Riverine Fish Flows Investigations

Federal Aid Project F-289–R4

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Job Progress Report

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Title: Riverine Fish Flow Investigations

Period Covered: July 1, 1997 - June 30, 2002

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 model. 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 microhabitat suitability curves used by IFIM, and also improve biological resolution of the method. Presently, however 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 original intent of this study is to develop and validate a methodology for determining instream flow recommendations for warm water fish communities in Colorado (Anderson 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.

A new study goal was added in 1999 to submit instream flow recommendations for the Yampa River and Colorado River in the 15-Mile Reach to the Colorado Water Conservation Board (CWCB), with biological justifications for water right filings in those rivers, by August 2002. The CWCB withdrew water rights filings made in 1995 for these rivers. 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)]. In a more recent study Modde et al. (1999) used an infection point method to assess minimum stream flow needs for Colorado pikeminnow (*Ptychocheilus lucius*) on the Yampa River. Even though the intent of these studies was the same, to determine stream flow requirements for endangered fish, the methods in each study were different. The CWCB expressed a desire to have a more standardized approach for instream flow filings and it is hoped that recommendations using this approach will be acceptable to agencies involved with endangered species recovery.

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

A new study site was added to the Yampa River in 2000 increasing the total number of study areas to three. The two sites established in 1998 are Sevens and Duffy and are described in earlier reports. The Sevens station is located at River Mile (RM) 63 and Duffy is

at River Miler (RM) 109 (Figure 1). These two sites were electro-fished in 1998, 1999 and 2000 and the habitat was mapped in 1999. The new study site was located at Lily Park, which is 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. The Cross Mountain Ranch is the landowner for most of the river in this section. The Lily Park site was added because fish and habitat in this section of the river differs from the two upstream sites. Data collected by the Recovery Program indicated that this section of river has a high composition of native fishes.

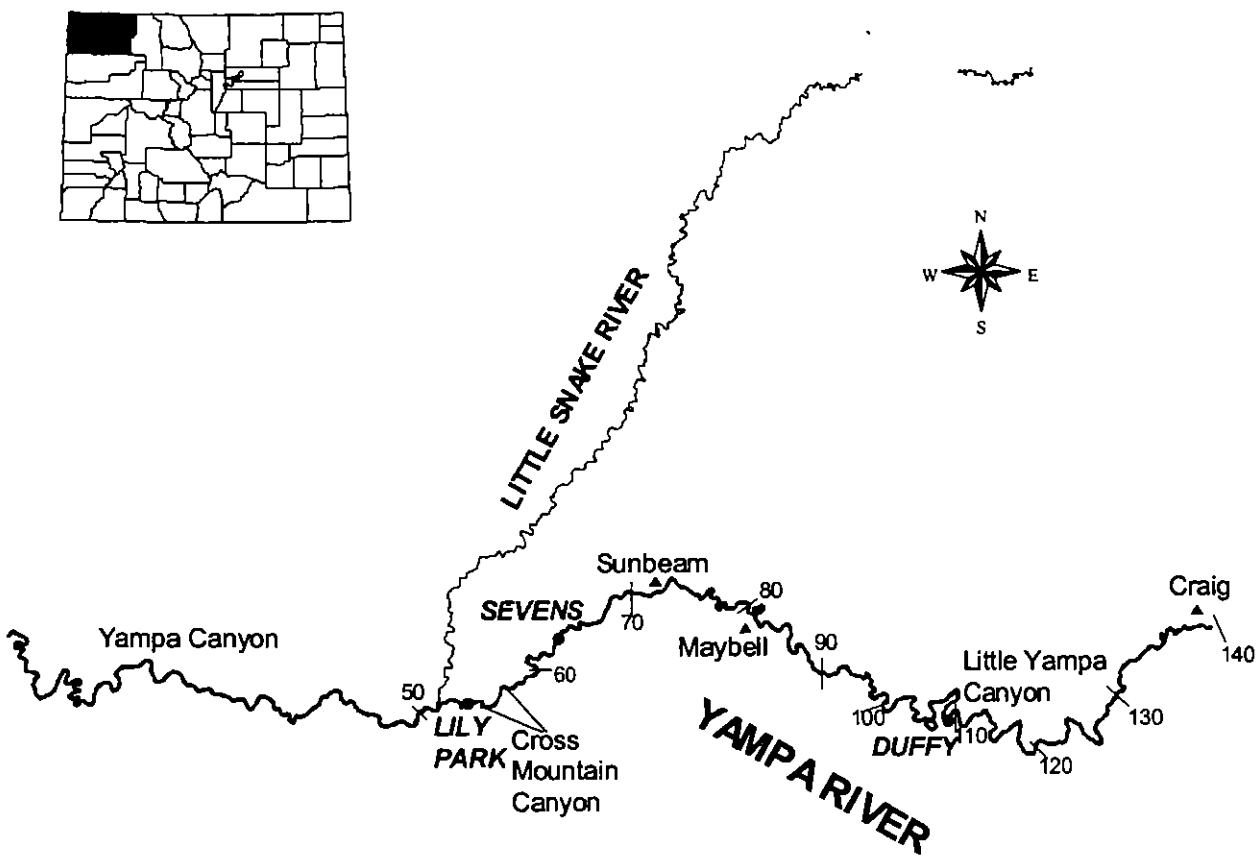

Figure 1. Location of the three study sites for the Yampa River, Lily Park, Sevens and Duffy.

Spring and peak flows recorded at the Maybell gage were fairly similar for the years 1998, 1999 and 2000, with peak flows of 10,040 cfs, 9,980 cfs and 9,830 cfs, respectively (Figure 2). Also since the median peak flow for the period of record for the Maybell gage (84 years) is 10,000, these three years are in the range of a normal peak flow. The 2000 spring hydrograph dropped fast and by mid June flows were well below those of the two prior years (Figure 2).

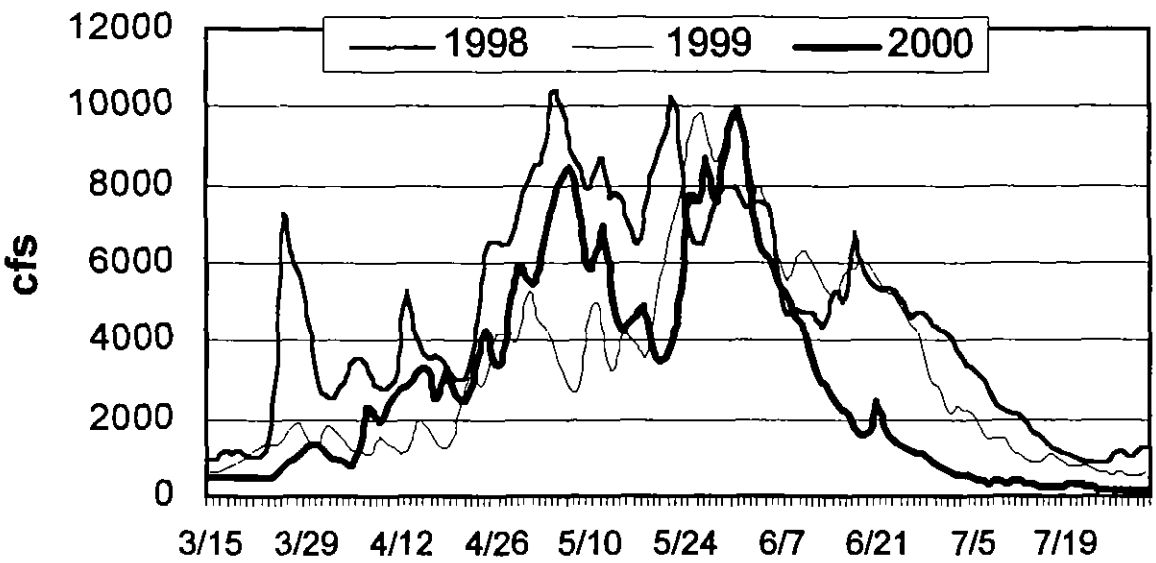

Figure 2. Mean daily flow between March 15 and July 31 at the Maybell gage, Yampa River for 1998, 1999 and 2000.

Summer flows were below normal in 2000 which provided an opportunity to sample the river under different flow conditions than the two prior years, which were near normal (Figure 3). The minimum flow in 2000 was 30-cfs compared to 166 cfs in 1999 and 115 cfs in 1998. The median minimum summer flow for the period of record is 128 cfs. The 10-day minimum flow (tenth lowest during the summer) in 1998, 1999, and 2000 was 170 cfs, 212 cfs, and 50 cfs, respectively with a median condition of 153 cfs. Flow was below 93 cfs

reference flow for 0, 0, and 34 days in 1998, 1999 and 2000. The 93 cfs reference flow was identified by Anderson (1997) and Modde et al (1998) as a minimum flow needed to avoid severe habitat degradation in the Yampa River.

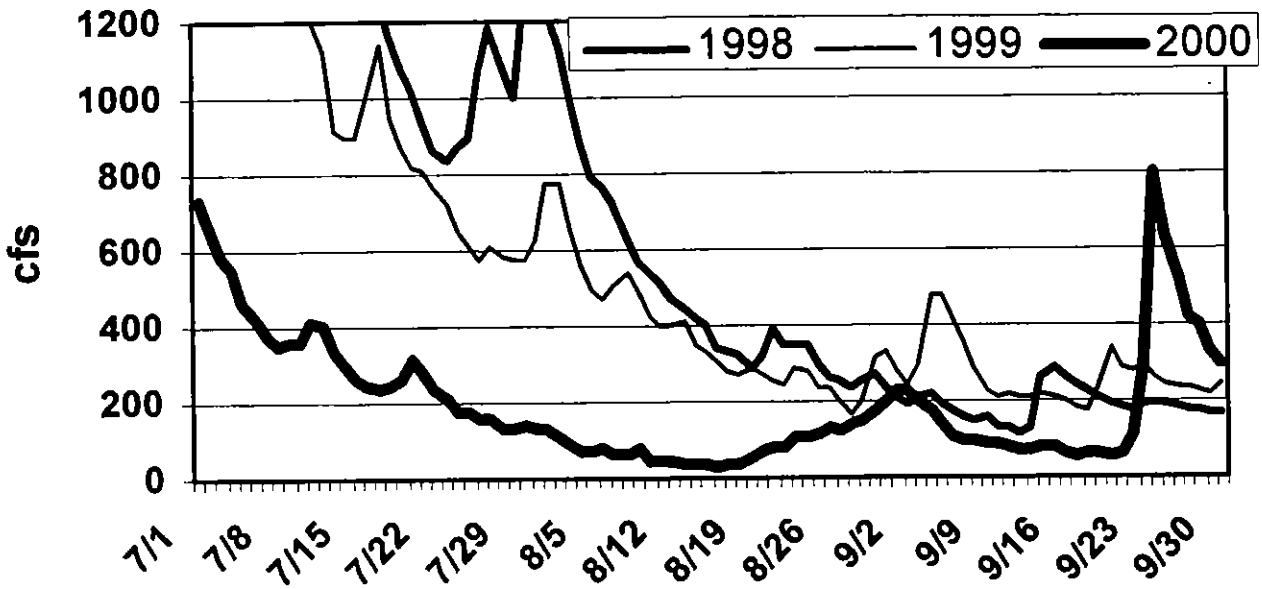

Figure 3. Mean daily flow between July 1 and October 15 at the Maybell gage, Yampa River for 1998, 1999 and 2000.

