too controversial due to lack of support from the Service. A tentative date for instream flow recommendations was set, but this date has been moved back a year due to difficulties with contract administration and flow recommendations are expected to be submitted in August 2003.

The CWCB also expressed a desire to have a more standardized approach for instream flow filings for rivers having endangered fish concerns. Up to now, all flow study concerning endangered fish have used different methodologies. The lack of consistency was viewed by the CWCB as troublesome. By using the same methodology for both the Yampa and the Colorado River, it was thought that some of the scientific and social difficulties could be avoided. Also, this study will provide guidance and recommendations for the design and evaluation of future flow studies.

Study Objectives:

1). Model fish habitat availability on warm water sections of three rivers (Yampa, Colorado and Dolores) using the established methods (1d models) and evaluate the practically of using 2d flow models to quantify fish habitat.

2). Determine community structure, density and biomass for fish assemblages for river reaches listed above.

3). Test for relationships between habitat availability and fish abundance.

4). Develop and validate methodologies that use 1-D and 2-D flow models for the Division of Wildlife to use for minimum instream flow recommendations for the warm water sections of the Yampa and Colorado rivers.

Study Area

Yampa River

There are three study areas on the Yampa River. The two sites established in 1998 are Sevens and Duffy and Lily Park was added in 2000. The Sevens station is located at River Mile (RM) 63 and Duffy is at River Miler (RM) 109 (Figure 1). Sevens and Duffy were electro-fished in 1998, 1999, 2000 and 2001 and the habitat was mapped in 1999. Seining samplings were also made in 1999 and 2001. 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 is from RM 52.7 to RM 54.5. The bridge on County Road (CR) 25 is located at RM 52.5.

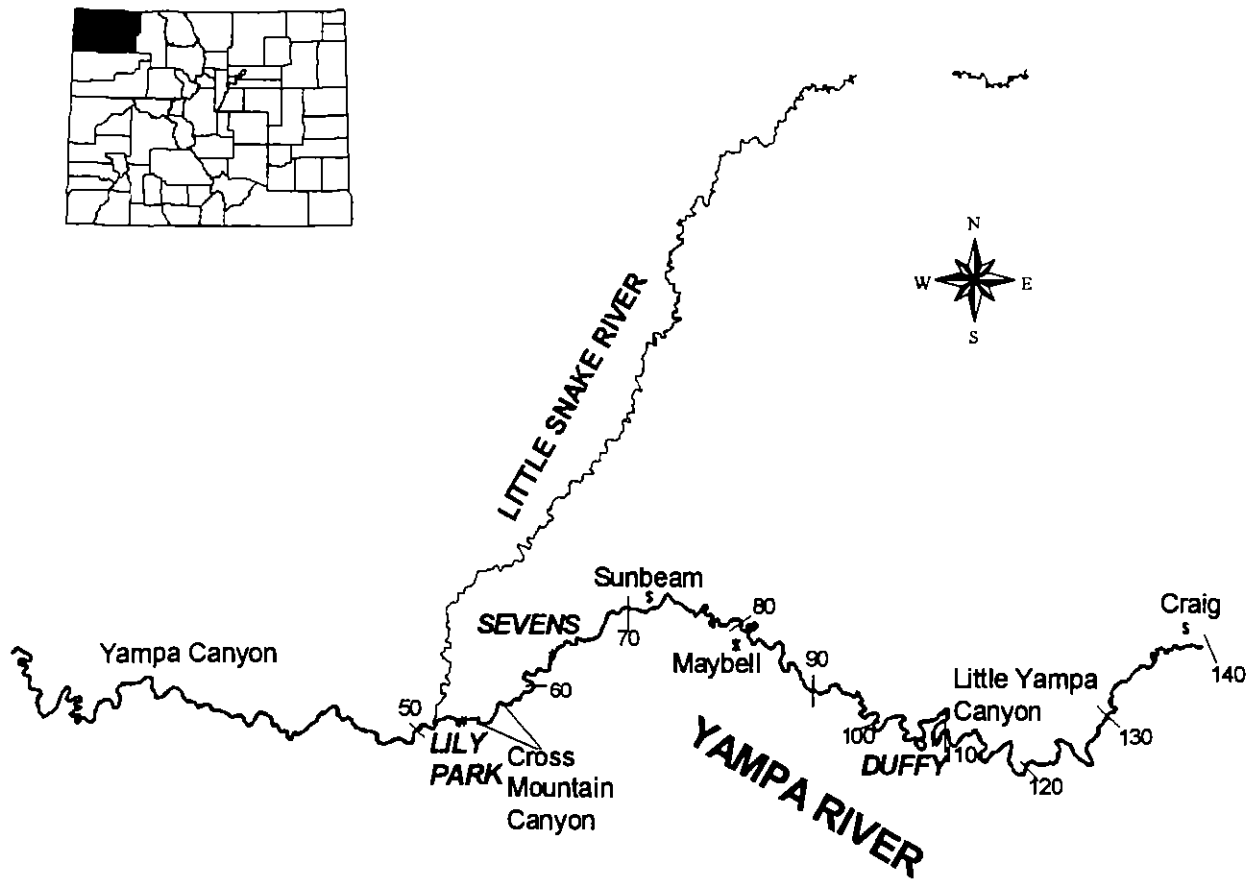


Figure 1. Location of the three study sites for the Yampa River, Lily Park, Sevens and Duffy.

The Cross Mountain Ranch is the landowner for most of the river at Sevens and Lily Park. The BLM is the primary landowner at Duffy. In general, each site on the Yampa River has distinctly different fish and habitat characteristics. Duffy is located in Little Yampa Canyon and has some deep pools with large boulders that provide cover. Duffy is low gradient and the primary habitat during the base flow period is shallow pools. Sevens is also low gradient and primarily with shallow, low-velocity habitats at typical base flows. Sevens appears to have higher riffle composition and pools are mid channel and exposed. The channel gradient is high at Lily Park and substrate for most of this site is cobble and boulders. Faster flowing habitats (runs and riffles) dominate in Lily Park. The Lily Park site was added because of poor native fish composition at Duffy and the habitat of this site appears much more similar to the Colorado River in the 15-Mile Reach than the other two Yampa sites.

Peak flows recorded at the Maybell gage were fairly similar for the years 1998, 1999 and 2000, at 10,040 cfs, 9,980 cfs and 9,830 cfs, respectively. Peak flows in these three years are near the magnitude of the median peak flow of 9,980 cfs for the 86 year period of record (Figure 2). Peak flow in 2001 was 7,650 cfs, which has been exceeded in 77% of the years during the period of record. The peak flow in 1997 was 16,400, and has been exceeded in only 5% of the period of record (Figure 2).

Impacts of low flows are one of the primary objectives of this study. There are several ecological problems associated with low flows, which will be addressed in the discussion section. Instream flows are founded on the principle of a relationship between low flows and detrimental conditions to the fish population. In a prior flow study on the Yampa River, Modde et al. (1999) used a cross section methodology (modified R2Cross) to identify habitat availability for endangered fish at low flows on the Yampa River. The result was a recommendation that 93 cfs be used as a reference flow for future stream flow studies and the significance of the 93 cfs was that it signals the beginning of severely degraded conditions. The 93-cfs reference flow was deliberately not presented as an instream flow recommendation since instream flows are typically based on a community perspective for protecting habitat and nearly always indicate a flow that should not be violated. Some authors (Modde et al 1999) felt that endangered fish can survive the severely degraded conditions that exist at flows below 93 cfs at least for a short term, and were not concerned with flow needs for non-endangered native fish.

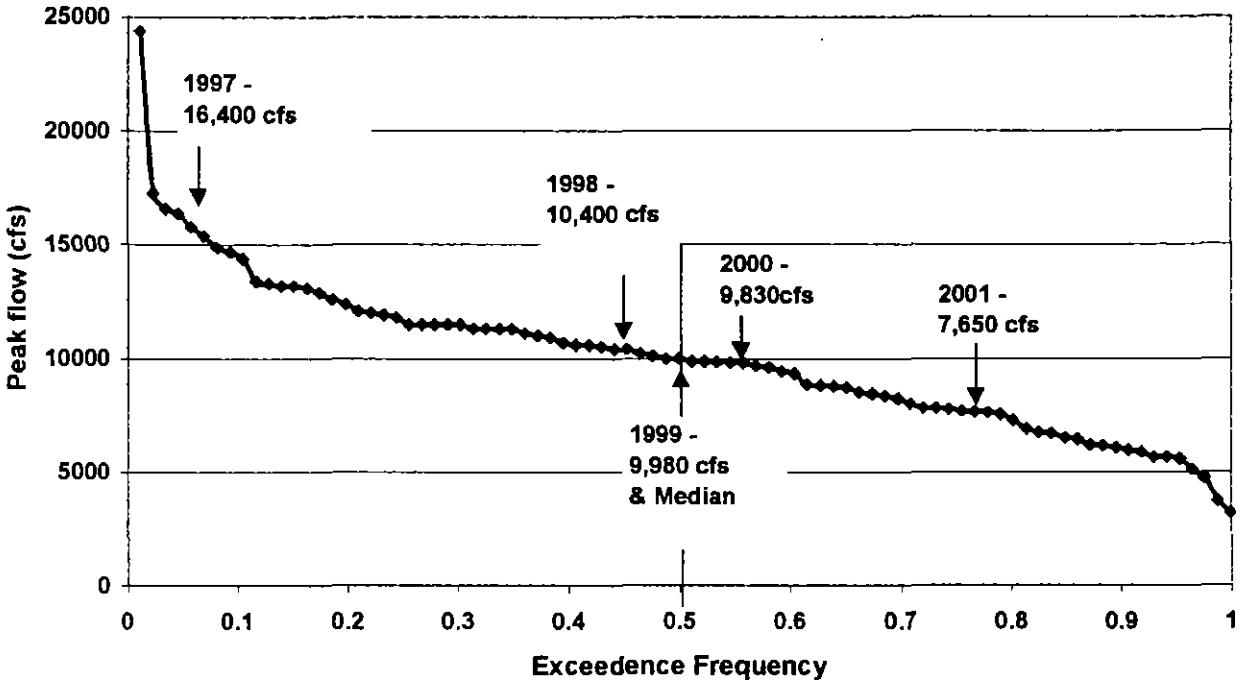


Figure 2. Peak flow during the study period at the Maybell gage with exceedence frequency for the period of record.

Minimum flows recorded at the Maybell gage for 1997, 1998, 1999, 2000 and 2001 were 320 cfs, 115 cfs, 166 cfs, 30 cfs and 50 cfs, respectively. The 86 year median (50% exceedence flow) minimum flow is 126 cfs (Figure 3). The 2000 minimum flow of 30 cfs was exceeded in 93% of the years, and the 2001 minimum flow of 50 cfs was exceeded in 83% of the years for the period of record (Figure 3). Flow did not drop below 93 cfs in 1998 and 1999, but flow was less than 93 cfs in 34 days in 2000 and 17 days in 2001.

Two consecutive years of low flow may have more significant and lasting impacts on the aquatic community (carrying capacity) than a single low flow year. Again, using the 93-cfs reference flow (Modde et al 1998), flow was less than 93 cfs for 0 days in 1997, 2 days in 1996, 0 days in 1995. In 1994, the minimum flow was 8 cfs and flow was less than 93 cfs for 73 days that year. Presumably habitat was severely restricted in 1994 and there were impacts to the fish community. The four-year interval between 1994 and the start of sampling in 1998 may have been enough time to allow the fish community to adjust back to a carrying capacity based on physical habitat availability provided by normal base flows. There were two days of flow below 93 cfs in 1996 and these were 79 and 88 cfs. In 2000 flow had not been below 93 cfs for the previous three years. However, 2001 was a low flow year that immediately followed a low flow year (Figure 3).

Colorado River – 15-Mile Reach

The 15-Mile Reach of the Colorado River is from Palisade, Colorado (RM 185) downstream to the confluence of the Gunnison River at about RM 170 (Figure 4). The Colorado River Recovery Program (Osmundson et al. 1995) considers the 15-Mile Reach important for endangered fish management. Flows are an issue because of two major upstream diversions that dewater the river during the irrigation season (April 1 to November 1). 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.

A USGS gage is located about 0.4 km downstream from the intake for the Grand Valley canal (Figure 4) and began operation in 1990. Flows at the Palisade gage are typically 1200 to 1600 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. Flows recorded at the Cameo gage (RM 199.9) appear to be at least native or higher due to senior water right calls at the Shoshone power plant in Glenwood Canyon. Also there can be additional releases for power generation from Green Mountain Reservoir (Per comm. Karen Flogequest (USBR).) Flows recorded at the Palisade gage are usually higher than at Cameo between November and April due to Plateau Creek, which joins the river at RM 193.3.

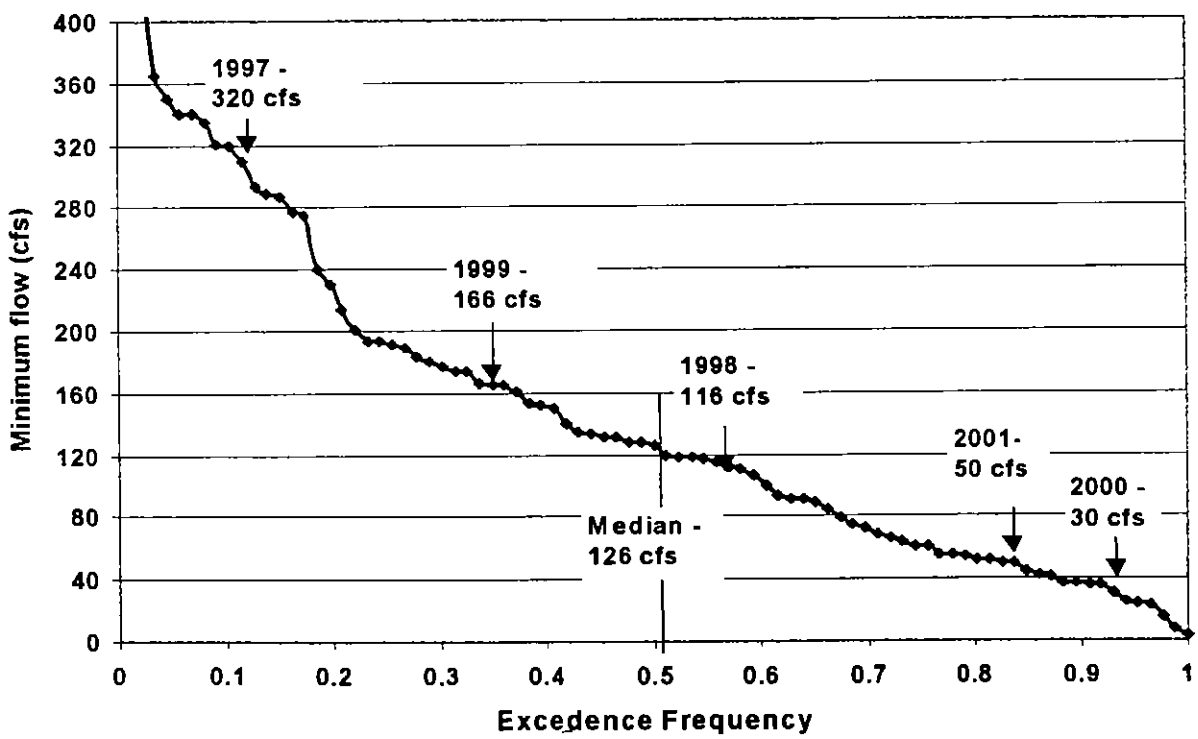


Figure 3. Minimum flows during the study period recorded at the Maybell gage with exceedence frequency for the period of record.

There are two study sites in the 15-Mile Reach. In 1999, a site was mapped using the boat surveyor method from the boat launch at Corn Lake (RM 177.5) downstream to RM 175.3 (Figure 4). This station is named the **Corn Lake Site**. The Corn Lake site length was 4.0- km and has an average width of 55.2 m at a flow of 1400 cfs and was electro-fished in 1999, 2000 and 2001. The river in this section includes 5 small backwaters, and flow was generally confined within the main channel, as opposed to a braided channel (Figure A54).

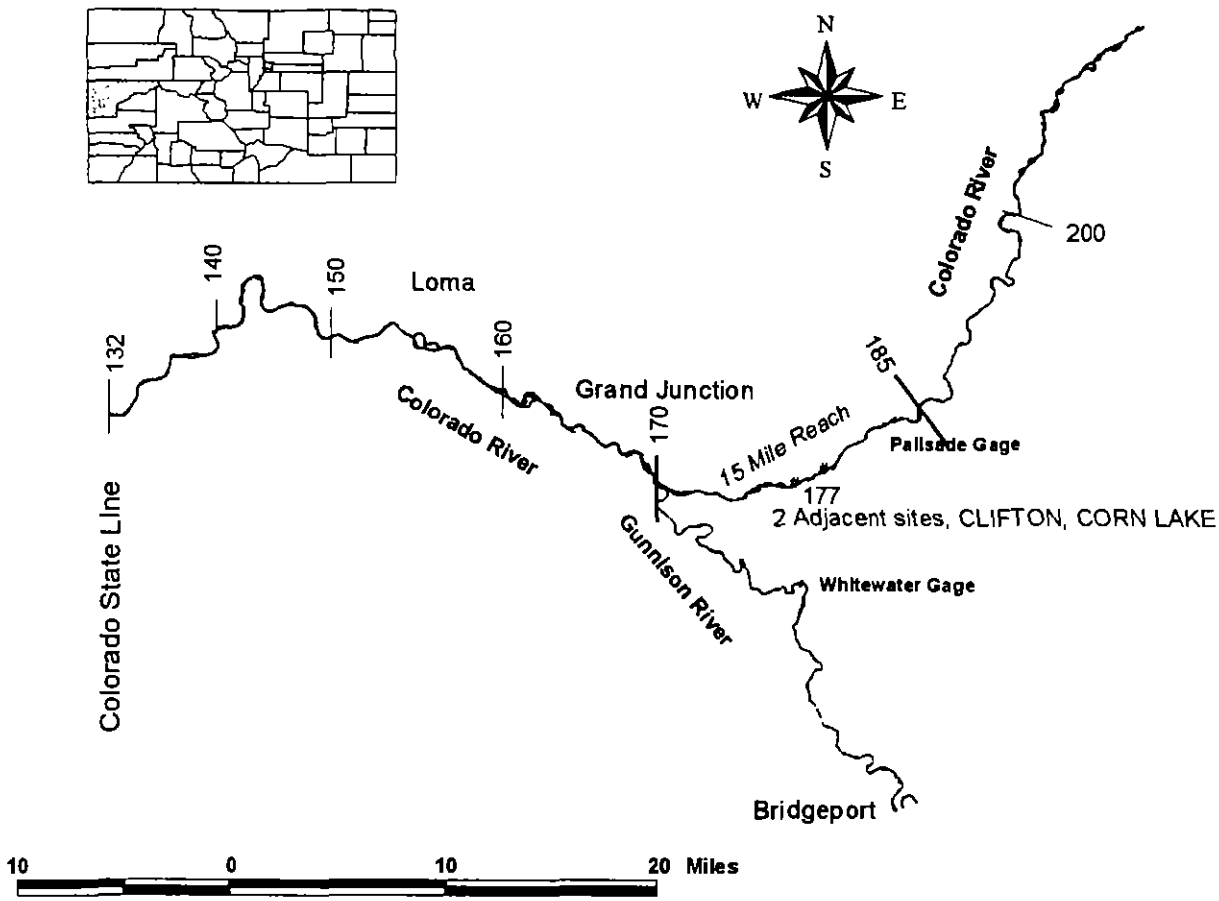


Figure 4. Location of the two study sites in the 15-Mile Reach, Colorado River, Corn Lake and Clifton.

Another study site was added in 2000 and was named the **Clifton Site**. This station is just upstream with only a short section (about 300 m) between it and the Corn Lake site. The Clifton site is from RM 177.7 to 180.4 and has a total length of 4.1 km. In this section, the river has split flow in two large sections of the channel and there is an old diversion structure located at RM 179.7. This structure backs up water along the north shoreline and there is a large backwater at lower flows, but smaller backwaters are not common in this site (Figure A54).

The peak flow for the Palisade gage in 1999 was 12,700 cfs on June 10. The peak flow in 2000 was 13,500 cfs on May 31 and in 2001 the peak flow was 8,410 cfs on May 21. The median peak flow for the 11-year Palisade gage history is 13,500 cfs indicating that peaks for 1999 and 2000 were near normal. Typically, flows in March are near 2,000 cfs, but in some years flows can drop after April 1 due to diversions into the Government Highline and Grand Valley canals. In 1999, flows during the ascending limb (April and May) of the hydrograph flow dropped to 435 cfs on April 15, 1999 and was the minimum flow for the year. The minimum spring flow was 1,110 cfs on April 5th, 2000, and it was 500 cfs on April 17th, 2001.

Summer flows were much less in 2000 and 2001 than in 1999 and as was the case for the Yampa River, this provided an opportunity to sample the fish population at reduced flows. Osmundson et al. (1995) made instream flow recommendations for the 15-Mile Reach based on a study of habitat availability for endangered fish. The recommendations from Osmundson et al (1995) were somewhat complex because he wanted to avoid using a single minimum flow. These instream flow recommendations were given as mean monthly (not mean daily) minimums flows and varied by season and depending on wet, average, and dry flow-year categories determined from historic flow data. The lowest mean monthly flow recommendation is 810 cfs (Table 1), and it should only occur at the same frequency as dry years, which he defined as two in ten years. In half the years, the mean monthly minimum flow for August to September should have exceed 1,630 cfs (Table 1).

Table 1. Recommended mean monthly flows [Osmundson et al (1995)] for the 15-Mile Reach in cubic ft/sec. Exceedance percent indicates frequency that the given flow should be met. For example, during a ten-year period, half the years should exceed a mean flow of 1630 cfs in August, September and October, three of the years should exceed 1240 cfs and two years should exceed 810 cfs for a mean monthly flow.

Exceedence	July Mean Monthly (cfs)	August Mean Monthly (cfs	September Mean Monthly (cfs)	October Mean Monthly (cfs)
50% (Wet)	5,370	1,630	1,630	1,630
80% (Normal)	3,150	1,240	1,240	1,240
100% (Dry)	1,480	810	810	810

Since the recommendations from Osmundson et al. (1995) are presented as averages, minimum flow are not the primary consideration. For example, the minimum flow for 2000 was 542 cfs and it was 477 cfs in 2001. The median minimum summer flows for the period of record (11 years) is 588 cfs. In spite of the fact that flows were less than the 810 for 32 days in both 2000 and 2001, these years do not violate Osmundson et al (1995) recommendations. Summer flows in 1999 exceeded the 50% exceedence (wet year) recommendations for all months except July (Table 2) indicating flows in 1999 would be considered optimal. Summer flows in both 2000 and 2001 exceeded the 100% (dry year criteria) in all months except July (Table 2). However, the federal recommendations would not be "met" if another "dry year" happens before 2009.

Table 2. Mean monthly and monthly minimum flows recorded at the Palisade gage, 15-Mile Reach, Colorado River for summer months during the three years of the study.

Year		July (cfs)	August (cfs)	September (cfs)	October (cfs)
1999	Mean	4,721	2,221	1,752	1,837
	Minimum	2,500	1,380	1,180	1,430
2000	Mean	1,271	913	986	916
	Minimum	648	581	665	543
2001	Mean	995	1,133	1,014	809
	Minimum	477	686	754	535

Dolores River

The headwaters of the Dolores River are in the San Juan Mountains and it flows mostly 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 its course. McPhee dam has a capacity of 381,000 acres/feet and began storing water in 1984. The San Miguel River is of comparable size and joins the Dolores about 117 miles below McPhee reservoir and has a relatively unregulated flow.

Access points for boat launches and take-outs were found to be very limited over most of the river. A suitable site was found in the Big Gypsum Valley, which is 14 miles down river from the Slick Rock Bridge and 34 river miles upstream of the Bedrock boat launch. The Dolores River Guidebook (DeVries and Maurer 1977) starts with River Mile (RM) 0.0 at the Bradfield Bridge and the confluence of the Dolores with the Colorado River is RM 171. This study used the river guide in reverse RM order to identify landmarks. Beginning at the confluence as River Mile 0.0, the Utah-Colorado State line is RM 22.4, and the **Big Gypsum Study Site is RM 108.2 to 109.9**. The study site starts at the BLM Gypsum Valley Recreation site and ends about 1.6 miles downstream at the 20R (county road) bridge crossing. The study station is about 70 river miles downstream of McPhee Reservoir. A site map and a summary of flows will put together and presented in the next report.

METHODS

Fish Samples

Fish were electro-shocked and netted from an Achilles raft between 1998 and 2000. The self-bailer rafter was equipped for electrofishing in 2001 using the same Smith-Root electro-fisher, 5000-watt generator and anode array mounted on a forward boom as in the three earlier years. The boat was maneuvered by either oars or by a battery powered 40 pound 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. Only fish over 150 mm were marked and therefore used for mark and recapture population estimates. Density estimates were made for the each study site on the Yampa, Colorado and Dolores Rivers.

The Darroch multiple mark method (Everhart and Youngs 1981) was used to make the population estimate with ninety-five percent confidence intervals. An estimate was made for the total fish collectively and for each species. Recapture rates generally vary between species and size-groups. In this study, larger suckers had highest recapture probabilities and species with appreciably lower recapture probabilities were catfish, bass, pike and carp (the lower group). The total fish estimate blends recapture rates, but should produce a reliable comparison of fish abundance at a given station between years, when species and size composition was consistent. For rare species (pikeminnow, etc) with zero or one recapture in the sample, abundance was estimated by dividing the number in the sample by the mean recapture probability of the lower group.

The z-test with an alpha of 0.05 ($z = 1.96$) was used to test for significant differences in density estimates between years at each station. At stations with three or more years of sampling, the Bonferroni inequality was also used to control the overall significance level (.05) for the simultaneous comparison of all pairs of years (Dr. David Bowden, CSU, pers. communication). At stations with 4 years of data, (Duffy and Sevens) the z value (2.631) corresponds to an alpha of 0.05 divided by six (0.0083).

The fish data was further summarized into sampling sub-units referred to as polygons for future habitat suitability analysis. A polygon refers to a specific section of river and could vary in size, but typically a polygon is 25m to 50m in length depending on habitat homogeneity. Each polygon has a set of fish attribute data, which allows for a qualitative assessment of species composition and relative abundance within subsets of the study area. Following completion of hydraulic modeling, the physical attributes of each polygon will be determined for the analysis between fish and habitat characteristics.

On the Yampa River, a different mark was used for each run-riffle sequence, which allowed for determining if recaptured fish had moved up, down or had not moved between captures. Fish sampling was earlier on the Yampa in 2001 than the previous year. Flows were again very low in the 2001 field season, but the Achilles shocking boat was replaced with a self-bailer Hyside raft which made sampling at low flows somewhat easier. Flows below 120 cfs were highly problematic for the Achilles boat since the boat had to be frequently dragged, and this became the case for the Hyside at flows less than 100 cfs.

Three mark and recapture electrofishing passes were made at Sevens on the Yampa River in 2001 on August 24 and 30, September 4 and mean daily flow on those dates (Maybell gage) were 114 cfs, 70 cfs, and 64 cfs, respectively. Four passes were made for the entire station at Duffy on August 21, 23, 28 and September 6 and flows on those dates were 105, 98, 77, and 57 cfs, respectively. The upper deep run at Duffy, directly upstream of the launch site, were electro-fished on August 20, and 27 at flows of 123 cfs, and 94 cfs, respectively. The Lily Park site was electro-fished on August 22 and 29 and on September 5 at flows of 91, 77 and 61 cfs recorded at the Maybell gage. However, there is a USGS gage located on the Yampa River (above the Little Snake), and this gage is located within 1km of the Lily Park study site. Flows recorded for August 22, 29 and September 5 from the Above Little Snake gage were 151, 110 and 96 cfs, respectively and these flows should be used to represent this station. From now on, any reference to mean daily flow for the Yampa River in regard to Lily Park will be from the Above the Little Snake gage and corrections should be noted since Maybell gage reading were used in 2001 report.

On the Colorado River, fish in both study sites in the 15-Mile reach were marked to designate the upper, middle and lower sections of the site in order to give a general idea of movement within the station. In 1999, four electrofishing passes were made on the left half and four on right side of the river. Sampling was modified in 2000 and the electrofishing boat sampled twice along the right shoreline, left shoreline and mid river for a total of six passes in each site. In 2001 the same sampling scheme was used as in 2000 and the number of polygons was the same, 35 polygons on the Corn Lake site and 50 at Clifton. A total of sevens shocking passes were made at both sites in 2001 with the additional pass in mid river. The additional pass was found necessary to improve the standard error of the estimate. The dates and the mean daily flow (cfs) for the Palisade gage on the day of fish sampling at Corn Lake were 9/16 (701), 9/19 (915), 9/24 (857), 9/26 (859), 9/28 (790), 10/2 (715) and 10/4 (689). The dates and the flows (cfs) of the fish sampling at the Clifton station were 9/20 (904), 9/21 (901), 9/25 (891), 9/27 (824), 10/1 (735), 10/3 (684) and 10/9 (543). Fish from the Clifton site were given a unique mark so they could be distinguished from fish marked downstream in the Corn Lake station.

The Dolores River was electro-fished in July 2001. On July 16, 17 and 18, block nets were placed at the downstream end of each run (upstream of riffles) and each run was repetitively electro-fished three to five times. Fish from each pass were held in nets, then marked and released into the same run of capture. This process was continued over the entire reach. The entire study site was resampled on July 19 and 23. Block nets were not used on the second and third samples made on July 19 and July 23. Summer flows are regulated by releases from McPhee dam and flows generally vary between 65 and 80 cfs.

Habitat Mapping

Global Positioning Systems and Sonar

In 1999 and 2000, bathymetric surveys of the channel were taken of the six study sites using the Global Positioning Systems (GPS) and sonar technology. This technique, described in the Anderson and Stewart (2000), is performed from a moving boat and gathers a large amount of bathymetry data in a short amount of time. The GPS system used in this study was a Javad Oddessy L1/L2 RTK GPS with Glonass and Multi-path reduction options turned on. This

system has a published vertical accuracy of 15mm +/- 1.5 mm. The sonar unit used was an ODOM Hyrographic Systems, Hydrotrac - Single Frequency, Portable Survey Sounder. This unit used a 200kHZ frequency with a published accuracy of 1cm +/- 1% of depth and an output resolution of 1cm. The sonar unit pings and logs 20 depth readings per second and the GPS logs one position per second. The GPS system output a NMEA GGA string at a rate of 1HZ while the sonar output text strings indicating depth at a rate of 10HZ. Data from these instruments was sent to a laptop computer and recorded using the COMLOG software from ODOM Hydrographic. Because the GPS and Sonar data were received at different rates, all data entries collected by the COMLOG software were time-tagged to the millisecond using the computer's clock. The depth readings immediately before and after the GPS reading were interpolated by the computer clock time (nearest millisecond) to produce the XYZ coordinates used to map bed topography of the river channel.

One of the greatest hindrances to using sonar to map the channel bottom is that there is a minimum depth requirement. In order for the sonar to get a reading off the bottom of the channel, the transducer must have at least half a meter of water underneath it. The transducer was located approximately 15cm underwater as to give room to roll and minimize air entrainment under the transducer head making it difficult to gather bathymetric data in areas shallower than 75cm.

Yampa River, Sevens

On July 12 1999, bathymetric data was collected along a 1.3km section of the Yampa River at the Sevens study section using the GPS/sonar technique. The length of this site was felt to be fairly short given the nature of the associated fish data and the habitats represented in this reach. The Sevens site was enlarged on June 23, 2000 by surveying another 1.3km immediately upstream and overlapping the site mapped the previous year. The survey in 2000 used the same boat and GPS/sonar equipment in both years. In order to compare bed and water surface elevations between years, three longitudinal profiles were made in the 1999 site and water lines and were recorded for the entire 2.6 km station. Collection of bathymetric data was hampered in 2000 by the low and unusually short runoff period.

The base pin established in 1998 was used as the reference position for both the 1999 and 2000 surveys. Shoreline and water surface shots were made using the Psion data collector running Field Face software. Waterline shots for the entire reach were surveyed on October 30 and 31, 2000. Another series of water edge/surface shots were made in June 26 & 27 and July 5 & 6 2001.

Yampa River, Lily Park

A semi-permanent base pin was established at Lily Park so that additional data can be collected using the same reference location. Bathymetric data was collected along a 2.8 km section of the Yampa River at Lily Park on June 12, 13 and 14, 2000, using the GPS/sonar technique. Collection of bathymetric data was hampered in 2000 by the low and unusually short runoff period. There was a large, wide and shallow riffle near mid station that could not be surveyed by boat and was surveyed at a later time by logging points while walking. The shallow

riffle was surveyed on August 8 and 9 and again on October 19 and 20, 2000. Waterline shots were made on June 27 and 28, 2001, and at a lower flow on July 31 and August 1.

Colorado River, Clifton study site

A second study site in the 15-Mile Reach of the Colorado River was labeled the Clifton station. A 4.25 kilometer stretch of the between river miles 177.7 and 180.4 was surveyed on May 31, June 1, 2, 4 and 5, 2000. This site is just upstream of the original site, surveyed in 1999, now called the Corn Lake station but in prior reports it was named the 15-Mile Reach station. A total of 45,000 usable bathymetric survey points were collected at the Clifton station using the boat GPS/sonar equipment.

Aerial photography of the 15Mile reach of the Colorado River has been digitized by Mesa County Survey System and was purchased from them to aid in identification of landmarks and waterline boundaries. We accomplished this by using the latitude and longitude brass marker at the intersection of 31 and C Road for a reference pin for our survey. Therefore, both the Corn Lake and Clifton survey can have associated photography.

Waterline/water surface measurements were taken with the GPS walking method on August 1, 2 and 3, 2000, January 23, 24, 25 and 26, 2001 and the final set on June 18,19 and 20, 2001.

Dolores River, Big Gypsum study site

Over a three-day period, May 16, 17, and 18, 2000, bathymetric data was collected along a 3-km section of the Dolores in the Gypsum valley. As was the case with the Yampa River, there were lower than normal runoff flows made data collection using the sonar more difficult and certain parts of the river were too shallow for the sonar. Several days were spent in June and July 2000 logging addition points by the walking method. This walking method logs points from the GPS with a Psion data collector running Field Face software. Waterline/water surface shots were made on July 6 and 7, 2000 and on June 13 and 14, 2001.

Acoustic Doppler and Marsh McBernie Velocity Meters

For model calibration, it is important to have observed measurements of depth and velocity at known flows. While depth can be gathered using the same technologies that are used in determining bathymetry, velocity measurements require another set of instruments. Two different technologies were used for measuring velocities in this project, the GPS and flow meter/wading rod, and the GPS and Acoustic Doppler. Because of low summer flows the boat-mounted acoustic-Doppler was not used to gather velocity data in 2000. A detail description of both techniques was given in Anderson and Stewart (2000).

Data Reduction and Preparation

The use of GPS, sonar, and the COMLOG program produced a large number of coordinate points at each site, and data sets had to be checked for quality and quantity. The

process followed was described in Anderson and Stewart (2000). It involved using an Excel-macro written by Mr. Stewart that stripped out non-sensible or incomplete points so only points that met the defined standard were used in the final survey. The excel-macro eliminated all non-RTK hits, indicated by a code 4 in the GGA string. Consistency in sonar data is also checked, since fish or woody debris can sometimes cause spikes in the sonar data. Spikes were eliminated based on the running average of the 3 sonar pings prior to and after a given sonar ping. If the elevation recorded in a given reading was different than the moving average of the 6 readings surrounding the given reading by more than 15cm, that ping was marked as "bad". If an RTK GPS reading had a "bad" sonar ping recorded directly before or after it, that GPS reading was ignored. For those RTK GPS signals with "good" sonar recordings before and after them, the depth for that GPS position was determined through a linear interpolation of the sonar data based on the time tags. Topographic data were also examined visually using ArcView. In ArcView, bed elevations could be examined by using the Triangular Irregular Network (TIN) module or by color coding coordinate points by elevation.

Hydraulic Simulation

In the first two years of the project, hydraulic simulation and 2-D flow modeling was contracted with the Earth Resources Department of Colorado State University (CSU). Greg Stewart, a graduate student at CSU, collected and input the data RMA2-hydraulic modeling and performed the analysis during the time period June of 1998 to June 2000. Anderson and Stewart (2000), and Stewart (2001, the M.S. thesis) gives details on hydraulic methods, problems and innovations used for making flow simulations on the Colorado River 15-Mile Reach (Corn Lake) and the Yampa River site at Duffy Tunnel.

Greg Stewart performed most of the installation and operation of technical equipment and data handing for the 2-D modeling. Following his departure, no 2-D modeling was performed until a new contractor was found. An attempt to start a new contract (sole source) for hydraulic simulations in 2000/20001 fiscal year failed. In January 2001 a competitive bid process was initiated and a contract was finalized in mid November 2001 with Utah State University. The lost year for 2-D modeling meant a delay in producing instream flow recommendations. This identified a need to perform 2-D modeling in-house. Given direction from management to continue to utilize this project and this researcher for 2-D flow models, fish habitat mapping, and flow recommendations; the principal investigator is planning to become proficient in the computer modeling process.

Dr. Craig Addley, contract administrator for 2-D modeling at Utah State, oversees modeling for the remaining four sites. His lab uses a 2-dimensional, quasi-3-dimensional model developed Jonathan Nelson of the USGS. The technical description of this model and underlying equations can be found in Nelson (1996), Thompson et al. (1998), Nelson et al. (1995), McLean et al. (1999), Topping et al. (2000).

Habitat Availability

An objective of this study is to determine if consistent results in fish composition, size and density found at different locations are correlated to the physical habitat composition at those sites. If strong relationships are found, these data can be use to justify habitat suitability for these fish and used in future modeling of impacts of flow on habitat availability. Pools, runs,

riffles and rapids are general habitat categories and are referred to as meso-habitats. Pools have low velocity, runs have moderate velocity, riffles are swift areas and rapids are areas with fastest current.

Habitat availability is a function of channel morphology and flow. Channel morphology is relatively stable during the base flow period and at this time habitat availability varies mostly with flow. To quantify fish habitat availability, it is necessary to define habitat in terms that distinguish between good, poor and unsuitable conditions for each species and age groups. A value can be assigned to each combination of depths and velocity to indicate the relative value of that condition for a fish species. Habitat types, defined by depth and velocity criteria are mapped at each flow for statistical analysis of surface area and distribution. As a starting point, sixteen habitat types were defined for analysis of habitat availability (Table 1). Pools had a velocity of zero to 0.15 m/sec and had five differing depths from very shallow (< 0.2m) to deep (>2m). The velocity of runs ranged from 0.15 to 0.6 m/sec and depths were the same as for pools. Riffles had velocity ranging from 0.6 to 1.5 m/sec and rapids had velocities over 1.5 m/sec.

Table 3. Depth and velocity criteria used to define meso-habitat types.