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). A reach description with hydrographs representing flow records of the Palisade gage was given in last years' progress report (Anderson and Stewart 2000). The 15-Mile Reach study site established in 1999 was located from the 32 road bridge, from the boat launch at Corn Lake at RM 177.5 downstream to RM 175.3 (Figure 4). This station is now referred to as the Corn Lake Site. The length of this station was 4.0- km with an average width of 55.2 m at a flow of 1400 cfs. Stream width in last year's report was given as 100 m, but that is nearer the

bankfull flow. The river in this section includes 5 small backwaters, and flow was generally confined within the main channel.

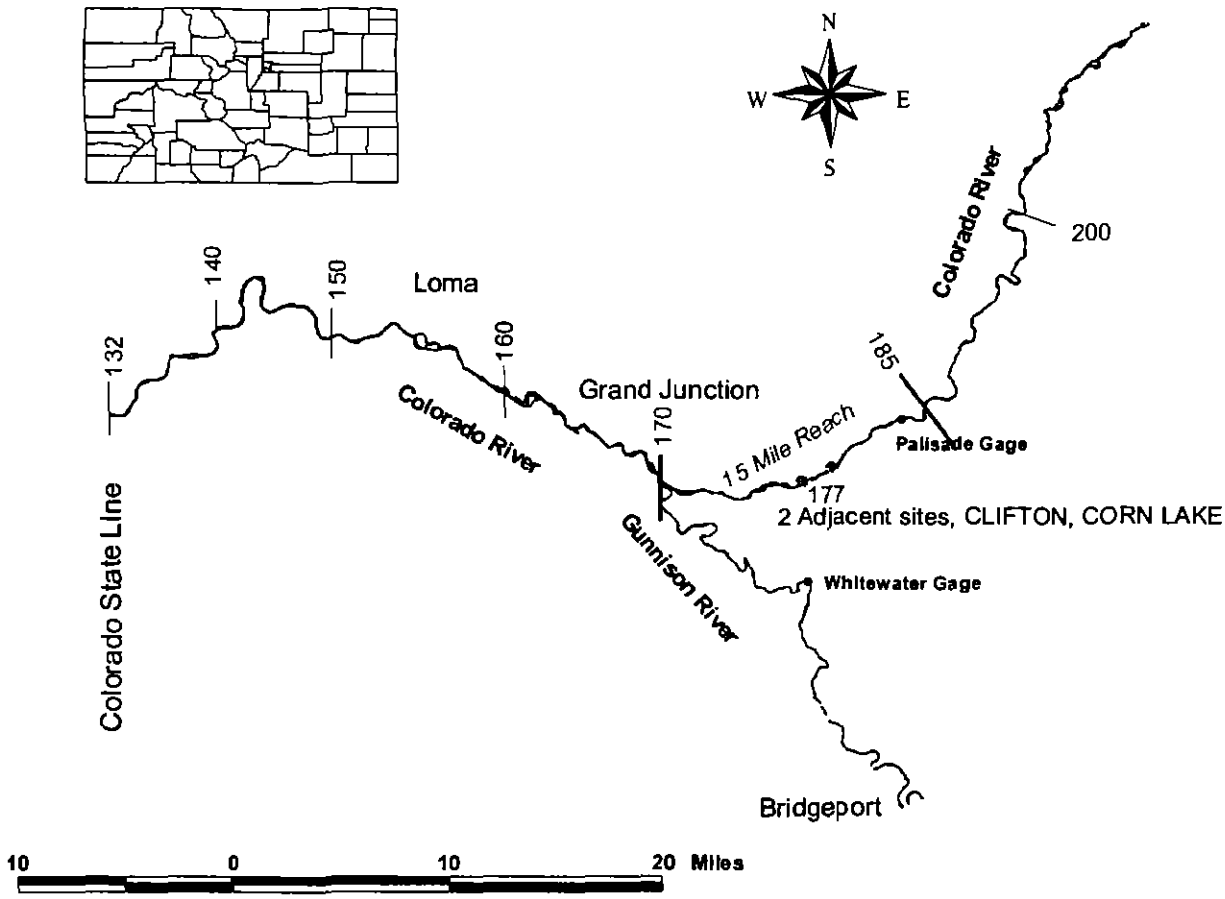

Figure 4. Location of the two study sites in the 15-Mile Reach, Colorado River, Corn Lake and Clifton.

An addition study site was added in 2000 and is known as the **Clifton Site**. This station is just upstream and a short section of river separates it from the Corn Lake station. The new site is from RM 177.7 to 180.4. In this section the river has split flow in two sections of the channel and there is an old diversion structure located at RM 179.7. This structure forms a large backwater upstream along the north shoreline, but small backwaters are not common in this site.

The peak flow for the Palisade gage in 1999 was 12,700 cfs on June 10 and in 2000 the peak flow was 13,500 cfs on May 31. The median peak flow for the 10-year Palisade gage history is 13,950 cfs indicating that peaks for these two years were near normal. In 1999 flows during the ascending limb (April and May) of the hydrograph dropped to 435 cfs on April 15 1999 and was the minimum flow for the year. 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. The minimum spring flow in 2000 was 1,110 cfs on April 5th, and this was also lower than the March flows. In the year 2000, flows quickly dropped and flows in June were lower than in 1999 (Figure 5).

Summer flows were also below normal in 2000 on the Colorado River in the 15-Mile Reach. As was the case for the Yampa River, the flows in 2000 provided an opportunity to sample the fish population under lower than normal flow conditions. The summer minimum flow in 2000 was 530 cfs compared to 1180 cfs in 1999 (Figure 6). The median minimum flow during summer for the period of record (10 years) is 686 cfs. Osmundson (1995) recommended a minimum flow of 810 cfs for the Colorado River in the 15-Mile Reach. Flows were below 810 cfs 0 days in 1999 and 35 days in 2000.

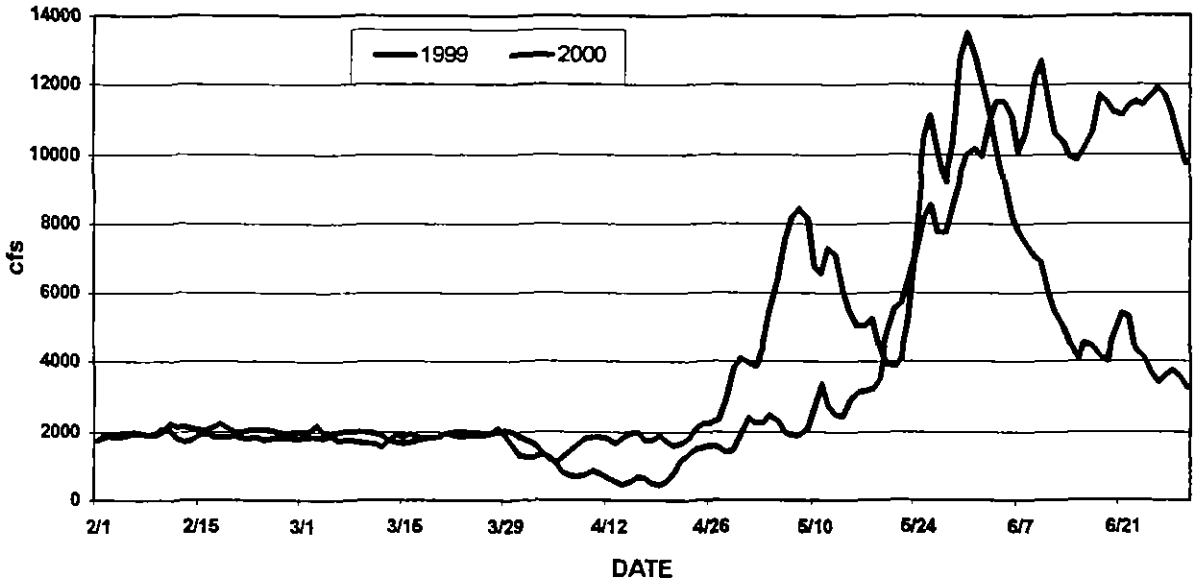

Figure 5. Mean daily flows recorded at the Palisade gage, Colorado River in 1999 and 2000 between February 1 and June 30.

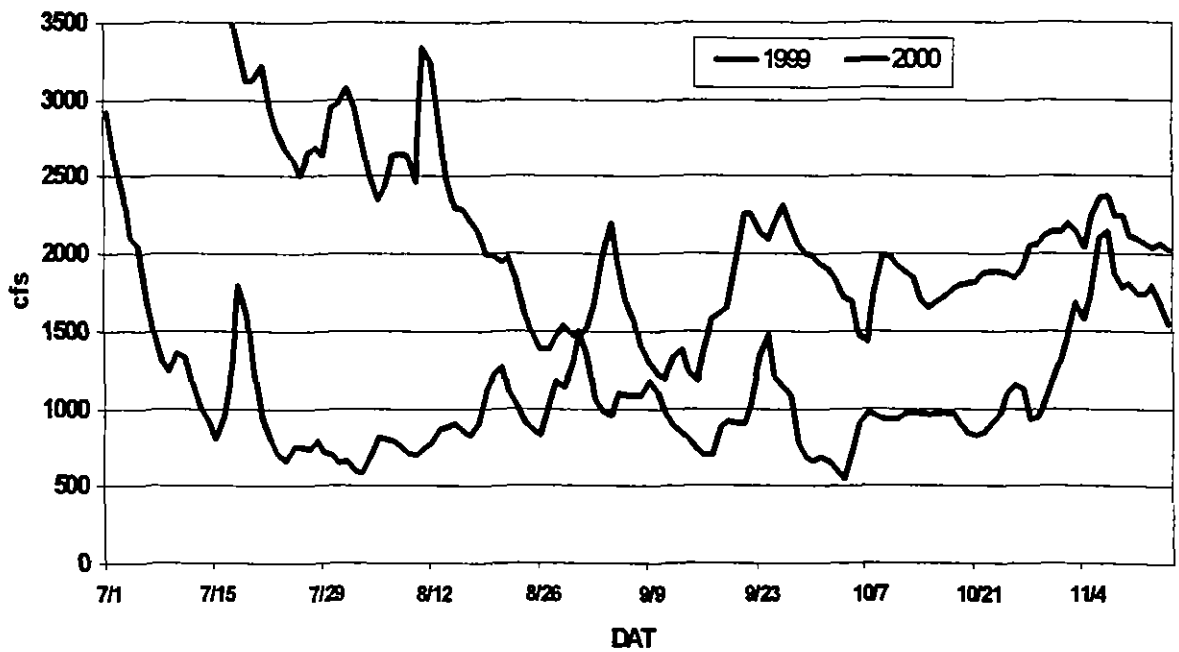

Figure 6. Mean daily flows recorded at the Palisade gage, Colorado River in 1999 and 2000 between July 1 and November 15.

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 acre 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 guide (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 be presented in the next progress report.

METHODS

Fish Samples

Fish were electro-shocked and netted from an Achilles raft using a Smith-Root electro-fisher powered by a 5000-watt generator with the anode mounted on a forward boom. 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 150mm 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 estimate abundance with ninety-five percent confidence intervals.

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 later in 2000 than previous years because flows were too low to float the shocking boat during most of September. In general it was found that the boat could be floated for most of the river at flows over 150 cfs. Flows under 120 cfs are problematic for electrofishing due to long reaches of shallow habitat. Flow was down to 65 cfs on September 21, but rose to 797 cfs on September 24, following 2 days of rain (Figure 3). Most sampling was completed after that.

Three mark and recapture electrofishing passes were made at Sevens on the Yampa River in 2000 on September 28, October 4 and 9 and mean daily flow on those dates (Maybell gage) were 400 cfs, 240 cfs, and 210 cfs, respectively. Three passes were made for the entire station at Duffy on September 12, 26 and October 10 and flows on those dates were 69 cfs,

518 cfs, and 206. The upper deep run directly upstream of the launch site were electro-fished on September 11, 19 and 25 at flows of 79 cfs, 57 cfs, and 632 cfs, respectively. The lower half of Lily Park was electro-fished on September 13 at a flow of 70 cfs. The upper half of the station is dominated by riffles and the flow was too low to float the boat prior to September 24. The lower half of the station is deep runs or pools separated by short riffles. The complete Lily Park site was sampled on September 27, October 3 and 5, at flows of 420, 260 and 216 cfs, respectively. The number of polygons for the Yampa River sites at Duffy, Sevens and Lily Park was 12, 12 and 16, respectively.

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 along the right shoreline, left shoreline and mid river to order to be more site specific with fish distribution. There are a higher number of polygons on the Colorado River. In 2000 there were 35 polygons on the Corn Lake site and 50 at Clifton.

Six electrofishing passes were made on each study site in the 15-Mile Reach, in general two samples for each polygon. The dates and the flows (cfs) of the fish sampling at Corn Lake were 8/15 (903), 8/17 (821), 8/22 (1,110), 8/24 (907), 9/5 (1,100), and 9/8 (1,090). The dates and the flows (cfs) of the fish sampling at Clifton were 8/16 (853), 8/18 (902), 8/23 (1,020), 8/25 (856), 8/30 (1,290), and 9/6 (1,080). 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 2000. On July 11, 12 and 13 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 sampled for the second time on July 18 and 19. Block nets were not used on the third and fourth samples made on July 20 and July 27. 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 2000, bathymetric surveys of the channel were taken at four sites using the Global Positioning Systems (GPS) and sonar technology. This technique, described in detail in the 2000 progress report (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.

2000 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 sample 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 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. Bathymetric data was collected using the same boat, GPS and sonar equipment in both years. Shoreline and water surface shots were made using the Psion data collector running Field Face software. The waterline was surveyed on October 30 and 31, 2000

2000 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 2.8km 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. A wide and shallow riffle near mid station could not be surveyed by boat and had to be 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 Colorado River, Clifton study site

A new study site was established in the 15-Mile Reach of the Colorado River, known as 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 site surveyed in 1999, which is now called the Corn Lake station (last year 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 shots were made on August 1, 2 and 3 and another set on Jan 23, 24, 25 and 26, 2001.

2000 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 which hampered data collection using 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.

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 requires 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 last years report.

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 that described in the 2000 report (Anderson and Stewart 2000). It involved using an Excel macro written by Mr. Stewart that stripped out nonsensical or incomplete points and the remaining points are to be used in the final survey. The macro eliminates 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, input the data for hydraulic modeling and performed the analysis during the time period June of 1998 to June 2000. Last years progress report and the M.S. thesis authored by Mr. Stewart details 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. For documentation on modeling techniques refer to those reports.

Greg Stewart was instrumental in installation and operation of technical equipment and data handing for the 2-D modeling and his departure from the project meant no new 2-D modeling until a replacement contractor was found. An attempt to instate a new contract (sole source) to continue hydraulic simulations in 2000/20001 fiscal year failed, therefore only

limited progress has been made this year for modeling the four new study sites. In January 2001 a competitive bid process was initiated to find a contractor with the necessary expertise to proceed with the hydraulic simulation. A contract should be in place by July 2001. At that time analysis of the 2000 bathymetric data can continue.

The impact of switching contractors mid project has been significant. Not only was time lost in modeling but the new contractor will have a learning curve in order to get familiar with prior work, the data processing steps and local field/hydraulic conditions. Mr. Stewart conducted the field surveying, data reduction and the modeling. It is now required that the principal investigator will have to spend much more time in these activities. New study sites will not be added to the project until all existing sites have been modeled. This necessitates new techniques evolve for producing flow simulations needed to map fish habitat. It may be that these functions could be performed in-house in the future and therefore these changes may result in a more efficient data collection and processing in the future.

Habitat Availability

An objective of this study is to determine if consistent trends 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 on impacts of flow on habitat availability. Pools, runs, riffles and rapids are the broad 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 relative constant in 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 fish. 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 1. Depth and velocity criteria used to define meso-habitat types.

Habitat Types	Depth (m)	Velocity (m/s)
Wetted sand	0.01 - 0.2	< 0.15
Shoal pool	0.2 - 0.5	< 0.15
Shallow pool	0.5 - 1.0	< 0.15
Medi –pool	1.0 - 2.0	< 0.15
Deep pool	> 2.0	< 0.15
Wetted run	.01 - 0.2	0.15 - .6
Shoal-run	0.2 - 0.5	0.15 - .6
Shallow run	0.5 to 1.0	0.15 - .6
Medi-run	1.0 to 2.0	0.15 - .6
Deep run	> 2.0	0.15 - .6
Shallow riffle	< 0.2	0.6 - 1.5
Riffle	0.2 to 0.5	0.6 - 1.5
Deep riffle	0.5 to 1.0	0.6 - 1.5
Very deep riffle	> 1.0	0.6 - 1.5
Shallow rapid	< 0.5	> 1.5
Deep rapid	> 0.5	> 1.5

RESULTS AND DISCUSSION

YAMPA RIVER FISH SAMPLES

Species Composition – Duffy and Sevens 1998 to 2000

A high degree of consistency was found in species composition of fish over 15 cm captured by electrofishing between the three year period *1998, 1999* and *2000* at the Sevens and Duffy sampling stations (Table A1). Flannelmouth suckers varied between 46% and 50% of the catch at Sevens but were only 5% at Duffy. Bluehead sucker was between 18 and 22% at Sevens, while only 4 to 6% at Duffy. Roundtail chub were fairly similar between sites with 4 to 6% of the catch at Sevens and 3 to 4% at Duffy. Colorado pikeminnow were only 0.2% of the catch at Sevens, but ranged from 0.6 to 1.5% at Duffy. Native fish were more common at Sevens and were 72% in 1998 and 68 % in 1999 and 76% in 2000. At Duffy native fish comprised only about 14% of the fish population in all three years.

The most common fish at Duffy in all three years was white sucker and white sucker hybrids (white x flannelmouth and white x bluehead cross). The white sucker with crosses comprised between 69 and 73% of the catch at Duffy, compared to 13 to 17% at Sevens for the three-year period (Table A1). The next most common fish at Duffy was another non-native species, smallmouth bass ranging from 6% to 10% over the three years.

The consistent or stable species composition at these two sites with three years of fish data (Table A1) suggests composition is a likely a function of habitat availability of these areas. The discrepancy in species composition of smallmouth bass between Duffy and Sevens strongly appears to be a function of channel morphology or habitat since both sites have similar physical conditions for flow and temperature. Nesler (1995) proposed it was reasonable to assume normal runoff flows would be adverse enough to prevent stable recruitment of smallmouth base in the Yampa River. This may be correct at Sevens, but large

numbers of YOY smallmouth bass were collected in each year at Duffy with similar counts between years with higher and lower runoff flows. 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 felt the extreme low flows he observed could be beneficial to the native fish population because nonnative fish were not common in his study sites. His conclusions for the Little Snake are not consistent with results of this study. In the Yampa River species composition was similar in the years with low base flow compared to the other years indicating non-native fish survival is comparable to native fish under flows experience between 1998 and 2000. The data do not indicate that peak or minimum flows have hampered or repressed abundance of most nonnative fish species in the Yampa River.

The Duffy station, because of its low composition of native fish, does not appear to be a suitable site for making inferences about habitat use by native fish. When the Duffy study site was selected it was believed to be representative of the Yampa between Juniper and Craig for both fish and habitat composition. However it appears that competition and predation are influencing population structure at this site (and river reach) independent of habitat composition. Because of this it was necessary to add a new site on the Yampa River, one with a higher native fish composition. So in 2000 a site was added at Lily Park.

Species composition was more variable between years for fish under 15 cm for the 1998 to 2000 period (Table A2). Sand shiners were the most common small fish at Sevens in all three years, but smallmouth bass was most common at Duffy. In the year 2000, there was noticeably fewer native species in the sample, only 3% at Sevens and 6% at Duffy. Very few speckled dace and mottled sculpin, both species generally associated with riffle habitats, were observed or collected at both stations in 2000 compared to 1998 and 1998. This indicates

these native fish may be less tolerant of low base flows (those observed in 2000) than nonnative cyprinids.

Species Composition – 2000

Species composition was highly variable between the three stations (Lily Park, Sevens and Duffy) sampled in 2000. Lily Park had by far the largest sample size, with 4058 fish handled in four passes (Table 2). The most common species in Lily Park was flannelmouth sucker, which comprised 48% of the total catch of fish >15 cm. The next most common fish was channel catfish, which was 40% and the third most common species was bluehead sucker at 9%. Because of the very high number of flannelmouth sucker and channel catfish at Lily Park, the percentage of other species such as smallmouth bass, carp, northern pike and Colorado pikeminnow were smaller than at other stations, relative to numbers caught. White sucker were rare and only one roundtail chub was caught in Lily Park (Table 2).

Species composition was found to vary between electrofishing passes at Lily Park (Table 3). On the first pass only the lower half of the site was sampled, on September 13 at a flow of 70 cfs, flannelmouth were 74% of the total fish captured. At 70 cfs most flannelmouth were confined in deeper non-flowing habitats and sampling efficiency was felt to be very high. Subsequent passes were made for the entire station at flows of 420, 260 and 216 cfs, respectively. The second pass was made at a high flow and was also the first time the entire reach was sampled. Under these conditions channel catfish were the most common fish and percent composition of bluehead sucker increased. Species composition was fairly similar for the third and fourth passes (Table 3).

Table 2. Species composition for fish **Over and Under 15 cm** caught in the **Yampa River** in September, October 2000.

	LILY PARK 2000	**SEVENS** 2000	**DUFFY** 2000	**LILY PARK** 2000	**SEVENS** 2000	**DUFFY** 2000
Species	**>15cm**	**>15cm**	**>15cm**	**<15cm**	**<15cm**	**<15cm**
Flannelmouth Sucker	47.8%	49.8%	5.0%		0.22%	
Bluehead Sucker	8.5%	22.2%	3.5%	1.7%		
Roundtail Chub	0.02%	3.8%	3.6%			
Colo. Pikeminnow	0.07%	0.2%	0.8%			
White sucker	0.15%	10.6%	23.0%			
White X Flannelmouth	0.12%	6.0%	40.5%			
White X Bluehead	0%	0.4%	9.0%			
White S. + Crosses	0.27%	17.0%	72.5%	0.6%	25.9%	5.8%
Channel Catfish	40.2%	1.9%	3.2%			
Carp	2.1%	3.8%	0.8%	0.6%		0.6%
Smallmouth Bass	0.8%	0.5%	9.6%	79.9%	14.3%	83.5%
Northern Pike	0.2%	0.2%	0.9%			
White Crappie	0%	0.1%	0%			
Mottled Sculpin				10.3%		4.7%
Speckled Dace				1.7%	2.4%	1.2%
Sand Shiner				5.2%	56.9%	1.3%
Fathead Minnow					0.22%	
Creek Chub						2.7%
Green Sunfish						0.3%
Sample size	4058	810	1294	174	455	937
Recaptures	324	93	250			

Table 3. Species composition for **fish >15 cm** by electro-fishing pass at **Lily Park**, 2000.