	Habitat Types	Depth	Velocity
		(m)	(m/s)
1	Wetted-pool	0.01 – 0.2	< 0.15
2	Shoal-pool	0.2 - 0.5	< 0.15
3	Shallow-pool	0.5 - 1.0	< 0.15
4	Medi–pool	1.0 - 2.0	< 0.15
5	Deep-pool	> 2.0	< 0.15
6	Wetted-run	.01 - 0.2	0.15 - .6
7	Shoal-run	0.2 - 0.5	0.15 - .6
8	Shallow-run	0.5 to 1.0	0.15 - .6
9	Medi-run	1.0 to 2.0	0.15 - .6
10	Deep-run	> 2.0	0.15 - .6
11	Shallow-riffle	< 0.2	0.6 - 1.5
12	Riffle	0.2 to 0.5	0.6 - 1.5
13	Deep-riffle	0.5 to 1.0	0.6 - 1.5
14	Very-deep-riffle	> 1.0	0.6 - 1.5
15	Shallow-rapid	< 0.5	> 1.5
16	Deep-rapid	> 0.5	> 1.5

RESULTS AND DISCUSSION

YAMPA RIVER FISH SAMPLES

Species Composition – fish over 15 cm

Native species composition for fish over 15 cm was found to be distinctive for the three stations (Lily Park, Sevens and Duffy) in 2001 as was also found in 2000 (Anderson and Stewart 2001). Lily Park had by far the largest sample size, with 2,990 fish (Table 4). Flannelmouth sucker was the most common species at Lily Park (68%) and Sevens (53%), but was rare at Duffy with 2% of the fish (Table 2). Bluehead sucker composition was 7%, 13%, and 4% at Lily Park, Sevens and Duffy, respectively. Roundtail chub were very rare at Lily Park with only 1 fish collected or 0.03% of the catch. Roundtail chub comprised 3% at both Sevens and Duffy (Table 4). Colorado pikeminnow were rare to absence at all sites in 2001 with .03% at Lily Park, zero at Sevens and 0.6% at Duffy.

Also, nonnative species composition for fish over 15 cm was distinctive between stations in 2001. The second most common species at Lily Park was channel catfish, and was 18%. Channel catfish comprised 5% at Sevens and 4% at Duffy (Table 4). At Duffy, the most common fish taxa is the white sucker complex, which includes white-flannelmouth and white-bluehead crosses. White sucker and crosses were 50% at Duffy, 16% at Sevens and only 0.2% at Lily Park in 2001. The second most common species at Duffy was smallmouth bass with a composition of 32%, but smallmouth composition was 5% at both Sevens and Lily Park (Table 4). Carp were uncommon at all sites and at 2%, 4% and 2% at Lily Park, Sevens and Duffy, respectively Northern pike have become rare at all sites and in 2001 were at 0.2%, 0.3% and 1% and Lily Park, Sevens and Duffy, respectively.

Table 4. Species composition for fish **Over and Under 15 cm** caught in the **Yampa River** in August/September 2001.

	LILY PARK 2001	**SEVENS** 2001	**DUFFY** 2001	**LILY PARK** 2001	**SEVENS** 2001	**DUFFY** 2001
Species	**>15cm**	**>15cm**	**>15cm**	**<15cm**	**<15cm**	**<15cm**
Flannelmouth Sucker	67.7%	53.1%	2.0%			
Bluehead Sucker	7.1%	13.2%	4.4%			.08%
Roundtail Chub	0.03%	3.4%	3.1%			
Colo. Pikeminnow	0.03%	0%	0.6%			
White sucker	0.07%	10.2%	17.9%			
White X Flannelmouth	0.13%	5.0%	26.9%			
White X Bluehead	0%	0.4%	4.7%			
White S. + Crosses	0.2%	15.6%	49.5%	1.2%	6.0%	0.8%
Channel Catfish	17.7%	5.2%	4.4%			
Carp	2.1%	4.1%	2.2%			0.3%
Smallmouth Bass	5.1%	5.0%	32.4%	79.9%	58.3%	98%
Northern Pike	0.2%	0.3%	1.0%			
White Crappie	0%	0.0%	0%			
Mottled Sculpin				3.7%		0.7%
Speckled Dace					2.0%	0.2%
Sand Shiner				15.2%	33.8%	0.2%
Fathead Minnow						
Creek Chub						0.03%
Stickleback						0.03%
Sample size	2,990	676	859	164	151	3,854

The very high degree of consistency in species composition of fish over 15 cm for the first three years 1998, 1999, and 2000 was somewhat maintained at Sevens, but poorly maintained at Duffy in 2001(Table A1). Flannelmouth suckers at Sevens varied between 46% and 53% during the four-year period (Table A1). At Duffy, flannelmouth composition was 5% between 1998 and 2000 and dropped to only 2% in 2001 (Table A1). Bluehead sucker composition at Sevens was between 18 and 22% during the first three years but dropped to 13% in 2001. Bluehead sucker composition at Duffy varied between 4 to 6% over the four years. Roundtail chub were fairly consistent between sites comprising between 3 to 6% of the catch at Sevens and 3 to 4% at Duffy over the study period (Table A1). No Colorado pikeminnow were caught in Sevens in 2001, slightly down from 0.2% in earlier years. At Duffy, pikeminnow composition was 1.5%, .06% and 0.8% in 1998, 1999, and 2000 respectively and was 0.6% in 2001. For the over 15-cm size group, native fish were common at Sevens and were 72% in 1998, 68 % in 1999, 76% in 2000 and 70% in 2001 (Table A1). At Duffy, native fish comprised about 14% of the fish population in the first three years, but dropped to 10% in 2001 (Table A1).

The white sucker with crosses group comprised between 69 and 73% of the catch at Duffy between 1998 and 2000, but dropped to 50% in the 2001 sample (Table A1). In contrast, there was a large increase in species composition for smallmouth bass in 2001. Smallmouth bass comprised 8%, 6% and 10% of the catch over 15 cm between 1998 and 2000, but strongly

increased in 2001 to 32% (Table A1). At the Sevens station, white sucker and white crosses were stable between all years at 13% in 1998, 15% in 1999, 17% in 2000 and 16% in 2001. Smallmouth bass at Sevens comprised only 1% in 1998, 2.5% in 1999, and 0.5% in 2000, but increased to 5% in 2001 (Table A1).

A major shift in species composition was observed at the Lily Park station for fish over 15 cm between 2000 and 2001. In 2001, flannelmouth sucker was 68% compared to 48% in 2000 (Table A3). Sample size was similar for flannelmouth sucker between the two years and the increase in the flannelmouth percentage was strictly due to much fewer catfish caught in the 2001 sample. In 2000, catfish comprised 40% of the fish sample with a sample size of 1,631, but in 2001 catfish composition was 18% and sample size dropped to 528 (Table A3). The very low base flows in the Yampa River in 2000 (Figure 2) appear to be a main factor explaining this change in catfish species composition at Lily Park. It was suggested in Anderson and Stewart (2001) that catfish were probably atypically overabundant in the Lily Park in 2000 and this was attributed to a suspension of channel catfish migration due to very low flow conditions that appeared to interfere with upstream movements. The 2001 data is consistent with this explanation and catfish composition in the neighborhood of 18% is probably a more accurate long-term description of this site.

Bluehead sucker, roundtail chub and Colorado Pikeminnow composition were similar between years (2001 versus 2000) at Lily park: (9% versus 7%), (0.02% versus 0.03%) and (0.07% versus 0.03%), respectively (Table A3).

The only species at Lily Park to show a strong shift in species composition (independent of catfish sample size) was smallmouth bass. In 2000, smallmouth bass comprised only 0.8% of the fish over 15 cm. In 2001, smallmouth bass were 5% (Table A3).

Fish less than 15 cm

Species composition was less variable between stations for fish less than 15 cm in 2001 than it was for > 15 cm. For the first time during the 4-year study period, smallmouth bass YOY was the dominant fish for this size group at all three Yampa stations. Smallmouth bass were 80% at Lily Park, 58% at Sevens and 98% at Duffy (Table 4). These rates were the highest of the sampling period and strongly indicate the increase in YOY smallmouth bass is a function of increased habitat availability in 2001 for this species compared to earlier years. At Duffy, species composition of YOY (n or sample size) smallmouth bass collected by electrofishing in 1998, 1999, 2000 and 2001 was 45% (673), 42% (703), 84% (741) and 98% (3,698), respectively (Table A2). The very large increase in YOY bass sample size at Duffy in 2001 more dramatically demonstrates the increased habitat availability for this fish in 2001 relative to earlier years. At Sevens, smallmouth bass composition (n) in 1998, 1999, 2000 and 2001 was 0.3% (1), 26% (3), 14% (64) and 58% (82), respectively (Table A2), and indicating a widespread experience for improved YOY bass habitat in 2001 compared to 1998 and 1999.

The less than 15-cm fish composition for native species was very rare at both Duffy and Sevens compared to earlier years. At Duffy, speckled dace were only 0.2% and mottled sculpin were at 0.8% in 2001 (Table 4). The species composition (n) at Duffy in 1998, 1999, 2000 and 2001 for speckled dace were 13% (196), 8% (143), 1.2% (11) and 0.2% (8), respectively and was

19% (278), 27% (467), 5% (44) and 0.8% (28) for mottled sculpin, respectively (Table A2). Both dace and sculpin were common in 1998 and 1999, the years with normal base flow, but rare in 2000 and 2001, years with low flows and dewatered riffle habitats. In 2001 a deliberate effort was made to collect all dace observed up to the first 40 for preserving as museum specimens. Because extra attention was made to collected dace, it is believed that the 8 dace and 28 sculpin counted collected in 2001 at Duffy (4 passes of 7.2 km each) is an accurate indication that these species were indeed very rare in this section of the Yampa River.

Dace were also very rare upstream of the Duffy site. Electrofishing surveys were made from RM 124 to 105 in July 2001 for the purpose of obtaining DNA samples for native species and hybrids. During this electrofishing survey only 3 speckled dace were collected from the riffles that were shocked. Several riffles appeared to be suitable habitat for speckled dace, but instead were occupied by large numbers of YOY smallmouth bass.

Low densities or abundance of dace and sculpin was also observed at Sevens. Speckled dace species composition (n) in 1998, 1999, 2000 and 2001 was 38% (123), 13%(10), 2% (11) and 2% (3), respectively and for mottled sculpin it was of 5% (16), 0%, 0%, and 0%, respectively (Table A2).

Sand shiner was the most common small fish sampled or observed by electrofishing at Sevens in all years except 2001 and were at 34% in 2001 (Table 4). At Duffy, sand shiners were rare in 2001 at only 0.2%. White sucker YOY were common at Duffy in 1998 (10%) and 1999 (18%) and fairly common in 2000 (6%), but were very rare in 2001 (0.8%) (Table A2). At Sevens, white sucker YOY were 6%, 18%, 26% and 6% in 1998, 1999, 2000 and 2001, respectively (Table A2). Intuitively low flow regimes should provide abundant habitat availability for both sand shiner and white sucker YOY, since shiners and YOY fish occupy shallow, slow habitats. Their numbers should not be adversely impacted by low flows but low flows may allow improved survival of bass. Juvenile size (100 –160 mm) smallmouth bass would be an efficient predator on all YOY size (20 – 90 mm) fish and a large increase in juvenile bass would likely account for reduced numbers of sand shiners and white sucker YOY at these stations.

Species Composition - Seining collections (fish<15 cm)

Results of seining in 1999 were given in Anderson and Stewart (2000) in Tables A2.3. A2.4 and A2.5. Large shifts in species composition were observed for Duffy with the seine samples for roundtail chub, speckled dace, white sucker, and smallmouth bass (Table 5). Number of speckled dace collected in 1999 was 538 or 24% of the total, but in 2001 seining collected zero speckled dace. The number of white sucker collected in seines in 1999 was 497 for 22% of the total catch, but in 2001 the 11 white sucker caught were only 1% of the total. Smallmouth bass numbers were 35 for 1.5% in 1999 but increased to 540 bass for 67% of the total catch in 2001 (Table 5). The seining data shows independently of the electrofishing data that YOY smallmouth bass numbers greatly increased in 2001. Habitats (riffles and shoreline with cover) that contained dace and sucker in 1999 were either empty or filled with YOY bass. It was also observed from length frequency histograms that 2001 had a larger population of juvenile bass compared to earlier years. It appears that juvenile bass are very efficient predators on fish under 80 cm and that juvenile bass survival was higher in 2001 compared to earlier years.

At Sevens, sand shiners were the dominant species in 1999 collected in seine hauls and were also the most common species in 2001 (Table 5). Clearly sand shiners are the most common fish in this section of the Yampa River and these fish are associated with habitat that is not very common at Lily Park just 15 km downstream. The shift in species composition between 1999 and 2001 was not as dramatic at the Sevens, when compared to Duffy. There were much fewer white suckers collected in 2001 (n=88, 4%) than in 1999 (n=588, 27%) (Table 5). Smallmouth bass increased very slightly between 1999 (n=9, 0.4%) and 2001 (n=30, 1.5%). However histogram data shows juvenile smallmouth bass increased in 2001, and this could explain the fewer white sucker YOY seined at Sevens in 2001.

Table 5. Species composition from seine hauls at the Sevens and Duffy sites in 1999 and 2001, Yampa River.

STATION	SEVENS	SEVENS	DUFFY	DUFFY
YEAR	1999	2001	1999	2001
TOTAL (n)	2165	2026	2272	803
	% (n)	% (n)	% (n)	% (n)
Flannelmouth sucker	1.1 (23)	5.4 (109)	1.0 (23)	0
Roundtail Chub	1.4 (34)	2.2 (45)	34 (733)	1.4 (11)
Speckled Dace	3.8 (83)	1.9 (39)	24 (538)	0
Sand Shiner	57 (1241)	82 (1662)	13.9 (315)	29.5 (237)
White Sucker, &crosses	27 (588)	4.3 (88)	21.9 (497)	1.2 (11)
Smallmouth bass	0.4 (9)	1.5 (30)	2.5 (57)	67 (540)
Fathead minnow	3.6 (77)	2.5 (50)	0.4 (10)	0.1 (1)
Carp	4.3 (93)	0	1.5 (35)	0.2 (2)
Stickleback	0.7 (16)	0.1 (3)	0.4 (9)	0
Redside shiner	0.05 (1)	0	0.04 (1)	0
Plains Killifish	0.05 (1)	0	0	0

Yampa - Species composition discussion

Species composition for fish over 15 cm was strongly consistent at both Sevens and Duffy over the first three years, but consistency was not maintained in 2001 (Tables A1). A stable species composition indicates stability in habitat availability or biological factors (competition or predation) that regulate population dynamics. Intrinsically it is understood there is a relationship between habitat availability and species composition and abundance. If habitat availability changes, then a concomitant change in the fishery is expected. An objective of this study is to quantify habitat availability of these sites and determine the strength of the relationship between habitat composition and fish composition by sampling site with different habitats. The minor shift at Sevens and the major shift at Duffy in species composition in 2001 compared to earlier years suggest environmental changes that have been advantageous to smallmouth bass at Duffy. This environmental change is the extreme low flow conditions of 2000, exacerbated by another very low flow year in 2001.

The discrepancy in species composition and more specifically for smallmouth bass between Duffy and Sevens strongly suggests local channel morphology or habitat availability is

responsible, since both sites have similar physical conditions for flow and temperature between years. Nesler (1995) proposed it was reasonable to assume normal runoff flows would be adverse enough to prevent stable recruitment of smallmouth bass in the Yampa River. Sevens apparently has a lack of habitat availability for YOY smallmouth bass which indicates Nesler (1995) was probably correct in regard to this section of the Yampa. However large numbers of smallmouth bass YOY have been produced in all years, even with normal runoff flows, at Duffy and throughout Little Yampa Canyon. This large section of the river provides a stable source of smallmouth bass YOY for colonization to downstream sections like Sevens.

Hawkins et al (1997) reported the occurrence of nonnative fish were fairly rare in the Little Snake River and attributed this to highly variable physical factors such as flows, temperature and turbidity. Hawkins et al (1997) suggested the extreme low flows he observed in the Little Snake River during sampling in 1994, might explain the high percent of native fish population collected during his sampling. Because nonnative fish were not common in their study sites on the Little Snake River, they concluded native fish could tolerate the extreme low flow that year. Those conclusions for the Little Snake are not consistent with results found on the Yampa River during this study. In the Yampa River, native fish versus nonnative composition was found to be primarily a function of local channel morphology or habitat availability, not water quality parameters. Also the Little Snake River fish population was mostly comprised of fish less than 15 cm, not the larger or adult size fish typical of the Yampa, whose habitat requirements need to be a strong consideration in regards to flow assessment.

In the Yampa River nonnative species composition for fish less than 15 cm improved greatly in years with low base flows at all sites and it is suspected that this will impact the over 15 cm fish population in the long-term. The low flows in 2000 nearly eliminated all riffle habitats, defined as areas with velocity over 0.6 m/sec, from the Duffy section. Riffles are the principle habitat for speckled dace and aquatic invertebrates, and presumably carrying capacity for riffle obligate species was negatively impacted in 2000 and 2001. The reduced velocities experienced at 2000 flows may not exclude dace from remaining riffles in and of itself, but reduced velocities in riffles made them suitable habitat for YOY smallmouth bass. In 2001 it was found that YOY smallmouth bass occupied riffle habitats in Little Yampa Canyon. This makes it clear that YOY smallmouth bass are very tolerant of low flows and are an efficient predator and/or competitor with species that require habitat with swift currents.

It could be that smallmouth bass YOY will not occupy riffle habitats when velocities and flow in riffles exceed a certain threshold. However it is not likely that dace can quickly become reestablished in the Yampa River even if high base flows return in the near future. The long-term implications of low base flows are that trophic relationships natural to native fish have been impacted. There appears to be a relationship between YOY bass abundance and reduced YOY of most other species. In 2001 YOY bass could forage on invertebrates in the productive riffle habitat, but not dace or sculpin which explains the YOY bass population increase in 2001. It does not appear that any of the native species are an efficient predator on YOY bass and that larger bass may be their only efficient predator. Northern pike were probably a significant predator on juvenile bass, but pike numbers have been noticeably reduced in 2000 and 2001 either due to unsuitable habitat, forage or management activities (pike removal by the recovery program). It appears that smallmouth bass numbers and composition for fish over 15 cm will continue to increase given flow conditions observed in recent years.

The three stations used during this flow study turned out to be excellent for observing the progress of smallmouth bass in establishing dominance at Duffy in the Yampa River. The habitat at Duffy is optimal for smallmouth bass and recruitment was strong during all 4 years. At Sevens there does not appear to be much suitable habitat for spawning or YOY bass in normal runoff years, but local production increased in 2001. Lily Park is the most productive of the three sites and even though bass comprised only 5% in 2001, the number of bass over 15 cm collected there were higher than at Duffy. 2001 was the last year of sampling fish on the Yampa for this project. It would be extremely interesting to monitor these sites for a few more years to follow the fishery during its transition. I suggest the nonnative management section consider this as a priority issue.

COLORADO RIVER

Species Composition - Fish longer than 15 cm

Flannelmouth sucker was the most common species found at both sites (Corn Lake and Clifton) in 2001 comprising 40% and 42% of the fish over 15 cm, respectively (Table 6). For the three year period 1999, 2000 and 2001 flannelmouth sucker composition at Corn Lake was 38%, 31% and 40%, and at Clifton it was 33%, 33% and 42%, respectively (Table A4). Bluehead sucker was a very close second place in 2001 comprising 37% of fish >15 cm at Corn Lake and 27% at Clifton (Table 6). In 1999, 2000 and 2001 bluehead sucker composition at Corn Lake was 35%, 36% and 37%, and at Clifton it was 23%, 41% and 27%, respectively (Table A4). These two species combined made up about 70% of the larger fish group during the study period and these native suckers combined had consistently higher composition, although only slightly, at Corn Lake compared to Clifton.

Table 6. Species composition for **fish over 15 cm and less than 15 cm** for **Corn Lake and Clifton** in the 15-MILE Reach, Colorado River, September/October 2001

	Corn Lake	Clifton	Corn Lake	Clifton
Species	2001 >15 cm	2001 >15 cm	2001 < 15 cm	2001 <15 cm
Flannelmouth Sucker	39.5%	42.0%	2.4%	3.4%
Bluehead Sucker	38.1%	26.8%	1.9%	1.8%
Roundtail Chub	2.9%	5.9%	5.5%	12.3%
Colo. Pikeminnow	0.03%	0.09%		0.0%
Razorback Sucker	0.06%	0.04%		
White sucker	5.1%	3.3%	8.8%	2.6%
White X Flannelmouth	0.5%	0.7%		0.0%
White X Bluehead	0.6%	0.09%	0.1%	0.0%
Channel Catfish	4.7%	5.7%	0.1%	
Carp	6.1%	13.8%	13.1%	6.9%
Smallmouth Bass			0.1%	0.4%
Largemouth bass	0.4%	0.8%	5.4%	6.1%
Green Sunfish	0.3%	0.3%	26.6%	16.9%
Brown trout	1.4%	0.2%	0.0%	0.0%
Rainbow trout		0.04%	0.2%	0.0%
Black Bullhead		0.40%	1.6%	0.3%
W. Crappie			0.1%	0.0%
Speckled Dace			33.4%	47.2%
Mottled Sculpin			0.8%	1.8%
Red Shiner			Xx	0.0%
Sand Shiner			Xx	
Fathead Minnow			Xx	
Bluegill				0.3%
NATIVE	80.7%	74.8%	44.0%	66.4%
Sample size	3463	4485	1630	1481

Roundtail chub composition was higher at Clifton than Corn Lake in the three years. In 2001 roundtail chub were 3% at Corn Lake and 6% at Clifton. In 1999, 2000 and 2001 roundtail chub percentages at Corn Lake were 3%, 4% and 3%, respectively and were 7%, 5%, and 6%, respectively at Clifton (Table A4). Colorado pikeminnow are very rare in the samples with only one collected at Corn Lake and four at Clifton in 2001. All razorback sucker were hatchery fish and only two at each station were captured in 2001. Native fish comprised 76%, 72% and 81% of the catch at the Corn Lake station in 1999, 2000 and 2001, respectively. At Clifton native fish composition was 63%, 78% and 75% from 1999, 2000 and 2001, respectively.

The stability in species composition for flannelmouth, bluehead and roundtail chub has been generally maintained over the three years. This indicates stability in environmental factors and that habitat availability was consistent for these fish during the study period. The sample in 2000 differed somewhat from the other years in that flannelmouth were less common (31%) in Corn Lake and bluehead were more common (41%) at Clifton compared to other years. Also

flannelmouth sucker composition at Clifton in 2001 (42%) was somewhat higher than the prior year. Factors that could explain these minor discrepancies in species composition include that it could be there was a true shift in species composition or that it could be an artifact of sampling efficiency between years. It is more likely that the variation noted for 2000 is a result of sampling efficiency. Sampling efficiency can be influenced by flows, visibility of water, effort, and ability of netters. Flow conditions during sampling was fairly similar in 2000 and 2001, but flows were much higher 1999 (Figure 3). In 2000 sampling after thunderstorms or during reduced water visibility was more common, and there were fewer passes made in 2000 than in 1999 and 2001. Also shoreline habitats received proportionally more effort in 2000. Therefore, it is believed that differences between years for flannelmouth and bluehead composition is less than the data in Table 3 indicates.

Common carp was the most common nonnative species of fish over 15 cm collected at both sites in 2001. Carp were 6% at the Corn Lake site and 14% at Clifton (Table 6). In 1999 and 2000 carp comprised 11% and 14% of the catch, respectively so the 6% of 2001 was much lower than in the two prior years. At Clifton carp composition was 16% in 1999, 12% in 2000 so the 14% in 2001 was very similar to prior years. The discrepancy in carp percentage at Corn Lake in 2001 (6%) could suggest more movement of carp during 2001.

White sucker plus white hybrids with flannelmouth and bluehead comprised 6.2% at Corn Lake in 2001 and 4.1% at Clifton in 2001 (Table 6). These percentages are similar for white sucker in Corn Lake in 1999 and 2000 at 5.6% and 5.3%, respectively and at Clifton at 5.0 and 3.7% respectively. Also white sucker were more common in backwater habitats than in the main channel. Channel catfish also had similar species composition between years with 4.7% in 2001, 6.3% in 2000 and 4.2% in 1999 at Corn Lake. In Clifton, catfish composition was 5.7% in 2001 and 5.1% in 2000.

Fish less than 15 cm

Since speckled dace were very common and occupy swift habitats somewhat difficult to sample, dace and mottled scuplin were not netted but counted by netters. Therefore, dace and sculpin composition is not based on catch rates so their composition is not proportional to their actual population size. However, these counts will be very useful for documenting their distribution and habitat associations in the Colorado River. In contrast, all sunfish sighted were netted, and most originated in backwater habitats. Sunfish removal was tried in 2001 and 2000, but not in 1999, since the recovery program was conducting sunfish removal during this time. Non-native cyprinds (NNC; red shiner, sand shiner and fathead minnows) were very abundant in shoreline habitat and backwater habitats, but relatively few were netted. No effort was made to quantify abundance or composition of NNC since these fish are not going to be used to justify flow recommendations and numerous other sources are available for data concerning this fish group, Valdez (1999), Bestgen et al (1999) and McAda (ISMP).

It is highly likely that the most common fish in the under 15-cm group for the 15-mile Reach belong in the NNC group. The next most abundant species is highly likely to be speckled dace, which had the highest composition as reported in 2001 at both sites (Table 6). YOY and juvenile flannelmouth and bluehead sucker and roundtail chub were collected in all years

indicating suitable habitat is available for the smaller life stages of these native species given habitat conditions during the surveys. Mottled sculpin were present but not very common, so this fish is not a good indicator species for showing trends related to environmental perturbations, as is the case with the Yampa River.

Sample size for fish less than 15-cm was highest in 2001 and this could reflect increased effort in sampling backwaters and shorelines or actual increases in number of small fish that year. Small fish typically increase in numbers during low flow conditions. Higher mean water temperatures are associated with low flow years and this means a longer growing season and more primary productivity. Given these conditions small-sized fish respond with more clutches and improved survival of YOY. Flow conditions in both 2000 and 2001 may have been more conducive for small fish than in 1999. However, in order to document a biological response in the sunfish group, individual backwaters and shoreline data need to be examined and that was not main intention of this study.

DOLORES RIVER

The Dolores River site at Big Gypsum was sampled for the first time in 2000 and again in 2001. Species composition differed greatly between the two years for fish over 15 cm. In 2001 flannelmouth sucker (58%) was the most common fish over 15 cm sampled, but was only 16% in 2000 (Table 7). Roundtail chub were second most common at 25% in 2001 but was the most common species (55%) in 2000 (Table 7). Bluehead sucker was 6% of the sample in 2001 and only 2% in 2000. Together these native fish comprised 88% of the fish population in 2001, higher than the 73% observed in the 2000 sample. The most common non-native fish in 2001 was channel catfish at 8%, but was 16% in 2000 (Table 7).

In the first less than 15 cm group, the number of fish caught in 2001 (2,159) was much higher than in 2000 (577) (Table 7). Many more red shiners were observed in 2001 and this was the most common species at 36% in the less than 15-cm group. Speckled dace was the next most common fish under 15 cm at 18%. The large bodied natives, flannelmouth sucker, bluehead sucker and roundtail chub were also well represented in small fish group with 10%, 14% and 17%, respectively. Native fish comprised 58% of the <15 cm fish sample in 2001 compared to 87% in 2000 (Table 7).

Table 7. Species composition for fish **Over** and **Under 15 cm** at the Big Gypsum site on the Dolores River, July 2001.

	Big Gypsum 2001	Big Gypsum 2000	Big Gypsum 2001	Big Gypsum 2000
Species	>15 cm	>15 cm	<15 cm	<15 cm
Flannelmouth Sucker	57.5%	16.0%	9.9%	5.2%
Bluehead Sucker	5.8%	2.2%	14.2%	0.0%
Roundtail Chub	24.5%	54.9%	16.5%	48.0%
Channel Catfish	8.3%	15.8%	0.4%	1.4%
Carp	1.7%	3.4%	0.0%	0.2%
Green Sunfish	1.4%	2.0%	1.5%	5.7%
Pumpkinseed	0.0%		0.5%	
Brown trout		0.6%		
Black Bullhead	0.6%	5.2%	0.5%	0.2%
Speckled Dace	0.0%		17.5%	33.8%
Mottled Sculpin				
Red Shiner	0.0%		36.3%	5.2%
Sand Shiner	0.0%		2.3%	0.2%
Fathead minnow	0.0%		0.5%	0.2%
Native species	87.9%	73.1%	58.1%	87.0%
Sample size	636	501	2159	577

The considerably large shift in composition between years could indicate an environmental change between years. Since the percent of native fish increased, it appears the shift could be a positive adjustment to changes in habitat conditions or predation rates. In spite of the fact the native species composition (88%) and diversity for fish over 15 cm increased in 2001, and was highest of any sites sampled, the native population on the Dolores appears to be highly stressed and unnatural. This is better indicated by trends in size structure and density.

Size Structure for the Yampa, Colorado and Dolores Rivers

Length frequency histograms for each station sampled in 1998 and 1999 are available in the progress report Anderson and Stewart (2000) and histograms for the 2000 sample are given in Anderson and Stewart (2001). Refer to these progress reports to make comparison between this year's data (Appendix Figures A1 to A53), and earlier years. Some histograms from 2000 at Sevens were incorrect (bluehead, flannelmouth and catfish) or not included (Lily Park, smallmouth bass) and are included here at the end of the Appendix.

At Sevens, the length frequency histograms for bluehead sucker in 2001 (Figure A1) had no fish under 19 cm, which was also found in 2000 (Figure A50). Both mean length and sample size were smallest in 2001 at Sevens (Table 8) and its 30.0 cm mean length was the smallest mean size for any site on the Yampa or Colorado Rivers. Bluehead sucker under 34 cm were rare at Duffy in 2001 (Figure A2), as was observed in earlier years and its mean length of 38 cm was the highest for any site on the Yampa or Colorado River (Table 8). Also, Duffy was the only site where mean lengths were not significantly different between years (Table 8). At Lily

Park, bluehead were rare under 28 cm and the 2001 histogram (Figure A3) was similar to 2000, even though sample size was less in 2001 (Table 8). On the Colorado River, juvenile size bluehead sucker were fairly common and there were no breaks in the histogram between 10 and 44 cm (Figure A5 and A6). The Dolores River bluehead sucker size structure in 2001 was noticeably different from all other sites. In both 2000 and 2001 no bluehead sucker over 28 cm were collected. In 2001 a very high number of yearling (325) bluehead were caught (Figure A4), but no fish in that size-group were collected in 2000. About the same number of fish between 19 cm and 28 cm were collected in both years (11 in 2000 and 18 in 2001).

Table 8. Mean lengths of Bluehead sucker captured during the study period (1998 to 2001), Yampa, Colorado and Dolores Rivers.

	1998,a	1999,b	2000,c	2001,d
	Mean length of bluehead sucker in cm			
Sevens	33.5,cd	33.6,cd	31.3,abd	30.0,abc
Duffy	36.5	37.9	37.6	36.2
Lily Park			34.4,d	33.5,c
Corn Lake		36.5,cd	33.3,bd	34.8,bc
Clifton			31.8,d	33.5,c
Dolores			23.6	12.1
	Total number in sample - Number less than 15 cm			
Sevens	314 - 0	187 - 0	180- 0	89 – 0
Duffy	56 – 0	102- 0	45 - 0	41 – 3
Lily Park			347 - 3	212 – 0
Corn Lake		1212 -3	1010 -16	1283 –31
Clifton			1374 - 51	1228 – 35
Dolores			11-0	343-308

*a, b, c, d following a mean length indicates significant difference (2 tail test) at @=0.5 for those years.

The mean length of bluehead sucker at Sevens in 2001 was smaller. Fewer large bluehead sucker is consistent with reduced riffle habitat availability due to low flows in 2000 and 2001. The smaller bluehead mean length (30 cm) at Sevens could be an indicator of a change in habitat availability. In contrast to Sevens, Duffy had the highest mean lengths for bluehead sucker consistently for the four years. The high Duffy mean length (36 to 38 cm, Table 8) is due to lack of fish under 35 cm, indicating Duffy had steady and heavy predation pressure throughout the study period. At Lily Park, bluehead sucker mean length was near 34 cm in both years even with fewer fish less than 28 cm in 2000 (Table 8). The mean length of bluehead in the Colorado River sites was 32 to 34 cm (Table 8) and appears to represent a healthy bluehead sucker size structure, since habitat is abundant and predation or competition is not a factor. The Dolores River had the smallest bluehead sucker mean length (12.1 cm) (Table 8) due to a very high number of yearling fish and a very low number of adults.

The length frequency histograms were very similar for flannelmouth sucker for the first three years at Sevens, but percentage of fish between 30 and 42 cm increased in 2001 (Figure A7) compared to prior years and mean length (43.8 cm) was significantly less (Table 9).

Because the number of flannelmouth was low at Duffy in 2001 (n=17) (Figure A8), the 2001 mean lengths (47.5 cm) was not significantly different from prior years (Table 9). At Lily Park, mean length was significantly less in 2001 (38.4 cm) than in 2000 (41.5 cm) (Table 9). This was due to more fish less than 29 cm in 2001 (153) than in 2000 (4) (Figure A9). Flannelmouth sucker from the Colorado River at Corn Lake (Figure A11) and Clifton (Figure A12) have all size groups represented in all study years. On the Dolores River, there was apparently very good survival of flannelmouth YOY produced in the prior year since the vast majority of fish were yearlings between 9 and 19 cm (Figure A10). Yearling flannelmouth were larger (16 to 26 cm) in 2000 than in 2001. As was found for bluehead suckers on the Dolores, yearling flannelmouth sucker were very numerous while large adult fish were very rare.

The mean length of flannelmouth sucker found at Sevens (46 cm) and Duffy (49 cm) (Table 9) are representative of populations without juvenile fish. The decrease in mean size for flannelmouth sucker at Sevens and Lily Park in 2001 could suggest reduced predation by northern pike that year relative to others, or some other factor that allowed the number of smaller fish to increase. At Lily Park in 2001, mean length decreased from 42 to 38 cm (Table 9). At Duffy, mean length was less in 2001, but sample size was also very poor. The reason for the lower number of flannelmouth at Duffy is difficult to pin point, but clearly very low flows and smallmouth bass are implicated. Reduced predation by northern pike at Duffy may not be detectable since very few predators can impact a population that is already in low abundance. ..

Table 9. Mean lengths of flannelmouth sucker captured during the study period (1998 to 2001), Yampa, Colorado and Dolores Rivers.

	1998a	1999b	2000c	2001d
	Mean length of flannelmouth sucker in cm			
Sevens	45.7,d	46.5,d	45.8,d	43.8,abc
Duffy	48.9	49.0	49.8	47.5
Lily Park			41.5,d	38.4,c
Corn Lake		41.2,cd	38.9,bd	40.6,bc
Clifton			38.3	38.8
Dolores			18.8d	14.2c
	Total number in sample - Number less than 15 cm			
Sevens	668 –0	476 – 0	404 - 1	359 – 0
Duffy	90 – 0	79 – 0	65 - 0	17 – 0
Lily Park			1,935 - 0	2,022 – 0
Corn Lake		1,384 –46	928 - 65	1,495 – 39
Clifton			1,106 - 55	1,934 – 53
Dolores			110 - 30	580 – 271

- a, b, c, d following a mean length indicates significant difference (2 tail test) at @=0.5 for those years.

The Colorado River appears to represent a flannelmouth sucker population with abundant habitat and a lack of predation and competition. Mean length of this population is 39 to 41 cm (Table 9). The size structure of flannelmouth in the Colorado River ranges from 7 to 55 cm with modes representative of all age groups. It is believed that in the Colorado River, both

flannelmouth and bluehead sucker are at 'carrying capacity' of the physical habitat. On the Dolores River only three adult flannelmouth were collected, less than in 2000. The low mean length is representative of a population that has either poor habitat or limited forage availability for adult size fish.

Size structures of roundtail chub at Sevens (Figure A13) and Duffy (Figure A14) in 2001 were very similar (not significantly different) to prior years, but sample size was less at both sites (Table 10). The small decrease in mean lengths in 2001 (Table 10) was due to only one or two additional small fish in the sample, not a shift in size distribution. The high mean length at Sevens (38 to 40 cm) and at Duffy (43 to 44 cm) for the study period are due to few yearling and juvenile fish in the population. Only one chub was collected at Lily Park in 2000 and the single chub in 2001was 18 cm in length (Figure A15). On the Colorado River, both large and small chubs were present in 2000 and again in 2001 at Corn Lake (Figure A17) and at Clifton (Figure A18). Mean lengths were not significantly different between Corn Lake (23.5, 20.9 cm) and Clifton (25.0, 22.1 cm) in the same year, but the differences were significant between 2000 and 2001 at both sites. On the Dolores River, chub ranged in size from 2 cm to 27 except for one large chub at 40 cm (Figure A16).

Table 10. Mean lengths of roundtail chub captured during the study period (1998 to 2001), Yampa, Colorado and Dolores Rivers.

	1998a	1999b	2000c	2001d
	Mean length of roundtail chub in cm			
Sevens	39.0	40.0,d	39.2	37.9,b
Duffy	43.5	44.5	44.2	43.4
Lily Park			40.3	18.0
Corn Lake		23.3,d	23.5,d	20.9,bc
Clifton*		28.9	25.0,d	22.1,c
Dolores			14.1,d	10.9,c
	Total number in sample - Number less than 15 cm			
Sevens	73 –0	39 - 0	31 - 0	23 - 0
Duffy	55 – 1	44 - 0	46 - 0	27 - 1
Lily Park			1 – 0	1 – 0
Corn Lake		188 - 78	145 - 26	193 - 89
Clifton*		47 - 4	196 - 29	446 - 186
Dolores			275 - 277	145 - 367

* a, b, c, d following a mean length indicates significant difference (2 tail test) at @=0.5 for those years.

The high mean size (38 to 44 cm) of roundtail chub in the Yampa River is a result of predation on small fish. The smallest mean length (10.9 cm) on the Dolores in 2001 was less than in 2000 (14. 1) (Table 10). As was the case for native suckers, there were few larger fish (>20 cm) in the Dolores River in 2001. The lack of adult size fish is consistent for all native species and between years and indicates a lack of habitat or forage availability. The size structure for roundtail chub on the Colorado River may be near ideal for this species and mean length was from 21 to 25 cm (Table 10).

The size structure for all three native species in 2001 was similar to earlier years at each site. There were very few to no small bluehead sucker, flannelmouth sucker, or roundtail chub at Sevens and Duffy on the Yampa. In contrast, the Dolores River had only small fish and mean size was smaller in 2001 than the prior year for all three species. The Colorado River had all sizes of these species. The factors that make the Colorado River more conducive for native fish include adequate instream flow that provides habitat availability for all age-groups. Nonnative fish predators were not impacting survival of YOY and recruitment of adult fish and also white sucker and white-native sucker hybrids are not significant in the Colorado River as is the case at Duffy. Size structure in the Yampa River would probably be more similar to the Colorado River if non-native predators and suckers were not present. The Yampa River has experienced two consecutive low flow years and during this period a shift from northern pike to smallmouth bass as the primary predator was observed. As this trend continues, the size structure of native fish may continue to change. The Dolores River probably had large adult size fish prior to regulated flow, but adults were rare at the study site. There was a high number of yearling fish in the 2001 sample showing adult fish must be reproducing successfully somewhere in the Dolores River. A very wide range in size structure for native fish was found between the rivers and sites and this will be studied in terms of habitat differences between them.