	First	Second	Third	Fourth
Flannelmouth sucker	74%	32%	50%	44%
Bluehead sucker	2%	9%	11%	9%
Channel catfish	21%	55%	36%	43%
Sample size (n)	706	1057	1121	1174

The very low base flows in the Yampa River in 2000 (Figure 2) appear to be the main factor explaining the variable species composition at Lily Park. At 70 cfs fish occupancy was restricted mostly to deep pool habitats, but with increased flow there was also increased

habitat availability and fish had more options for habitat selection. Areas with a high number (50-150) of flannelmouth suckers at 70 cfs, contained no flannelmouth during subsequent higher flows. Also it appeared catfish responded to the higher flows by shifting habitats and movements in and out of the study site. Therefore it is believed that the low flow conditions in 2000 biased species composition independently of habitat composition in the Lily Park site. To confirm species composition for this station it will be sampled again in the 2001 field season along with the other two Yampa sites.

Species composition of fish less than 15 cm also was highly variable between stations. Lily Park had the fewest number of small fish (174) and Duffy the highest number (937) in the sample (Table 2). Smallmouth bass YOY was the species with the highest percent composition at Lily Park and Duffy, but their numbers were much higher at Duffy. Sand shiner was the most common small fish sampled or observed at Sevens during the 2000 electrofishing operation. Few speckled dace were observed at all stations in 2000 and mottled sculpin were only common at Lily Park. Creek chub and green sunfish were collected for the first time in the Yampa River during the study at Duffy.

COLORADO RIVER FISH SAMPLES

Percentages of fish over 15 cm captured by electrofishing in the 15-mile reach were fairly consistent between years and between stations at both Corn Lake and Clifton. The 1999 data at Clifton represents only two electrofishing passes and that data was presented in last years progress report (Anderson and Stewart 2000). The most noticeable shift was that flannelmouth sucker was the most common fish caught at both sites in 1999, but bluehead suckers was the common species in 2000 (Table 4). Native fish comprised 76% and 72% of the catch at the Corn Lake station in 1999 and 2000, respectively. At Clifton native fish

composition increased from 63 to 78% from 1999 to 2000. Fewer channel catfish caught at Clifton in 2000 is the reason for the higher native composition.

Table 4. Species composition for **fish >15 cm** in the 15-MILE Reach Colorado River in October 1999, and in August 2000 for two stations, **Corn Lake and Clifton**.

	Corn Lake	Corn Lake	Clifton	Clifton
Species	1999	2000	1999	2000
Flannelmouth Sucker	38.4%	31.1%	32.8%	32.5%
Bluehead Sucker	34.5%	36.3%	22.6%	40.5%
Roundtail Chub	3.1%	4.3%	7.2%	5.1%
Colo. Pikeminnow	0.1%	0.04%	0.5%	0.03%
White sucker	3.7%	2.9%	3.8%	1.7%
White X Flannelmouth	1.2%	1.6%		0.6%
White X Bluehead	0.7%	0.8%	1.2%	1.4%
Channel Catfish	4.2%	6.3%	14.2%	5.1%
Carp	11.3%	14.1%	15.9%	11.7%
Smallmouth Bass	0.1%		0.5%	
Largemouth bass	0.7%	1.1%	0.2%	1.1%
Green Sunfish	0.1%	0.4%	0.2%	0.1%
Brown trout	0.4%	0.1%	0.5%	0.1%
Rainbow trout	0.03%	0.04%		
Black Bullhead	1.3%	0.6%	0.5%	0.2%
Razorback Sucker	0.2%	0.3%		
Sample size	3499	2784	575	3276
Recaptures	248	212	0	246

In last years progress report, species composition was separated for fish captured from the main channel and fish collected in backwaters. In this report, Tables 4 and 5 are for total fish collected at the stations without distinguishing main channel from backwater samples. Small (<15 cm) flannelmouth sucker, bluehead sucker and roundtail chub were collected at both sites in both years (Table 5). Speckled dace and mottled scuplin were only sampled qualitatively. Therefore dace and scuplin composition is biased low, because special effort was not made to collect these species, since they are common and occupy swift habitats in the main channel. Efforts were made to net all sunfish sighted, and most originated in backwater

habitats. Backwaters were sampled more intensively in 2000 than in 1999 with sunfish removed in 2000, but not in 1999. As was the case in 1999, non-native cyprinds (NNC; red shiner, sand shiner and fathead minnows) were very abundant in backwater habitats, and only relatively few were sampled so NNC composition is much higher than reported here. Refer to seining studies by Valdez (1999) and Bestgen et al (1999) for data on backwater species composition.

Table 5. Species composition for **fish <15 cm** in the 15-MILE Reach Colorado River at the **Corn Lake** station (October 1999, and August 2000) and **Clifton** (August 2000).

	Corn Lake	**Corn Lake**	**Clifton**	**Clifton**
Species	**1999**	**2000**	**1999**	**2000**
Flannelmouth Sucker	5.8%	5.6%	5.3%	6.3%
Bluehead Sucker	0.5%	1.4%	0.0%	6.2%
Roundtail Chub	22.3%	2.3%	3.9%	3.7%
Colo. Pikeminnow				
White sucker	4.6%	4.9%		2.4%
White X Flannelmouth				
White X Bluehead				
Channel Catfish				
Carp	3.6%	3.2%	2.6%	6.2%
Smallmouth Bass		0.8%		0.4%
Largemouth bass	5.8%	11.5%	0.0%	10.6%
Green Sunfish	7.4%	32.0%	2.6%	11.8%
Brown trout	0.1%	0.1%		0.1%
Rainbow trout				
Black Bullhead	0.8%	0.6%		
Razorback Sucker		4.2%		
Speckled Dace	2.8%	19.8%	21.1%	38.8%
Mottled Sculpin	0.5%	0.5%		1.3%
Red Shiner	20.7%	6.8%	43.4%	6.2%
Sand Shiner	21.5%	1.3%	5.3%	3.3%
Fathead Minnow	3.5%	3.6%	14.5%	1.7%
Bluegill	0.1%	0.5%	1.3%	0.3%
Mosquitofish		1.0%		0.4%
Mountain whitefish		0.1%		0.4%
Sample size	781	1151	87	780

DOLORES RIVER FISH SAMPLES

A Site on the Dolores River was sampled for the first time in 2000. A fairly equal number of fish over and under 15 cm were collected at the site. The most common fish over 15cm sampled was roundtail chub at 55% (Table 6). Flannelmouth sucker was 16% and bluehead sucker was only 2%. The most common non-native fish was channel catfish at 16%.

The most common fish under 15 cm on the Dolores River was also the roundtail chub (48%), followed by speckled dace (34%) (Table 6). Native fish were 87% of the small fish sample. The most common nonnative fish <15 cm was green sunfish. The Dolores is the only site sample that contained channel catfish <15 cm.

A quick comparison between data from this study and Valdez (1992), data from 1990 and 1991, shows fewer flannelmouth sucker and more roundtail chub now. The data extracted from Valdez (1992) in Table 6 is not sorted by size groups, but an effort will be made to provide a more direct comparison between these earlier and current collections in the final report.

Length Frequency (Yampa, Colorado and Dolores Rivers)

Length frequency histograms for each station sampled in 1998 and 1999 are available in last years progress report (Anderson and Stewart 2000). Refer to the 2000 report to compare prior years to this year's data given in the Appendix. The length frequency histograms for bluehead sucker were very similar between years (1998, 1999 and 2000) at the Sevens and Duffy sites on the Yampa River. As was observed in earlier years, bluehead sucker under 34 cm were rare at Duffy in 2000 (Figure A1), but smaller bluehead down to 28 cm were common at both Sevens (Figure A2) and Lily Park (Figure A3). All bluehead on the Dolores River were less than 28 cm (Figure A4). On the Colorado River the size spread of

bluehead sucker was similar between both stations (Figures A5 and A6) and there were no breaks in the histogram between 10 and 44 cm.

Table 6. Species composition for fish **Over** and **Under 15 cm** at the Big Gypsum site on the Dolores River, 2000.

	Big Gypsum 2000	**Big Gypsum 2000**	**Reach 5 Valdez***	**Reach 6 Valdez***
Species	**>15 cm**	**<15 cm**	**All fish**	**All fish**
Flannelmouth Sucker	16.0%	5.2%	45.2	21.7
Bluehead Sucker	2.2%	0.0%	7.8	3.5
Roundtail Chub	54.9%	48.0%	29.5	27.0
Channel Catfish	15.8%	1.4%	7.3	4.3
Carp	3.4%	0.2%	5.9	4.3
Green Sunfish	2.0%	5.7%	0.5	3.5
Brown trout	0.6%	0.0%		5.2
Rainbow trout				1.7
Black Bullhead	5.2%	0.2%	0.3	
Speckled Dace	0.0%	33.8%	3.1	23.5
Mottled Sculpin				0.9
Red Shiner	0.0%	5.2%	0.4	2.6
Sand Shiner	0.0%	0.2%		
Fathead minnow	0.0%	0.2%		1.7
Native species	73.1%	87.0%		
Sample size	577	501	?	?
Recaptures				

*Valdez, et al. (1992), Table 31 on page 56, data collected in 1990 & 1991, Reach 5 is Bedrock (74.8) to Disappointment Creek (128.7), Reach 6 is disappointment Creek to Bradfield bridge (RM 177). Big Gypsum is RM 109.

Each river and each station on the Yampa had dissimilar bluehead histograms. The Colorado River appears to represent a bluehead sucker length distribution where habitat is abundant and predation or competition is not regulating size structure. The lack of large bluehead on the Dolores River is apparently due to low quality and quantity habitat (deep riffles) since there are no predators and competitors of significance. The station with the most riffle habitat on the Yampa River is at Lily Park. All Yampa sites have large predators, which are believed to explain the lack of small bluehead in the Yampa. The Duffy station also has

the added situation of intense competition with a larger population of white sucker and white sucker X bluehead sucker crosses.

The length frequency histograms were very similar for flannelmouth sucker between the three years at Duffy and Sevens on the Yampa River. Flannelmouth are rare below 43 cm at Sevens (Figure A7) and absent at Duffy (Figure A8). In contrast flannelmouth length frequency approximates a normal distribution at Lily Park (Figure A9), with over half the fish below 43 cm (mean = 41.5 cm). On the Dolores River the majority of fish are small, under 28 cm, and large adult fish are uncommon (Figure A10). Flannelmouth from the Colorado River at Corn Lake (Figure A11) and Clifton (Figure A12) have all size groups represented and large adults range in size from 37 cm to 55 cm.

The environmental factors that appear to effect bluehead sucker size distribution also apply to flannelmouth, since both species exhibit the same pattern between rivers. The Colorado River appears to represent a flannelmouth sucker population with abundant habitat and a lack of predation and competition. Their size distribution 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 the few numbers of flannelmouth adults relative to juveniles is apparently a result of pool habitat availability and/or very low productivity (forage potential). A predator line at Sevens and Duffy is apparent in all three years of sampling those sites and few flannelmouth are present below 43 cm. However, at Lily Park flannelmouth become rare below 28 cm. This could suggest that pike large enough to prey on fish over 30 cm are less common at Lily Park, or that flannelmouth recruitment of juveniles is much higher at this site. Duffy has a very large population of white-flannelmouth sucker hybrids, strongly indicative of intense competition between native suckers and white sucker hybrids. The size structure of flannelmouth sucker in the Yampa River at Sevens and Duffy is

strongly influenced by predation and competition, which means size structure, as well as species composition, is not regulated by habitat availability and therefore is not what would be expected if nonnative predators were absent.

No small roundtail chub were collected in the Yampa River in 2000 and size ranged from 33 to 44 cm at Sevens (Figure A13) and from 41 to 48 cm at Duffy (Figure A14). Only one chub was collected at Lily Park in 2000 at 40 cm (Figure A15). On the Dolores River there were only small chub and sizes ranged from 2 cm to 30 cm (Figure A16). On the Colorado River both large and small chubs were present at Corn Lake (Figure A17) and at Clifton (Figure A18).

Size structure of roundtail chub has the same pattern as described for the native suckers, large fish in the Yampa, small fish in the Dolores and all sizes in the Colorado River. The fact that all three native species have similar tendencies in size structure indicates similar factors are responsible. The lack of a large predator population and the fact there is a high percent of native fish in the population in the Colorado River indicates size distribution reflects the potential that is a function of habitat availability. Length frequency for native fish on the Colorado River is probably nearest to pristine or ideal for the native species, bluehead and flannelmouth sucker and roundtail chub. However the Dolores River has a definite absence of larger individuals of all native fish. This is probably not a function of predation or competition, since predators would remove small not large fish. The lack of large fish is probably a function of habitat availability, indicating a lack of deep runs and riffles in this river. At this time it is not hypothesized whether size structure on the Dolores is pristine or is a recent result of habitat or flow modification which has reduced potential. The author felt that sedimentation in riffles was high and invertebrate numbers were relatively low. Native suckers have a normal shape to their length frequency larger fish at Lily Park site on the

Yampa River, but lacked small fish. In Sevens and Duffy the size distribution would probably be more similar to the Colorado River if non-native predators and suckers were not present.

Small white sucker were present at Sevens (Figure A19) and Duffy (Figure A20) indicating this species is better adapted to avoid predation than native suckers. Most of the white sucker on the Colorado River (Figures A21 and A22) were taken from slow backwater habitats and also since they are uncommon, this species is probably not a significant competitor for resources with native suckers. The white-flannelmouth cross size structure on the Yampa is comprised of large individuals (Figures A23 and A24), another indication that small fish have poor survival due to predation in the upper Yampa. Both the white-flannelmouth and the white-bluehead sucker crosses (Figures A 27 and A28) on the Yampa attain larger sizes than the pure flannelmouth and bluehead sucker, which could mean the hybrid suckers have an advantage in regard to competition and avoiding predation.

The size structure for carp mimics the generalized pattern described for other species in the Yampa River. Carp were few and very large (62 to 78 cm) at Duffy (Figure A32), more common and smaller at Sevens (45 to 68 cm) (Figure A31) and even more common and smaller still at Lily Park (33 to 52 cm) (Figure A33). Except for one YOY, carp in the Dolores River were between 49 and 62 cm. Most of the small carp (less than 30 cm) in the Colorado River were taken from backwater habitats, but large carp were very common in the main channel. This suggests more and better carp habitat is found in the Colorado River than is found on the Yampa and Dolores Rivers. In fact many carp in the Colorado River were sampled near outlets of sewage treatment ponds. The accumulated deposits at one such spot seemed very attractive as carp completely filled a small backwater. Also many carp in the Colorado River were found in shoreline habitat with overhanging trees that provided dense cover. Both conditions (enrichment and dense cover) were rare in the Yampa and Dolores Rivers.

Size distribution for channel catfish for the Yampa River in 2000 at Sevens and Duffy (Figures A37 and A38) was fairly similar to 1998 and 1999 in that catfish smaller than 30 cm have not been found at Sevens or Duffy over the three years. The main difference observed for catfish was sample size was much less at Sevens in 2000 (14) and Duffy in 2000 (41) than in earlier years. In contrast to these two upstream sites, catfish were super-abundant in Lily Park with a sample size of 1,631. Also catfish in the size range of 24 to 30 cm was very common and the minimum size at Lily Park was 17 cm. The Dolores River catfish sample had fish between 14 and 61 cm, with most below 30 cm in length (Figure A 40). The Colorado River catfish sample ranged in size from 25 to 60 cm (Figures A41 and A42) and size structure was fairly similar to the 1999 sample.

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 small catfish. Tim Modde of the USFWS routinely finds high numbers of small catfish (<30 cm) in Dinosaur Canyon (per. comm.). It has been suggested 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 support this concept. Small catfish on the Dolores indicate that nursery and juvenile habitat is available in the Big Gypsum site.

The majority of both largemouth bass in the Colorado River (Figures A 43 and A44), and smallmouth bass in the Yampa River at Sevens (Figure A45) and Duffy (Figure A 46) are smaller than 15 cm in length. In the Colorado River bass are generally found in backwaters and are not a predator on main channel species like speckled dace and mottled sculpin, but are considered a potential predator on young life stages of native fish that occupy backwaters during nursery and YOY periods. Both adult and young smallmouth bass in the Yampa River are in the main channel and are probably important predators on all small fish in all habitats.

Size of YOY smallmouth bass is similar to that reported last year for 1998 but growth rates appeared faster in 2000 than in 1999.

Density Estimation

YAMPA RIVER

Fish density estimates were similar in 1998 and 1999 at the **Duffy Reach** on the Yampa River, but estimates were significantly (alpha = .05) lower in 2000 than the two previous years (Table A3). The Duffy Reach is 7.2 km long and is electro-fished every year to indicate population abundance over a longer section. The length of this station has varied in each year. In 1998 the take-out was 0.8 km further downstream, in 1999 the starting point was 0.8 km upstream to match the area mapped by sonar. In 2000 neither the extra upper or lower 0.8 km was sampled. The data in Table A3 are from the same starting and ending points. Since the Duffy Reach is long, it is well suited to make inferences about local fish movements and the higher number of recaptures provide a more precise measurement for trends in abundance. It is felt the data for the Reach strongly indicates abundance of fish >15cm was less in 2000. It appears this could be related to the much lower flows in 2000 compared to flows in 1998 and 1999.

The **Duffy Reach** electrofishing station includes the **Duffy Site**. Fish density estimates from the mapped **Duffy Site** are higher than from the **Duffy Reach** in all three years (Table A4). This is probably due to different habitat compositions. A very large deep run dominates habitat composition in the **Duffy Site** and is located immediately upstream of the hydraulic control used to divert water to the Duffy Tunnel intake. The disproportional high availability of deep habitat in the Survey Site probably explains the higher fish density there. At flows over 150 cfs this habitat is a run, but at under 150-cfs velocities drop and it is considered a pool (Figure 3). The longer Reach has been sampled each year to determine how

fish composition compares between it and the shorter surveyed Site since deep runs of this size are not typical. The deeper habitat in the surveyed Site is even more attractive to large fish in low flow years like 2000 when more of the river is too shallow to be unusable habitat. Therefore fish concentrate in the deepest habitats and the density estimates in the Survey Site increased in the low flow years, even though a reduced density was estimated for the river in general.

The deep run habitat in the **Duffy Site** also appears to be more attractive to bass and white suckers during all three years. The surveyed Site estimate for smallmouth bass was three times higher and the white sucker estimate was more than doubled compared to the entire Reach in 2000. In contrast flannelmouth sucker were less common in the Site in 1998 and 1999 (high flow years) compared to 2000. Also large predators like northern pike and Colorado Pike minnow were more apt to be collected in this deep run.

Fish density estimates were similar in 1998 and 1999 at the **Sevens** on the Yampa River, but estimates were significantly (alpha = .05) lower in 2000 than in 1998 and 1999 (Table A5). Flannelmouth sucker density was also significantly less in 2000 and in 1998. The fact that total density was less in 2000 at both Yampa sites add credibility to suggesting that low base flows could be impacting fish abundance in the Yampa River.

Density estimates were very different for the three sites sampled in 2000. As the case in prior years, **Duffy Reach** density for total fish over 15 cm is very low at only 316 fish/km and is higher at **Sevens** with 778/km (Table 6). Density estimates are very poor for all native fish at **Duffy**: bluehead sucker (16/km), flannelmouth sucker (11/km), and roundtail chub (5/km). At **Sevens** density of native suckers were much better for bluehead, flannelmouth and roundtail chub at 309, 296 and 54 per kilometer, respectively. The estimate for total fish at **Lily Park** is exceptionally high at 6279 fish/km. Flannelmouth sucker were estimated at an

incredible 2,238/km, bluehead at a modest 552/km and roundtail chub at a very low 2/km. The channel catfish density estimate is inordinately high at 3,668 fish/km.

Table 7. Yampa River population estimates with 95% C.I. (recaptures), and density estimates (No./1000m), 2000. Mean stream with 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	6279 ±10% (324)	778±17% (92)	316 ±10%(250)
Bluehead Sucker	552±36% (25)	309±56%(10)	16 ±103%(3)
Flannelmouth S	2238±12% (205)	296±20%(59)	11 ±33%(15)
Roundtail Chub	2±NR(0)	54 ±126%(2)	5 ±23%(16)
Colo. Pikeminnow	5±NR(0)	3 ±NR(0)	4 ±NR(0)
White Sucker & Crosses	14±170% (1)	106+38%(15)	203 ±10%(197)
Smallmouth Bass	121±188% (1)	6±NR(0)	58 ±46%(14)
Channel Catfish	3668±20% (87)	22±NR(0)	15 ±129%(2)
Northern Pike	19±NR(0)	3±NR(0)	3 ±106%(2)
Carp	186±82% (5)	45±NR(1)	4 ±155%(1)
	Lily Park	**Sevens**	**Duffy Reach**
	No./1000m²	No./1000m²	No./1000m²
Total fish	**118.4**	**14.7**	**5.97**
Bluehead Sucker	**10.4**	**5.8**	**0.30**
Flannelmouth S	**42.2**	**5.6**	**0.21**
Roundtail Chub	**0.03**	**1.01**	**0.09**
Colo. Pikeminnow	**0.10**	**0.05**	**0.08**
White Sucker & Crosses	**0.26**	**1.99**	**3.84**
Smallmouth Bass	**2.28**	**0.11**	**1.09**
Channel Catfish	**69.2**	**0.42**	**0.28**
Northern Pike	**0.36**	**0.06**	**0.06**
Carp	**3.5**	**0.85**	**0.07**

The **Lily Park** site was established in 2000 because prior sampling (ISMP, Colorado River Recovery Program, Elmblad per. Comm.) indicated a higher density of native fish, which was confirmed. This is believed to be a function of habitat composition with mostly riffles and runs and therefore similar to habitat in the 15-Mile reach. Habitat composition has

not been analyzed at Lily Park at this time. However, the fish data strongly show that Lily Park is much more productive than the two upstream sites and has a much higher density of flannelmouth sucker. However the density estimates for flannelmouth and channel catfish appear suspect to be an overestimate. Stream flow was highly variable between electrofishing passes at Lily Park (Figure 3). On the first pass only the lower half of the site was sampled, on September 13 at a flow of 70 cfs, sampling efficiency was felt to be very high. Subsequent passes were made for the entire station at flows of 420, 260 and 216 cfs, respectively. It appears that fish movement was restricted during low flows in August and September and fish had to hold in deeper habitats. When flow increased both local and longer movements by fish were possible. The low number of recaptures for flannelmouth sucker and channel catfish suggests there was migration in and out of the study area between electrofishing passes. On the final pass only 26% of flannelmouth caught (413) were recaptures, from 1,321 previously marked. For channel catfish only 12% were recaptures in the final catch (451), with 1,093 fish marked on prior passes. The Lily Park reach will be sampled again in 2001.

Even given the above discussion, the differences in fishery characteristics between Lily Park and Sevens were very pronounced in 2000. Lily Park has eight times more total fish per 1000 m^2, 7.5 times more flannelmouth and 160 times more catfish compared to Sevens. Lily Park is only 10 river miles downstream of Sevens, suggesting similar temperature and water quality attributes at both sites. Also there appear to be a similar or larger predator population of northern pike and smallmouth bass at Lily Park. 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, 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. At Sevens the substrate is mostly sand. The habitat analysis in process should help

indicate how much of the observed differences in fish populations are explained by physical habitat availability.