A small number of YOY and yearling (< 15 cm) white sucker were present at Sevens in 1998 (14) and 1999 (15), but in 2000 the number of YOY (119) was much higher. The 2001 sampling found a strong mode at 18 cm for at Sevens (Figure A19) showing a strong 2000 year-class as age-one fish. The same is also the case at Duffy, a strong white sucker 2000 year-class was found in both 2000 as YOY in 2001 as age-one (Figure A20). Conversely, yearling bass (13 to 20 cm) were rare at both stations in 2000. The could indicate a predator prey relationship, few yearling bass and weaker predation in 2000 allowed a strong white sucker year-class to develop in 2000. In 2001, yearling bass were common at both Sevens and Duffy and in that year few YOY white sucker were found. White sucker between the sizes of 19 and 35 cm have been rare at both Sevens and Duffy during the study period. If white sucker move into this size-group in 2002, that would be very strong evidence that the northern pike population was been effectively reduced in that year.

Most of the white sucker on the Colorado River (Figures A21 and A22) were taken from slow backwater habitats, not the main channel as on the Yampa River. White sucker YOY numbers were very strong in 2001, indicating beneficial aspects to the lower flows in 2001 for their reproduction. Also, yearling white sucker were common in 2001. In general, main channel habitats on the Colorado River have faster currents and most white sucker were taken from backwaters. This suggests that adult white sucker are not significant competitors for resources with adult native suckers. However, the white-flannelmouth (Figures A25 & A26) and white-bluehead (Figure A29 & A30) are found in the main channel and probably are a competitor, but hybridization does not appear widespread at this time.

Size structure of the white-flannelmouth cross (Figures A23 and A24) and the white-bluehead sucker (Figures A 27 and A28) cross at the Sevens and Duffy (Yampa) sites has consistently shown the impacts of northern pike predation from 1998 to 2000. Their size structure in 2001 was again comprised primarily of only large individuals. Large size has apparently been their only defense against large predators, but large size is a disadvantage during low flows when habitat availability for large fish is restricted. Since the white sucker group has been the largest taxon at Duffy, this group should be most reactive to significant environmental

perturbations. Changes in size structure of the white sucker group would be an indirect measurement of changes in predation rates due to pike reduction, and or other environmental stresses. A decrease in sample size of large white and white suckers crosses was observed in 2001 compared to earlier years. Eventually geriatric fish expire and a certain amount of recruitment is required to maintain numbers. This could have been happening in 2001, but changes in size structure and species composition were apparent for the entire fish community at Duffy. Given this, a reduction in population size of large white sucker more likely indicates a change in carrying capacity than attrition of older individuals.

The size structure for carp was basically the same in 2001 at Sevens, Duffy and Lily Park as it was in prior years. Minimum sizes of 46 cm at Sevens (Figure A31), 58 cm at Duffy (Figure A 32) and 37 cm at Lily Park (Figure A33) also show predation is impacting small carp throughout the Yampa River. The length frequency histograms for carp on the Colorado River (Figures A 35 and A36) clearly show that 2001 was a very good year for YOY carp. YOY were much more common in 2001 at Corn Lake (Figure A35), the lower flow year compared to 1999 (Figure A54) the high flow year. This is an indication of more nursery habitat availability in 2001. Carp are already quite numerous in the Colorado River and it appears the carp reproduction had a positive response to low flows in 2001. YOY carp and most of the small carp (less than 30 cm) were taken from backwater habitats, but large carp occupy the main channel shoreline with boulder or tree snag cover. Another factor that appears advantageous to carp in the Colorado River, compared to the Yampa, is the magnitude of allochthonous input from treatment pond outlets that provide increased feeding opportunities. Carp size structure in the Dolores River was the same as other species, fewer larger carp and more of the smaller carp in 2001. Fewer large carp suggests reduced carrying capacity in 2001 in the Dolores River.

Size distribution for channel catfish for the Yampa River in 2001 at Sevens and Duffy (Figures A37 and A38) was fairly similar to 1998, 1999 and 2000. Smaller mean lengths of catfish were observed in 2001 at both Sevens (48.1 cm) and Duffy (46.4 cm) than in 2000, as was also found for other species. Mean size was also less in 2001 (Figure A 39) at Lily Park than in 2000 (Figure A 54) because of an increase in number of fish between 20 and 27 cm. Catfish smaller than 29 cm have not been found at either Sevens or Duffy during fours years of sampling. At Lily Park, the smallest catfish in the sample was 19 cm. The smallest catfish on the Colorado River in 2001 was 26 cm (Figures A41 and A42), except for one that was only 12 cm. Catfish mean size in 2001 increased on the Colorado River at both sites from last year. Catfish mean size in 2001 decreased on the Dolores River from last year as also happened with all other species in the Dolores. Catfish mean size in 2000 was 28.7 cm compared to 25.8 cm in 2001 (Figure A 40). Except for an obvious shift in the 2001 histogram, about 3 cm toward the y-axis the shape of the histogram was fairly similar between the two years.

Apparently catfish do not reproduce in the Yampa River near the Sevens and Duffy sites or this part of the river lacks some important aspect of habitat for spawning; probably temperature. Tim Modde of the USFWS routinely finds high numbers of small catfish (<30 cm) in Dinosaur Canyon (per. comm.). It has been proposed by Recovery Program biologists that large catfish migrate to Dinosaur Canyon for spawning and move upstream after they reach a minimum size of near 30 cm. The catfish size data from this study has been consistent with this concept. It was also observed in 2000, a year with very low flows, that there was a very high number of catfish at Lily Park. This would happen in years with low flows that prevent upstream movements over shallow riffles and also Cross Mountain Canyon may be a migration

barrier at low flows. The one YOY catfish found in the 15-Mile Reach in 2001 indicates local spawning that year. Temperatures would have warmed faster in 2001 due to the low runoff, which suggests low flow years could have a positive influence on local catfish reproduction. Small catfish on the Dolores indicate that nursery and juvenile habitat is available in the Big Gypsum site.

Several changes have been observed in the size structure of the smallmouth bass population in the Yampa River during the study period. In 1998, 1999 and 2000, YOY bass were numerous at Duffy. In 2000 the yearling bass (13 to 21 cm) presence was weak at all three sites [Lily Park (Figure A54), Sevens and Duffy]. In 2001 yearling bass were very strong and YOY was strongest of the study period (Figures A45, A46 and A47). Yearling bass may be predators on all YOY size fish, including its own species. The fact that YOY white sucker were strongly present in 2000 at Sevens and Duffy (see above) is strong testimony that yearling bass were rare in 2000. Habitat-wise yearling bass appear to be well adapted to survival in shallow, warm pools which would be the most available habitat at flow less than 120 cfs. In 2000, summer flows were in the range of flow from 30 to 70 cfs and given these flows all bass larger the YOY would be stranded in the few isolated deep pools remaining. A low number of predators such as yearling to adult northern pike or adult bass could effectively remove most yearling bass confined in the same habitat.

Forage-sized fish (12 to 30 cm) have been very rare in all years at Duffy for all species so in 2000 yearling bass would be the most available prey fish in that size range. The fact that yearling bass were very strong in 2001 strongly suggests reduced northern pike predation in 2001. Flows were not much higher in 2001 so escape habitat would be about the same between years. It could be that by the end of 2000 northern pike abundance might have had a negative adjustment in abundance because of lack of forage. Also, the recovery program actively removed northern pike from sections of the Yampa River in the spring of 2000 and 2001. The effectiveness of that removal is difficult to confirm, given the extreme environmental conditions of the last two years, but clearly this could have been a factor in the apparent decrease in northern pike and a concomitant increase in smaller bass and in 2001.

Northern pike appear to prey on smaller bass, but once bass achieve a size threshold (perhaps > 20 cm) their risk to predation is much reduced. Given reduced pike abundance and increased yearling bass abundance it appears reasonable to predict that bass abundance in the Yampa River will increase next year well beyond that measured during this study.

The majority of largemouth bass in the Colorado River (Figures A 43 and A44), are smaller than 15 cm in length. In the Colorado River, largemouth bass are generally not found in the main channel since velocities were much higher in the Colorado River than in the Yampa. As long as riffle habitats maintain high velocities, it is not likely that smallmouth or largemouth bass will be a predator on species like speckled dace and mottled sculpin in the Colorado River. However, largemouth bass are likely a considerable predator on young life stages of native fish (especially endangered fish) occupying backwaters for nursery and YOY habitat.

Density Estimation

Yampa River

The three stations: Duffy, Sevens and Lily Park, were sampled in 2001 using similar equipment, techniques and mark-recapture methods that were used in the three prior years. As was the situation for species composition and size structure, large differences exist between the three sites for fish densities. Lily Park had by far the highest total fish density of 3,168 fish/km while density at Sevens was only 653/km and it was only 430/km at Duffy (Table 11). These data strongly show that Lily Park has about 5 times more fish >15 cm than the upstream sites. Lily Park is only 10 river miles downstream of Sevens, suggesting similar temperature and water quality attributes. Also there appears to be a larger predator population of northern pike and smallmouth bass at Lily Park (Table 11). Most of the differences in fish density between Lily Park and Sevens appear to be a function of channel morphology. Lily Park is just downstream of Cross Mountain and just upstream of the Little Snake River confluence. The river in Lily Park has a steep slope and the substrate is larger rocks and cobble and habitat composition is primarily riffles and fast runs. At Sevens the substrate is mostly sand and habitat is mostly shallow pools at base flows.

The density data will be used to indicate habitat suitability for native species. For example, since flannelmouth sucker density (1,667/km) is much greater at Lily Park than Sevens (263/km) and Duffy (5/km) (Table 11), the suitability of the habitat is presumed to also be much higher. Bluehead sucker density is about 3 times higher at Lily Park than Sevens and Sevens is about 6 times higher than Duffy is. Habitat availability for bluehead is expected to have somewhat of a similar relationship between sites. Roundtail chub density for fish over 15 cm was highest at Sevens and lowest a Lily Park. Clearly a lack of habitat for roundtail chub at Lily Park is indicated. Lack of habitat for adult chub (over 15 cm) may not be the problem, it may be more likely spawning or YOY habitat is missing from this location.

The fish density/habitat availability relationship is not going to be a direct relationship due to documented predation at all Yampa sites, and particularly heavy predation at Duffy. Predation has been suppressing density below the level that habitat can support and this has clearly been happening for smaller fish of most species at both Sevens and Duffy. However, the Colorado River and Dolores River do not have the high level of predation as the Yampa. Comparison of densities between rivers with and without predators will help clarify habitat availability for native fish where predation has impacted size-structure and density.

Table 11. Yampa River population estimates with 95% C.I. (recaptures), and density estimates (No./1000m), 2001. Mean stream width is about 53 m at 125 cfs, (Stewart 2000).

	Lily Park	**Sevens**	**Duffy Reach**
	No./km ±C.I. (recaps)	No./km ±C.I. (recaps)	No./km ±C.I. (recaps)
Total fish	3,168 ±10% (312)	653±19% (74)	430 ±19%(80)
Bluehead Sucker	346±49% (13)	120±65%(7)	19 ±85%(4)
Flannelmouth S	1,667±10% (269)	263±22%(52)	5 ±88%(3)
Roundtail Chub	2±NR(0)	29 ±121%(2)	10 ±93%(3)
Colo. Pikeminnow	2±NR(0)	0 ±NR(0)	4 ±NR(0)
White Sucker & Crosses	2±61% (2)	138+58%(9)	185 ±26%(44)
Smallmouth Bass	501±84% (5)	37±120%(2)	215 ±44%(17)
Channel Catfish	1,395±40% (21)	46±NR(0)	23 ±130%(2)
Northern Pike	14±NR(0)	3±NR(0)	4 ±NR(0)
Carp	171±NR(0)	33±123(2)	2 ±30%(7)
	Lily Park	**Sevens**	**Duffy Reach**
	No./1000m²	No./1000m²	No./1000m²
Total fish	59.8	12.3	8.1
Bluehead Sucker	6.5	2.3	0.35
Flannelmouth S	31.4	5.0	0.09
Roundtail Chub	0.03	0.55	0.06
Colo. Pikeminnow	0.03	0.00	0.19
White Sucker & Crosses	0.03	2.61	3.48
Smallmouth Bass	9.45	0.69	4.05
Channel Catfish	26.3	0.86	0.44
Northern Pike	0.26	0.05	0.11
Carp	3.22	0.62	0.04

The Duffy Reach is 7.2 km long and fish density was estimated using a consistent mark-recapture method for a four-year period. Variation of density at the same site between years is empirical data that indicates a response to changes in environmental conditions between years. Flow conditions were found to be highly different between the years 1998 and 1999 and the year 2001. 1998 and 1999 were years of near median base flows and 2000 and 2001 were years of abnormally low base flows. Along with physical habitat availability, certain water quality variables (temperature, pH, oxygen, etc.) are correlated to flow. The density/flow relationship is usually the weakest link in habitat modeling studies. However, habitat suitability indices developed in this study include empirical data for both fish density and habitat, not just one or the other.

In 1998 and 1999 at the Duffy Reach, fish density estimates were very similar with 378 and 403 fish/km, respectively and not significantly different (alpha = .05) from each other. The 2000 estimate of 316 was significantly lower (alpha = .05) from two previous years and strongly suggests total density was reduced that year (Table 12). White suckers and white sucker crosses

were the most abundant taxa in 1998 (62%), 1999 (60%) and 2000 (64%) and smallmouth bass was next most common taxon at 10%, 14% and 18% in 1998, 1999 and 2000, respectively. Density estimates were down for all species except smallmouth bass in 2000 (Table 12). The species that decreased in 2000 were composed of large-bodied individuals (refer to size-structure section). Smallmouth bass were composed mostly of small-sized fish. Therefore, habitat conditions for most smallmouth bass probably improved in 2000 compared to 1998 and 1999.

Table 12. Fish density (fish/km) estimates for the Duffy station, Yampa River for 1998, 1999, 2000 and 2001. Significant differences (alpha = 0.05) between years are denoted by the letter (a, b, c, d) following estimate and * indicates alpha = 0.0083 (Bonferroni).

DUFFY	1998-a	1999-b	2000-c	2001-d
	fish/km	fish/km	Fish/km	fish/km
Total fish	387 c*d	403 c*	316 a*b*d*	430 ac*
Bluehead Sucker	24	23	16	19
Flannelmouth S	25 c*d*	15 d*	11a*d	5 a*b*c
Roundtail Chub	12 c	25	5a	10
Colo. Pikeminnow	8	5	4	3
White Sucker & Crosses	241cd	242 cd	203 ab	185 ab
Smallmouth Bass	40 d*	58 d*	58 d*	215 a*b*c*
Channel Catfish	19	29	15	23
Northern Pike	17	16	3	4
Carp	21 c*d*	8	4 a*	2 a*

The total density estimate for 2001 was highest of the study period at 430 fish/km and was significantly higher from 1998 and 2000 (Table 12). The highest density in 2001 was solely due to a large increase of smallmouth bass, mostly small-sized bass tolerant of low flows. In 2001, smallmouth bass strongly increased to 215/km and were 50% of the total density, while density for the white sucker group and flannelmouth sucker decreased. The density estimates for both white and flannelmouth sucker were significantly different from the three prior years and the lowest of the study period. The 2001 density data is consistent with the 2000 data. Large-size fish decreased and small size-fish (bass) increased in the years with very low flows from baseline conditions established in the years with higher base flows.

All three native species (flannelmouth and bluehead suckers, and roundtail chub) had very low densities in all study years at the Duffy site (Table 12). It has been strongly suggested in earlier progress reports that their abundance would increase given reduced predation by northern pike. In 2001, it appears that in spite of a much-reduced northern pike density, flannelmouth and white sucker was also reduced. Given similar or less predation, this suggests reduced habitat availability in 2001 as the regulating factor. Bluehead sucker and roundtail chub could have been both positively and negatively influenced by reduced predation and reduced habitat availability in 2001. Clearly habitat potential for the large-bodied native fish appears to be reduced in 2000 and 2001 compared to 1998 and 1999. Given the high number of yearling smallmouth bass in 2001, it is expected that bass density will also strongly increase and a large increase in bass will likely reorganize species composition, size structure and density of the fish

community for years to come. The data clearly shows that this nonnative predator has flourished in the low flow years.

As was the case at Duffy, total density estimates at Sevens were similar in 1998 (1,147km) and 1999 (1,115/km) (Table 13) indicating the carrying capacity of this area was near these values. The reduced density in 2000 (778/km) and 2001 (653/km) was significant at the alpha = 0.05 for both between years and simultaneously (Table 13). The lower densities were found in the years with the lower base flows and could indicate a reduced carrying capacity. Also consistent with Duffy is the appearance that the northern pike population was less in 2000 and 2001, suggesting predation was less a factor in regulating density than it would have been in 1998 and 1999.

Table 13. Fish density (fish/km) estimates for the Sevens station, Yampa River for 1998, 1999, 2000 and 2001. Significant differences (alpha = 0.05) between years are denoted by the letter (a, b, c, d) following estimate and * indicates alpha = 0.0083 (Bonferroni)

SEVENS	1998-a	1999-b	2000-c	2001-d
	fish/km	fish/km	fish/km	Fish/km
Total fish	**1147,c*d***	**1115,c*d***	**778a*b***	**653a*b***
Bluehead Sucker	**274bc**	**238a**	**309a**	**120**
Flannelmouth S	**395cd***	**376cd**	**296ab**	**263a*b**
Roundtail Chub	**73**	**41**	**54**	**29**
Colo. Pikeminnow	**4**	**3**	**3**	**0**
White Sucker & Crosses	**200c*d***	**189,c***	**105,a*b***	**138,a***
Smallmouth Bass	**20**	**29**	**6**	**37**
Channel Catfish	**111**	**109**	**22**	**46**
Northern Pike	**62**	**22**	**3**	**3**
Carp	**77**	**69**	**45**	**33**

Flannelmouth sucker was the most common fish >15 cm collected in all four years at Sevens and had the highest density estimates except in 2000. Flannelmouth sucker estimates were similar for 1998 and 1999, and similar in 2000 and 2001, providing consistently between years with higher versus lower base flows. The fewest number of bluehead sucker were caught in 2001, but the estimate was not significantly different than other years because of the lower number of recaptures (higher variance). Electrofishing effort was roughly equal between years at Sevens and it strongly appeared during sampling that bluehead were more scarce in 2001. The same applied to roundtail chub. Sample size was small for chub in all years and recapture rates were not high enough to produce tight confidence intervals (Table 13). In 2001, fewer fish were caught given similar sampling effort, but statistically the difference was not significant.

The fact that total fish density was less in 2000 and 2001 for native fish and suckers at both Sevens and Duffy indicates a common factor operating at both locations which adds credibility to suggesting low base flows were responsible. Correlating fish density with habitat availability will be examined when habitat simulations have been completed on the Sevens. Smallmouth bass density at Sevens was highest in 2001, but was relatively low compared to Duffy (Table 13). Similar trends in bass but different densities suggest a habitat-based (carrying

capacity) difference between the two sites for smallmouth bass. Smallmouth bass density is also likely to increase at Sevens, especially in years with base flow lower than the median.

Only two years (2000 and 2001) of data is available for Lily Park and they were strikingly different (Table 14). The greatest difference in density estimates was for channel catfish. This was expected and explained in detail in Anderson and Stewart (2001) why a catfish overestimate was strongly suspected in the 2000 sample. It was observed on the first electrofishing pass in 2000 that many fish were stranded in the deepest habitats and not found in runs that were too shallow. On subsequent passes, flow increased, fish movement over riffles was restored, and it was likely there was migration into and out of the study site during the sampling period. Also, catfish numbers in 2000 would be greatly inflated at Lily Park if Cross Mountain Canyon becomes a fish passage barrier at the flows experienced in the 2000 summer. The channel catfish estimate in 2000 was 3,667/km compared to 1,394 in 2001, a 50% decrease (Table 13). When flow increased and catfish were free to move upstream into Cross Mountain Canyon, recaptures rates would be biased low. This explains why 1,554 unmarked catfish were caught in 2000, but sample size dropped to 507 in 2001. The fact that catfish numbers at Sevens, just a few miles upstream of Cross Mountain Canyon, was much lower than earlier years supports this explanation. Refer the species composition and size structure sections for more supporting information.

Table 14. Fish density (fish/km) estimates for the Lily Park , Yampa River for 2000 and 2001. Significant differences (alpha = 0.05) between years are denoted by the letter (a, b, c, d) following estimate.

Lily Park	**2000-c**	**2001-d**
	fish/km	fish/km
Total fish	**6279d**	**3167c**
Bluehead Sucker	**552**	**346**
Flannelmouth S	**2237d**	**1666c**
Roundtail Chub	**5**	**2**
Colo. Pikeminnow	**2**	**2**
White Sucker & Crosses	**14**	**2**
Smallmouth Bass	**121**	**501**
Channel Catfish	**3667d**	**1394c**
Northern Pike	**19**	**14**
Carp	**186**	**171**

The 25% decrease in density for flannelmouth sucker between 2000 and 2001 is also likely due to low summer flows in 2000. Fish that were stranded in deepest available habitats were able to reoccupy runs after flow increased. Recaptures were biased low when fish were above to migrate in and out of the study area. However, flannelmouth sucker do not appear to have an upstream migration behavior and movement was probably local (up and down). The total number of unmarked flannelmouth caught was slightly higher in 2001 than 2000 (1,753 versus 1,735, respectively) showing the significant decrease in density in 2001 was not due to

fewer fish in the sample. In fact, sampling efficiently for flannelmouth was higher 2001 since more fish were caught using less electrofishing effort.

The bluehead sucker density decreased 37% in 2001 from the prior year. However, the total number of unmarked bluehead caught also decreased by 38% between 2000 and 2001 (322 versus 199, respectively). There is no ancillary evidence to suggest a bluehead sucker upstream migration, similar to the catfish. Given improved electrofishing efficiency for flannelmouth sucker in 2001, it seems reasonable to speculate the same for bluehead sucker. The 37% decrease in bluehead density could be the result of bluehead moving into the study site in 2000 to escape reduced habitat in other sections of the river, or it could be an actual reduced abundance due to loss of riffle habitat availability during low flows.

Roundtail chub population size was the same between years with only one fish collected in each year. These fish probably were not reproduced locally.

In spite of the problems identified with the 2000 density data, the sampling effort was quite beneficial for documenting the habitat availability at this location. Many flannelmouth sucker were collected from deep eddies and pools on September 13, 2000 at 114 cfs (Above Little Snake gage), but on subsequent passes at higher flows (September 27, October 3 and 5) were not captured from those backwaters, but in runs with suitable depths. These observations directly showed that flannelmouth sucker occupied habitats at lows (100 cfs) that were not preferred at higher flows (over 120 cfs). This habitat-switching pattern was also observed in 2001, but when flows were dropping. Flannelmouth did not occupy the eddies and pools when flow was above 120 cfs (August 22, 2001), but were captured in these habitats as flows drop to near 100 cfs on August 29th and September 5th, 2001.

Smallmouth bass was the only species in Lily Park to increase in 2001 (Table 14). This increase is believed to reflect a true increase in abundance since the number of unmarked bass caught in 2000 was only 31, but it was 144 in 2001 with reduced effort that year. The bass density estimate at Lily Park in 2001 (501/km) was highest of any of the sites on the Yampa River (Table 11).

Colorado River

Total fish density was estimated at **Corn Lake** and **Clifton** separately and by **Both Sites** combined. The sites were only separated by 0.2 km and pooling all data to make a longer reach is more sensitive to show changes between years. The density estimates for bluehead sucker and flannelmouth sucker were very similar between stations in 2001, and were 1,272/km and 1,206 for bluehead and 1,662 and 1,619 for flannelmouth at Corn Lake and Clifton, respectively (Table 15). The 2001 estimates indicate these river sections should have nearly an equal amount of habitat availability for native suckers, which is currently being analyzed.

The bluehead density estimate at Corn Lake (1,182/km) was also very similar to Clifton (1,179/km) in 2000, and also quite similar to the 2001 estimates (Table 15). This confirms that bluehead habitat availability is likely similar between the two sites, and adds confidence in identification of a habitat/density relationship for this species.

Consistency was not found for flannelmouth sucker between stations and years in the 2000 sample. The Corn Lake flannelmouth estimate was only 999/km and was 1887/km at Clifton. The combined estimate was significantly different for 2001 (1,664/km) and 2000 (1,370/km) (Table 15). The difference between 2000 and 2001 for flannelmouth sucker was due to fewer fish collected at Corn Lake and a low recapture rate at Clifton in 2000. Because of this, sampling effort was increased in 2001 and confidence is higher that the 2001 estimates closely indicate population size of flannelmouth sucker in the two study sites.

Density estimates for roundtail chub were lower in 2001 at both Corn Lake (171/km), Clifton (370/km) and combined (274/km) than in 2000 at the respective sites (357/km, 453/km and 402/km) (Table 15). Recaptures were also less in 2000 and the differences between years were not significant.

Consistent differences between stations in species abundance would suggest minor differences in physical habitat availability between the two reaches. However, density estimates were inconsistent for carp, catfish and white sucker between 2000 and 2001. The 2001 density estimates for carp were significantly different between Clifton and Corn Lake but not in 2000 (Table 15). Density estimates for catfish were significantly different between Clifton and Corn Lake in 2000, but were similar between sites in 2001 (Table 15). White sucker estimates were significantly different between sites in both 2000 and 2001, but Clifton had the higher estimate in 2000 and Corn Lake was higher in 2001. The inconsistent results for these species suggests to the author that the less intensive sampling effort in 2000 produced estimates that were less robust than the 1999 and 2001 efforts.

Table 15. Fish density estimates No./km) with 95% C.I. (recaptures) for the Colorado River at the Corn Lake, Clifton and both sites combined, 2000 and 2001.

	Corn Lake 2001	**Clifton 2001**	**Combined 2001**
	No./km ±C.I. (recaps)	No./km ±C.I. (recaps)	No./km ±C.I. (recaps)
Total fish	4,007 ± 5%(273)	4,712 ± 9%(385)	4,449 ± 5%(658)*
Bluehead Sucker	1,272 ± 9%(128)	1,206 ± 17%(108)	1,261 ± 8%(236)
Flannelmouth S	1,662 ± 8%(105)	1,619 ± 12%(195)	1,664 ± 8%(300)*
Roundtail Chub	171 ± 37%(6)	370 ± 44%(17)	274 ± 29%(23)
Carp	199 ± 29%(6)	876 ± 29%(39)	528 ± 20%(59)
Channel Catfish	441 ± 26%(6)	549 ± 56%(11)	503 ± 24%(17)
White Sucker & Crosses	552 ± 29%(8)	206 ± 46%(15)	330 ± 25%(23)*
	2000	**2000**	**2000**
Total fish	3417±7% (212)	3902 ±7%(246)	3,614 ±5%(458)*
Bluehead Sucker	1182±12%(81)	1179 ±12%(140)	1,159 ± 8%(221)
Flannelmouth S	999±10%(72)	1887 ±10%(57)	1,370 ± 8%(129)*
Roundtail Chub	357±43%(4)	453 ±43%(6)	402 ± 28%(10)
Carp	525±21%(28)	591 ±21%(35)	585 ± 10%(63)
Channel Catfish	301±34%(10)	664 ±34%(4)	401 ± 27%(14)
White Sucker & Crosses	124+26%(17)	345 ±26%(4)	163 ± 22%(21)*

The Clifton station was added to the study in 2000, because of overt differences in channel morphology compared to Corn Lake (Figure A.55). Also, differences in species composition were noted in 1999 in fish surveys between the two sites, the largest difference was for catfish (Anderson and Stewart 2001). In 2001, the largest difference between the two sites was in carp abundance (Table 15). Carp were found to be a mobile species and moved frequently between habitats and sampling trips. Near the end of sampling in 2001 when flow was lowest, habitats that had large number of carp at Corn Lake were vacant and it appeared relatively more carp were found in Clifton. In spite of minor differences in density for carp, catfish and white sucker, productivity was very similar between the Corn Lake and the Clifton Stations.

Endangered fish are rare in both the 15-Mile Reach and the Yampa River. The 15-Mile Reach had a much larger native fish population than was found on the Yampa River. It is a fact that both rivers have similar channel widths and the 15-Mile Reach has had much higher summer flows than the Yampa River. In regard to bluehead, flannelmouth and roundtail chub habitat suitability appears to have been maintained in the 15-Mile Reach in recent years, but habitat limitations appear to be impacting density of these fish in the Yampa River. The one exception is a similar flannelmouth sucker density in the 15-mile Reach (30.2 and 29.4 per 1000m^2) and Lily Park (31.4/1000m^2). However, Lily Park also has a much higher population of channel catfish, and smallmouth bass than the 15-Mile Reach. Habitat availability of these nonnative fish will also be examined using the 2-D flow simulations to help clarify the role of flow and habitat composition for these nonnative species.

Table 16. Colorado River density estimates (No./1000m^2) for Corn Lake and Clifton in 1999, 2000, 2001. Stream width is about 55 m at 1400 cfs (Stewart 2000).

	Corn Lake 1999	Corn Lake 2000	Corn Lake 2001	Clifton 2000	Clifton 2001
	No./1000m^2	No./1000m^2	No./1000m^2	No./1000m^2	No./1000m^2
Total fish	**71.6**	**62.1**	**72.9**	**70.9**	**85.7**
Bluehead Sucker	**28.6**	**21.5**	**23.1**	**21.4**	**21.9**
Flannelmouth S	**28.2**	**18.2**	**30.2**	**34.3**	**29.4**
Roundtail Chub	**3.5**	**6.5**	**3.1**	**8.2**	**6.7**
White Sucker & Crosses	**2.5**	**2.3**	**10.0**	**6.3**	**3.7**
Channel Catfish	**3.5**	**5.5**	**8.0**	**12.1**	**10.0**
Carp	**5.6**	**9.6**	**3.6**	**10.7**	**15.9**

Dolores River

The total fish and native density estimates for native fish over 15 cm per kilometer and per 1000m^2 in the Dolores River is low compared to the Colorado and Yampa Rivers (Table 17). Fish per 1000 square meter is based on a conservative estimated stream width of 18 m, since cross section results are not available at this time. Therefore, fish per square meter will be different when stream width is determined using channel surveys. The Dolores had the lowest bluehead sucker density estimate of all sites in 2000, but was higher than Duffy in 2001. The

Dolores site density estimate of bluehead sucker was higher in 2001 (13 fish/km) than in 2000 (3 fish/km), and was due to a very high number of yearling fish in 2001. The increased bluehead sucker density in 2001 is not going to be maintained in following years.

Density of flannelmouth sucker in 2001 was 106/km, significantly higher from 36/km in 2000 (Table 17). Likewise for the bluehead, the increased flannelmouth sucker abundance in 2001 was due to a strong yearling group (13 - 18 cm) and flannelmouth density is not expected to be maintained next year. The low level population of adult size native sucker in the Dolores River does not appear to be a function of lack of potential recruitment.

Table 17. Dolores River population estimates with 95% C.I. and (recaptures), and density estimates (No./1000m²) for the Big Gypsum station, 2001 and 2000. Significant differences (alpha = 0.05) between years are denoted by the letter a or b following estimate.

	Big Gyp, 2001	Big Gyp, 2001	Big Gyp, 2000	Big Gyp, 2000
	No./km ±C.I. (recaps)	No./1000m² a, SD-b	No./km ±C.I. (recaps)	No./1000m² b, SD-a
Total fish	232 ± 16% (90)	12.9	197±15% (102)	10.9
Bluehead Sucker	13 ± 47% (8)	0.70 b	3±67% (3)	0.17 a
Flannelmouth S	106 ± 19% (57)	5.9 b	36±39% (15)	2.0 a
Roundtail Chub	65 ± 34% (20)	3.6	81±16% (67)	4.5
Green Sunfish	6 ± 202%(1)	0.08	5±58% (5)	0.29
Channel Catfish	62 ± 62% (3)	3.5	69±61% (8)	3.8
Black Bullhead	4 ± NR(0)	0.2	14±78% (4)	0.76
Carp	6 ± 147% (1)	0.33	24±181% (1)	1.35
Brown trout	0	0	1.2±NR (0)	0.07

Density estimates of roundtail chub were less in 2001 (65/km) than in 2000 (81), but not significantly different. In 2000, there was a very high number of yearling chub (12 – 19 cm) collected, but the number of yearling fish caught in 2001 was much less. Apparently there was poor survival for chub over 22 cm since age-2 fish did not show strong survival from the prior year as yearlings.

It appears that proportionately, YOY and yearling habitat is much more available than habitat for adult sized (>28 cm) fish for the three native species bluehead sucker, flannelmouth sucker and roundtail chub. The habitat analysis should indicate how habitat composition at this site differs from the Colorado and Yampa River where adult fish are common.

Habitat Composition

At the time of this report, quantification of the 16 meso-habitats (Table 3) is still in process for the Lily Park, Sevens and Big Gypsum (Dolores River) sites. The 16 meso-habitats have non-overlapping combinations of depth and velocity and are comprised of five pool, five run, four riffle and two rapids categories. Meso-habitat composition will be used to indicate habitat diversity and composition of each study site. A hypothesis of this study was that habitat availability is strongly associated with species composition and abundance. Therefore, study sites with similar habitats should also have similar fisheries and the more habitat differs the more

fishery characteristics diverge. Because the habitat analysis is not complete for all sites, correlations between fish population parameters and physical habitat have not been performed. But the data that is available strongly indicates that fish occurrence is highly related to meso-habitat availability.

Stewart (2000) completed meso-habitat quantification for two sites, Duffy (Yampa River) and Corn Lake (Colorado River) for his Masters project including methods and 2-D modeling documentation for these results. Meso-habitat composition for Duffy and Corn Lake given in Anderson and Stewart (2000) are presented again in this report. As was found for the fishery characteristics there is also a very large difference in meso-habitat composition between Duffy and Corn Lake. At typical base flows (100-150 cfs) Duffy is dominated by the pool category (Figure 5), while at typical base flows (800 – 1200 cfs) Corn Lake is dominated by riffle habitats (Figure 6). Above 150 cfs the run category becomes dominant at Duffy and runs are about 80% of the total availability at 600 cfs (Figure 5). Run habitat composition increases with increasing flow at Duffy, but declines with increased flow on the Colorado River. At 600 cfs the run category at Corn Lake is the dominant type at about 55% of the total availability, and riffles are dominant at flows over 800 cfs (Figure 6).

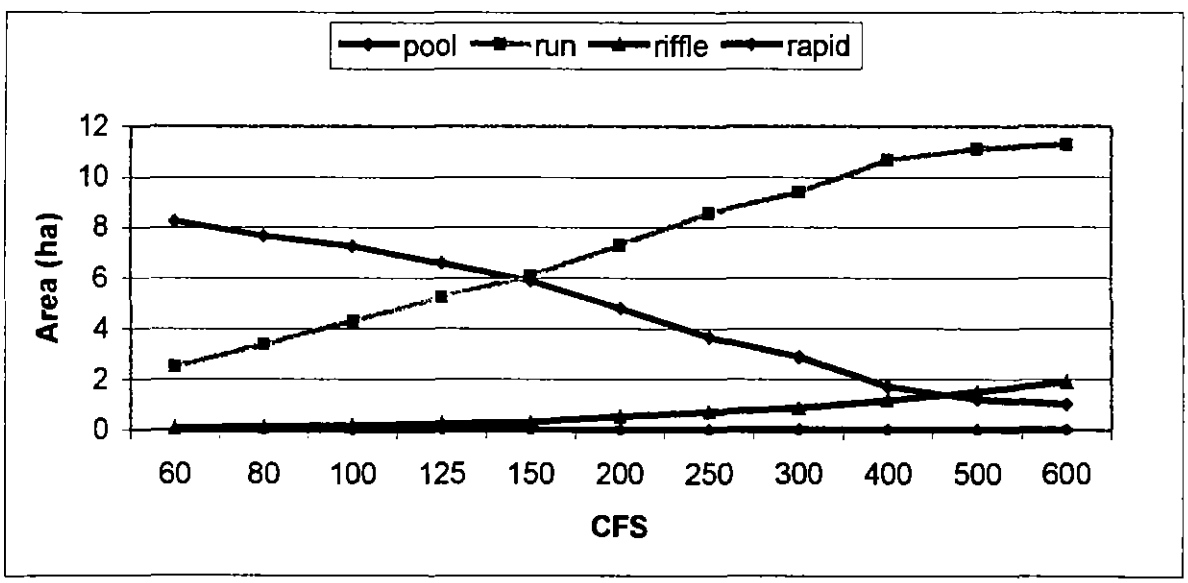


Figure 5. Composition of general habitat categories for the Duffy station on the Yampa River for flows of 60 to 600 cfs.

At Duffy, base flows are generally below 150 cfs and available habitats are those that are less than 0.5 m in depth. The five pool meso-habitats are distinguished by depth. The shoal-pool (depth from 0.2 to 0.5 m) is most common pool at Duffy at all modeled flows 60 to 600 cfs (Figure 9). The shoal-run (depth from 0.2 to 0.5 m) is the most common run at flows below 300 cfs and the shallow-run (0.5 m to 1.0 m) is most common at flows over 400 cfs (Figure 9). At

flows below 150 cfs, riffles are insignificant at Duffy Rifle and increase between 150 and 400 cfs. Deep riffles are virtually absent below 400 cfs (Figure 9).

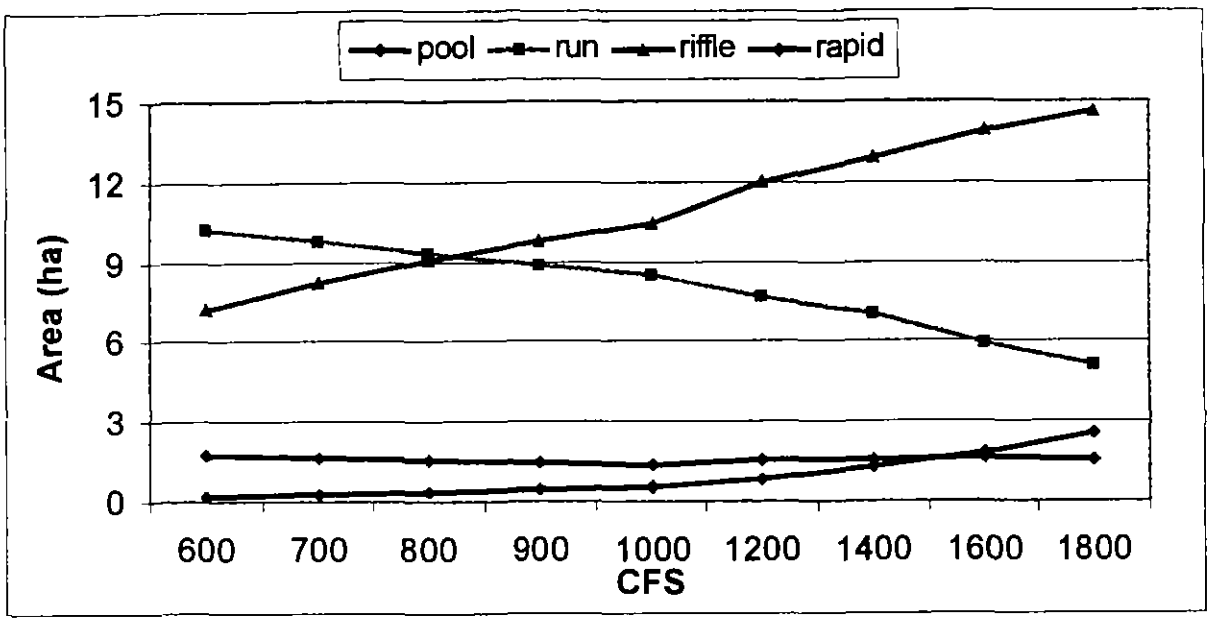


Figure 6. Composition of general habitat categories for the Corn Lake station on the Colorado River for flows of 600 cfs to 1800 cfs.

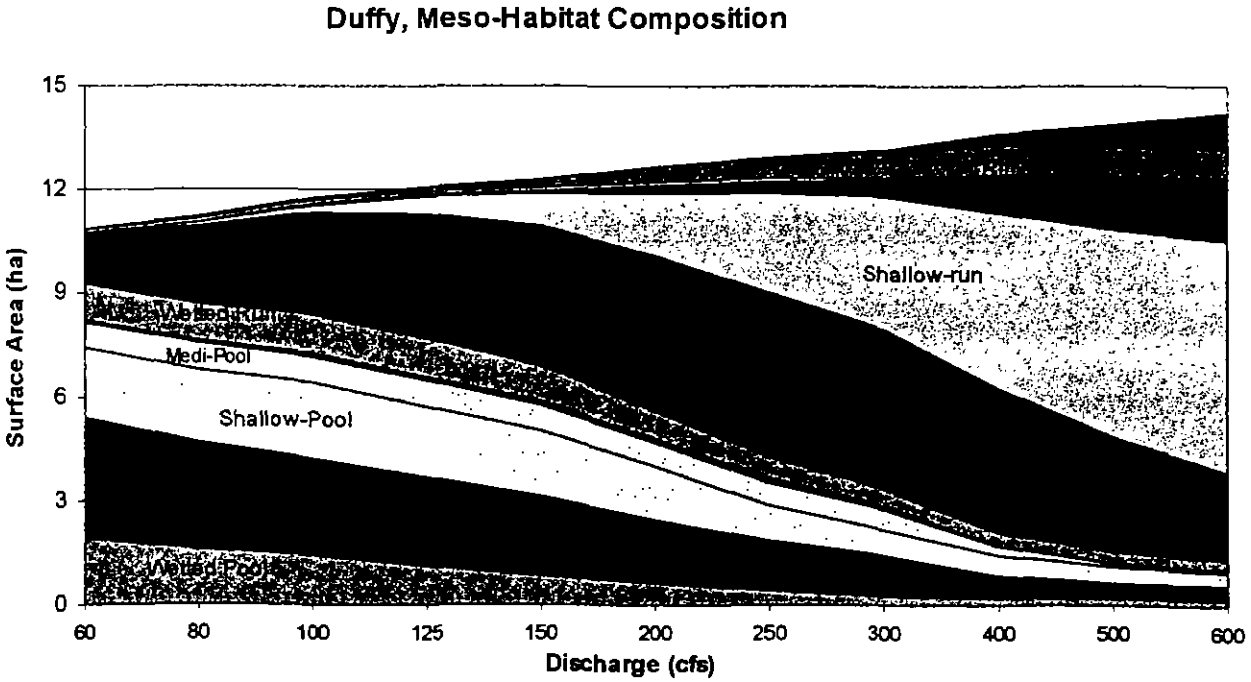
Meso-habitat composition at Corn Lake site is quite unlike Duffy. All pool meso-habitats are scarce at Corn Lake at flows above 600 cfs (Figure 7). At Corn Lake, the medi-run (1 to 2 m) is the most common run habitat at all flows (Figure 7). Riffles are the dominant habitat type at flows over 900 cfs at Corn Lake and deep-riffles and very-deep-riffles are common at flows over 1200 cfs (Figure 7).

The Duffy and Corn Lake sites have distinctly different habitat and fishery densities and compositions. At Duffy, only 4% of the habitat are riffle types at 200 cfs while it is 57% at Corn Lake at 1,400 cfs (Table 18). Total riffle density (ha/km) is 12.5 times greater at Corn Lake than Duffy. In the mapped study site at Duffy, the bluehead and flannelmouth sucker densities are about 10 fish/km and 15 fish/km, respectively (Table A6). In contrast, the habitat at Corn Lake is a run/riffle mixture and bluehead and flannelmouth sucker densities are about 1,200/km and 1,600/km, respectively (Table 15).

There are four meso-habitats in the riffle category. Duffy and Corn Lake have roughly an equivalent amount of shallow-riffle (0.9%), but Duffy has no very-deep-riffle habitat compared to 21% at Corn Lake (Table A8). The habitat type most likely associated with adult bluehead sucker is the deep-riffle and at Duffy there is only 0.001 ha/km (Table A8). The bluehead density in the mapped Duffy site was only 0.10 fish/1000m^2 in 2001 (Table A7). At Corn Lake, deep-riffle is very common at 1.43 ha/km (Table A8) and the bluehead density was 23.1 fish/1000m^2 in 2001 (Table 16).

The meso-habitat type most strongly associated with adult flannelmouth sucker is probably the medi-run. At Duffy, there is only 0.09 ha/km at 200 cfs while at Corn Lake there is 0.80 ha/km at 1,400 cfs (Table A8). At Duffy, the flannelmouth density estimate was 0.24 fish/1000m^2 in 2001 (Table A7) while it was 30.2 fish/1000m^2 at Corn Lake (Table 16). Medi-run availability at Sevens and Lily Park will be more informative than the Duffy site for establishing a habitat relationship for flannelmouth sucker. Sevens and Lily Park do not have a large non-native sucker population and without competition, habitat should more directly influence their abundance.

Riffles are also the primary habitat for most aquatic macroinvertebrates and the very low amount of riffle habitat at Duffy suggests a much lower potential for macroinvertebrate production compared to the Colorado River. Since invertebrate abundance is likely regulated by habitat availability, this would indicate that invertebrate availability, as fish forage is likely to greatly different between the two sites. The very low fish densities observed at Duffy could be an effect of reduced forage potential. This concept should become clearer after habitat data is available for Sevens and Lily Park.



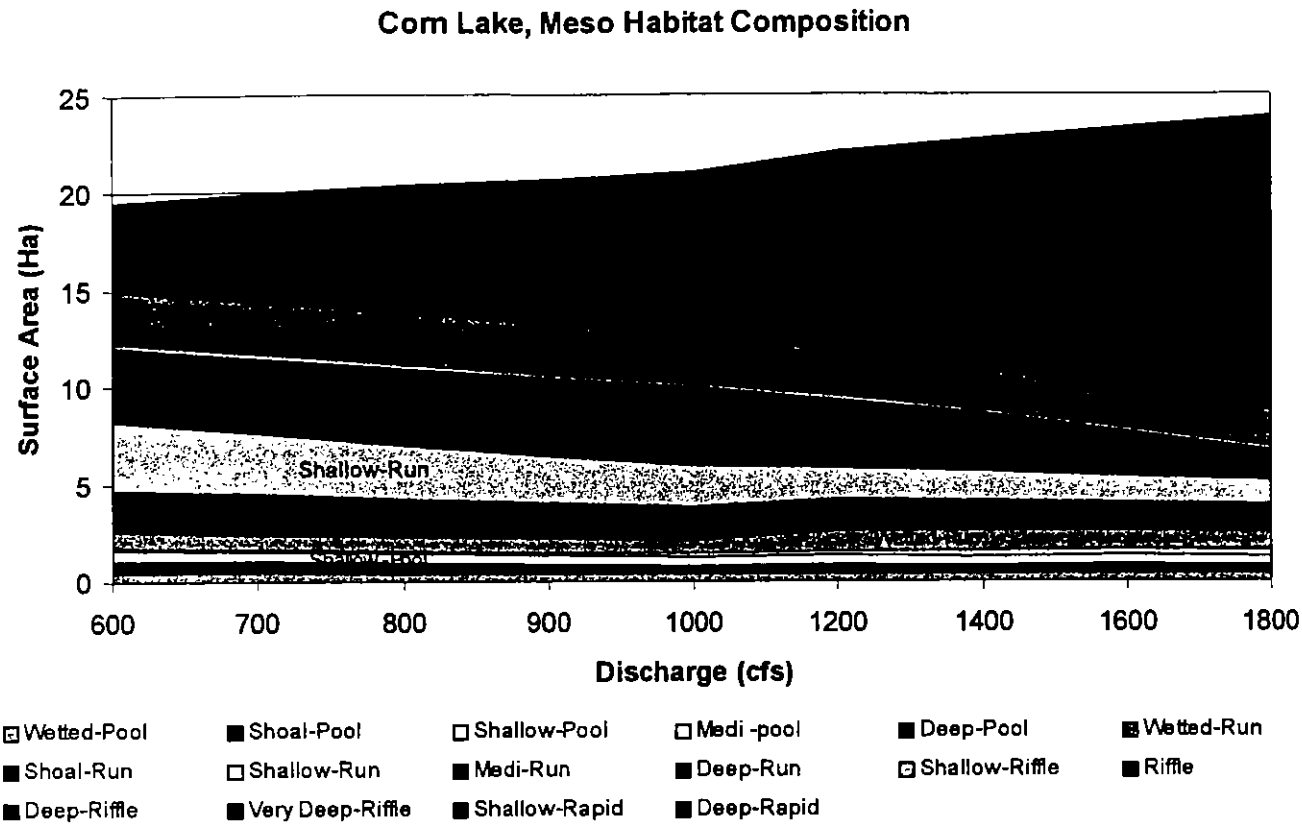


Figure 7. Meso-habitat composition at Duffy (first chart) for flows of 60 cfs to 600 cfs and Corn Lake (back chart) for flows of 600 cfs to 1800 cfs.

Table 18. Habitat composition in area/km and percent for general habitat categories at Duffy and Corn Lake based on 2-D flow modeling.

	CORN LAKE	DUFFY	CORN LAKE	DUFFY
	1400 cfs	200 cfs	1400 cfs	200 cfs
Habitat	Ha/km	Ha/km	Percent	Percent
Pool	0.393	2.14	6.8%	38.1%
Run	1.93	3.24	30.8%	57.6%
Riffle	2.98	0.239	56.6%	4.3%
Rapid	0.213	0.001	5.8%	0.0%
Total area	5.52	5.62		

Maximizing habitat diversity is generally considered beneficial for optimizing habitat availability and is usually a consideration for instream flow recommendations. Stewart (2000)

determined the Shannon Diversity index peaked at 1,200 to 1,400 cfs for the Corn Lake site (Figure 8) and 180 to 200 cfs at Duffy (Figure 9).

It is likely that one of the meso-habitats of the 16 used to represent habitat diversity and composition may not provide the strongest fit for correlations between habitat and fish occurrence. Habitat suitability indices still need to be determined for each native species. However, these data strongly suggest that these species have specific habitat requirements and their abundance between sites is likely correlated to habitat availability.

This data also identifies how habitat availability varies with flow. The meso-habitat composition is found to vary at the same site between years under different flow scenarios. In 2000 and 2001 base flows were between 30 and 80 cfs on the Yampa for most of the summer. At these flows, most of the river at Duffy is composed of wetted- and shoal-pools and riffles virtually disappear (Figure 9). In 2000 and 2001 riffle associated species like speckled dace and mottled sculpin were much rarer than in 1998 and 1999. In 2001, YOY smallmouth bass, which was a shoal-pool or bank- associated fish in prior years, became very common in riffles. The change in availability of the shallow-riffle meso-habitat type between 1998/1999 and 2000/2001 is due to reduced velocities at the lower flows and by definition former riffles become wetted runs. Absence of the riffle meso-habitats, at flow less than 100 cfs, appear to correspond to increased YOY smallmouth bass and decreased speckled dace numbers in 2001.

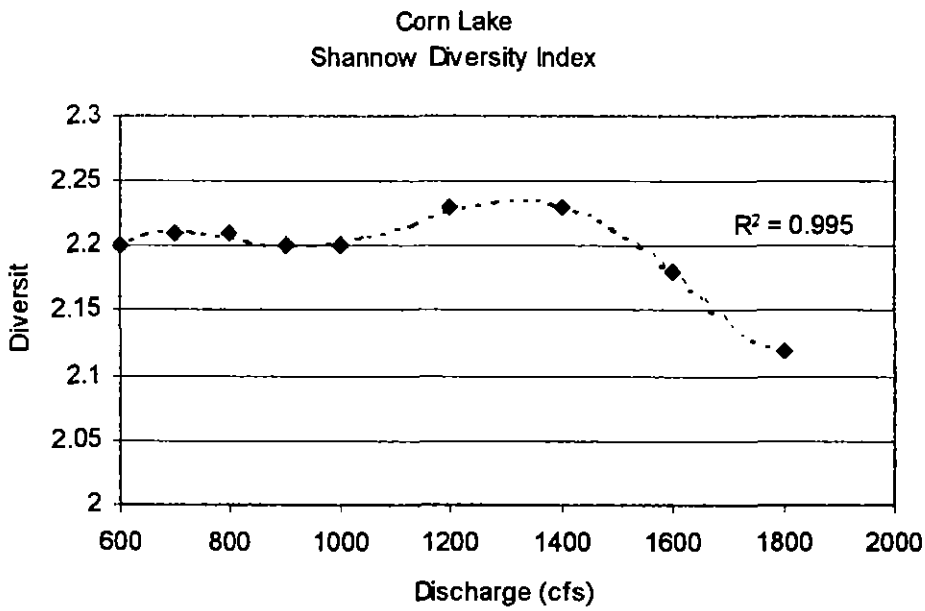


Figure 8. Shannon Diversity index versus flow at the Corn Lake site, Colorado River.

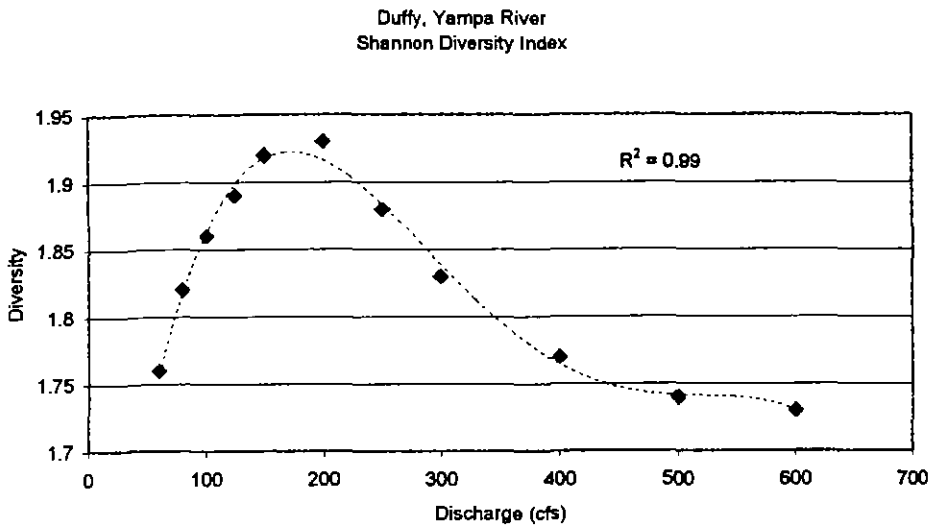


Figure 9. Shannon Diversity indices versus flow at the Duffy site, Yampa River.

Clifton

Some 2-D modeling results for the Clifton study site, under contract with Utah State, have been received at the time of this reporting. Appendix figure A55 shows meso-habitat distribution within the channel at a flow of 1,000 cfs for both sites. The Corn Lake site has more flow confined within a single channel and Clifton has more split flow and a large backwater. Meso-habitat composition at Clifton (USU contract in process) was found to be very similar to Corn Lake (Stewart 2000). Both sites have very similar amounts of the riffle category (Figure10). Clifton has slightly higher availability of the shallow-riffle meso habitats, while Corn Lake has higher availability of deep and very deep-riffles at 1,000 cfs (Figure 10). The largest difference in meso-habitat composition between these two sites is in the deep-pool type. At 1,000 cfs deep-pool habitat is more available at Corn Lake. The shoal- and shallow-run meso-habitats are somewhat more common at Clifton.

Clifton has more islands and bars than Corn Lake (Figure A54) and should have a higher proportion of the shallower meso-habitats types. Also, there is a small diversion dam at Clifton that creates a rather large run and backwater upstream. This large run and backwater were found to be unproductive for native fish during the fish surveys. As part of the analysis, fish distribution will be layered over the habitat distribution maps to help determine a relationship between them.

The Clifton site was modeled to a flow of 200 cfs, showing the relationship between flow and habitat availability for a wider range than was done at Corn Lake. The very-deep-riffle is abundant at flows over 1,000 cfs, remains common down to about 600 cfs and becomes rare at below 450 cfs. The deep-riffle is abundant above 800 cfs and probably not limiting as fish habitat. Deep-riffle drops off quickly below 450 cfs becoming unavailable to fish (bluehead sucker) associated this habitat. Run and pool types are fairly even between flows from 200 to

1,000 cfs and decrease in availability above 1,200 cfs. At flows over 1,800 cfs pools and runs are reduced and fish that are pool-obligates probably become restricted to shoreline areas. At ≥ 1,200 cfs, habitats with faster currents are well maintained and probably not limiting for fish, but appear to become much less available for native fish at flows less than 600 cfs.

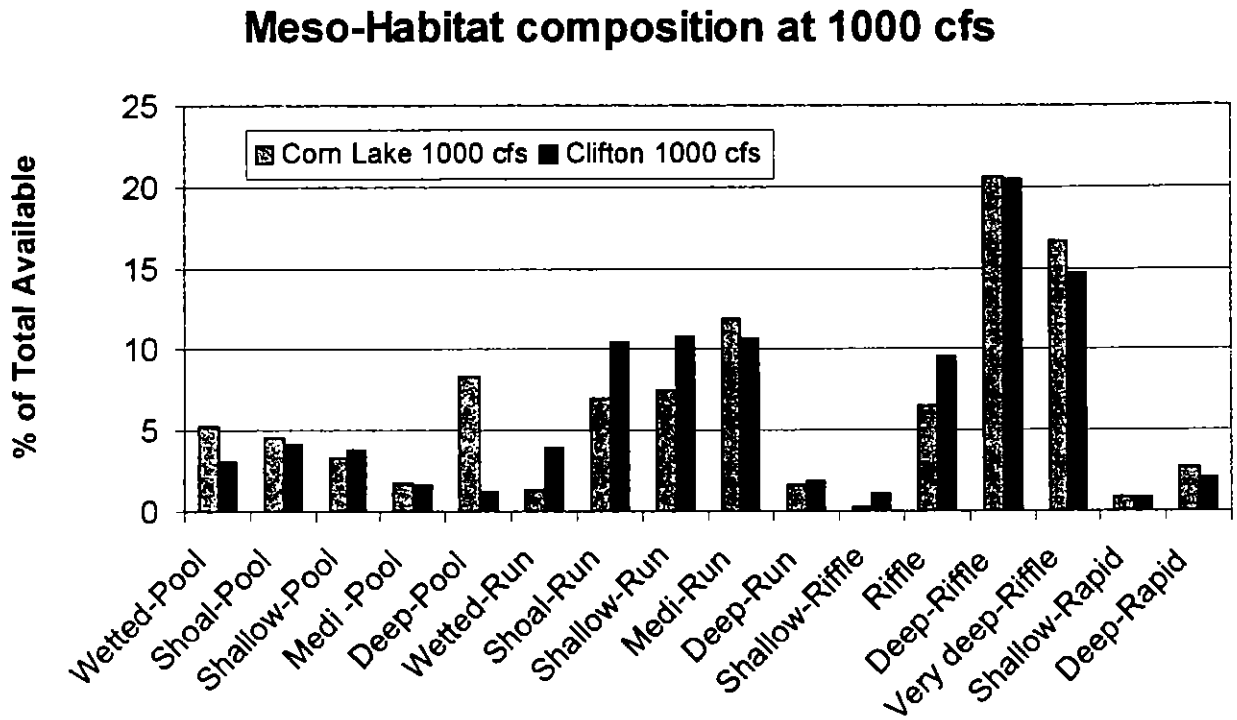


Figure 10. Meso-habitat composition for the two 15-Mile Reach stations (Corn Lake and Clifton) at a flow of 1,000 cfs.

The Corn Lake and the Clifton sites have nearly identical fish and habitat composition, which is expected since they are nearly contiguous. This greatly improves confidence that these sites are representative of both habitat availability and the fish community in the 15-Mile Reach and that native suckers (flannelmouth and bluehead) are strongly associated with higher velocity and deeper habitats.

The contract for 2-D modeling will end by June 30, 2002. Upon receipt of the flow simulations spatial analysis will begin to determine specific habitat needs of native fish. Habitat suitability, based on depth and velocity criteria, will be determined over a range of flows and used to make the instream flow recommendations in the Completion Report.

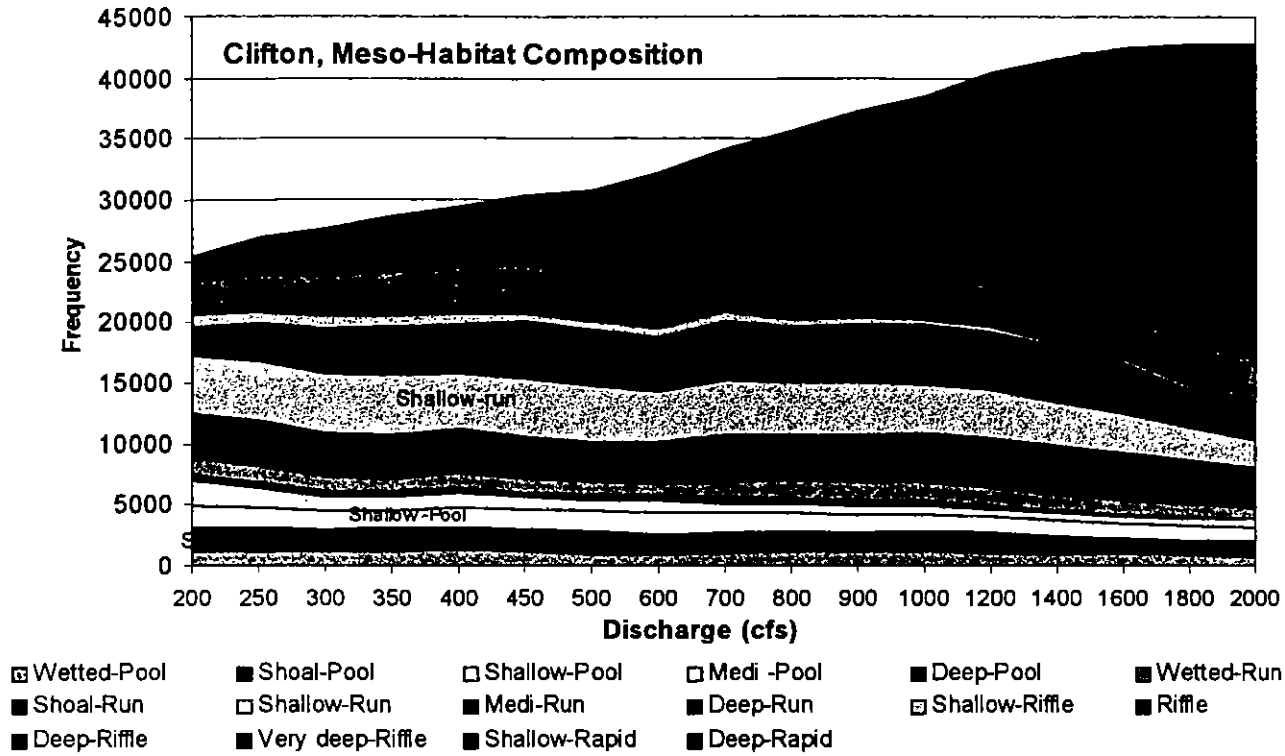


Figure 11. Meso-habitat composition for the Clifton site (15-Mile Reach) for flows from 200 to 2000 cfs.

Radio Telemetry

A pilot study was conducted to describe habitat use of roundtail chub, flannelmouth sucker and bluehead sucker during fall low-flow conditions in the Colorado River at the Corn Lake site (Anderson and Stewart 2001). The 2000 project was performed under contract with the Larval Fish Laboratory at Colorado State University. Four roundtail chub, five flannelmouth suckers and five bluehead suckers ranging from 306 to 562 mm total length were surgically implanted with internal radio transmitters. Fish were telemetered during day and night so that diel patterns could be described. This investigation showed that during the fall low-flow period, bluehead sucker, flannelmouth sucker, and roundtail chub made localized movements and were typically found near the location of their original capture (Byers et al. 2001).

A telemetry study of similar effort was conducted in the summer of 2001 under contract with Miller Ecological of Fort Collins. Data collected in 2001 was received, but has not been analyzed in regard to habitat suitability. Data from both telemetry efforts will be used to determine if and how the habitat categories used in this habitat analysis should be modified to more accurately represent habitat used by these three native species. Discussion of the telemetry work will be given in the final report.

SUMMARY

Electrofishing results in 2001 for species composition and size structure of fish over 15 cm were similar and consistent with earlier years except for the Duffy stations on the Yampa River. Much attention was given to the large increase in smallmouth bass composition at Duffy in 2001. Reduction in total fish density from earlier years (1998 and 1999) on the Yampa River were explained by suggesting a reduced carrying capacity due to very low summer flows. Density estimates were higher in 2001 at the Corn Lake and Clifton stations on the Colorado River than in 2000. It was suggested that fish abundance estimates in 2000 were biased low that year.

Lily Park on the Yampa River was sampled only in 2000 and 2001. Fishery characteristics were somewhat different between years and grossly different from Sevens and Duffy stations. The observed differences in species composition, density, and sizes between Yampa sites appear to be a function of differences in meso-habitat availability (gradient, substrate particle size, riffle/run ratios) rather than differences in predatory pressure, temperature or water quality. The between years differences appears to be related to lower flows in 2000 and 2001. Flannelmouth sucker density at Lily Park was very similar to the Colorado River, and it is excepted that medi-run habitat composition will also be similar.

Large differences were observed between the Yampa and Colorado River fisheries. The Colorado River has a different species composition, size structure and much higher total fish and native fish densities. Large predator fish were rare in the 15-Mile Reach and all size and age groups were present. In contrast, predator fish are common in the Yampa and obviously impacts that community. In general on the Yampa, there is a lack of fish under 30 cm, and higher mean lengths for virtually all species at Duffy and Sevens.

Habitat analysis completed on the Duffy and Corn Lake sites found very large differences in habitat composition between these two stations. Stream width and therefore total wetted area (habitat potential) at most flows of interest were higher at Duffy than at Corn Lake. Habitat diversity peaked at 1,200 cfs at Corn Lake and 180 cfs at Duffy. Most of the differences in species composition and density appear explainable by differences in habitat availability, and predation on the Yampa River impacted size structure.

Riffle habitat is rare at Duffy but abundant at Corn Lake and suggests a direct relationship between riffle habitat availability and bluehead sucker density at these sites. Also the difference in riffle habitat availability between the two sites suggests macroinvertebrate production would also be much different. It was suggested that the abundant and stable riffle habitat at Corn Lake provides abundant macroinvertebrate forage which likely explains higher fish densities in the 15-Mile Reach compared to Duffy.

Shallower low velocity pool habitats are very common at Duffy and rare at Corn Lake at flows common in the base flow period. This is reflected in the fish community at these two sites. Duffy is primarily composed of non-native species that prefer pools habitats like white suckers and smallmouth bass and these fish are very rare at Corn Lake. Roundtail chub are rare at Duffy in spite of pool habitat availability, but chub are probably near carrying capacity at Corn Lake

and Clifton. Run habitats increase with increasing flows at Duffy, but runs decrease as flow increases at Corn Lake. Flannelmouth sucker is a native species associated with deeper runs and are rare at Duffy but numerous at Corn Lake. We believe that future habitat analysis will confirm that run habitats are much more common at the Lily Park site compared to the other two Yampa sites.

The low flows observed in 2000 and 2001 provide empirical data in regard to justifying instream flow recommendations. 2001 was the last year fish sampling will be conducted for this project. The next step is to determine a relationship between fish density and habitat availability and use it to model habitat over a range of flows. Habitat suitability indices will be based on density data obtained during the study period.

CONCLUSIONS and/or RECOMMENDATIONS

- Large differences were found in habitat and species composition between Duffy on the Yampa River and Corn Lake in the 15-Mile reach of the Colorado River.

- It is believed that the fishery is near the physical habitat carrying capacity in the 15-Mile Reach and in the Dolores River, but predation is impacting density on the Yampa River.

- Large differences were found in species composition at Duffy between 2001 and the three prior years. It was concluded that low flows of 2000 and 2001 facilitated the large increase in smallmouth bass observed in 2001. It would be interesting to monitor the three Yampa River sites for the next few years and it was recommended that management take that responsibility at the end of this project.

- The 2-D flow modeling clearly produces excellent habitat mapping results and is absolutely necessary for this project to develop biologically justified instream flow recommendations for the Yampa and Colorado Rivers.

- A contract to continue 2-D modeling was not approved in 2000 resulting in a one-year delay in making instream flow recommendations for the Colorado River and the Yampa.

- A new contract was finalized in November 2001. 2-D modeling results are due by June 30, 2002.

- Spatial analysis will be conducted in the 2002/2003 fiscal year. Habitat suitability indices will be determined for native species and used to model habitat availability versus flow. The strength of the correlations between habitat and density will be used as biological justifications for the flow recommendations.

- Ironically, at the time of this reporting (May 2002), the state is experiencing a very poor snow pack and runoff and stream flow conditions are forecast to be near record lows. Since this is an instream flow study, it was be highly appropriate to sample fish during severe drought conditions. However the opportunity to sample fish this fiscal year is limited and

flow recommendations will not be postponed. Efforts will be made to see if sampling can be accomplished on the Yampa and the Colorado Rivers in the fall of 2002.

- Radio telemetry work will be processed during 2002/03. The telemetry work completed so far provides valuable data on habitat use and movement of bluehead sucker, flannelmouth sucker and roundtail chub.

- It is recommended that the principle investigator become trained in hydrology principles and computer processing aspects of 2-D modeling. Most of the delays and unexpected hassles have been related to administering contracts. The trade off is that fish sampling fieldwork will have to be sacrificed in order for the researcher to become proficient and perform the 2-D work himself.

- It is recommended that a large block of time be allotted in 2002/03 for consultation with DOW and CWCB senior staff to determine if and when 2-D modeling should be applied in fish management and future flow studies. If there is large demand for this approach then this project should add a training component to it objectives.

ACKNOWLEDGEMENTS

In 1998 and 1999, the hydraulic modeling was contracted with Colorado State University, the Department of Earth Resources. The contract was administered and supervised by Dr. Ellen Wohl, and Greg Stewart performed the work for his M.S. project. Greg supervised the habitat quantification portion in the field and performed the hydraulic modeling for Duffy and Corn Lake. I greatly appreciated the enthusiasm and energy Greg put into this study and the long hours he spent setting up the technical equipment and calibrating the SMS model. Greg graduated in the fall of 2000 and is now enrolled at Oregon State University. The 2-D modeling for Clifton, Lily Park, Sevens and Dolores was done in 2002 by contact administered by Craig Addley, Dept. Civil & Environmental Engineering, Utah Water Research Laboratory, at Utah State University. It was a great pleasure to work with Mr. Addley and I learned much about the modeling process from him and his associates. District Wildlife Managers, Brad Petch and Chuck Woodward were very helpful and provided valuable assistance and information concerning landowners and logistics on the Yampa River. I am very grateful to Tom Deacons who allowed us access to the river on his property in the Duffy area. Also, I thank the Cross Mountain Ranch and Phil George for allowing access to the Sevens Ranch and Lily Park for habitat surveying and the other property owners on the river that granted access for electrofishing. On the 15-Mile reach, the main property owner was the BOR and the property managers at the CDOW are Steve Yamashita and Lyle Sidener and also Charlie Shannon who graciously worked with us for radio-tracking fish on the property. The Clifton Water District (Dave Reinertsen and Dale Tooker) made access to the Clifton site on the Colorado River possible. Dr. Dan Byers, Cris Sodergren, Jay Bundy and Kevin Bestgen of the Larval Fish Laboratory at CSU did an excellent job with the radio telemetry work in 2000. A copy of their report is available upon request. David Rees of Miller Ecological in Fort Collins performed radio telemetry work in 2001 with DOW seasonal employees. Dave Harper, the DWM in Dove Creek was helpful setting up the study site on the Dolores River. Dr. David C. Bowden, professor of statistics at CSU reviewed the methods and the section for population estimates and

tests for significance. Lastly, I want to thank all the seasonal and temporary employees for their hard work in doing fieldwork and data entry for this project.

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APPENDIX

Tables and Figures

Table A1. Species composition for **fish larger than (>) 15 cm** at the **Sevens & Duffy** stations in 1998, 1999, 2000 and 2001, Yampa River.

	SEVENS	SEVENS	SEVENS	SEVENS
Species	**1998**	**1999**	**2000**	**2001**
Flannelmouth Sucker	47.0%	45.8%	49.8%	53.1%
Bluehead Sucker	21.0%	18.0%	22.2%	13.2%
Roundtail Chub	5.7%	3.8%	3.8%	3.4%
Colo. Pikeminnow	0.2%	0.2%	0.2%	0%
White sucker	9.8%	10.0%	10.6%	10.2%
White X Flannelmouth	2.9%	4.4%	6.0%	5.0%
White X Bluehead	0.3%	0.19%	0.4%	0.4%
Channel Catfish	6.4%	7.2%	1.9%	15.6%
Carp	3.9%	4.8%	3.8%	5.2%
Smallmouth Bass	1.0%	2.5%	0.5%	4.1%
Northern Pike	1.5%	1.8%	0.2%	5.0%
White Crappie	0.4%	1.3%	0.1%	0.3%
White S. + Crosses	13.0%	14.6%	17.0%	15.6%
Sample size	1516	1040	810	676
Recaptures	260	113	93	
	DUFFY	**DUFFY**	**DUFFY**	**DUFFY**
Species	**1998**	**1999**	**2000**	**2001**
Flannelmouth Sucker	5.3%	5.1%	5.0%	2.0%
Bluehead Sucker	4.4%	5.6%	3.5%	4.4%
Roundtail Chub	3.3%	2.9%	3.6%	3.1%
Colo. Pikeminnow	1.5%	0.6%	0.8%	0.6%
White sucker	34.9%	33.4%	23.0%	17.9%
White X Flannelmouth	28.1%	32.8%	40.5%	26.9%
White X Bluehead	6.0%	5.9%	9.0%	4.7%
Channel Catfish	3.0%	4.0%	3.2%	4.4%
Carp	2.7%	1.1%	0.8%	2.2%
Smallmouth Bass	8.2%	6.3%	9.6%	32.4%
Northern Pike	2.8%	2.3%	0.9%	1.0%
White Crappie	0.1%	0.1%	0.0%	0%
White S. + Crosses	68.9%	72.0%	72.5%	49.5%
Sample size	1654	2092	1294	859
Recaptures	270	440	250	81

Table A2. Species composition for **fish less than (<) 15 cm** at the **Sevens & Duffy** stations in 1998, 1999, 2000 and 2001, Yampa River.

Species	1998 <15cm	1999 <15cm	2000 <15cm	2001 <15cm
	SEVENS	**SEVENS**	**SEVENS**	**SEVENS**
Flannelmouth Sucker	0.6%		0.22%	
Bluehead Sucker	0.0%			
Roundtail Chub	6.5%			
White S. + Crosses	6.2%	18.4%	25.9%	6.0%
Carp	0.0%			
Smallmouth Bass	0.3%	26.3%	14.3%	58.3%
White Crappie	0	6.6%		
Mottled Sculpin	5.0%			
Speckled Dace	37.5%	13.2%	2.4%	2.0%
Sand Shiner	42.1%	35.5%	56.9%	33.8%
Fathead Minnow	0.3%		0.22%	
Redside shiner				
Brook Stickleback				
Mountain Whitefish				
Red Shiner	1.5%			
Native	50%	13%	3%	
Non-native	50%	87%	97%	
Sample size	323	76	455	151
	1998	**1999**	**2000**	**2001**
	DUFFY	**DUFFY**	**DUFFY**	**DUFFY**
Flannelmouth Sucker	0.07%	0.11%		
Bluehead Sucker		0.06%		.08%
Roundtail Chub	0.07%	2.4%		
White S. + Crosses	9.8%	18.4%	5.8%	0.8%
Carp	0.3%		0.6%	0.3%
Smallmouth Bass	45.4%	42.1%	83.5%	98%
White Crappie	0.2%			
Mottled Sculpin	18.7%	26.5%	4.7%	0.7%
Speckled Dace	11.0%	8.1%	1.2%	0.2%
Sand Shiner	14.0%	2.4%	1.3%	0.2%
Fathead Minnow	0.13%			
Redside shiner	0.13%			
Brook Stickleback	0.07%			0.03%
Mountain Whitefish	0.07%			
Creek Chub			2.7%	0.03%
Green Sunfish			0.3%	
Native	30%	37%	6%	1%
Non-native	70%	63%	94%	99%
Sample size	1483	1763	937	3,854

Table A3. Species composition for **fish larger than (>) and less than (<) 15 cm** at the Lily Park station in 2000 and 2001, Yampa River.

	Lily Park	Lily Park	Lily Park	Lily Park
Species	2000 >15	2001 >15	2000 <15	2001<15
Flannelmouth Sucker	47.8%	67.7%		
Bluehead Sucker	8.5%	7.1%	1.7%	
Roundtail Chub	0.02%	0.03%		
Colo. Pikeminnow	0.07%	0.03%		
White S. + Crosses	0.3%	0.2%	0.6%	1.2%
Channel Catfish	40.2%	17.7%		
Carp	2.1%	2.1%	0.6%	
Smallmouth Bass	0.8%	5.1%	79.95	79.9%
Northern Pike	0.2%	0.2%		
Mottled sculpin			10.3%	3.7%
Speckled Dace			1.7%	
Sand Shiners			5.2%	15.2%
Sample size	4,058	2,991	174	164

Table A4. Species composition for **fish larger than (>) 15 cm** in the 15-MILE Reach at the **Corn Lake** and **Clifton** stations, Colorado River.

	Corn Lake	Corn Lake	Corn Lake	Clifton	Clifton	Clifton
Species	1999	2000	2001	1999*	2000	2001
Fm Sucker	38.4%	31.1%	39.5%	32.8%	32.5%	42.0%
B Sucker	34.5%	36.3%	38.1%	22.6%	40.5%	26.8%
Rtc	3.1%	4.3%	2.9%	7.2%	5.1%	5.9%
C Pikeminnow	0.1%	0.04%	0.03%	0.5%	0.03%	0.09%
back Sucker	0.2%	0.3%	0.06%			0.04%
White sucker	3.7%	2.9%	5.1%	3.8%	1.7%	3.3%
White Xfm	1.2%	1.6%	0.5%		0.6%	0.7%
White Xbh	0.7%	0.8%	0.6%	1.2%	1.4%	0.09%
Catfish	4.2%	6.3%	4.7%	14.2%	5.1%	5.7%
Carp	11.3%	14.1%	6.1%	15.9%	11.7%	13.8%
Sm Bass	0.1%			0.5%		
Louth bass	0.7%	1.1%	0.4%	0.2%	1.1%	0.8%
Green Sunfish	0.1%	0.4%	0.3%	0.2%	0.1%	0.3%
Brown trout	0.4%	0.1%	1.4%	0.5%	0.1%	0.2%
Rainbow trout	0.03%	0.04%				0.04%
Bullhead	1.3%	0.6%		0.5%	0.2%	0.4%
Sample size	3499	2784	3463	575	3276	4485
Recaptures	248	212		0	246	
Native			80.7%	74.8%		

*1999. Only two passes were made in 1999 (Anderson and Stewart 2000).

Table A5. Species composition for **fish less than (<15 cm)** in the 15-MILE Reach at the **Corn Lake** and **Clifton** stations, Colorado River.