COLORADO RIVER

Total fish density was estimated at 3,962 per km at **Corn Lake** in 1999 and 3,417/km in 2000 (Table 6). Total fish density was significantly different at the Corn Lake station between 2000 and 1999 (Table 7). The estimates for both bluehead and flannelmouth sucker were significantly less in 2000 (1182 and 999 per km) compared to 1999 (1573 and 1550 per km). Density estimate for roundtail chub were higher in 2000 (357/km) than in 1999 at 192/km and is significant at the 0.05 level (Table 7). Also the estimate for carp and catfish increased in the lower flow year of 2000. The only estimate not significantly different between the two years was for white sucker.

As was suggested for the Yampa River, the differences in density estimates between years at **Corn Lake** could be due to the different flow conditions between years. Mean flow in August 1999 was 1800 cfs and in August 2000 it was 800 cfs (Figure 6). Estimates for bluehead and flannelmouth, species that utilize run and riffle habitats, were less, but species that primarily use pool habitats (chub, carp and catfish) were higher in the years with low flows. This shift in species abundance is consistent with a shift in habitat conditions that result from lower flows observed in 2000. More detail will be given to this issue in the final report when the habitat analysis is completed. Also fish data collected in 2001 will help confirm if the decrease in bluehead and flannelmouth densities in 2000 reflects a drop in carrying capacity of the river as opposed to fish relocating to other reaches as was observed on the Yampa River. However it is believed the stations may be long enough to contain local movements, a total of 6.8 km shocked in 2000 for both stations.

Table 8. Colorado River population estimates with 95% C.I. (recaptures), and density estimates (No./1000m²) for the 15Mile-Reach, 2000. Stream width is about 55 m at 1400 cfs (Stewart 2000).

	Corn Lake 1999	**Corn Lake 2000**	**Clifton 2000**
	No./km ±C.I. (recaps)	No./km ±C.I. (recaps)	No./km ±C.I. (recaps)
Total fish	3939 ±11% (247)	3417±7% (212)	3902 ±7%(246)
Bluehead Sucker	1573±20% (85)	1182±12%(81)	1179 ±12%(140)
Flannelmouth S	1550±17% (110)	999±10%(72)	1887* ±10%(57)
Roundtail Chub	192±83% (5)	357±43%(4)	453 ±43%(6)
Colo. Pikeminnow	5		5 ±NR
Carp	309±36% (24)	525±21%(28)	591 ±21%(35)
Channel Catfish	195±54% (11)	301±34%(10)	664 ±34%(4)
White Sucker & Crosses	139±51% (12)	124+26%(17)	345 ±26%(4)

	Corn Lake 1999	**Corn Lake 2000**	**Clifton 2000**	**Corn Lake 2000vs1999**	**2000 Clif.vsCorn**
				Alpha	Alpha
	No./1000m²	No./1000m²	No./1000m²	0.05%	0.05%
Total fish	**71.6**	**62.1**	**70.9**	SIG	SIG
Bluehead Sucker	**28.6**	**21.5**	**21.4**	SIG	NOTDIF
Flannelmouth S	**28.2**	**18.2**	**34.3**	SIG	SIG
Roundtail Chub	**3.5**	**6.5**	**8.2**	SIG	NOTDIF
Colo. Pikeminnow					
Carp	**5.6**	**9.6**	**10.7**	SIG	NOTDIF
Channel Catfish	**3.5**	**5.5**	**12.1**	SIG	NOTDIF
White Sucker & Crosses	**2.5**	**2.3**	**6.3**	NOTDIF	SIG

Significant differences in density estimates between **Clifton** and **Corn Lake** were found for total fish, flannelmouth sucker and the white sucker group. The differences between stations suggest minor differences in physical habitat between the two reaches. The estimate for flannelmouth sucker numbers appears elevated because of the fairly low number of recaptures in the sample. This could be an indication of migration into the study area. However none of the flannelmouth marked in Corn Lake were recaptured upstream. Also the electrofishing and telemetry data collected to date indicate this species behavior is mostly local movements during the base flow period. Flannelmouth sucker were very dense in the

split channel below the diversion dam and we may not have spent a proportionate amount of effort resampling that habitat. More attention will be paid to this in the 2001 sampling.

Density estimates in fish/km for the Colorado and Yampa Rivers are similar for both the 1999 and 2000 reports. However fish per 1000 m^2 are different in this report from those reported last year. A mean stream width of 100 meters was used to calculate fish per square meter in last year's report (Anderson and Stewart 2000). Based on results of Stewart (2000) a stream width of 55 meters is used this year, since it represents wetted width at 1400 cfs, a flow typical in the base flow period (discussion in habitat section).

The Colorado River in the 15 Mile Reach averaged 4.5 times more fish /1000 m^2 than the Yampa River at Sevens and 11.1 times more fish than Duffy in 2000. For the 1999 data, Corn Lake station (Colorado River) was 3.0 times higher than Sevens and 9.4 times higher than Duffy. It is recognized that predation is a major impact to density on the Yampa River, especially at Duffy, and it will be considered in the analysis. However a hypothesis of this study that habitat availability is an important factor determining carrying capacity and the fact there is an extreme difference in density between the two rivers indicates habitat is a principle factor.

The Lily Park station is an interesting contrast to the other Yampa River sites. It has a higher total fish and flannelmouth sucker density than found on the Colorado River and bluehead is only about half of the Colorado River. It is likely that habitat at Lily Park will be more similar to the Colorado River than to the other Yampa sites.

DOLORES RIVER

The total fish density estimate per kilometer and per hectare in the Dolores River is low compared to the Colorado and Yampa Rivers (Table 7). Fish per 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 a standardized stream

width is determined using channel surveys. But even with the 18 m width the Dolores had the lowest density estimate for bluehead of all sites. Density of roundtail chub and catfish were only somewhat less than the Colorado stations and higher that the Yampa River at Duffy and Sevens.

Table 9. Dolores River population estimates with 95% C.I. and (recaptures), and density estimates (No./1000m²) for the Big Gypsum station, 2000.

	Big Gyp, 2000	Big Gyp, 200
	No./km ±C.I. (recaps	No./1000m
Total fish	197±15% (102)	10.9
Bluehead Sucker	3±67% (3)	0.17
Flannelmouth S	36±39% (15)	2.0
Roundtail Chub	81±16% (67)	4.5
Green Sunfish	5±58% (5)	0.29
Channel Catfish	69±61% (8)	3.8
Black Bullhead	14±78% (4)	0.76
Carp	24±181% (1)	1.35
Brown trout	1.2±NR (0)	0.07

Habitat Composition

Analysis of habitat composition has been completed for two sites, the Duffy on the Yampa River and the Corn Lake site on the Colorado River. Stewart (2000) presents the methods and documentation for these results but this report only provides a summary of his presentation of that data.

Wetted stream width was found to be higher on the Yampa River for most flows of interest. At a flow of 600 cfs the wetted width at Duffy is 63.1 m compared to 48.6 m at Corn Lake (Colorado River). An adjustment was made for this report to present fish density (number per surface area) based on the wetted width at a typical base flow. In prior reports the fish density was based on the Colorado River having a wider channel (based on bankfull

flow). Density data is now based on wetted width of 55.2 m at 1,400 cfs for the Colorado River and a wetted width of 56.2 m at a flow of 200 cfs for the Yampa River.

In theory streams with higher habitat diversity support a more diverse community. Habitat diversity was found to be higher in the 15-Mile Reach and peaked near 1,400 cfs, with the peak at Duffy near 180 cfs (Stewart 2000). Traditional instream flow methods have based flow recommendations on optimizing habitat availability. We believe this is generally valid ... and are attempting in this study to collect data to show how the fish community interacts with habitat.

Results of habitat analysis show large differences in habitat composition between Duffy (Yampa River) and Corn Lake (Colorado River). Duffy is comprised of low velocity habitats. At flows below 150 cfs pools are the dominant meso habitat, and above 150 cfs runs are in the majority (Figure 5). The shoal pool (depth from 0.2 to 0.5 m) is the most common type of pool at Duffy at all modeled flow (Figure A51). The shoal run (depth from 0.2 to 0.5 m) is the most common run type at flows below 300 cfs and at flows over 400 cfs shallow run habitat becomes most common (Figure A51). Riffle area increases between 150 and 400 cfs, and deep riffles are very rare below 400 (Figure A51.)

Pools are uncommon in the Colorado River at 1400 cfs and for the range of flows mapped (Figure 6). Deep pool was the only pool habitat to increase with flows (Figure A52). Runs decline with increased flow on the Colorado River in contrast to an increase in run habitat at Duffy with increasing flow. The medi-run (1 to 2 m) is the most common run habitat at all flows at Corn Lake (Figure A52). Riffles are the dominant meso-habitat type at flow over 900 cfs at Corn Lake. At 1400 cfs deep and very deep riffles are common (Figure A52).

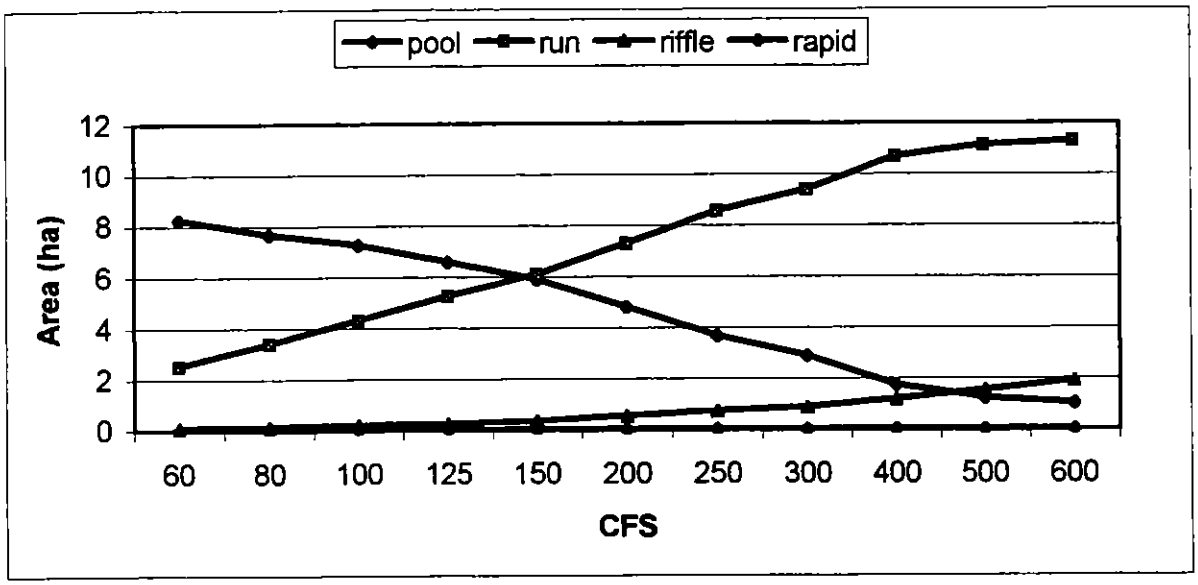

Figure 7. Meso habitat composition for the Duffy station on the Yampa River for a range of flow typical of the base flow period.

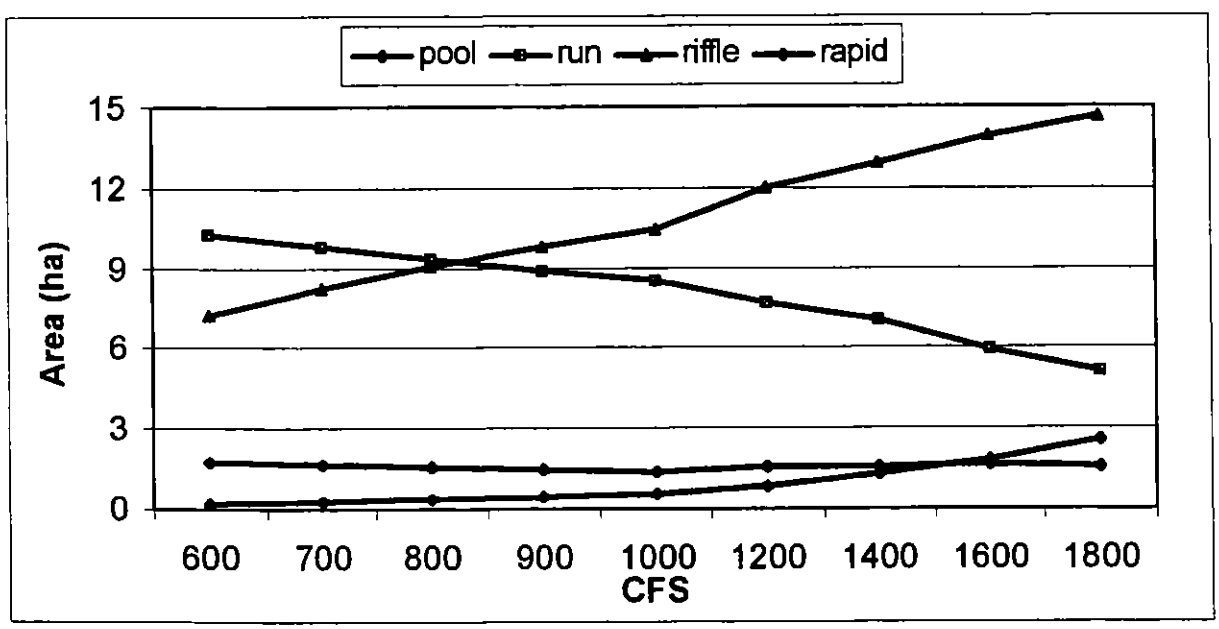

Figure 8. Meso habitat composition for the Corn Lake station on the Colorado River for a range of flow typical of the base flow period.

In 2000 the base flows were much lower than in 1998 and 1999 with flows between 30 and 80 cfs on the Yampa for most of the summer. At these flows, runs and riffles become rare at Duffy and most of the river is shallow, composed of wetted and shoal pools (Figure A51).

At Duffy only 4% of the habitat is riffle at 200 cfs and 57% is riffles at Corn Lake at 1400 cfs (Table 10). Total riffle density is 12.5 time greater at Corn Lake than Duffy. 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 A6). The habitat type most likely associated with adult bluehead sucker is the deep riffle and at Duffy there is only 0.001 ha/km. Bluehead density in the Surveyed Site is 0.26 fish per 1000 m^2. At Corn Lake deep riffle is very common at 1.43 ha/km (Table A6) and bluehead density is 21.5 fish per 1000 m^2.

Table 10. Habitat composition in area/km and percent for major 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		

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

The Duffy station is the least desirable of the Yampa sites to make inferences about relationships between native fish and physical habitat. This is mostly due to the low native fish composition. However adult native suckers have a habitat preference for deep runs and riffles, habitats that are rare at Duffy and very abundant at Corn Lake. Native sucker at Duffy have been replaced by white sucker and white sucker hybrids, and these fish are more associated with pool habitat than native suckers. Smallmouth bass is another pool-associated fish that is doing very well at Duffy, but is very rare in the Colorado River. Roundtail chub is a native fish generally associated with pool habitat, but this species has been severely impacted by predation, and therefore its abundance is not limited by habitat availability.

Progress is expected to accelerate in development of meso-habitat suitability indices as 2-D modeling is performed. Fish data was reorganized to allow for this analysis. Fish data collected by electrofishing were reorganized according to the specific location of their catch. The electrofishing units have been digitized as arc-view polygons to overlay the river. Each polygon has a fish attribute table and an attribute table for physical habitat. Physical characteristics from each polygon will be determined based on the flow simulation that matches closest to the flow at the time of the sample. The fish attribute table contains the number of fish by four size-groups for each species representing YOY, juveniles, small and large adults. Polygons will be sorted by greatest to least fish abundance and in that way habitat characteristic will also be sorted from most suitable to unsuitable. The maximum number of polygons for each river is: Colorado River, Corn lake (40), Clifton (50); Dolores, Big Gypsum (16); Yampa, Sevens (16), Duffy (16), Lily Park (16). The fish data will be presented in this format when the corresponding habitat data becomes available.

Fish sampling efforts will be attempted made in the 2001 field season to more accurately map fish by established polygons. Observations will be made on fish that were

seen but not netted. It is anticipated that 2-d modeling will be performed in the 2001-02 fiscal year for the other four stations in the study. A contract was awarded and should be ready to start by July 1, 2001. Future modeling will follow the procedures developed by Stewart (2000).

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. This 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 follow up telemetry study is to be conducted in the summer of 2001, subject to funding. Data collected from 2000 and 2001 will be analyzed 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. Detailed discussion of the telemetry work will be given in the final report.

SUMMARY

Electrofishing results in 2000 for species composition and size structure of fish over 15 cm were similar and consistent with earlier years at all stations. But total fish density was somewhat lower than in earlier years (1998 and 1999) on the Yampa River and also lower at the Corn Lake station on the Colorado River. It was suggested that the lower fish abundance in 2000 could be an effect of the lower base flows experienced that year.

A third station was added to the Yampa River in 2000 at Lily Park. This site had grossly different fishery characteristics compared to Sevens and Duffy stations. The observed differences in species composition, density, and sizes between Yampa sites appear to be more related to differences in meso-habitat availability (gradient, substrate particle size, riffle/run ratios) than to differences in predatory pressure, temperature or water quality.

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. On the Yampa there is a lack of fish under 30 cm, and higher mean lengths for virtually all species at Duffy and Sevens. Even at Lily Park where flannelmouth sucker were abundant, none were sampled under 28 cm.

Habitat analysis completed on the Duffy and Corn Lake sites found very large difference in habitat composition between these two locations. 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 1400 cfs at Corn Lake and 180 cfs at Duffy. This is a function of greatly differing channel morphology between the sites. Most of the differences in

fish populations appear explainable by differences in habitat availability, even though predation was an influence on the Yampa River.

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

Shallower low velocity pool habitats are very common at Duffy and rare at Corn Lake. 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. The percent of roundtail chub in the population is similar to pool habitat availability at Corn Lake, but at Duffy in spite of pool habitat availability, chub are rare due to obvious predation.

Run habitats increase with increasing flows at Duffy, but runs decrease as flow increase 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 habitat is also more common at the Lily Park site compared to the other two Yampa sites.

The low flows observed in 2000 provide empirical data in regard to justifying instream flow recommendations. One more year of fish sampling will be conducted for this project. This will provide an opportunity to see if fish densities remain at the 2000 level, drop lower, or return to the 1998 and 1999 levels. A relationship between fish density and habitat availability has always been an undocumented assumption of instream flow studies, and this data will help dentify this relationship. Given the level of interest in this project, increased

efforts will be made for mapping fish distribution and abundance. Fish maps (polygons) will be made so that meso-habitat suitability can be determined in each of the study sites.

CONCLUSIONS and RECOMMENDTATIONS

- 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.
- The 2-D flow modeling clearly produces excellent habitat mapping results and is absolutely necessary for this project to develop instream flow recommendations for the Yampa and Colorado Rivers. Stewart (2000) summarizes the 2-D modeling work completed at this time.
- 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.
- Attempts to start a new contract are in process. An RFP (Request for Proposal) was announced in an open competitive bidding and the RFP was awarded to a contractor. At this time approval for the contract has not be give by DNR, but anticipate that it will be so that work can resume in July 1, 2001.
- Radio telemetry work will continue in 2001 given approval to contract the field work via a purchase order. The telemetry work completed so far provide valuable data on habitat use and movement of bluehead sucker, flannelmouth sucker and roundtail chub.

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APPENDIX

Table A1. Yampa River species composition for fish >15 cm at the Sevens & Duffy stations in 1998, 1999 and 2000.

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

Table A2. Species Composition for fish <15 cm caught by electrofishing in the Yampa River for 1998, 1999, 2000.

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

Table A3. Density estimates for fish collected in the Duffy Reach (7.2 km) for the three years 1998, 1999, 2000. Mean stream width is 53m.

	1998	1999	2000	98/99	98/00	99/00
	Fish/km	Fish/km	fish/km	Alpha	Alpha	Alpha
				0.05	0.05	0.05
TOTAL	387	403	316	NOTD	SD	SD
WS&WSX	241	242	203	NOTD	SD	SD
FM	25	15	11	NOTD	SD	NOTD
BH	24	23	16	NOTD	NOTD	NOTD
RTC	12	25	5	NOTD	SD	NOTD
CS	8	5	4	NOTD	NOTD	NOTD
SMB	40	58	58	NOTD	NOTD	NOTD
NP	17	16	3	NOTD	NOTD	NOTD
CP	22	8	4	NOTD	SD	NOTD
CC	19	29	15	NOTD	NOTD	NOTD

Table A4. Density estimates for fish collected in the mapped study Duffy Site (1.6 km) for the three years 1998, 1999, 2000. Mean stream width of 53 m.

	1998	1999	2000	98/99	98/00	99/00
	Fish/km	Fish/km	fish/km	Alpha	Alpha	Alpha
				0.05	0.05	0.05
TOTAL	635	469	632	SD	NOTD	SD
WS&WSX	405	343	431	NOTD	NOTD	SD
FM	19	8	14	NOTD	NOTD	NOTD
BH	31	14	17	NOTD	NOTD	NOTD
RTC	24	10	11	NOTD	NOTD	NOTD
CS	17	7	9			
SMB	177	76	167	NOTD	NOTD	NOTD
NP	48	20	6	NOTD	NOTD	
CP	9	1	0		NOTD	
CC	N.E.	N.E.	N.E.			

Table A5. Density estimates for fish collected in the Sevens Reach (2.9 km) for the three years 1998, 1999, 2000. Mean stream width of 53m.

	1998	1999	2000	98/99	98/00	99/00
	Fish/km	Fish/km	fish/km	Alpha	Alpha	Alpha
				0.05	0.05	0.05
TOTAL	1147	1115	778	NOTD	SD	SD
FM	395	376	296	NOTD	SD	NOTD
BH	274	238	309	SD	NOTD	NOTD
RTC	4	3	3			
CS	73	41	54	NOTD	NOTD	NOTD
WS&WSX	200	190	106	NOTD	SD	NOTD
SMB	20	29	6	NOTD	NOTD	NOTD
NP	62	22	3	NOTD	NOTD	NOTD
CP	77	69	45	NOTD	NOTD	NOTD
CC	111	109	22	NOTD	NOTD	NOTD

Table A6. Habitat composition by area and percent for the 16 habitat types at a flow of 600 cfs for both site and at a typical base 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.7. Length frequency histograms for 2000 data, Appendix Figures A1 to A50.