	Corn Lake	Corn Lake	Corn Lake	Clifton	Clifton	Clifton
Species	1999	2000	2001	1999*	2000	2001
FM Sucker	10.6%	6.4%	2.4%	14.3%	7.1%	3.4%
BH Sucker	0.9%	1.6%	1.9%		6.9%	1.8%
RT Chub	41.0%	2.6%	5.5%	10.7%	4.2%	12.3%
RZ Sucker		4.7%	0.1%			0.0%
Speckled Dace	5.2%	22.4%	33.4%	57.1%	43.7%	47.2%
M. Sculpin	0.9%	0.6%	0.8%		1.4%	1.8%
White sucker	8.5%	5.5%	8.9%		2.7%	2.6%
Carp	6.6%	3.6%	13.1%	7.1%	6.9%	6.9%
SM Bass		0.9%	0.1%		0.4%	0.4%
LM bass	10.6%	13.0%	5.4%		12.0%	6.1%
Green Sunfish	13.7%	36.2%	26.6%	7.1%	13.3%	16.9%
Bluegill	0.2%	0.6%			0.3%	
C. Catfish			0.1%			
B. Bullhead	1.4%	0.7%	1.6%			0.3%
Brown trout	0.2%	0.1%	0.0%		0.1%	0.0%
Rainbow trout			0.2%			0.0%
M whitefish		0.1%			0.4%	
Red Shiner	X^	X^	X^	X^	X^	X^
Sand Shiner	X^	X^	X^	X^	X^	X^
Fathead M.	X^	X^	X^	X^	X^	X^
Mosquitofish		1.1%		3.6%	0.4%	0.3%
Sample size	424	1017	1630	28	693	1481

*1999. Only two passes were made in 1999 (Anderson and Stewart 2000).

Table A6. Density estimates (fish/km) for fish collected in the **mapped study Duffy Site** (1.6 km) for the four years 1998, 1999, 2000 and 2001. Significant differences (0.05) between years are indicated by the letter a,b,c and d following the estimate.

	1998-a	**1999-b**	**2000-c**	**2001-d**
	Fish/km	fish/km	fish/km	fish/km
Total fish	648bd	512cd	697bd	1068abc
White sucker & hybrids	405	343c	430b	370
Flannelmouth sucker	19	8	14	13
Bluehead sucker	31	14	17	5
Roundtail chub	24	10	11	5
Colorado pikeminnow	17	7	9	5
Smallmouth bass	177d	76d	167d	595abc
Northern pike	48	20	6	22
Carp	9	1	0	2
Channel catfish	9	30	99	38

Table A7. Density estimates (fish/1000 m^2) for fish collected in the **mapped study Duffy Site** (1.6 km) for the four years 1998, 1999, 2000 and 2001. Mean stream width of 53 m.

	1998-a	**1999-b**	**2000-c**	**2001-d**
	Fish/km	fish/km	fish/km	fish/km
Total fish	12.2	9.7	13.1	20.1
White sucker & hybrids	7.6	6.5	8.1	7.0
Flannelmouth sucker	0.36	0.15	0.26	0.24
Bluehead sucker	0.59	0.27	0.33	0.10
Roundtail chub	0.45	0.19	0.20	0.10
Colorado pikeminnow	0.32	0.14	0.16	0.10
Smallmouth bass	3.3	1.4	3.2	11.2
Northern pike	0.91	0.38	0.07	0.41
Carp	0.18	0.03	0.00	0.04
Channel catfish	0.18	0.57	1.86	0.72

Table A8. Habitat composition by area and percent for the 16 habitat types at a flow of 600 cfs for both site and at a flow of 200 cfs on the Yampa and 1400 cfs on the Colorado River.

Habitat Types	Depth	Velocity	**Corn Lake**	**Duffy**	**Corn Lake**	**Duffy**
	(m)	(m/s)	**600 cfs**	**600 cfs**	**600 cfs**	**600 cfs**
			ha/km	ha/km	Percent	Percent
Wetted Sand	0.01 - 0.2	< 0.15	0.115	0.078	2.4%	1.2%
Shoal	0.2 - 0.5	< 0.15	0.155	0.178	3.2%	2.8%
Shallow pool	0.5 - 1.0	< 0.15	0.128	0.172	2.6%	2.7%
Medi -pool	1.0 - 2.0	< 0.15	0.029	0.025	0.6%	0.4%
Deep pool	> 2.0	< 0.15	0.001	0.000	0.0%	0.0%
Wetted area	.01 - 0.2	0.15 - 0.6	0.205	0.149	4.2%	2.4%
Shoal-run	0.2 - 0.5	0.15 - 0.6	0.541	1.115	11.1%	17.7%
Shallow run	0.5 to 1.0	0.15 - 0.6	0.880	2.953	18.1%	46.8%
Medi-run	1.0 to 2.0	0.15 - 0.6	0.913	0.698	18.8%	11.1%
Deep run	> 2.0	0.15 - 0.6	0.032	0.096	0.6%	1.5%
Shallow riffle	< 0.2	0.6 - 1.5	0.079	0.019	1.6%	0.3%
Riffle	0.2 to 0.5	0.6 - 1.5	0.671	0.376	13.8%	5.9%
Deep riffle	0.5 to 1.0	0.6 - 1.5	0.844	0.423	17.4%	6.7%
Very deep riffle	> 1.0	0.6 - 1.5	0.207	0.022	4.3%	0.3%
Shallow rapid	< 0.5	> 1.5	0.041	0.008	0.8%	0.1%
Deep rapid	> 0.5	> 1.5	0.015	0.000	0.3%	0.0%
Total			4.855	6.312	100%	100%
Mean stream width			48.6 m	63.1 m		
Habitat Types	Depth	Velocity	**Corn Lake**	**Duffy**	**Corn Lake**	**Duffy**
	(m)	(m/s)	**1400 cfs**	**200 cfs**	**1400 cfs**	**200 cfs**
			ha/km	ha/km	Percent	Percent
Wetted Sand	0.01 - 0.2	< 0.15	0.100	0.279	1.6%	5.0%
Shoal	0.2 - 0.5	< 0.15	0.113	0.805	1.9%	14.3%
Shallow pool	0.5 - 1.0	< 0.15	0.125	0.703	2.2%	12.5%
Medi -pool	1.0 - 2.0	< 0.15	0.053	0.299	1.1%	5.3%
Deep pool	> 2.0	< 0.15	0.002	0.055	0.1%	1.0%
Wetted area	.01 - 0.2	0.15 - 0.6	0.257	0.353	4.5%	6.3%
Shoal-run	0.2 - 0.5	0.15 - 0.6	0.392	1.992	6.7%	35.5%
Shallow run	0.5 to 1.0	0.15 - 0.6	0.417	0.799	6.6%	14.2%
Medi-run	1.0 to 2.0	0.15 - 0.6	0.779	0.093	11.4%	1.7%
Deep run	> 2.0	0.15 - 0.6	0.086	0.000	1.6%	0.0%
Shallow riffle	< 0.2	0.6 - 1.5	0.056	0.052	0.9%	0.9%
Riffle	0.2 to 0.5	0.6 - 1.5	0.590	0.185	9.5%	3.3%
Deep riffle	0.5 to 1.0	0.6 - 1.5	1.426	0.001	24.9%	0.0%
Very deep riffle	> 1.0	0.6 - 1.5	0.912	0.000	21.3%	0.0%
Shallow rapid	< 0.5	> 1.5	0.059	0.001	1.1%	0.0%
Deep rapid	> 0.5	> 1.5	0.154	0.000	4.7%	0.0%
Total			5.521	5.618	100%	100%
Mean stream width			55.2 m	56.2 m		

Table A.9. Length Frequency Histograms for fish collected in 2001 as Appendix Figures A1 to A53.

A1. Bluehead Sucker length frequency at the Sevens site, August 2001 Yampa River.
A2. Bluehead Sucker length frequency at the Duffy site, August 2001 Yampa River.
A3. Bluehead Sucker length frequency at the Lily Park site, August 2001 Yampa River.
A4. Bluehead Sucker length frequency at the Big Gypsum site, July 2001 Dolores River.
A5. Bluehead Sucker length frequency at the Corn Lake site, September 2001 Colorado River.
A6. Bluehead Sucker length frequency at the Clifton site, September 2001 Colorado River.
A7. Flannelmouth Sucker length frequency at the Sevens site, August 2001 Yampa River.
A8. Flannelmouth Sucker length frequency at the Duffy site, August 2001 Yampa River.
A9. Flannelmouth Sucker length frequency at the Lily Park site, August 2001 Yampa River.
A10. Flannelmouth Sucker length frequency at the Big Gypsum site, July 2001 Dolores River.
A11. Flannelmouth Sucker length frequency at the Corn Lake site, September 2001 Colorado River.
A12. Flannelmouth Sucker length frequency at the Clifton site, September 2001 Colorado River.
A13. Roundtail Chub length frequency at the Sevens site, August 2001 Yampa River.
A14. Roundtail Chub length frequency at the Duffy site, August 2001 Yampa River.
A15. Roundtail Chub length frequency at the Lily Park site, August 2001 Yampa River.
A16. Roundtail Chub length frequency at the Big Gypsum site, July 2001 Dolores River.
A17. Roundtail Chub length frequency at the Corn Lake site, September 2001 Colorado River.
A18. Roundtail Chub length frequency at the Clifton site, September 2001 Colorado River.
A19. White Sucker length frequency at the Sevens site, August 2001 Yampa River.
A20. White Sucker length frequency at the Duffy site, August 2001 Yampa River.
A21. White Sucker length frequency at the Corn Lake site, September 2001 Colorado River.
A22. White Sucker length frequency at the Clifton site, September 2001 Colorado River.
A23. White-Flannelmouth Cross length frequency at the Sevens site, August 2001 Yampa River.
A24. White-Flannelmouth Cross length frequency at the Duffy site, August 2001 Yampa River.
A25. White-Flannelmouth Cross length frequency at the Corn Lake site, September 2001 Colorado River.
A26. White-Flannelmouth Cross length frequency at the Clifton site, September 2001 Colorado River.
A27. White-Bluehead Cross length frequency at the Sevens site, August 2001 Yampa River.
A28. White-Bluehead Cross length frequency at the Duffy site, August 2001 Yampa River.
A29. White-Bluehead Cross length frequency at the Corn Lake site, September 2001 Colorado River.
A30. White-Bluehead Cross length frequency at the Clifton site, September 2001 Colorado River.
A31. Carp length frequency at the Sevens site, August 2001 Yampa River.
A32. Carp length frequency at the Duffy site, August 2001 Yampa River.
A33. Carp length frequency at the Lily Park site, August 2001 Yampa River.
A34. Carp length frequency at the Big Gypsum site, July 2001 Dolores River.
A35. Carp length frequency at the Corn Lake site, September 2001 Colorado River.
A36. Carp length frequency at the Clifton site, September 2001 Colorado River.
A37. Channel Catfish length frequency at the Sevens site, August 2001 Yampa River.
A38. Channel Catfish length frequency at the Duffy site, August 2001 Yampa River.
A39. Channel Catfish length frequency at the Lily Park site, August 2001 Yampa River.
A40. Channel Catfish length frequency at the Big Gypsum site, July 2001 Dolores River.
A41. Channel Catfish length frequency at the Corn Lake site, September 2001 Colorado River.
A42. Channel Catfish length frequency at the Clifton site, September 2001 Colorado River.
A43. Largemouth Bass length frequency at the Corn Lake site, September 2001 Colorado River
A44. Largemouth Bass length frequency at the Clifton site, September 2001 Colorado River.
A45. Smallmouth Bass length frequency at the Sevens site, August 2001 Yampa River.
A46. Smallmouth Bass length frequency at the Duffy site, August 2001 Yampa River.
A47. Smallmouth Bass length frequency at the Lily Park, August 2001 Yampa River.
A48. Northern Pike length frequency at the Sevens site, August 2001 Yampa River.
A49. Northern Pike length frequency at the Duffy site, August 2001 Yampa River.
A50. Bluehead Sucker length frequency at the Sevens site, September 2000 Yampa River.
A51. Flannelmouth Sucker length frequency at the Sevens site, September 2000 Yampa River.
A52. Channel Catfish length frequency at the Lily Park site, September 2000 Yampa River.
A53. Smallmouth Bass length frequency at the Lily Park, September 2000 Yampa River.
A54 Carp length frequency at the Corn lake site, September 1999, Colorado River.

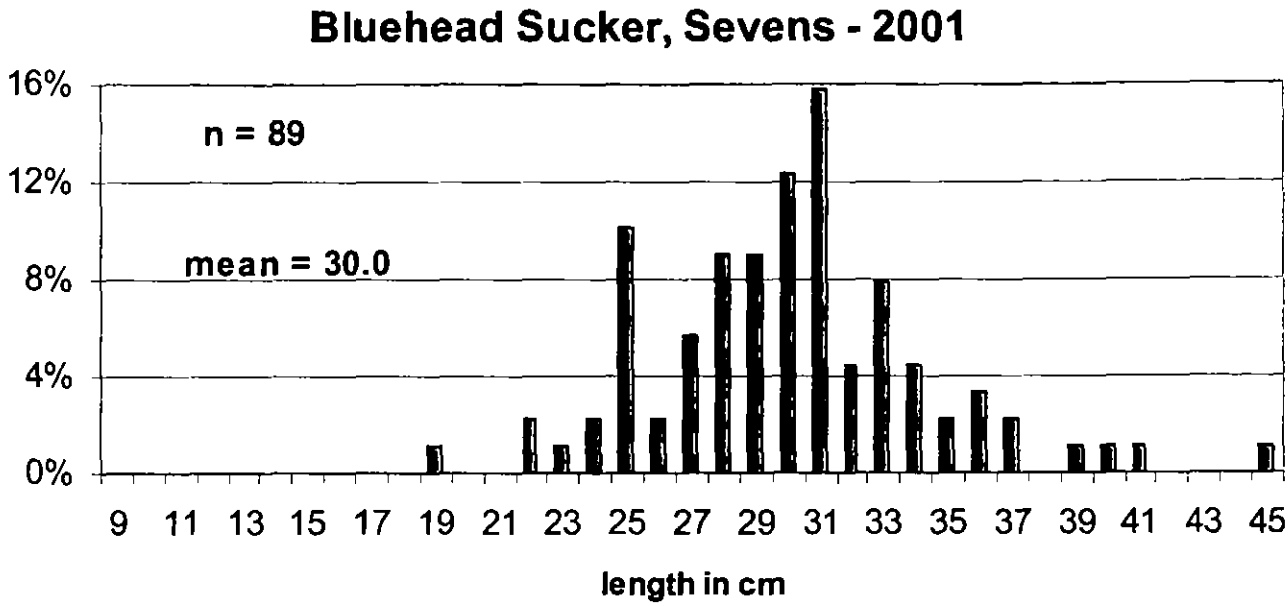

Figure A1. Bluehead Sucker length frequency at the Sevens site, August 2001 Yampa River.

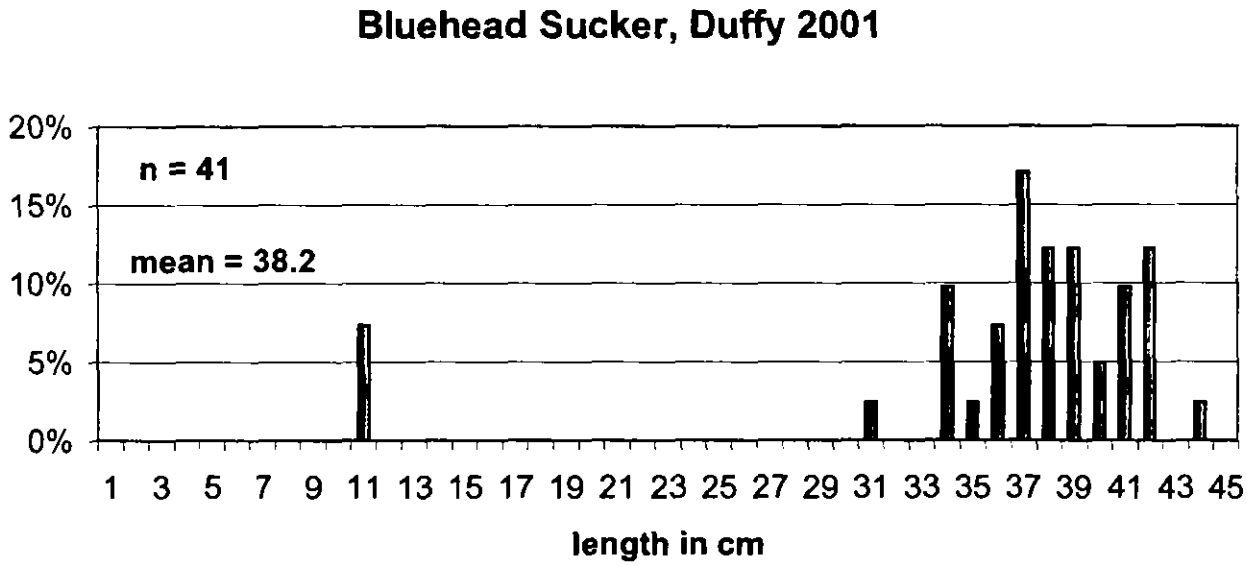

Figure A2. Bluehead Sucker length frequency at the Duffy site, August 2001 Yampa River.

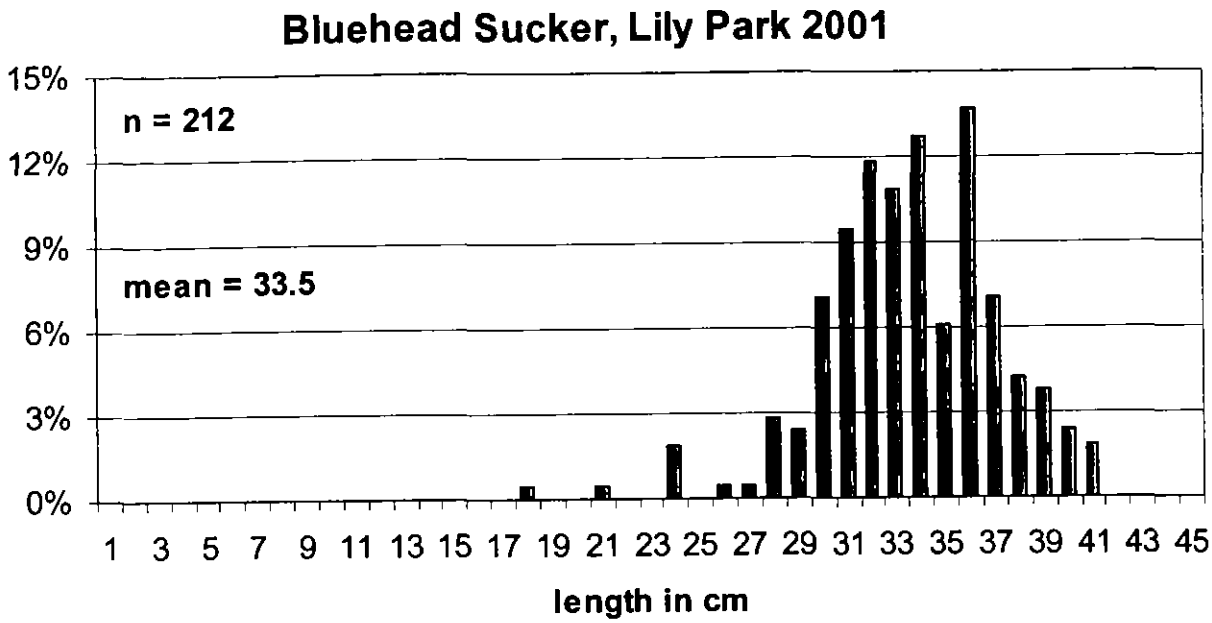

Figure A3. Bluehead Sucker length frequency at the Lily Park site, August 2001 Yampa River.

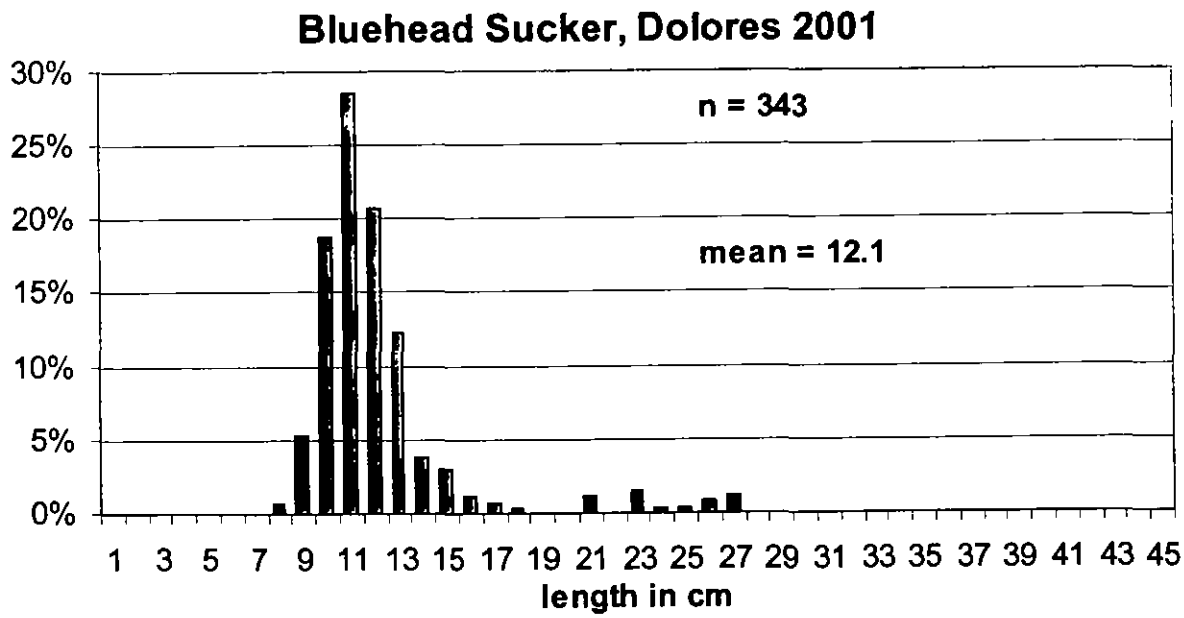

Figure A4. Bluehead Sucker length frequency at the Big Gypsum site, July 2001 Dolores River.

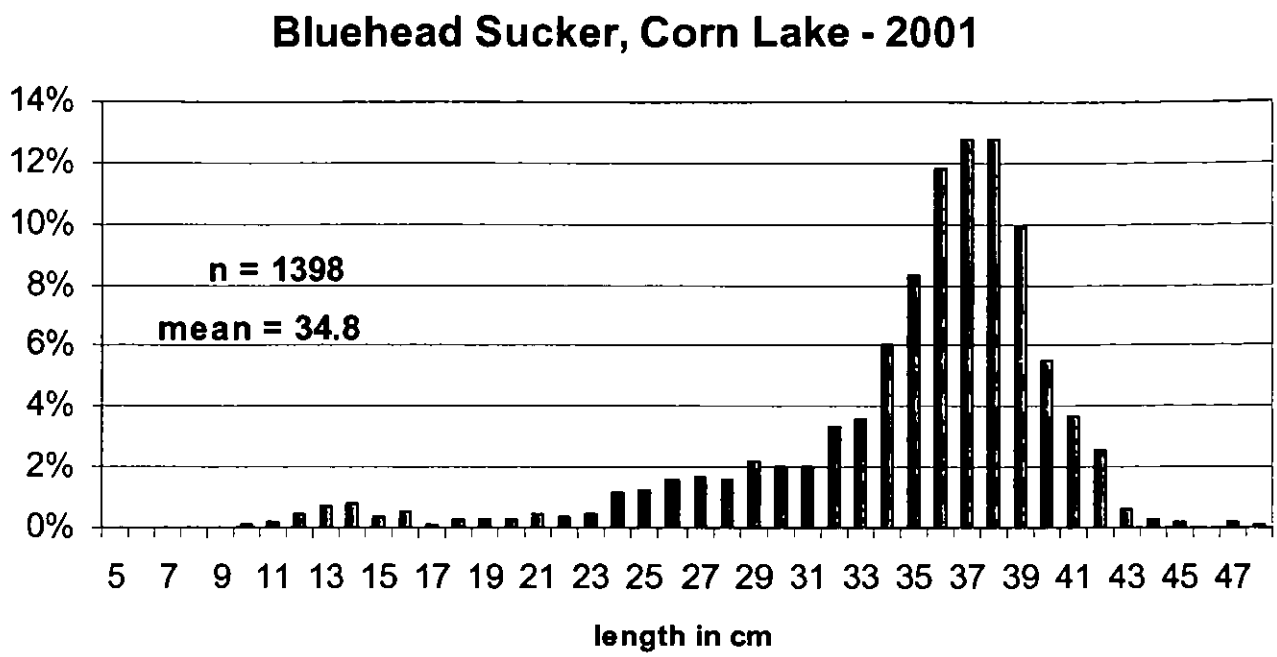

Figure A5. Bluehead Sucker length frequency at the Corn Lake site, September 2001 Colorado River.

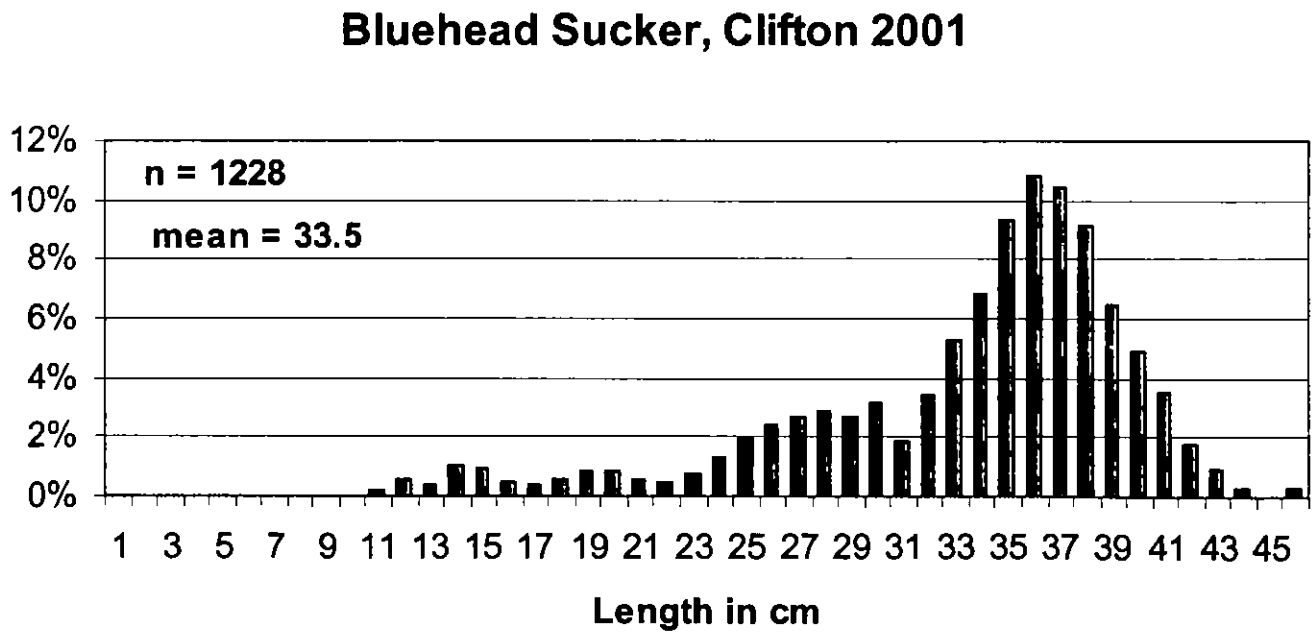

Figure A6. Bluehead Sucker length frequency at the Clifton site, September 2001 Colorado River.

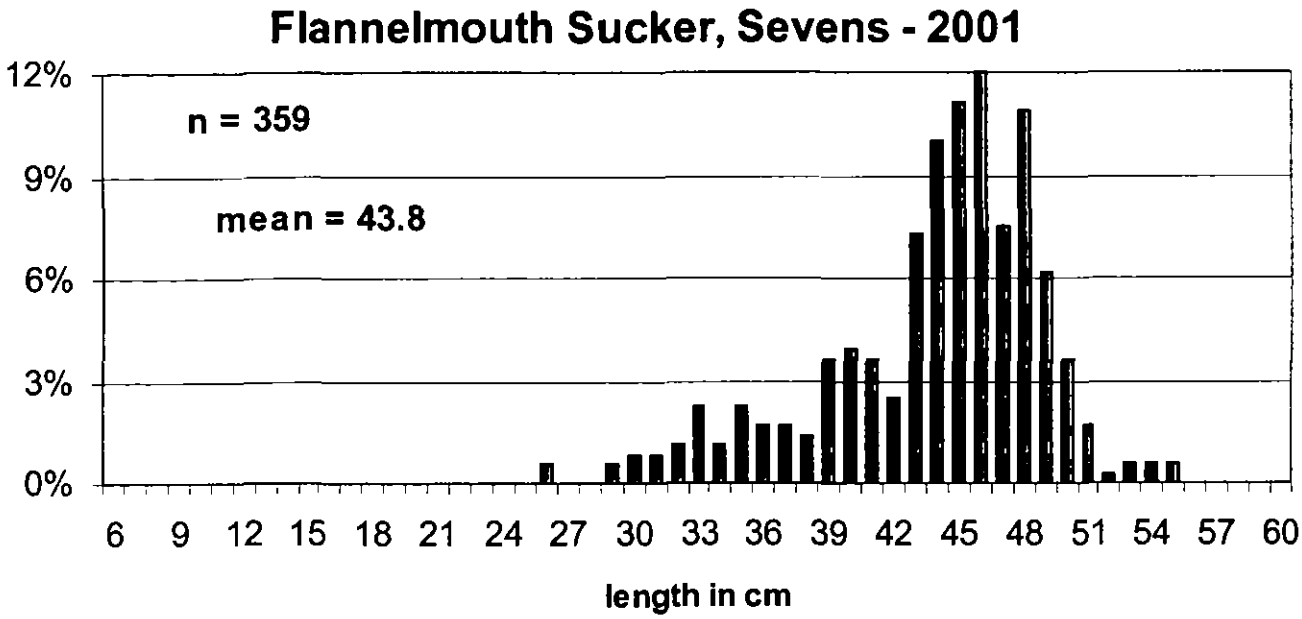

Figure A7. Flannelmouth Sucker length frequency at the Sevens site, August 2001 Yampa River.

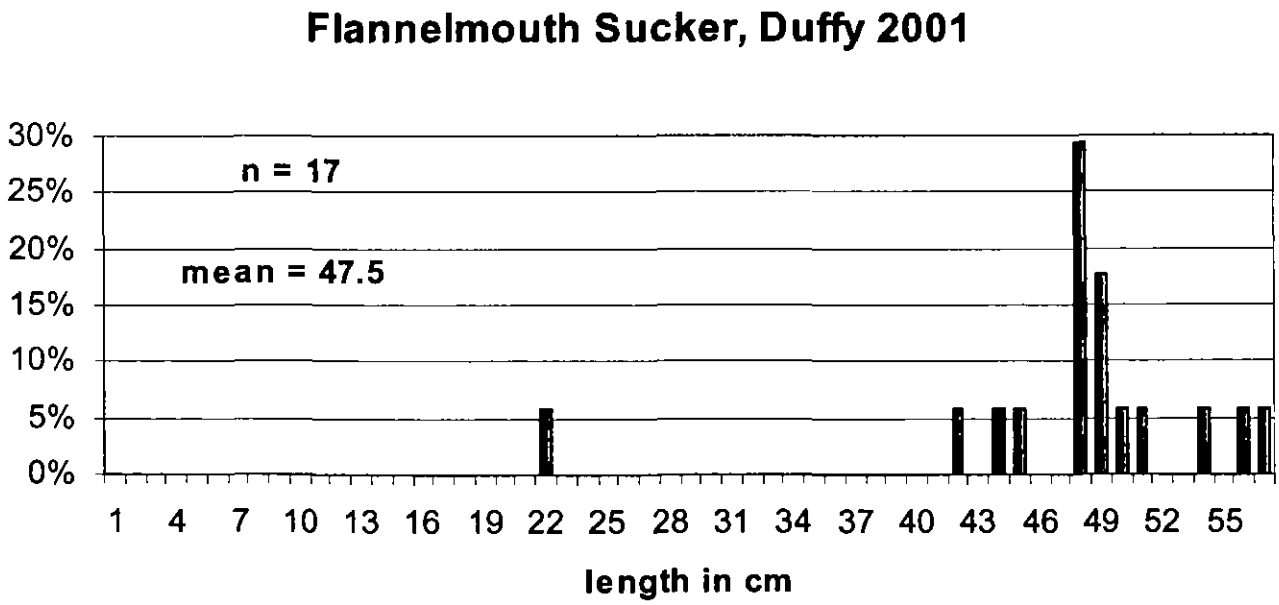

Figure A8. Flannelmouth Sucker length frequency at the Duffy site, August 2001 Yampa River.

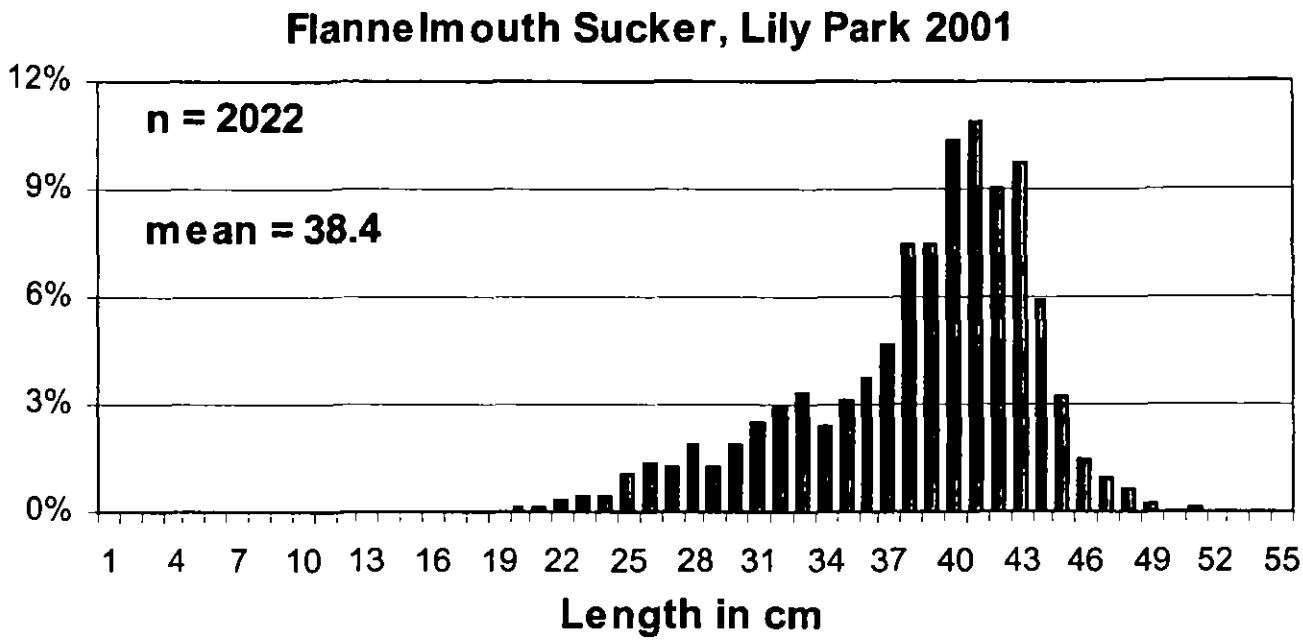

Figure A9. Flannelmouth Sucker length frequency at the Lily Park site, August 2001, Yampa River.

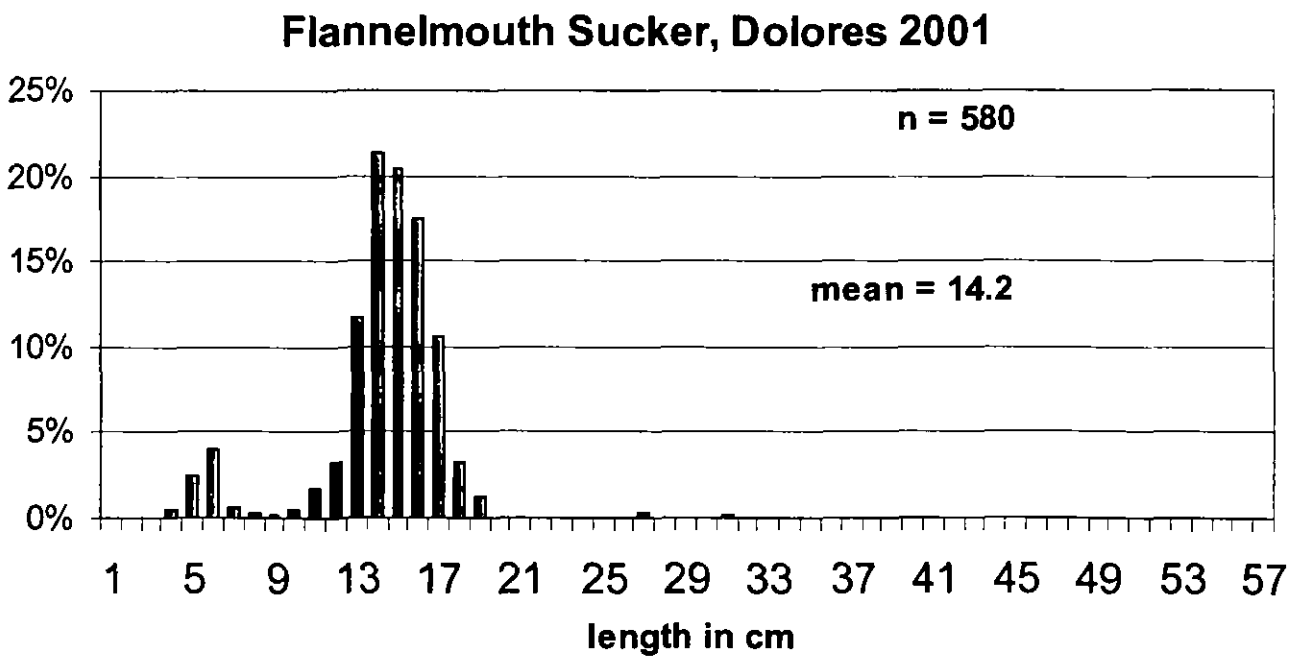

Figure A10. Flannelmouth Sucker length frequency at the Big Gypsum site, July 2001 Dolores River.

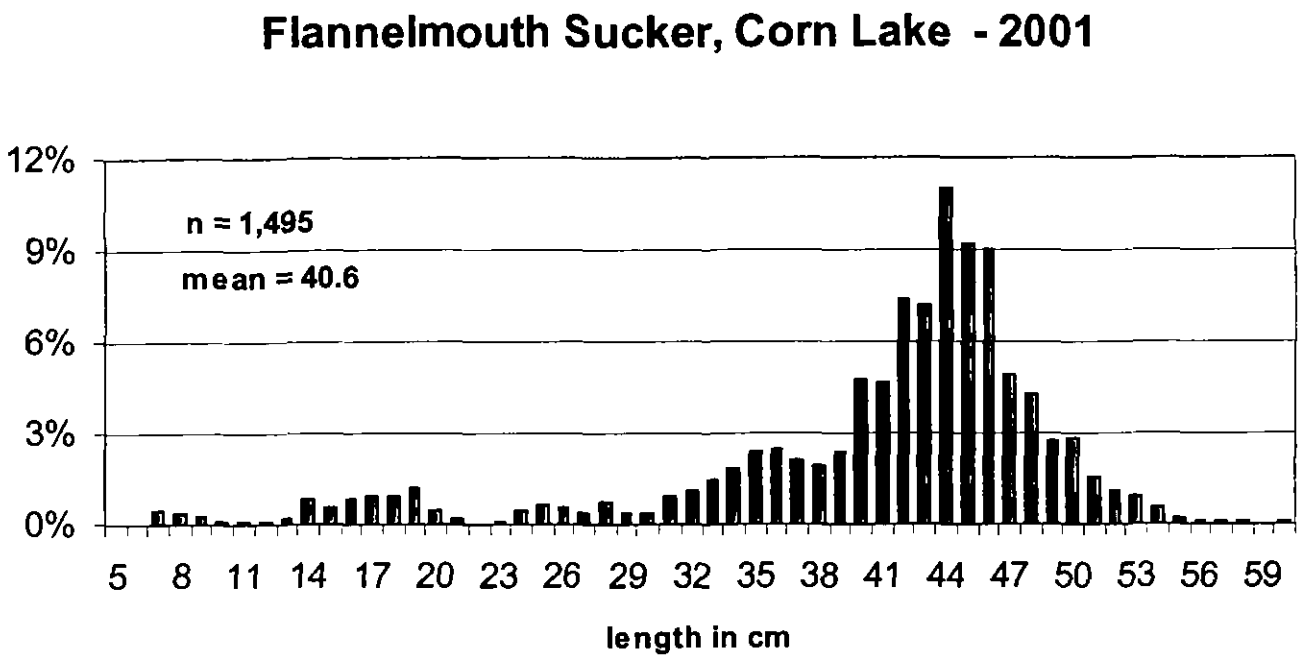

Figure A11. Flannelmouth Sucker length frequency at the Corn Lake site, September 2001 Colorado River.

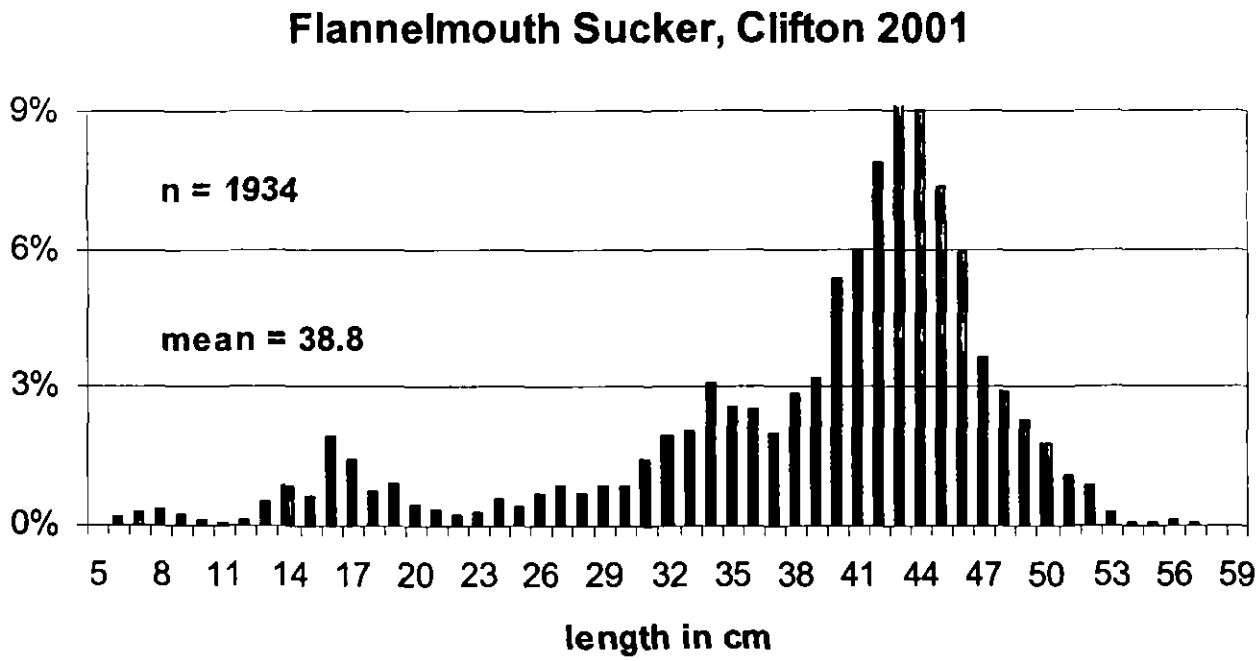

Figure A12. Flannelmouth Sucker length frequency at the Clifton site, September 2001 Colorado River.

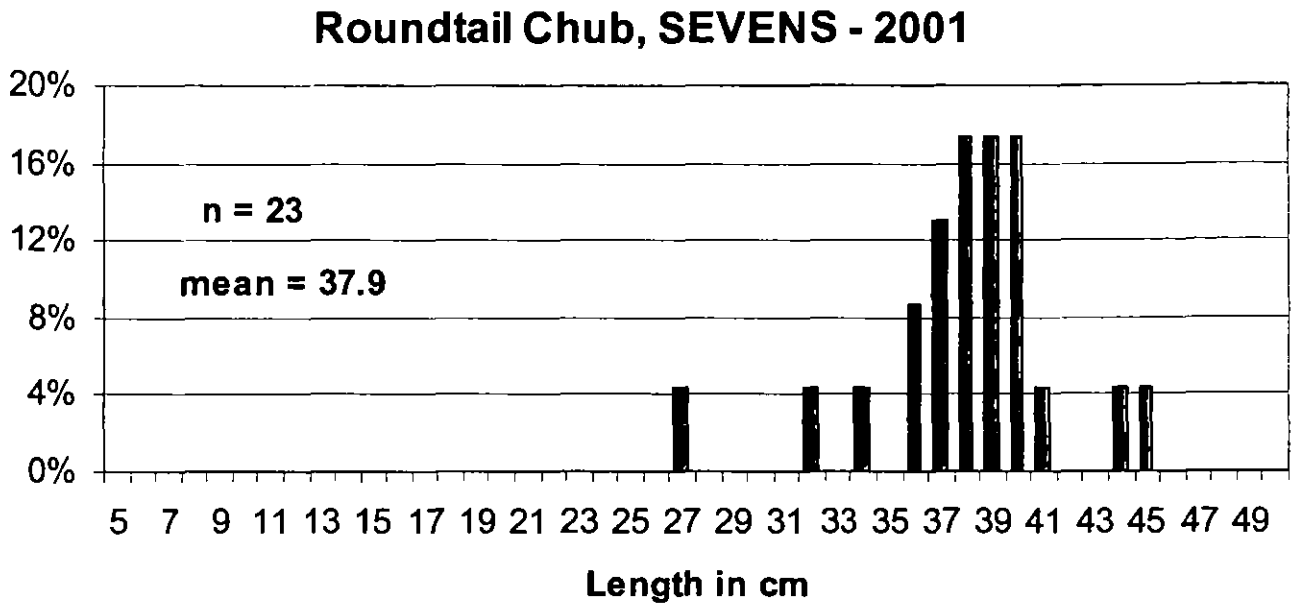

Figure A13. Roundtail Chub length frequency at the Sevens site, August 2001 Yampa River.

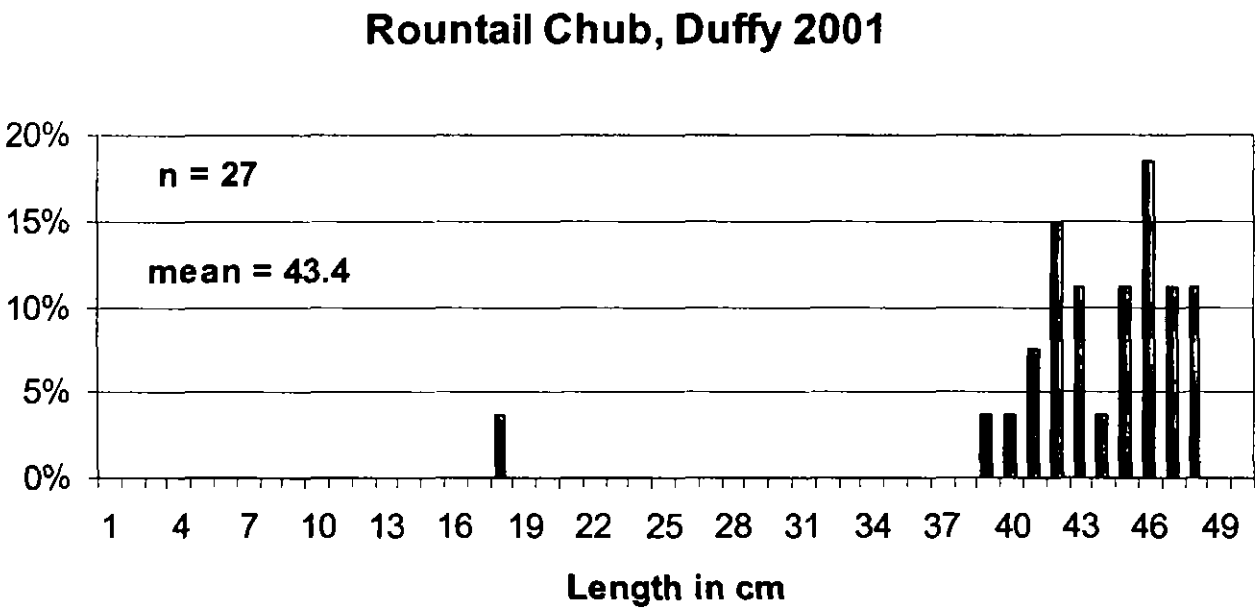

Figure A14. Roundtail Chub length frequency at the Duffy site, August 2001 Yampa River.

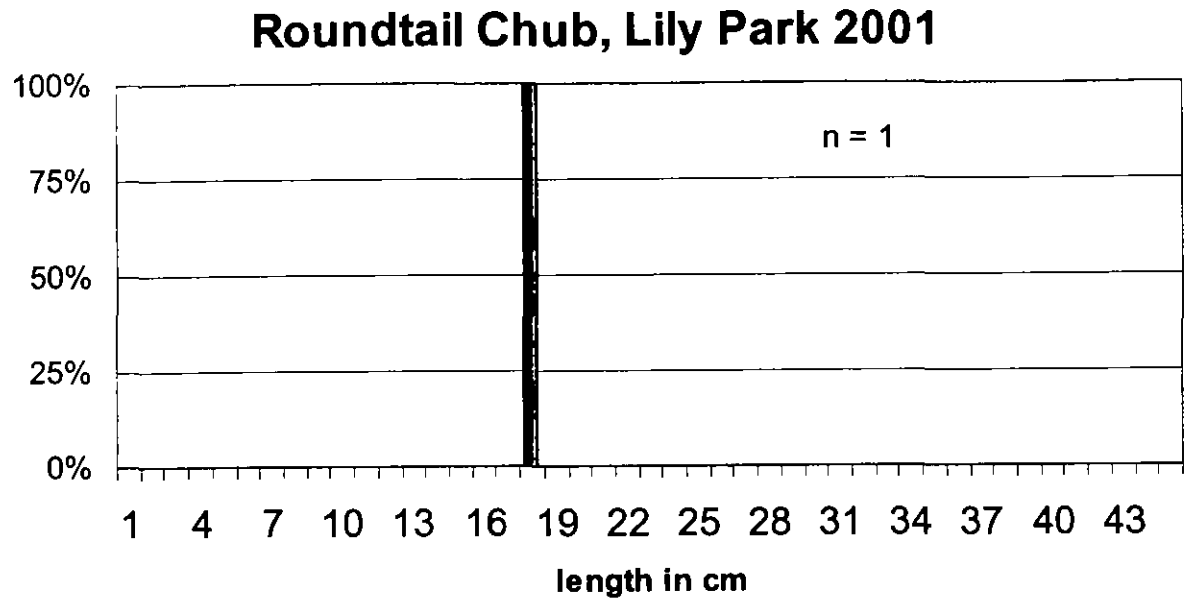

Figure A15. Roundtail Chub length frequency at the Lily Park site, August 2001 Yampa River.

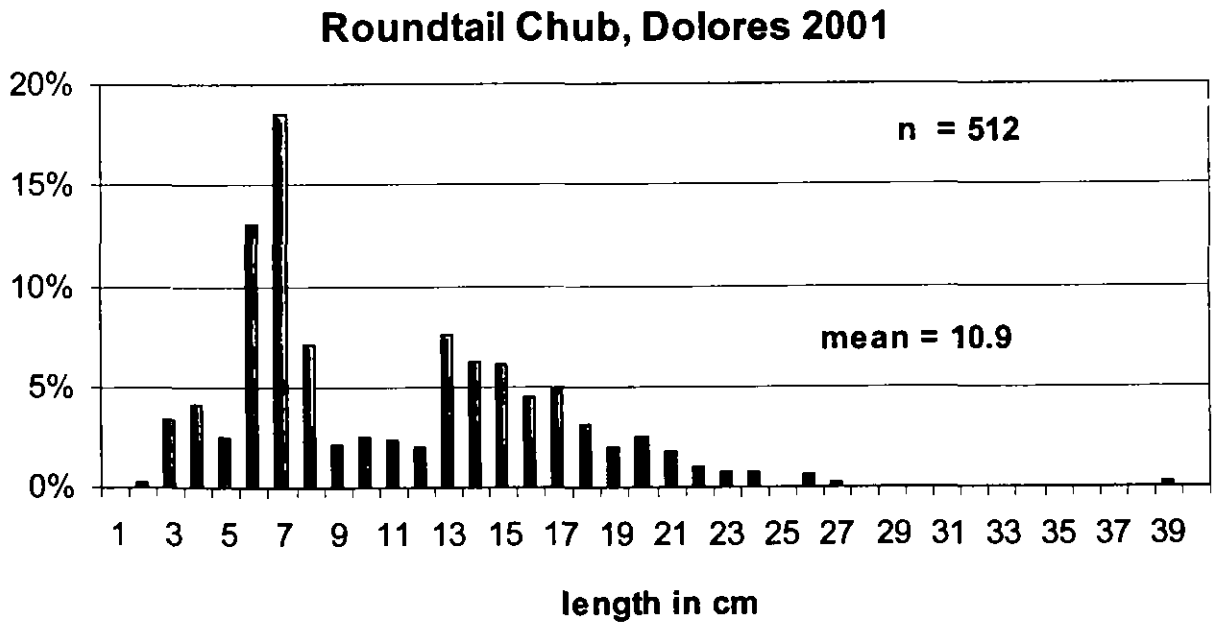

Figure A16. Roundtail Chub length frequency at the Big Gypsum site, July 2001 Dolores River.

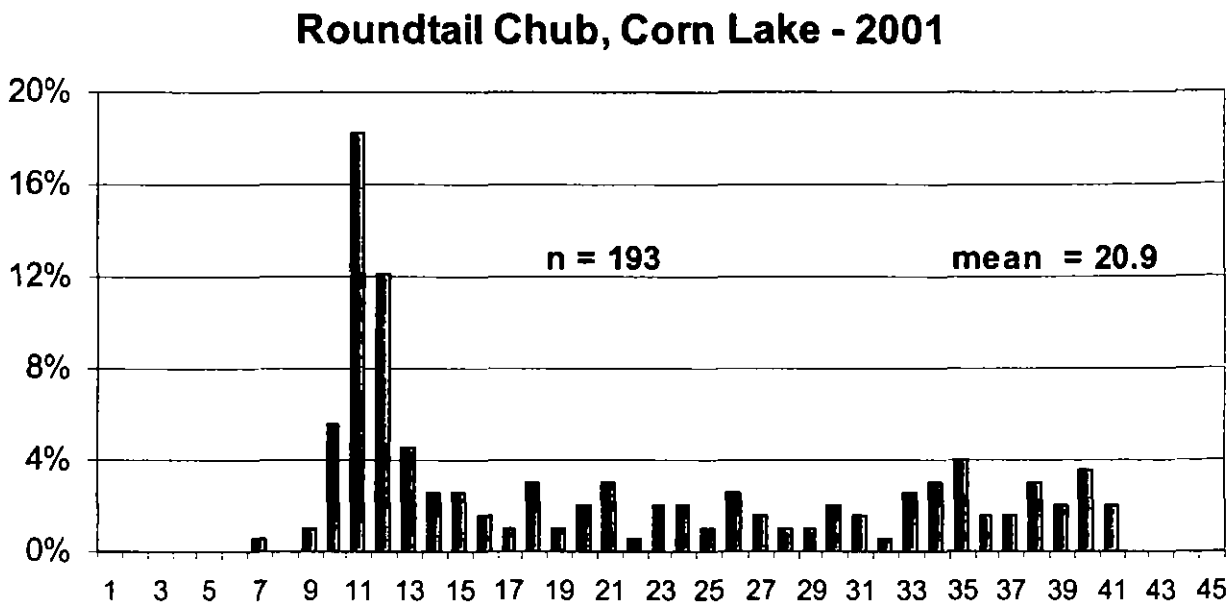

Figure A17. Roundtail Chub length frequency at the Corn Lake site, September 2001 Colorado River.

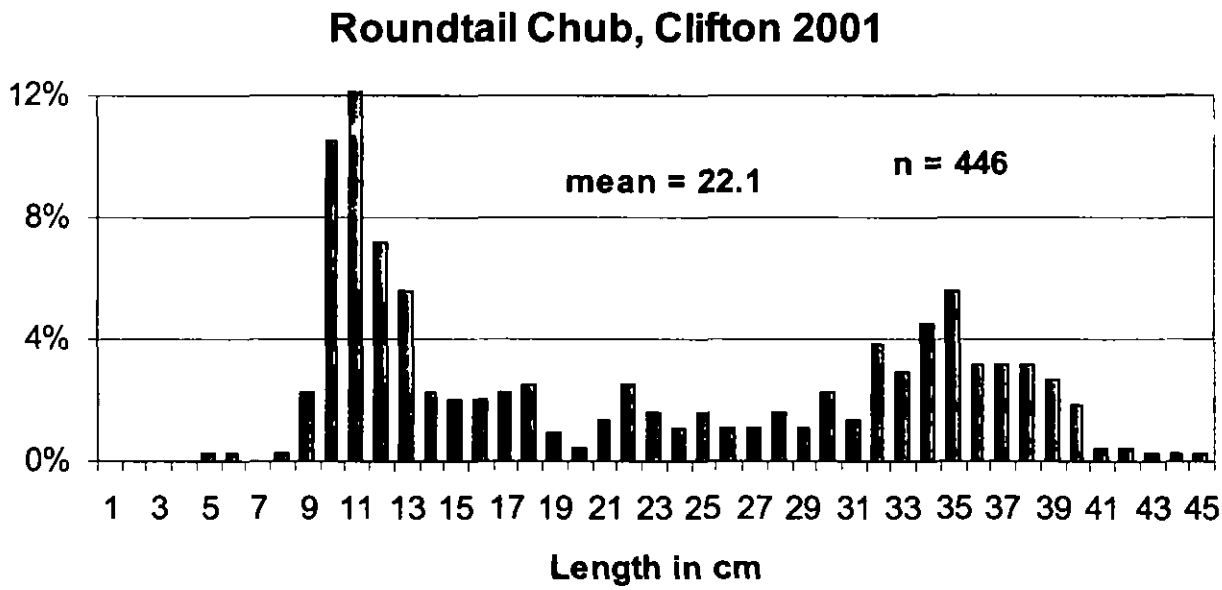

Figure A18. Roundtail Chub length frequency at the Clifton site, September 2001 Colorado River.

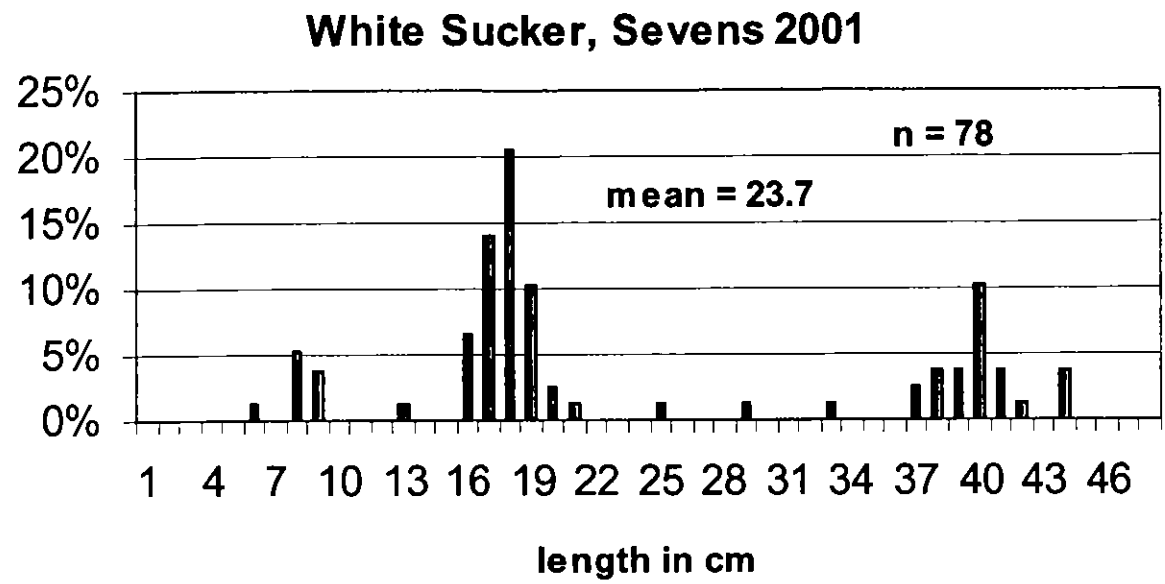

Figure A19. White Sucker length frequency at the Sevens site, August 2001 Yampa River.

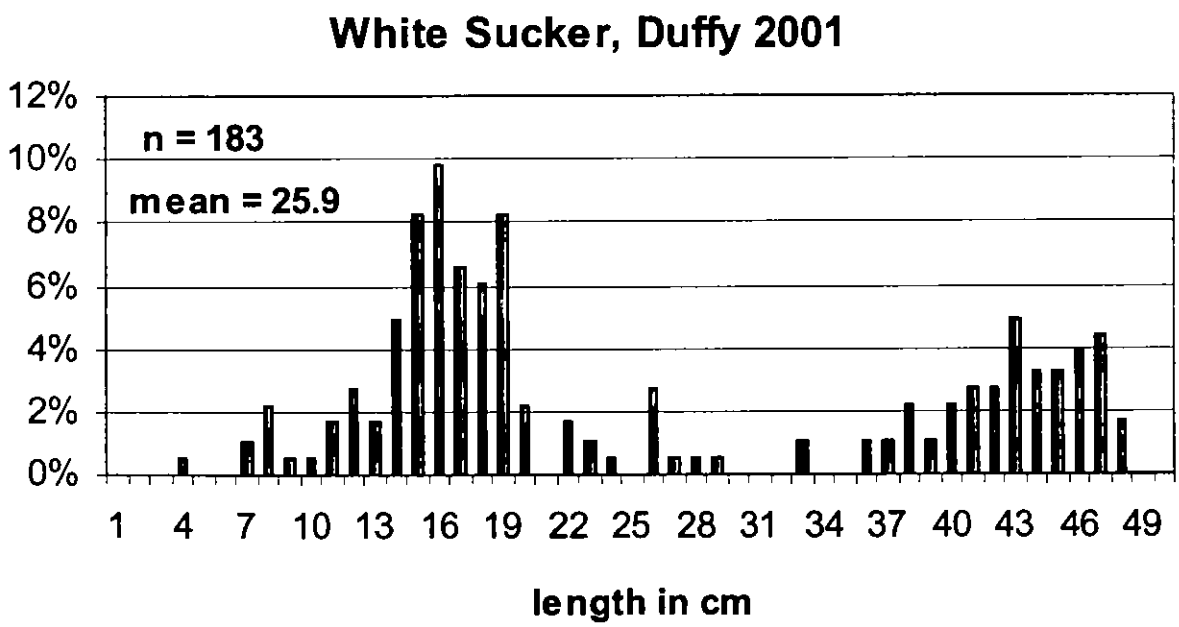

Figure A20. White Sucker length frequency at the Duffy site, August 2001 Yampa River.

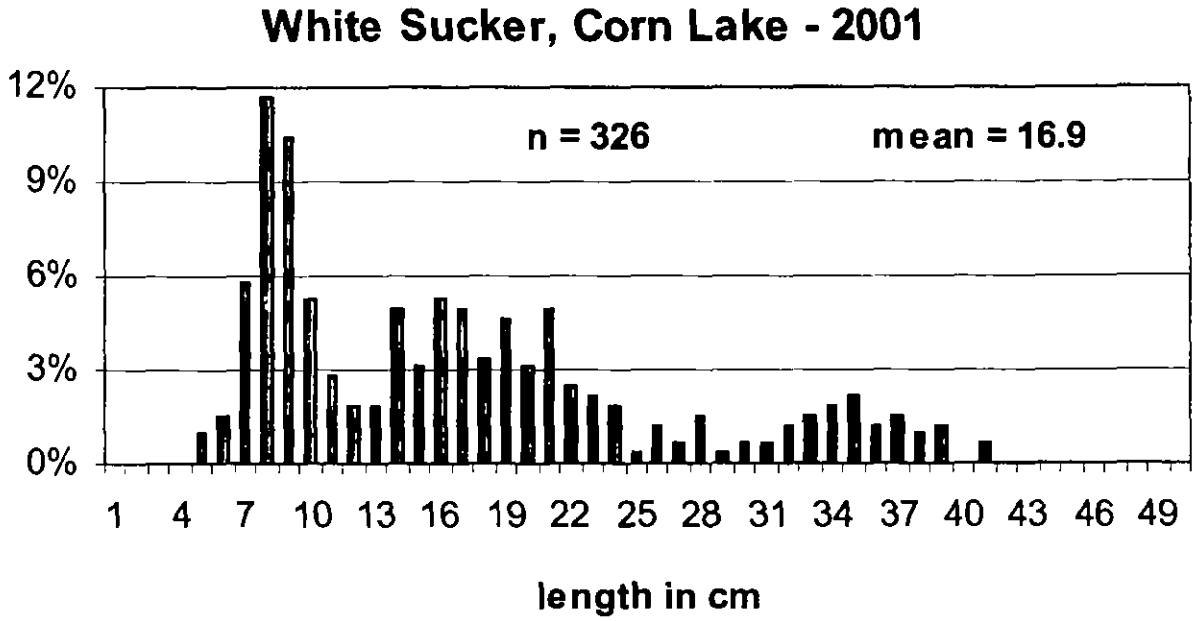

Figure A21. White Sucker length frequency at the Corn Lake site, September 2001 Colorado River.

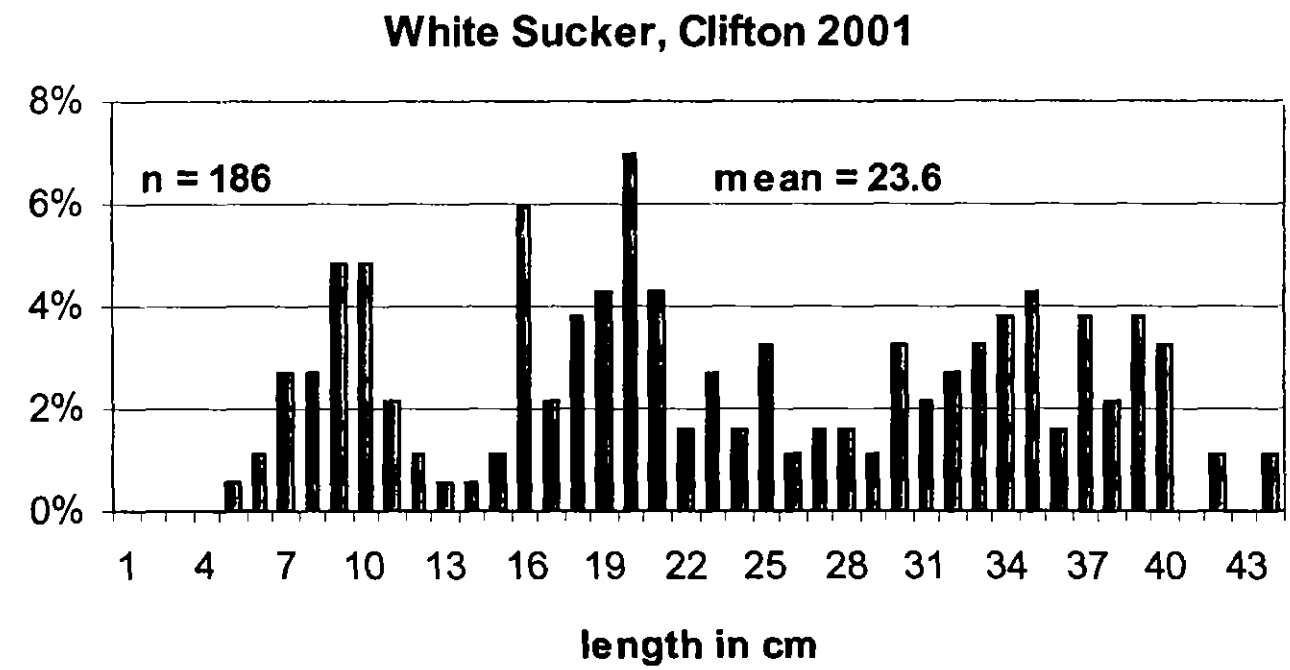

Figure A22. White Sucker length frequency at the Clifton site, September 2001 Colorado River.

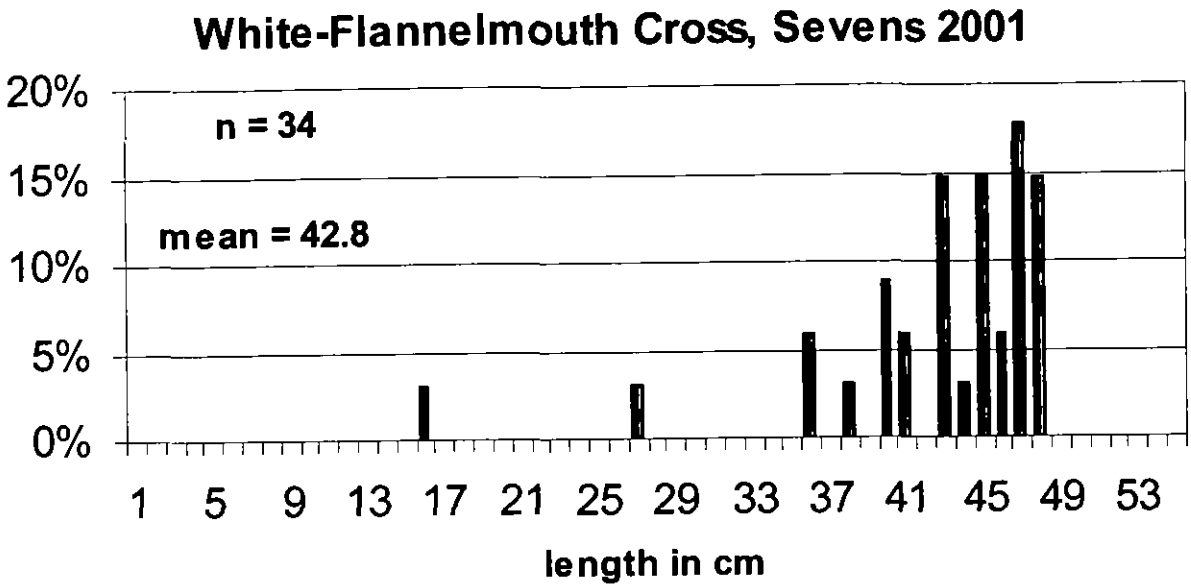

Figure A23. White-Flannelmouth Cross length frequency at the Sevens site, August 2001 Yampa River.

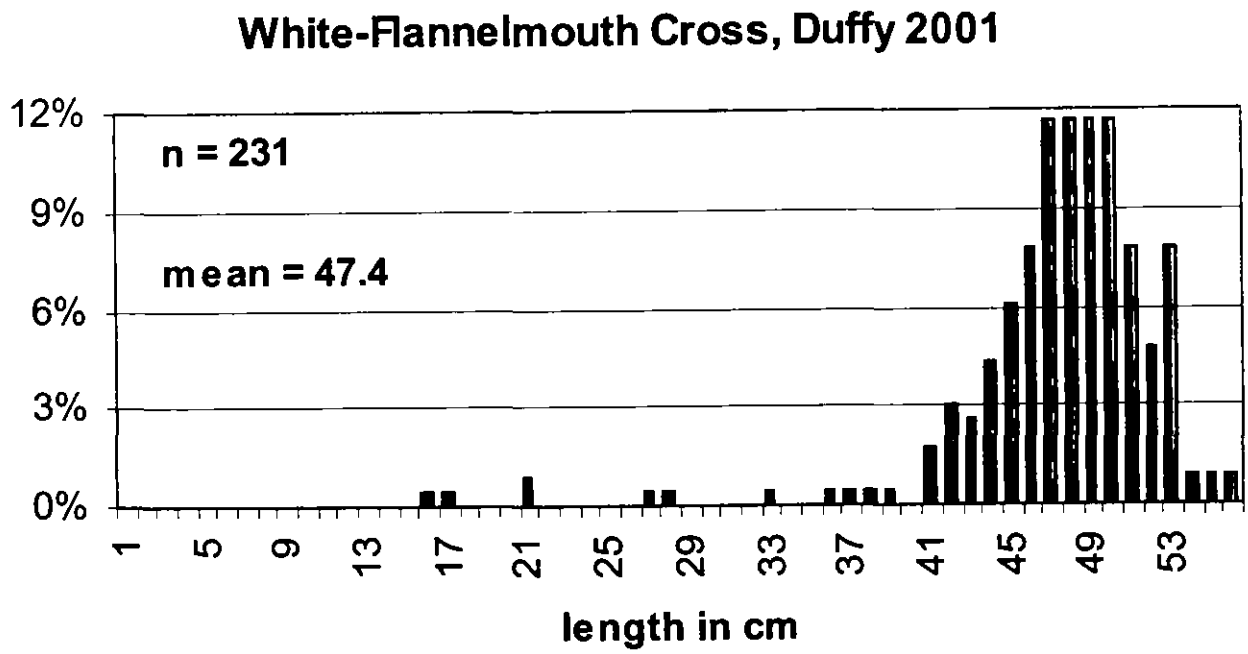

Figure A24. White-Flannelmouth Cross length frequency at the Duffy site, August 2001 Yampa River.

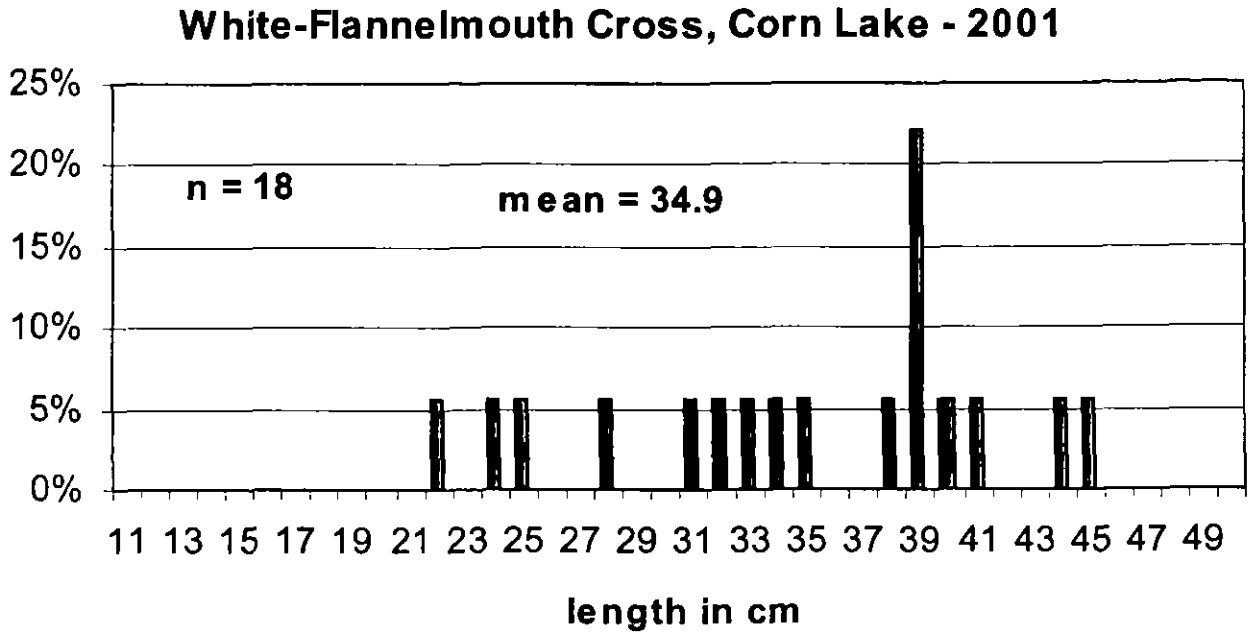

Figure A25. White-Flannelmouth Cross length frequency at the Corn Lake site, September 2001 Colorado River.

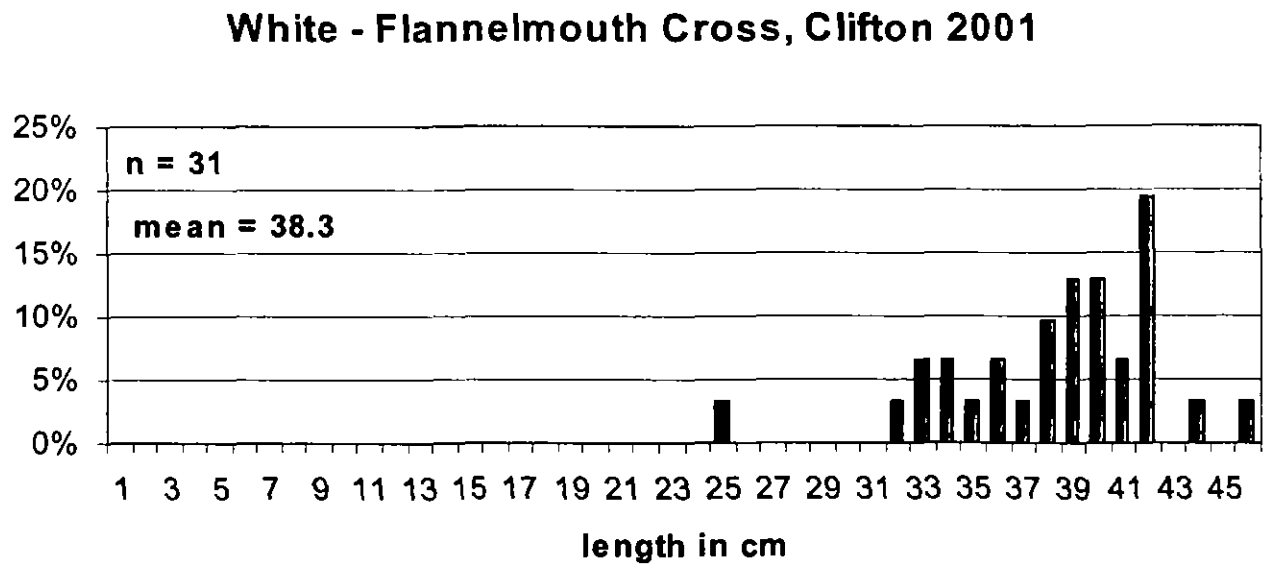

Figure A26. White-Flannelmouth Cross length frequency at the Clifton site, September 2001 Colorado River.

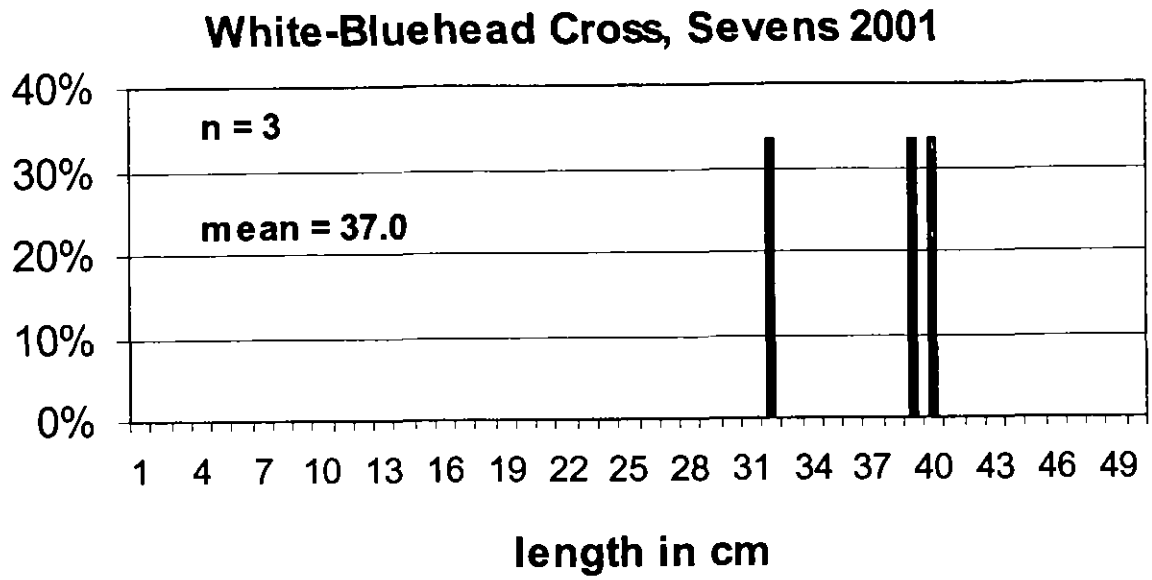

Figure A27. White-Bluehead Cross length frequency at the Sevens site, August 2001 Yampa River.

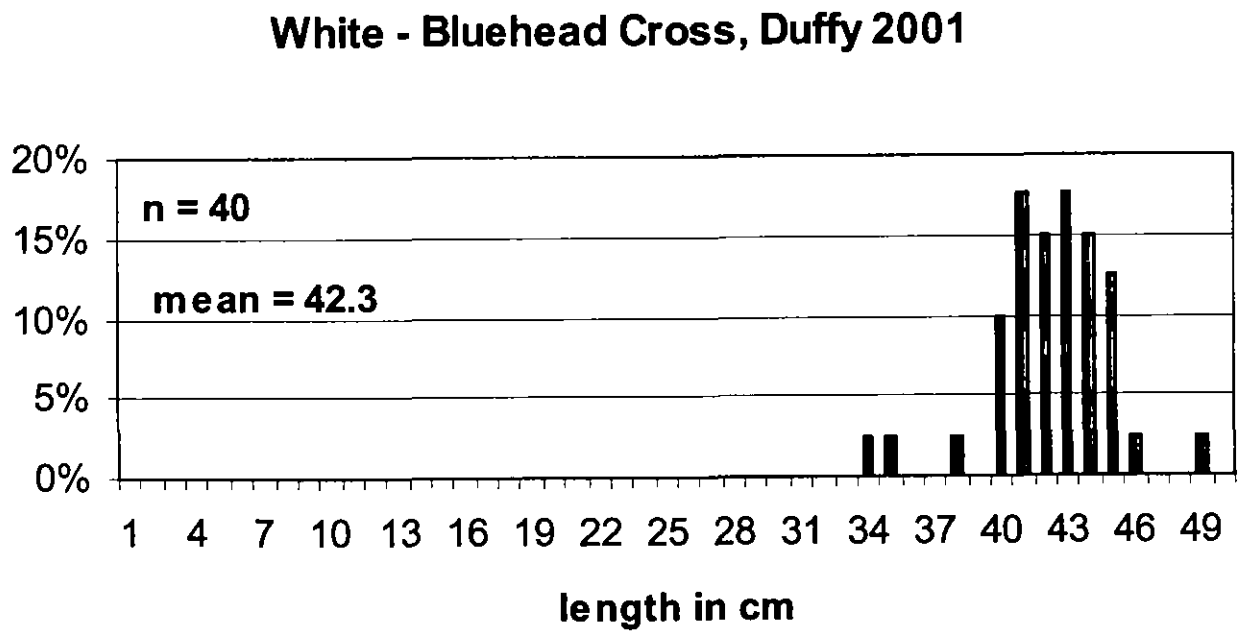

Figure A28. White-Bluehead Cross length frequency at the Duffy site, August 2001 Yampa River.

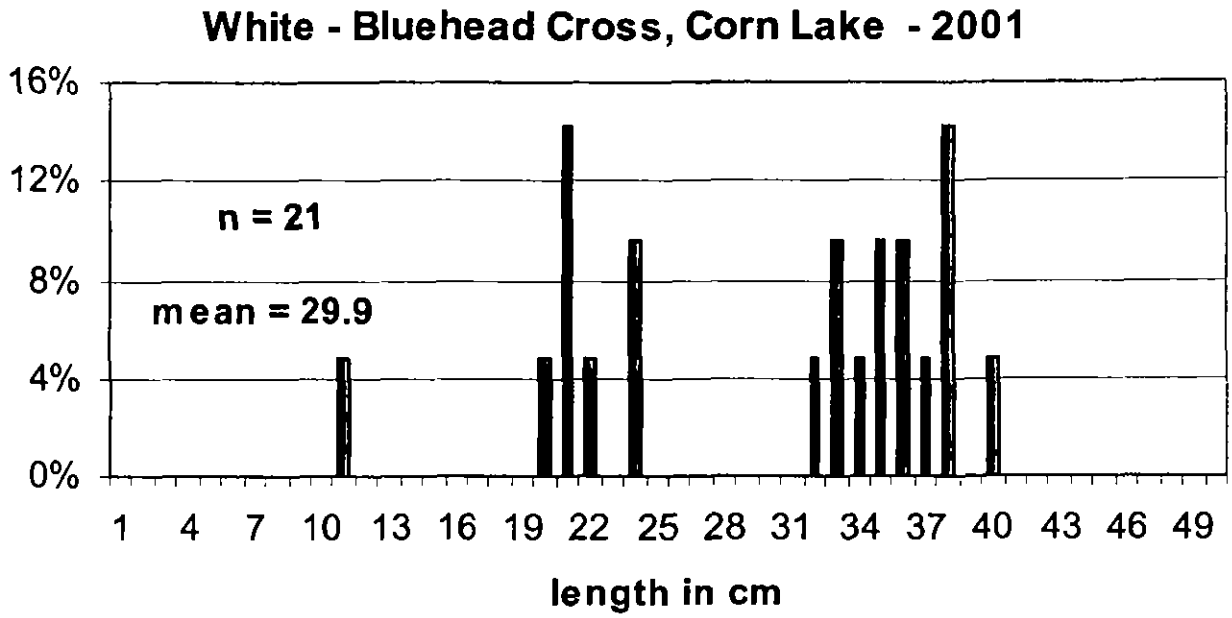

Figure A29. White-Bluehead Cross length frequency at the Corn Lake site, September 2001 Colorado River.

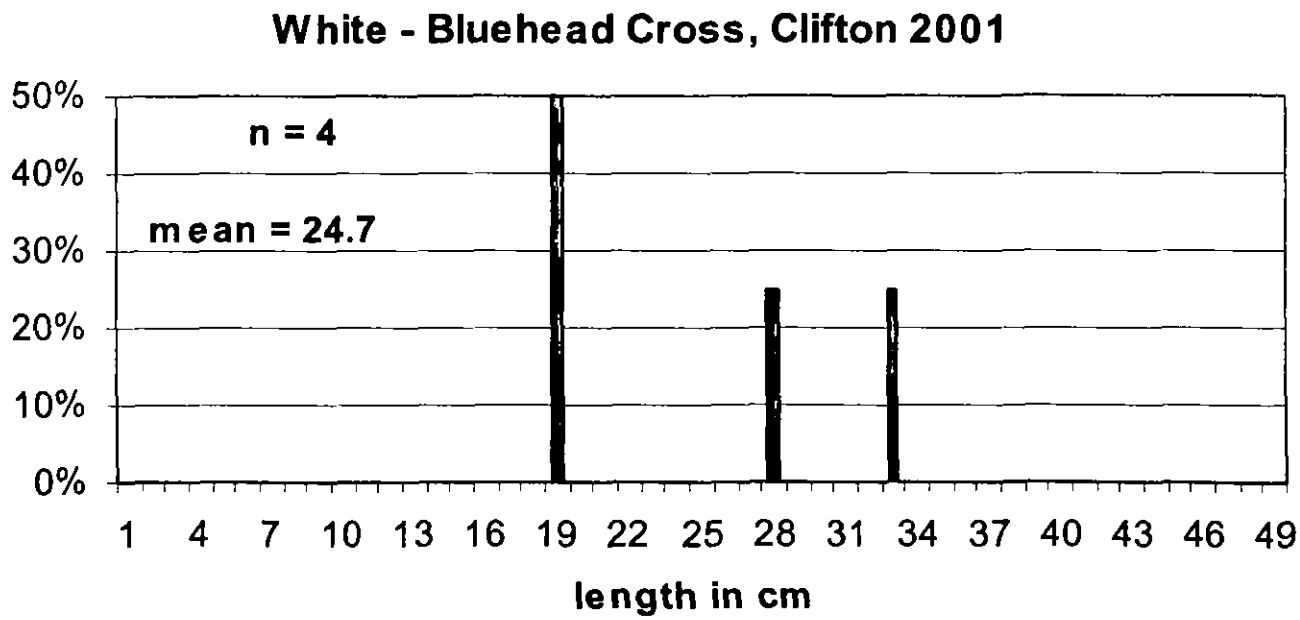

Figure A30. White-Bluehead Cross length frequency at the Clifton site, September 2001 Colorado River.

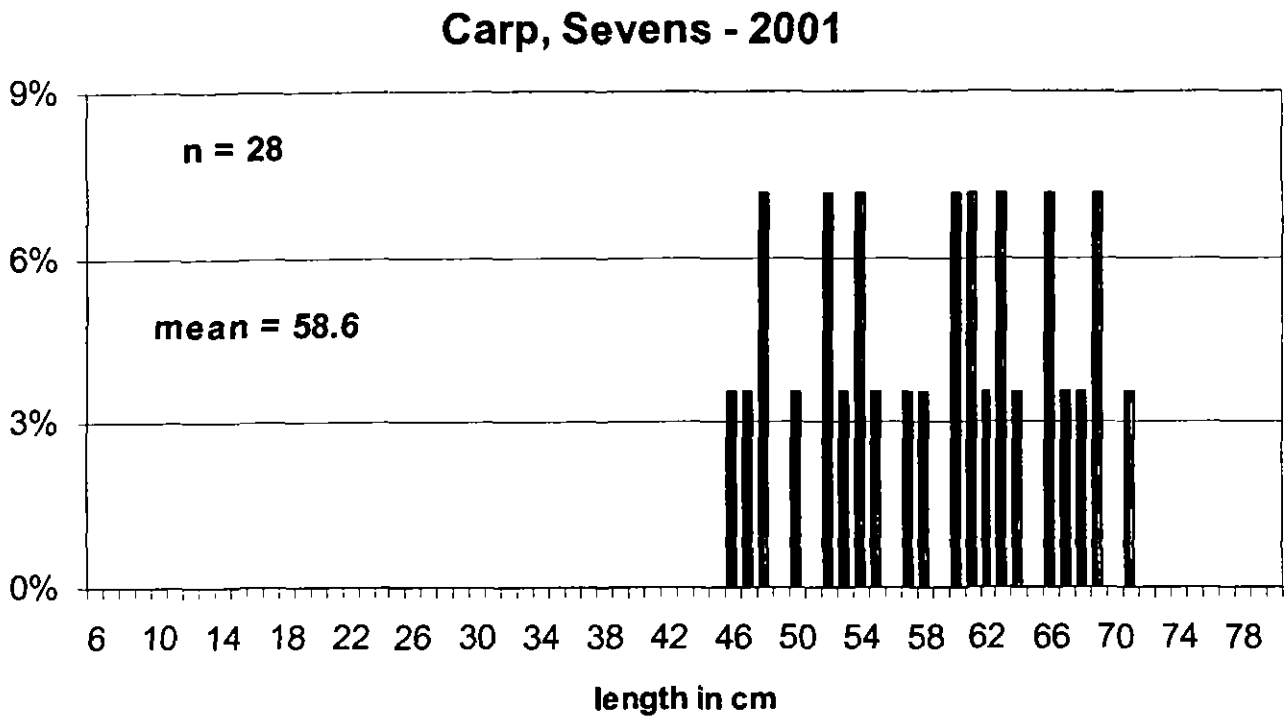

Figure A31. Carp length frequency at the Sevens site, August 2001 Yampa River.

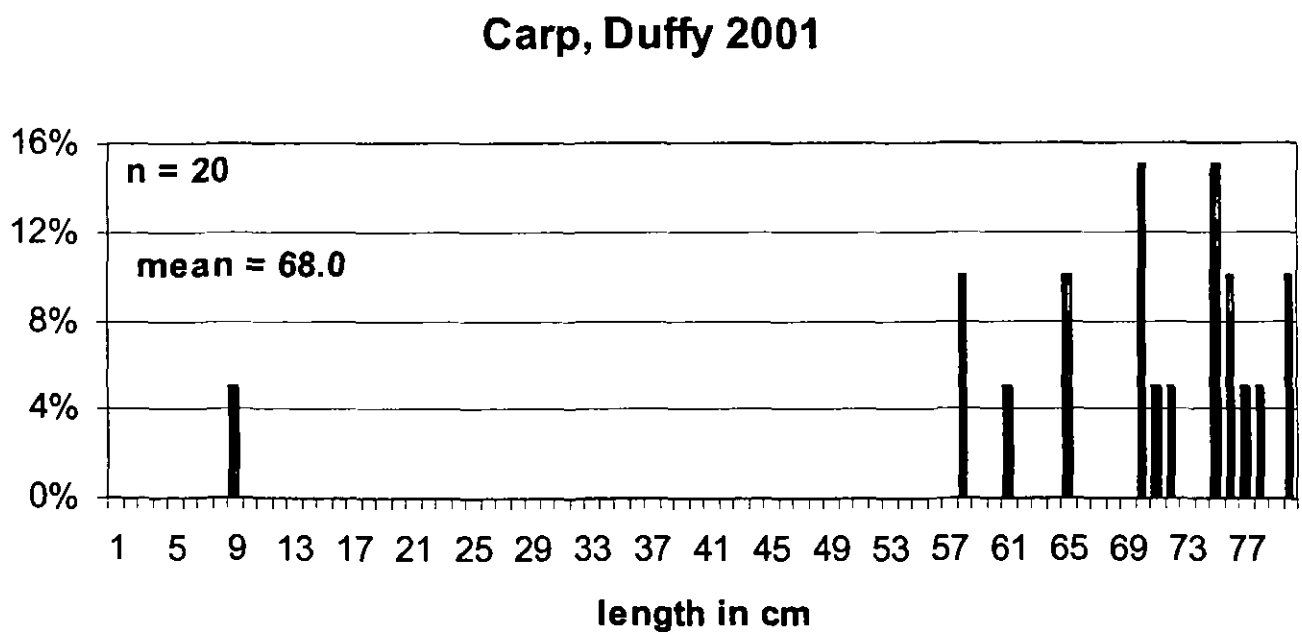

Figure A32. Carp length frequency at the Duffy site, August 2001 Yampa River.

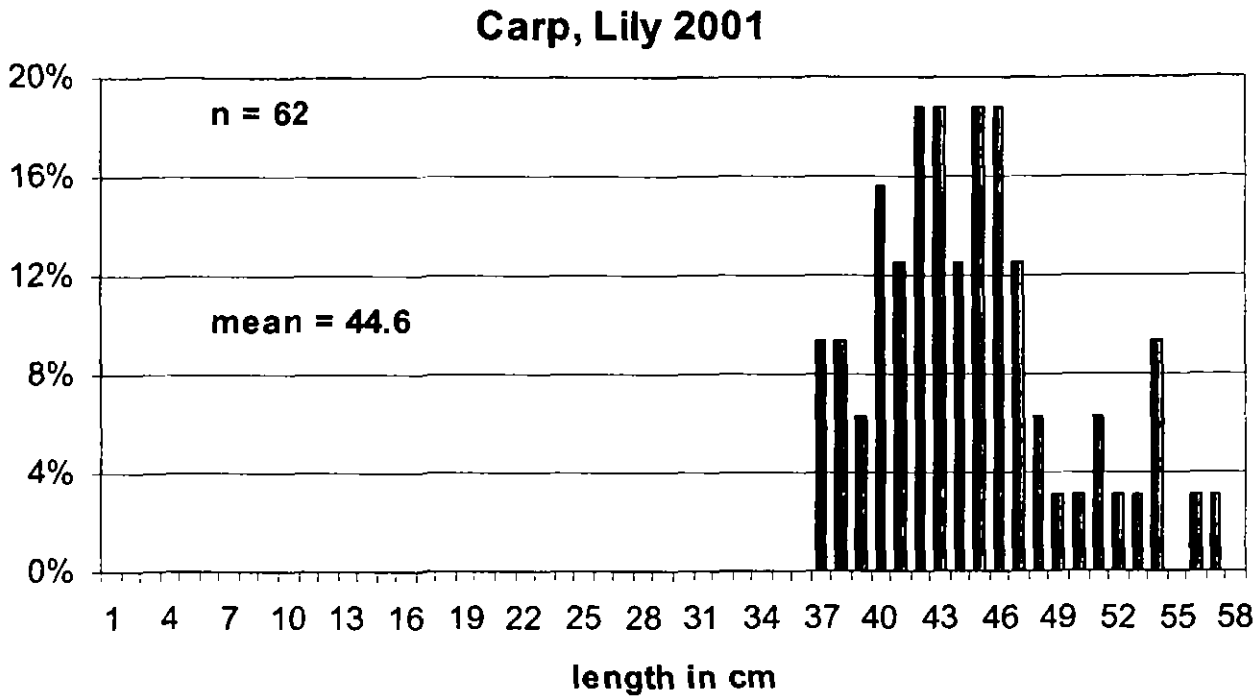

Figure A33. Carp length frequency at the Lily Park site, August 2001 Yampa River.

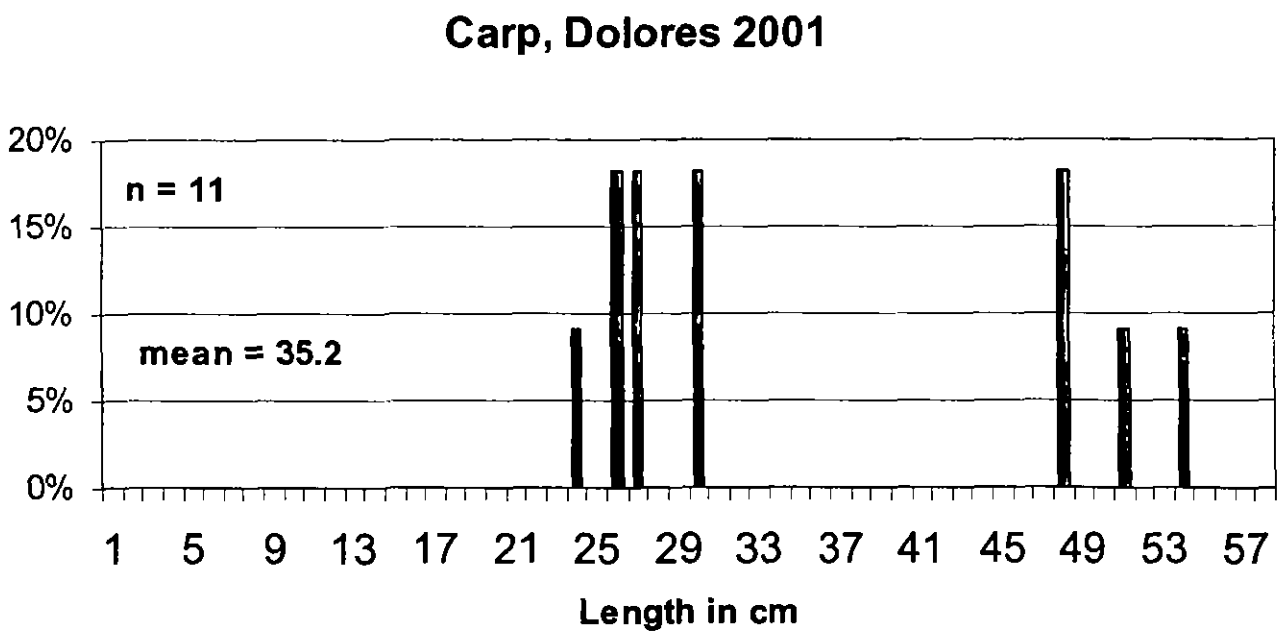

Figure A34. Carp length frequency at the Big Gypsum site, July 2001 Dolores River.

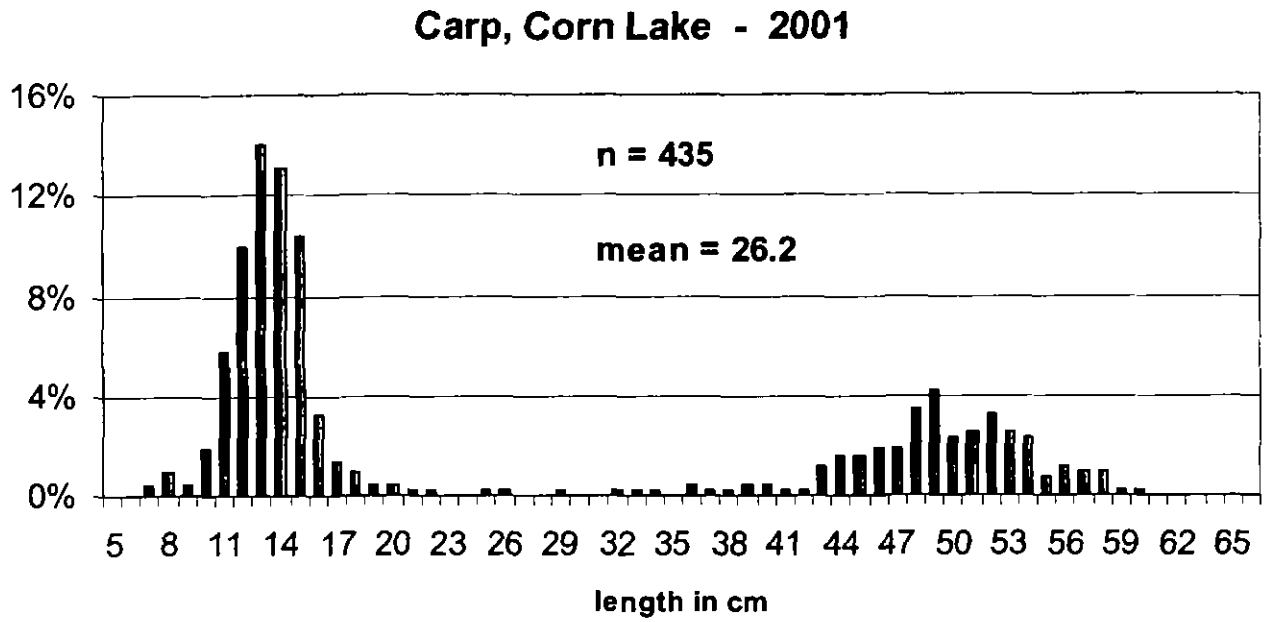

Figure A35. Carp length frequency at the Corn Lake site, September 2001 Colorado River.

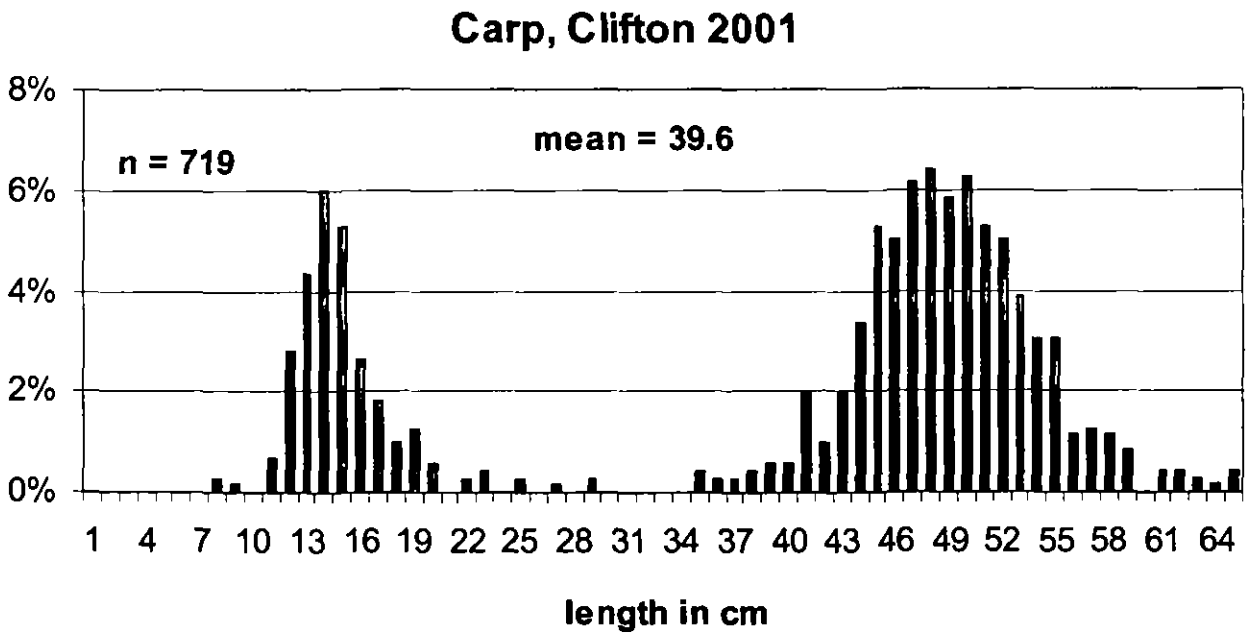

Figure A36. Carp length frequency at the Clifton site, September 2001 Colorado River.

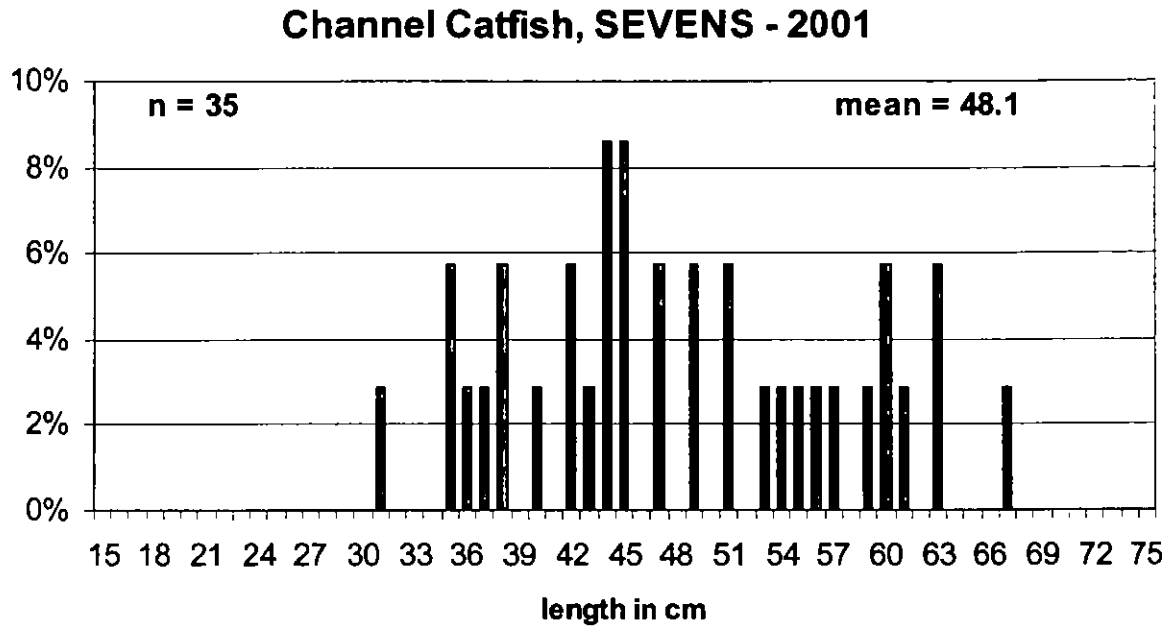

Figure A37. Channel Catfish length frequency at the Sevens site, August 2001 Yampa River.

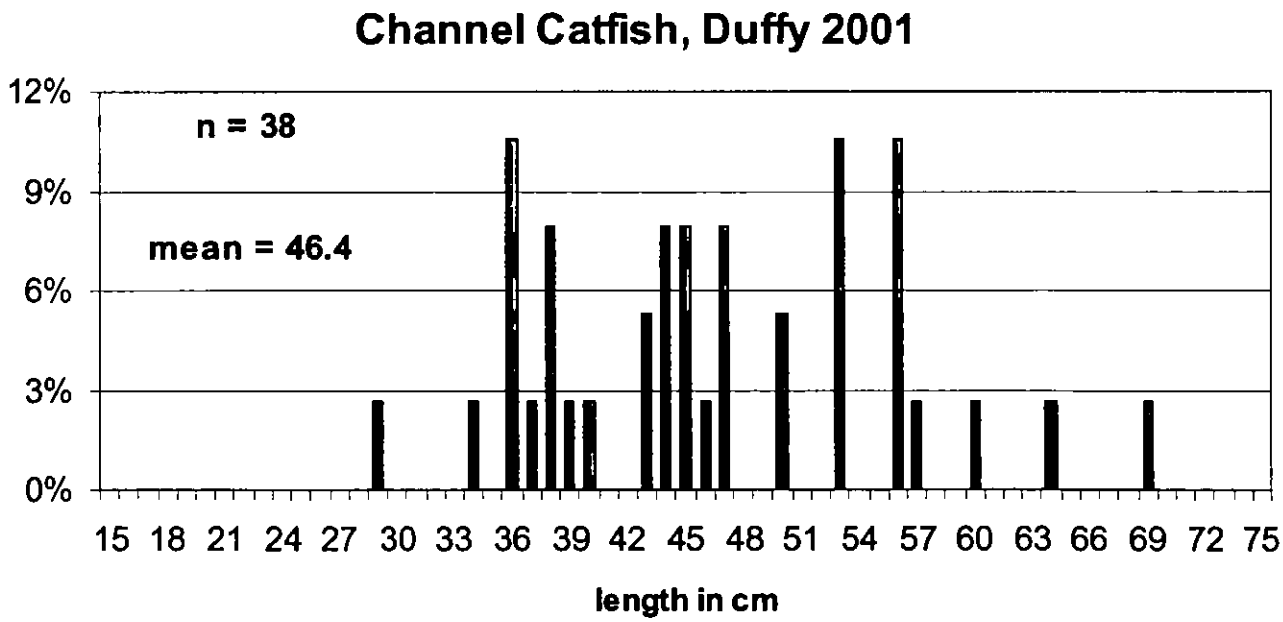

Figure A38. Channel Catfish length frequency at the Duffy site, August 2001 Yampa River.

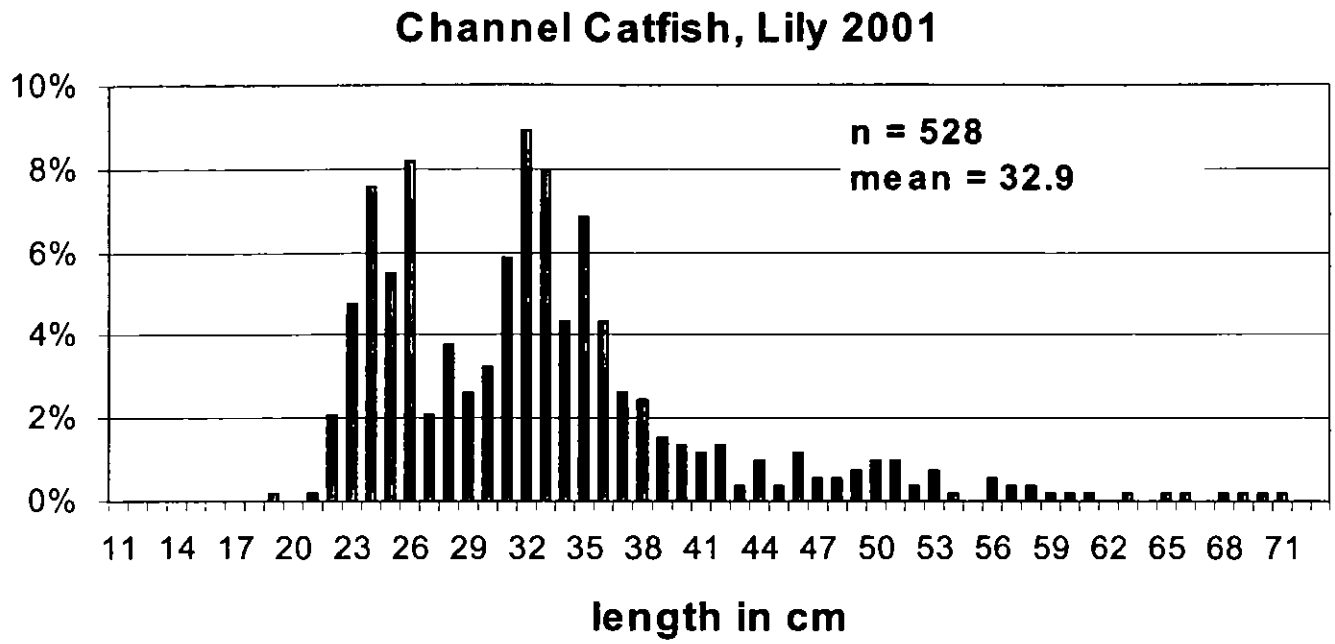

Figure A39. Channel Catfish length frequency at the Lily Park site, August 2001 Yampa River.

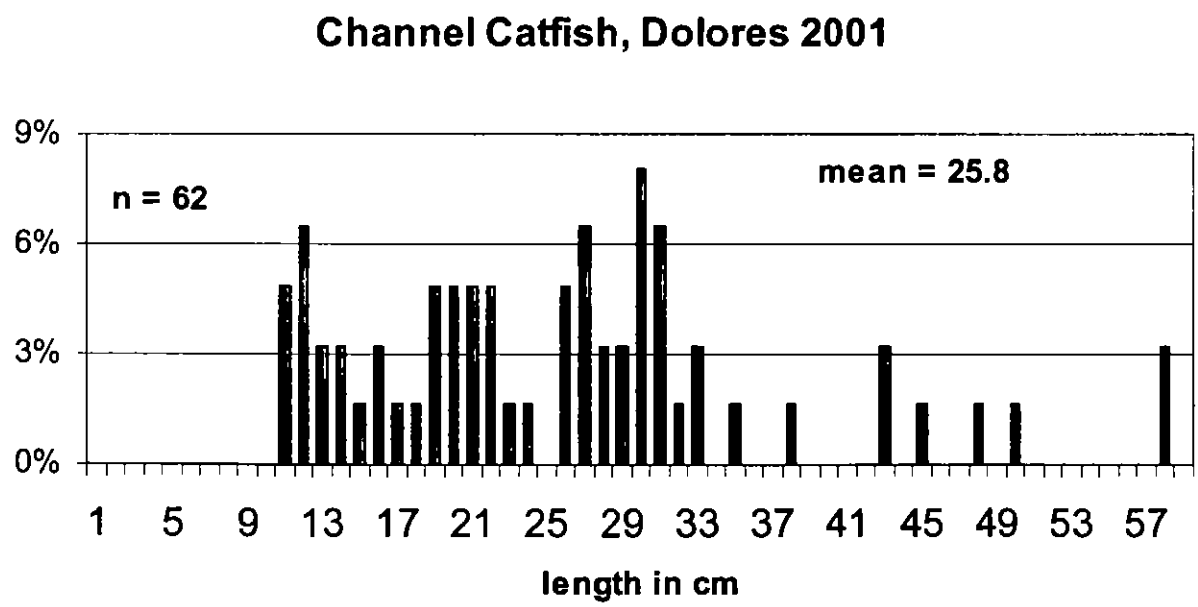

Figure A40. Channel Catfish length frequency at the Big Gypsum site, July 2001 Dolores River.

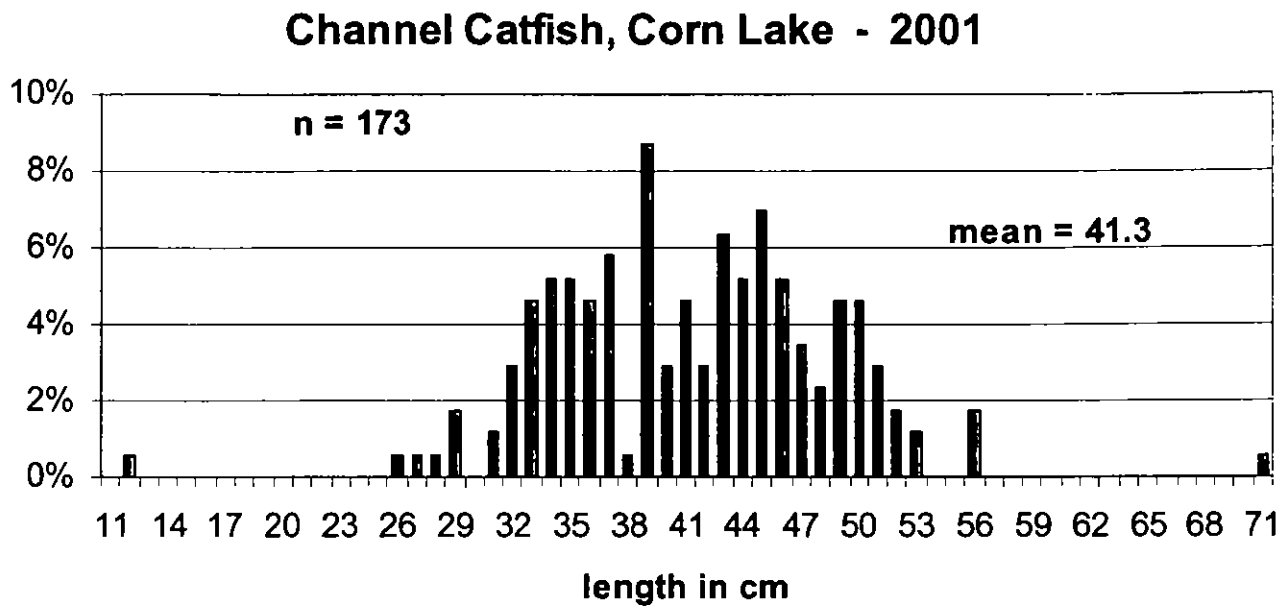

Figure A41. Channel Catfish length frequency at the Corn Lake site, September 2001 Colorado River.

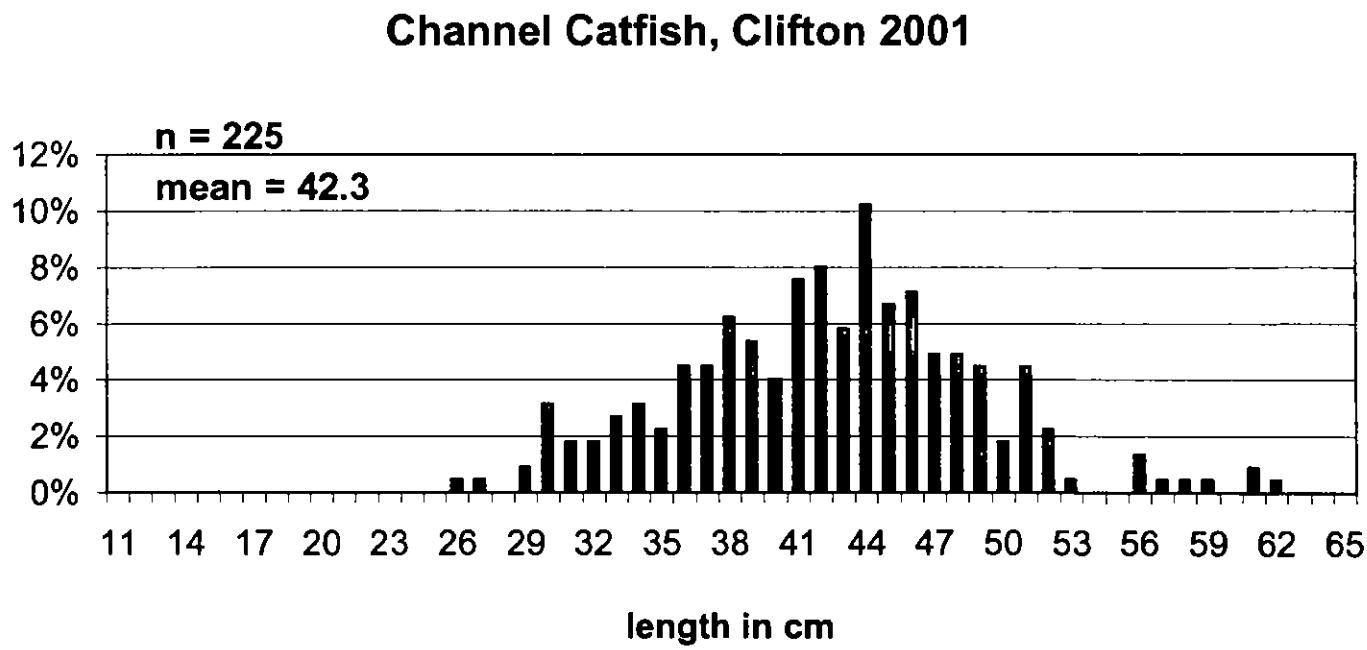

Figure A42. Channel Catfish length frequency at the Clifton site, September 2001 Colorado River.

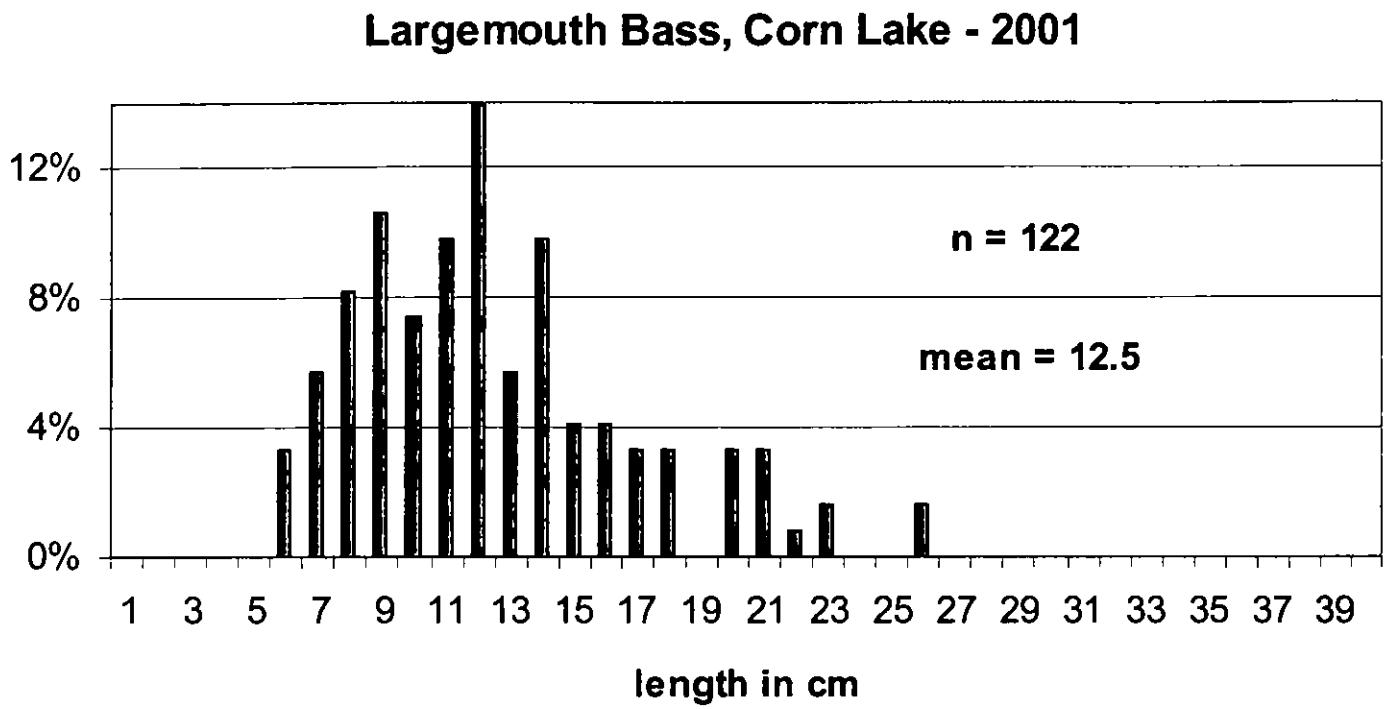

Figure A43. Largemouth Bass length frequency at the Corn Lake site, September 2001 Colorado River.

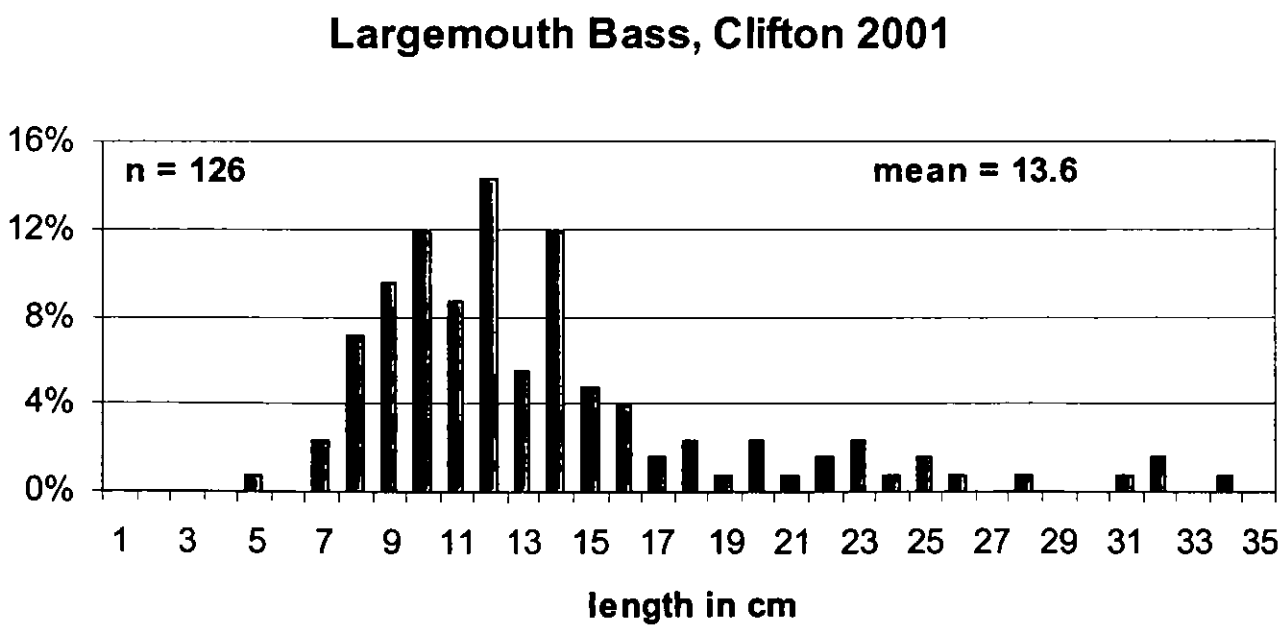

Figure A44. Largemouth Bass length frequency at the Clifton site, September 2001 Colorado River.

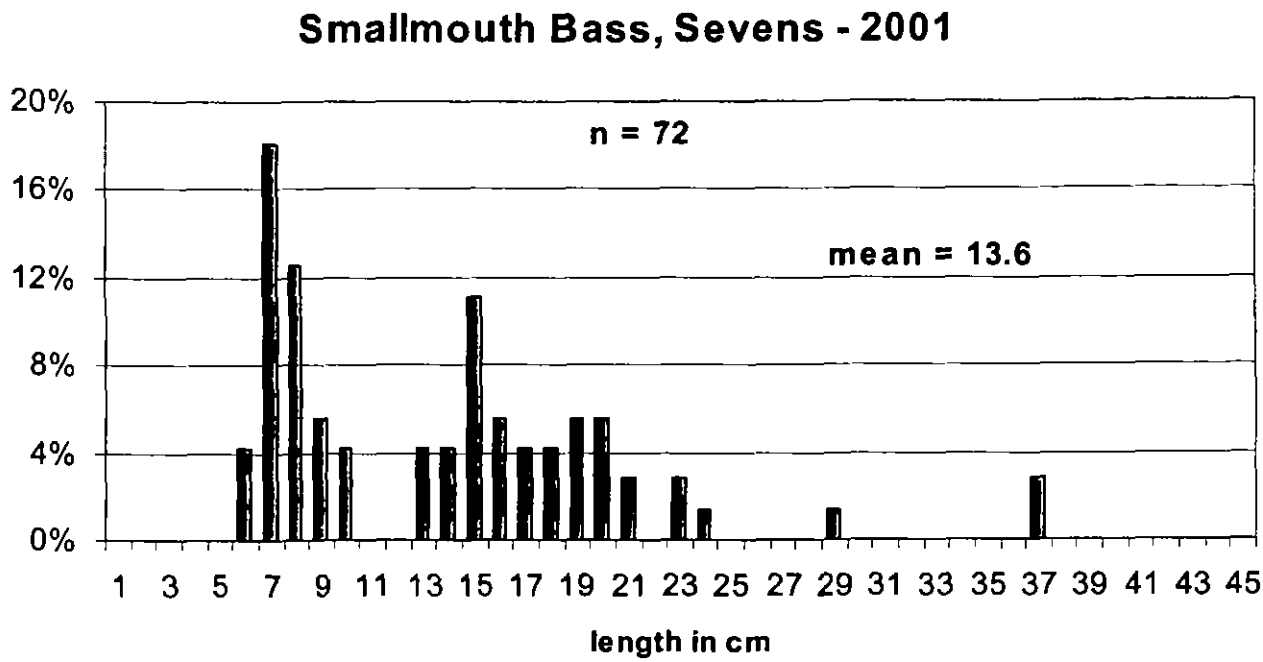

Figure A45. Smallmouth Bass length frequency at the Sevens site, August 2001 Yampa River.

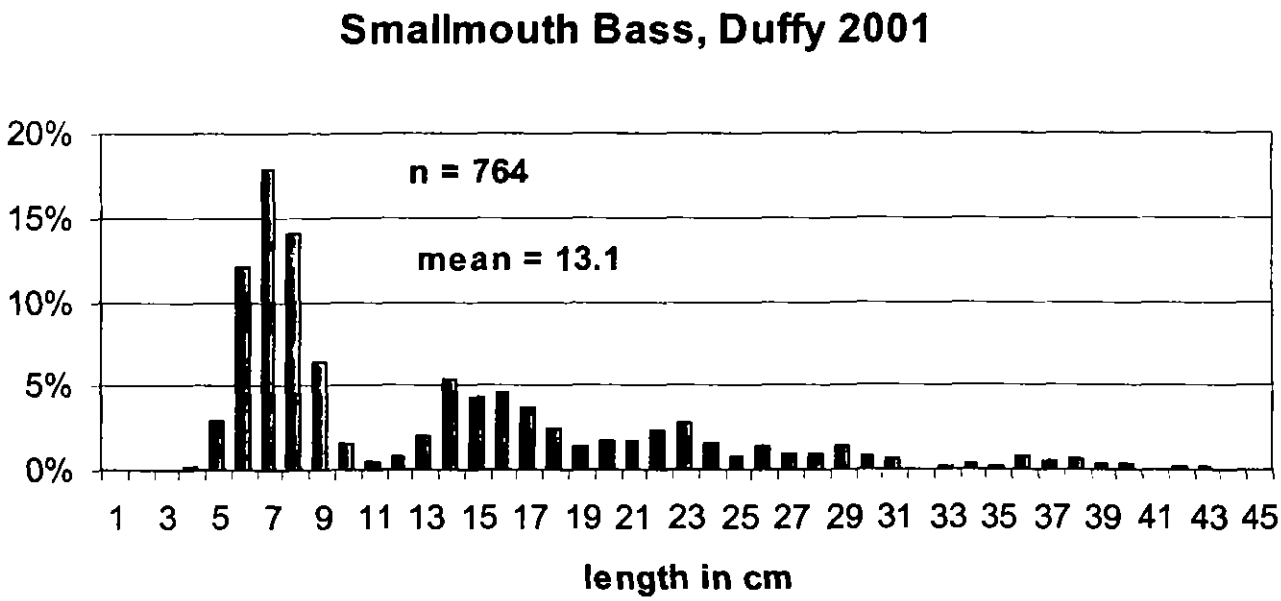

Figure A46. Smallmouth Bass length frequency at the Duffy site, August 2001 Yampa River.

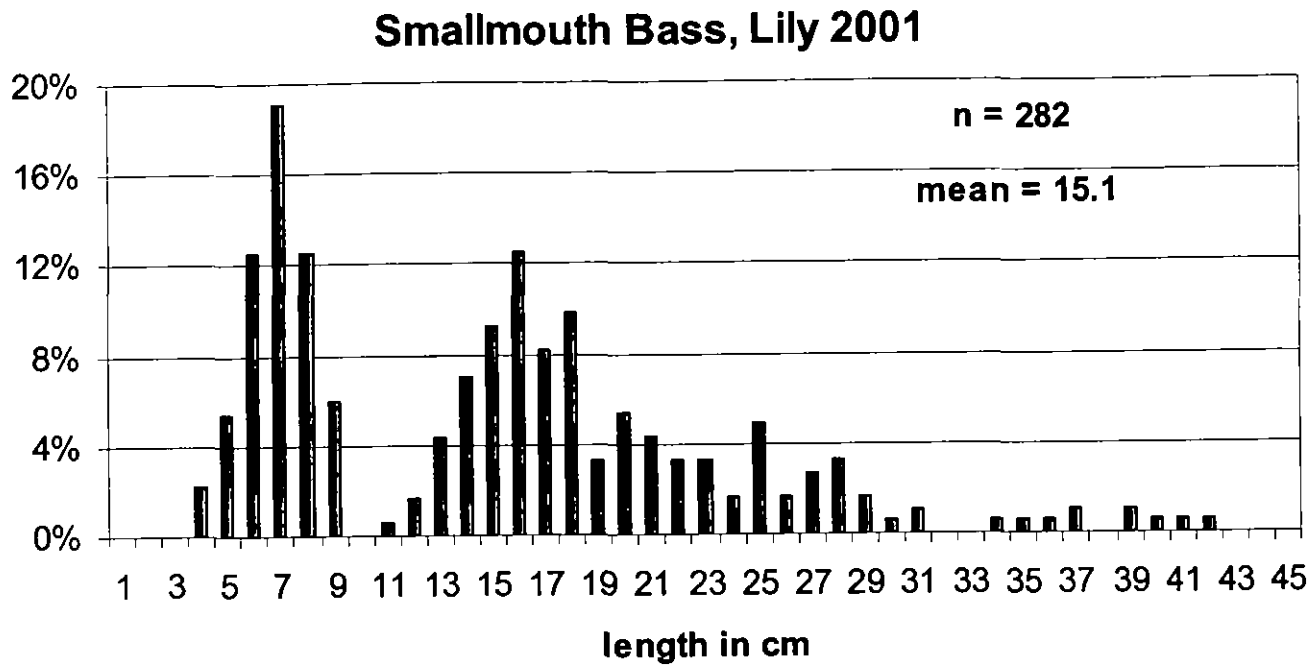

Figure A47. Smallmouth Bass length frequency at the Lily Park site, August 2001 Yampa River.

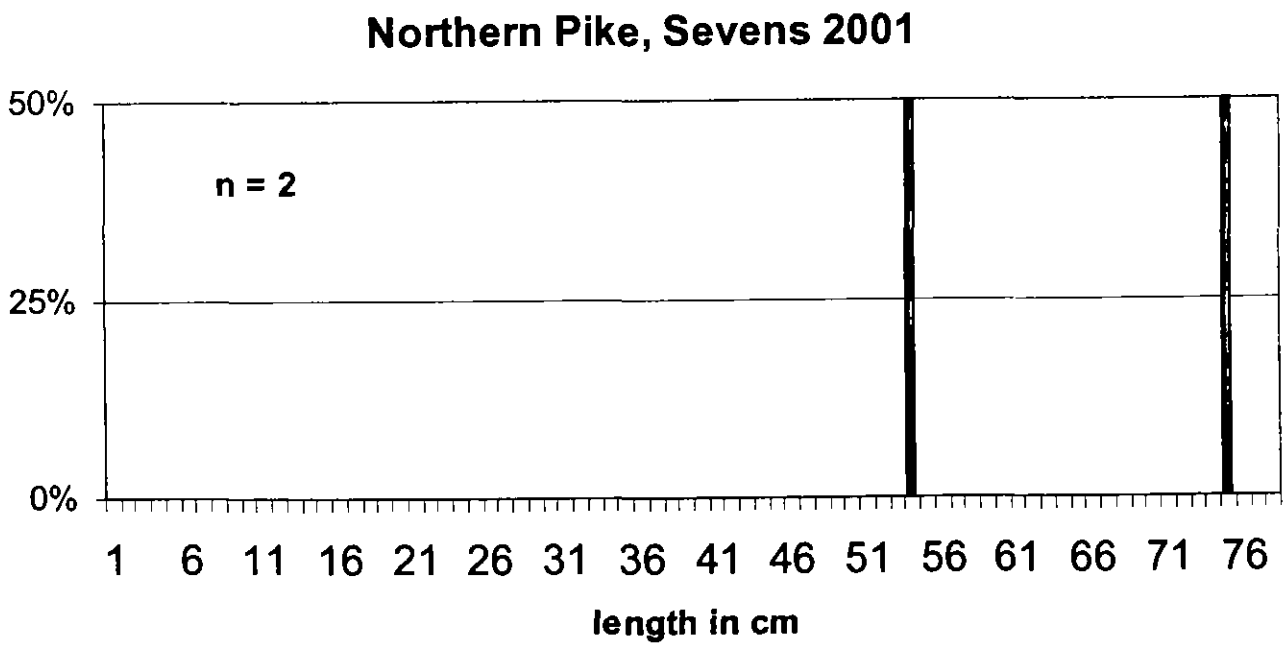

Figure A48. Northern Pike length frequency at the Sevens site, August 2001 Yampa River.

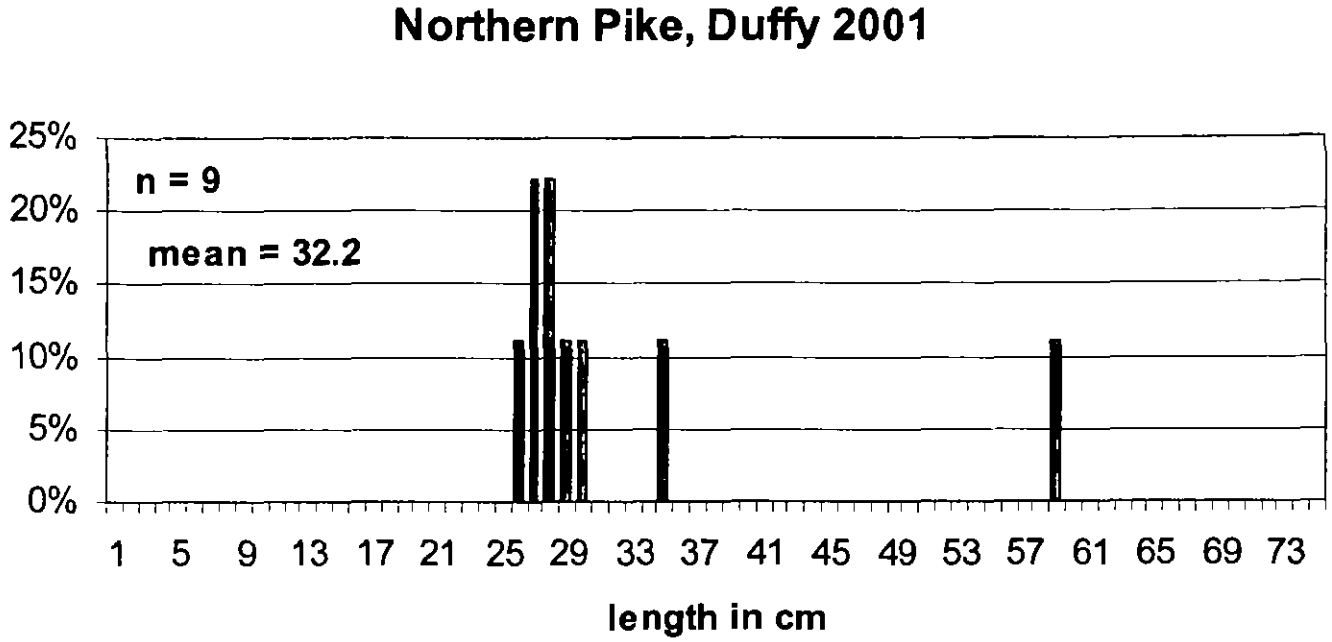

Figure A49. Northern Pike length frequency at the Duffy site, August 2001 Yampa River.

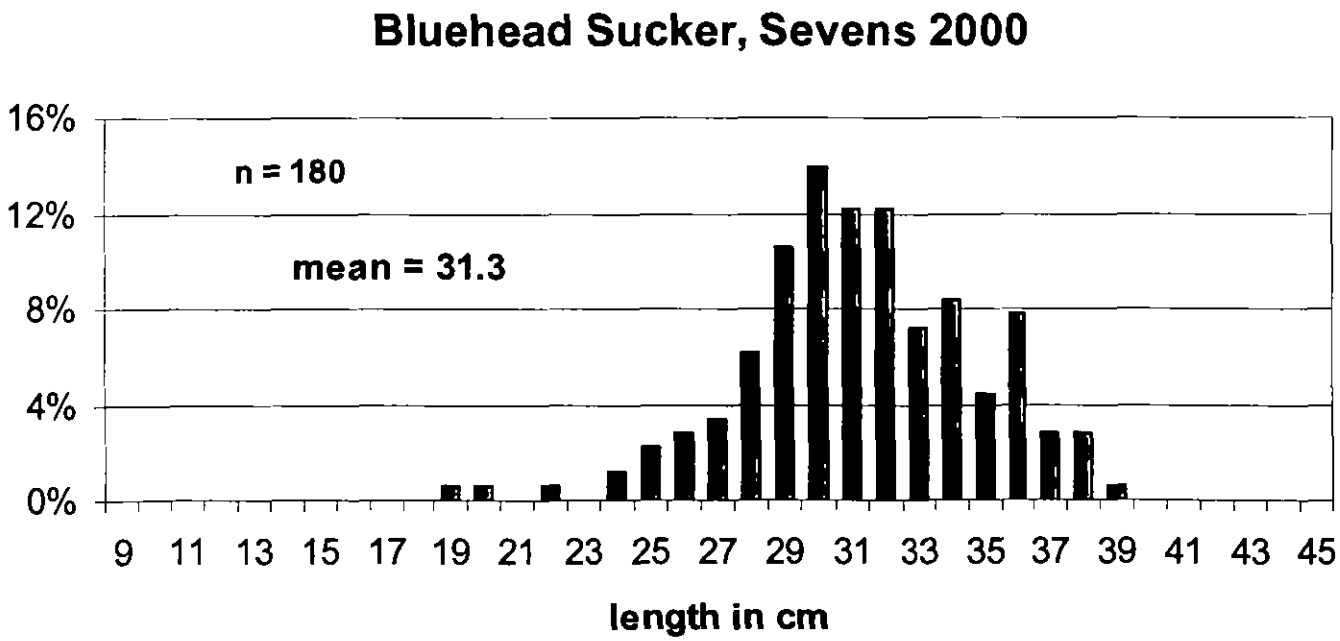

Figure A50. Bluehead Sucker length frequency at the Sevens site, September 2001 Yampa River.

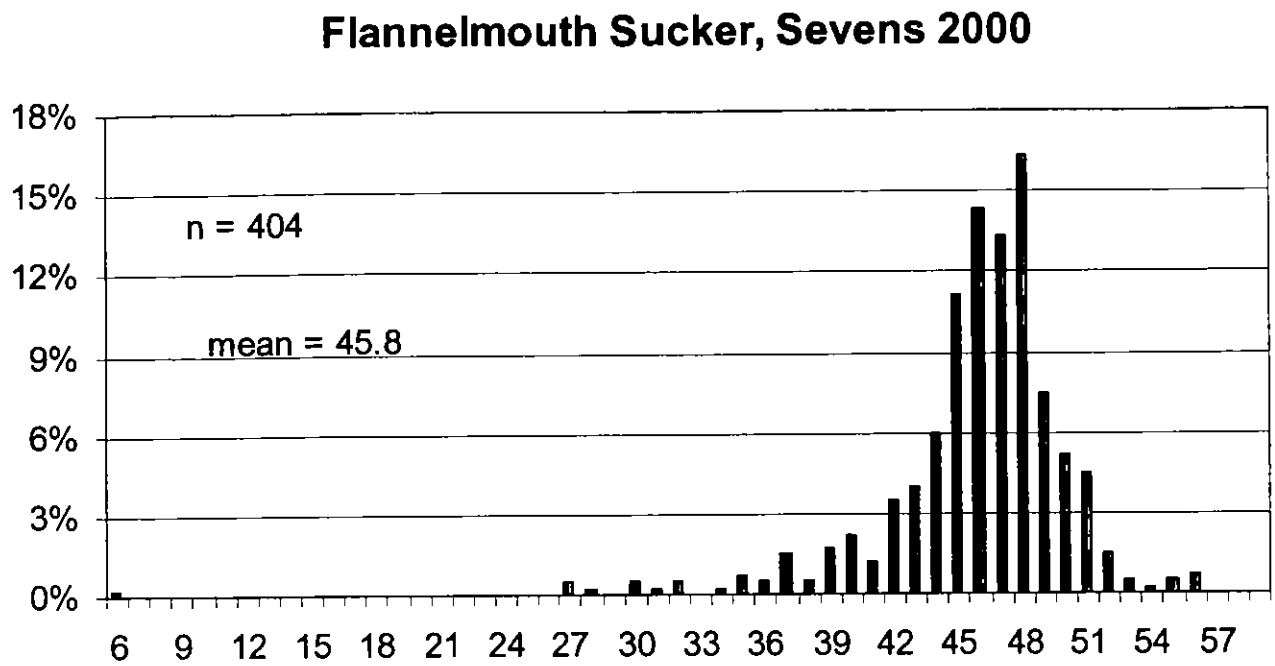

Figure A51. Flannelmouth Sucker length frequency at the Sevens site, September 2001 Yampa River.

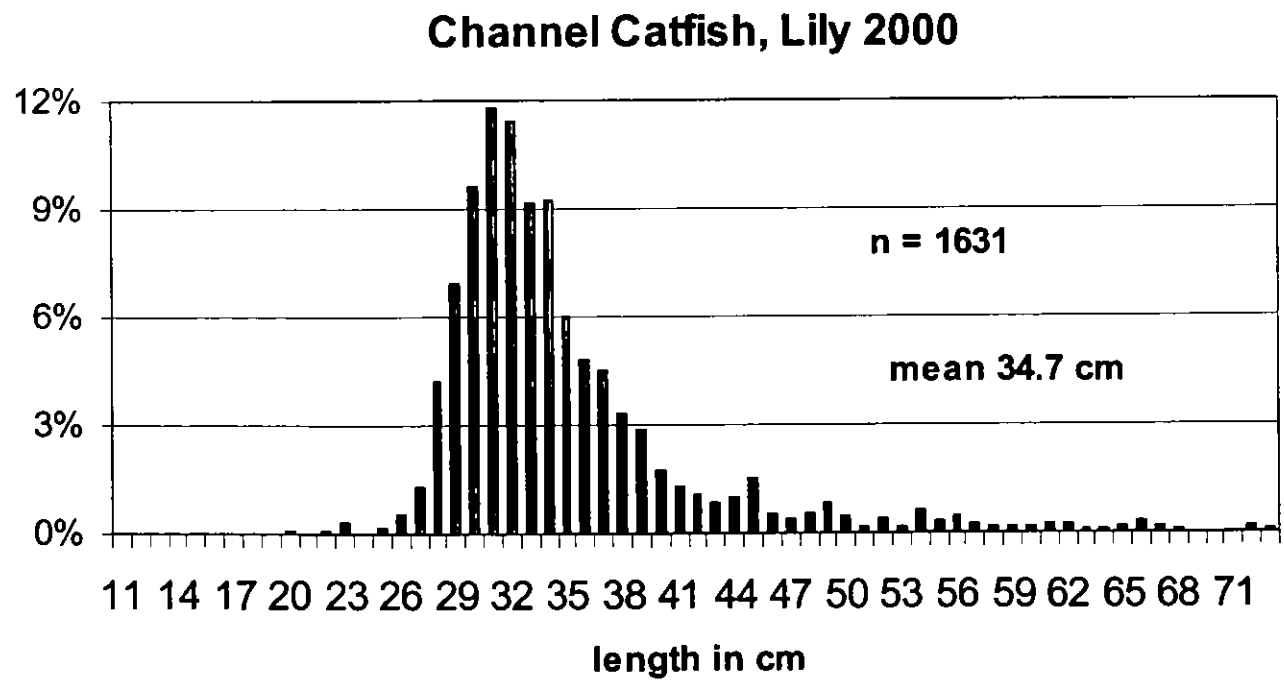

Figure A52. Channel Catfish length frequency at the Lily Park site, September 2001 Yampa River.

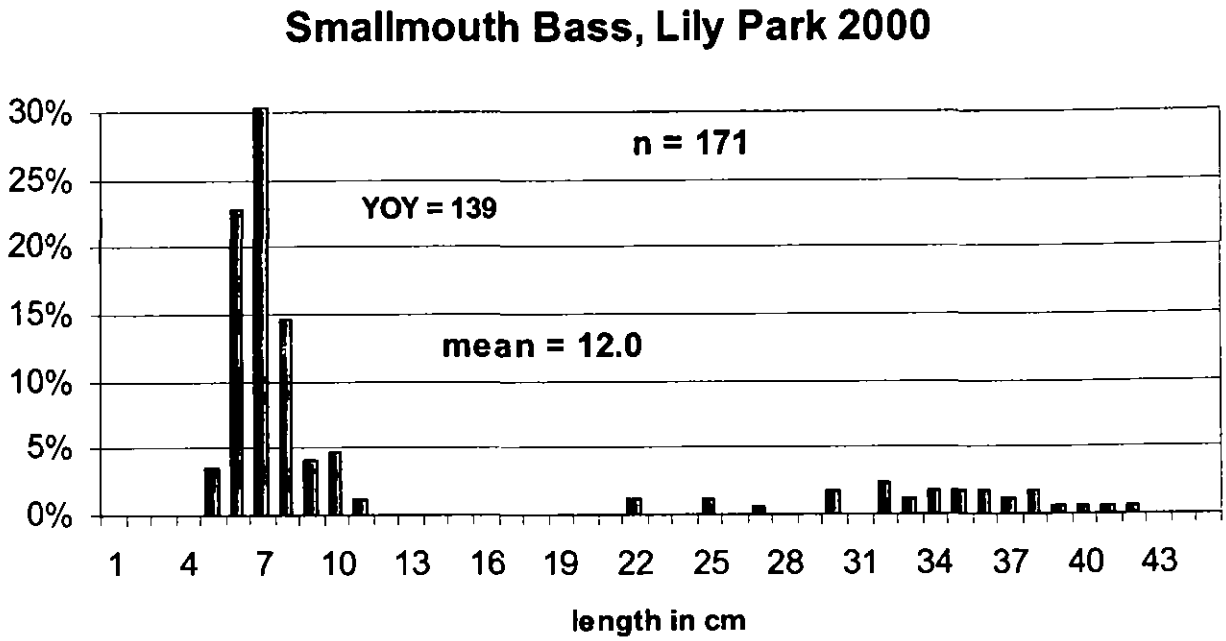

Figure A53. Smallmouth Bass length frequency at the Lily Park site, September 2001 Yampa River.

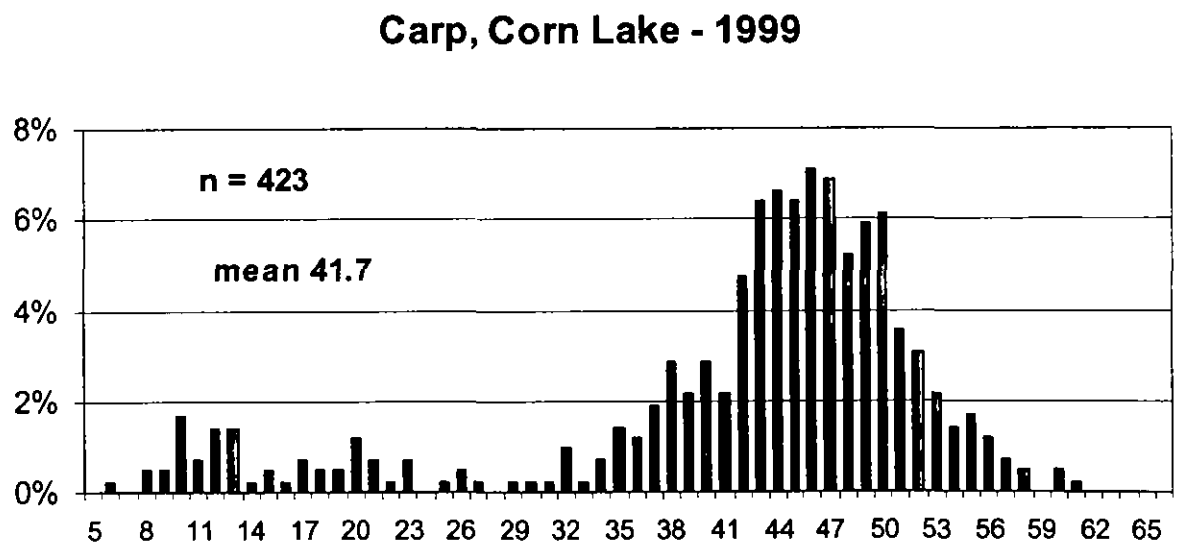

Figure A54. Carp length frequency at the Corn Lake site, September 1999, Colorado River.

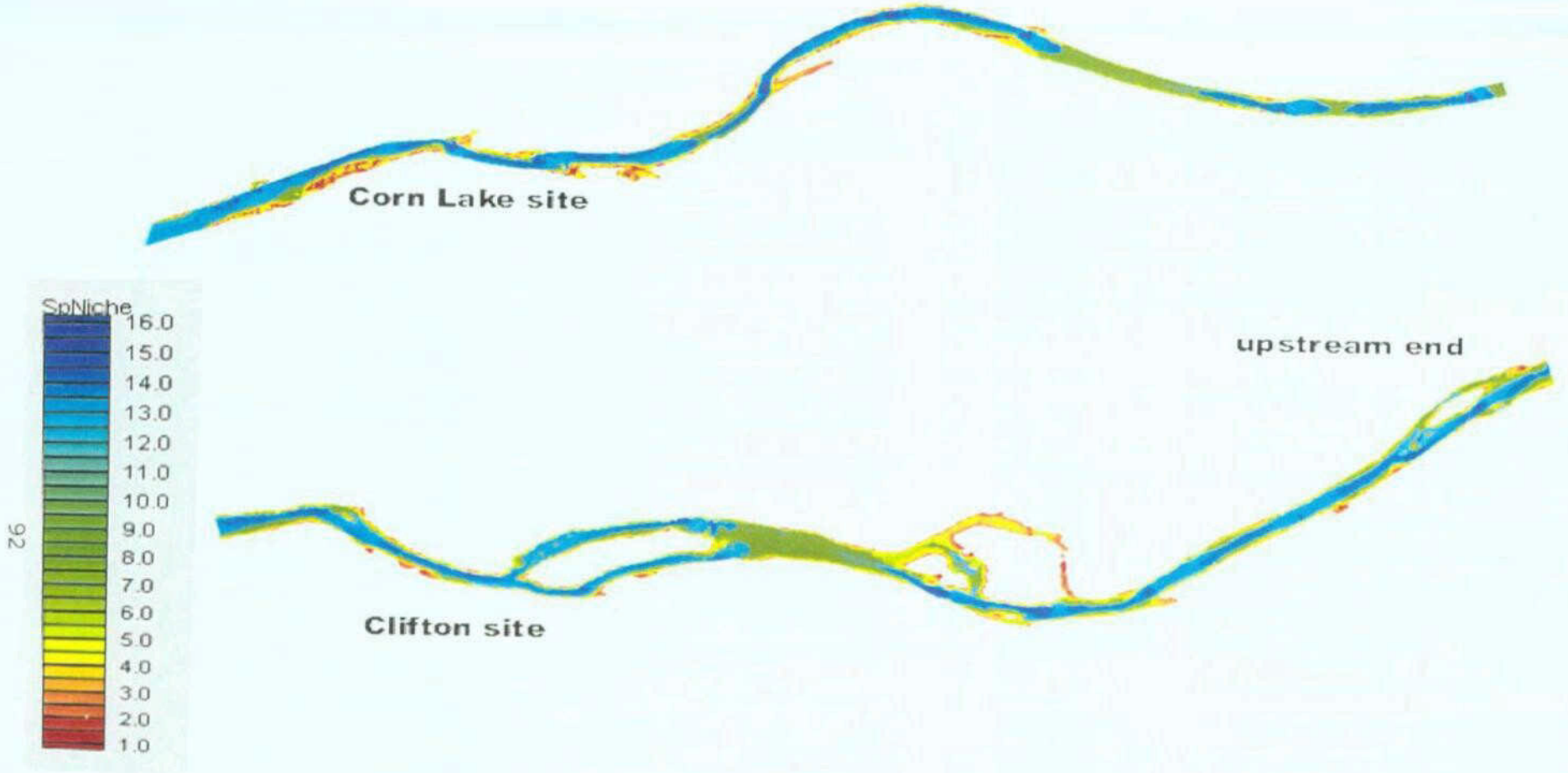

Figure A.55: Channel configuration with display of meso-habitat distribution in the Corn Lake study site (upper) and the Clifton study site (lower), Colorado River at a flow of 1,000 cfs.