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

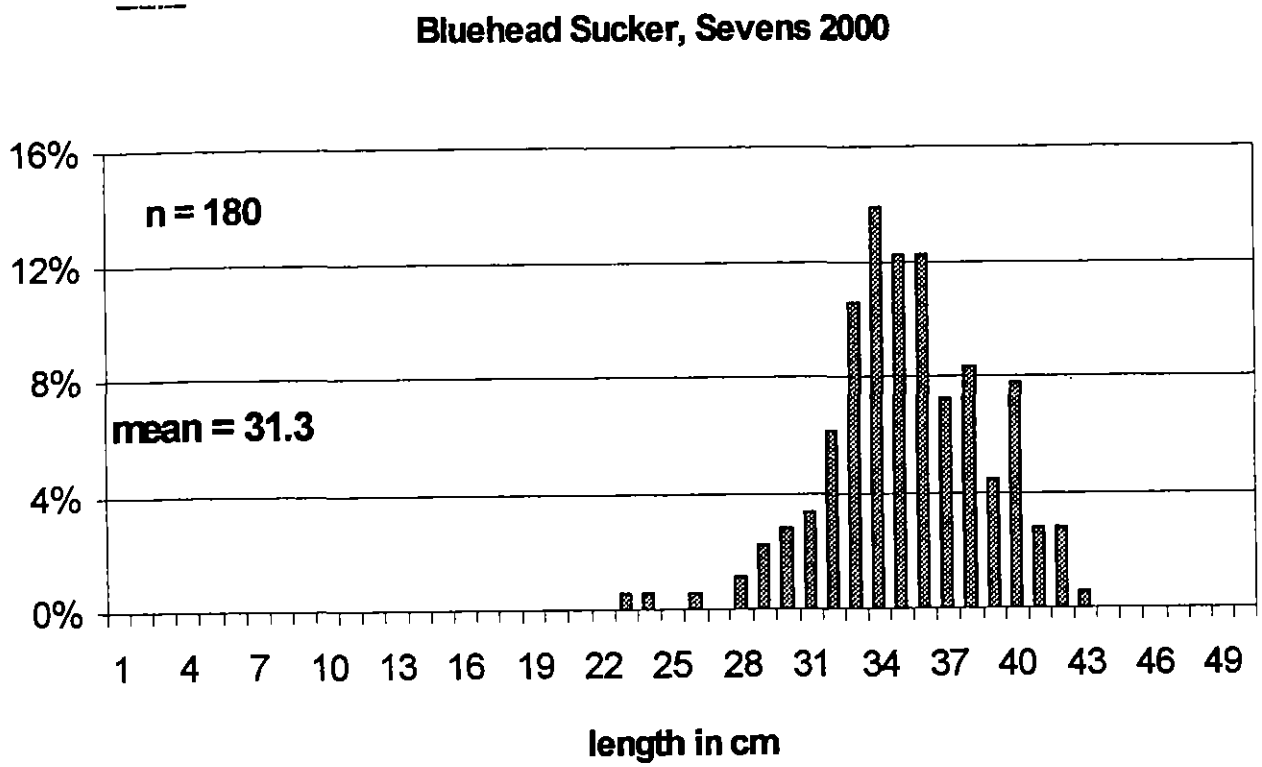


Figure 1. Bluehead Sucker length frequency at the Sevens site, September 2000, Yampa River.

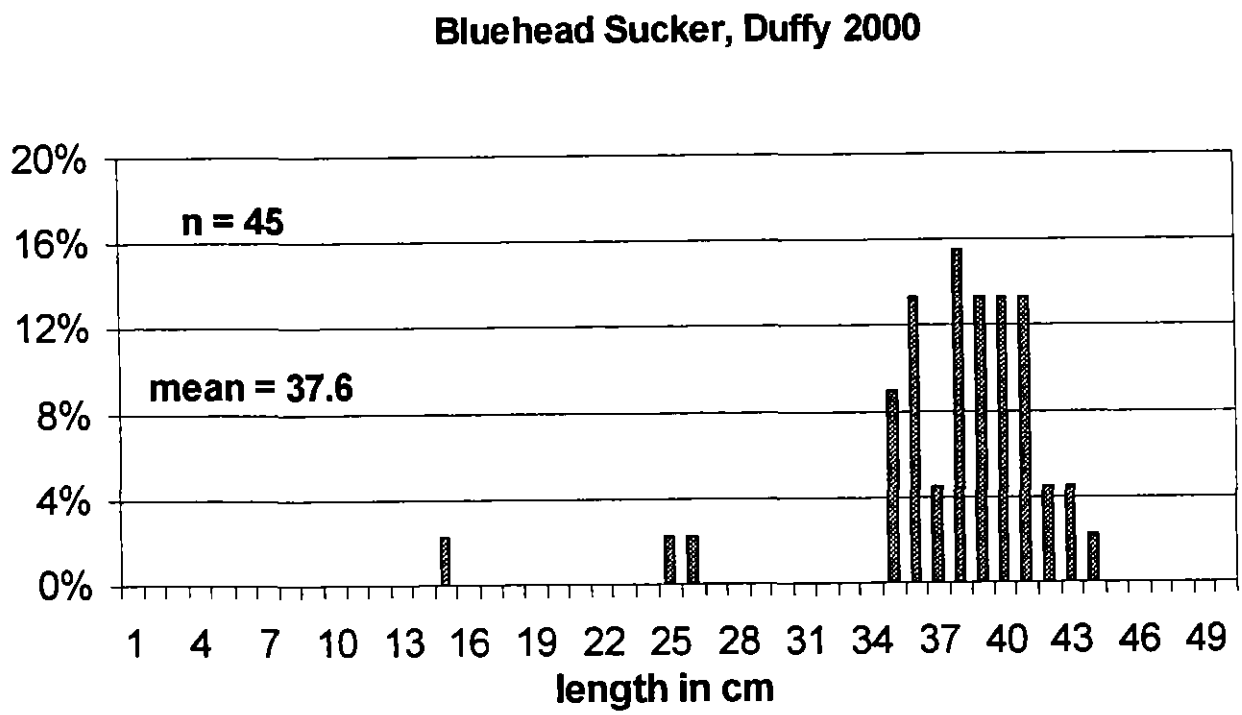


Figure 2. Bluehead Sucker length frequency at the Duffy site, September 2000, Yampa River.

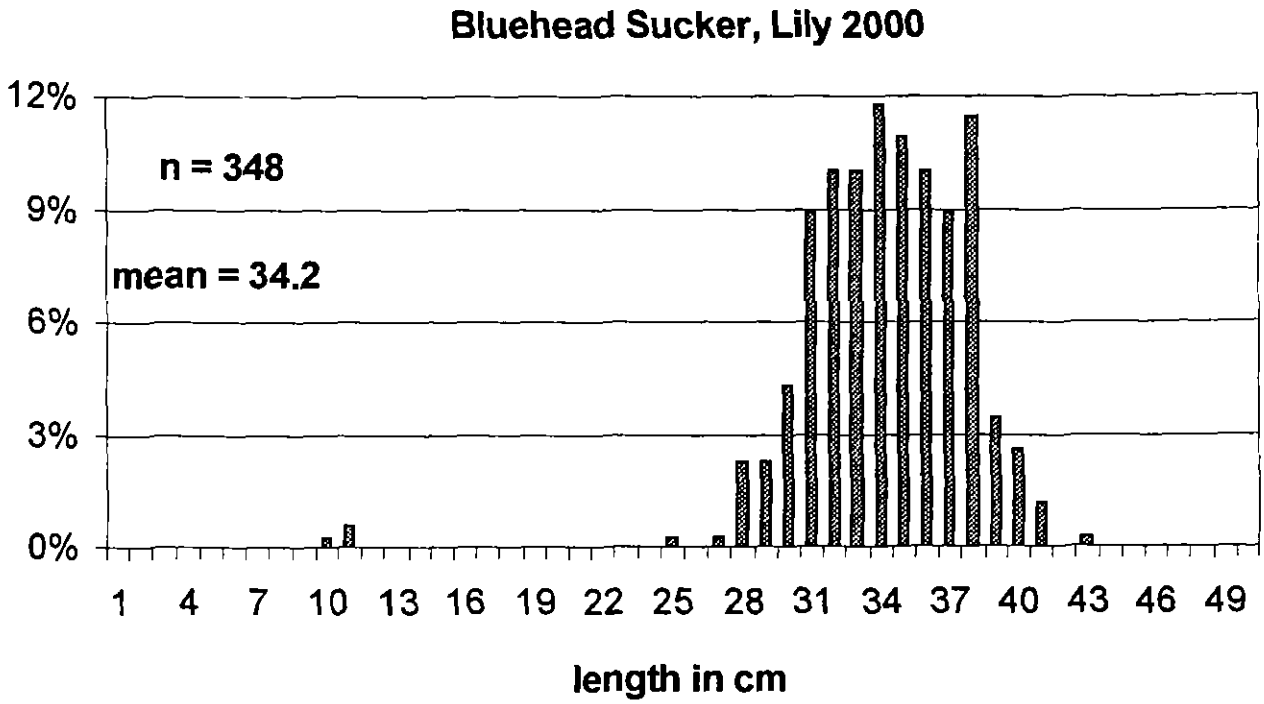


Figure 3. Bluehead Sucker length frequency at the Lily Park site, September 2000, Yampa River.

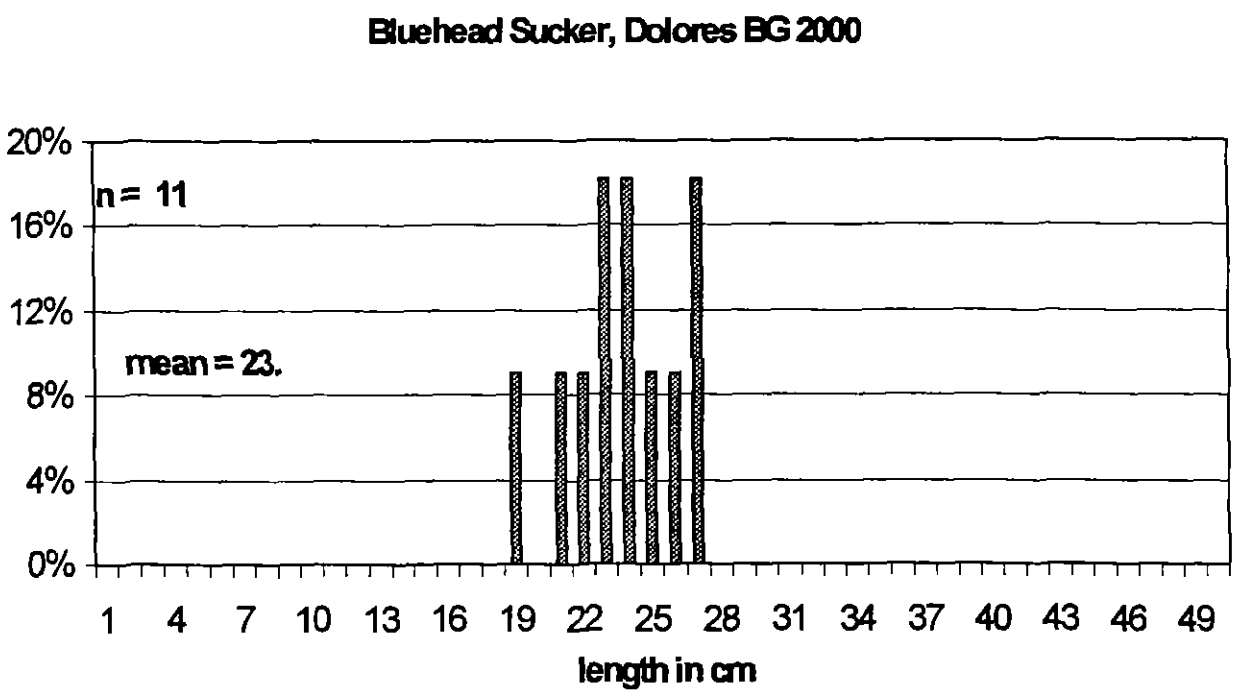


Figure 4. Bluehead Sucker length frequency at the Big Gypsum site, July 2000, Dolores River.

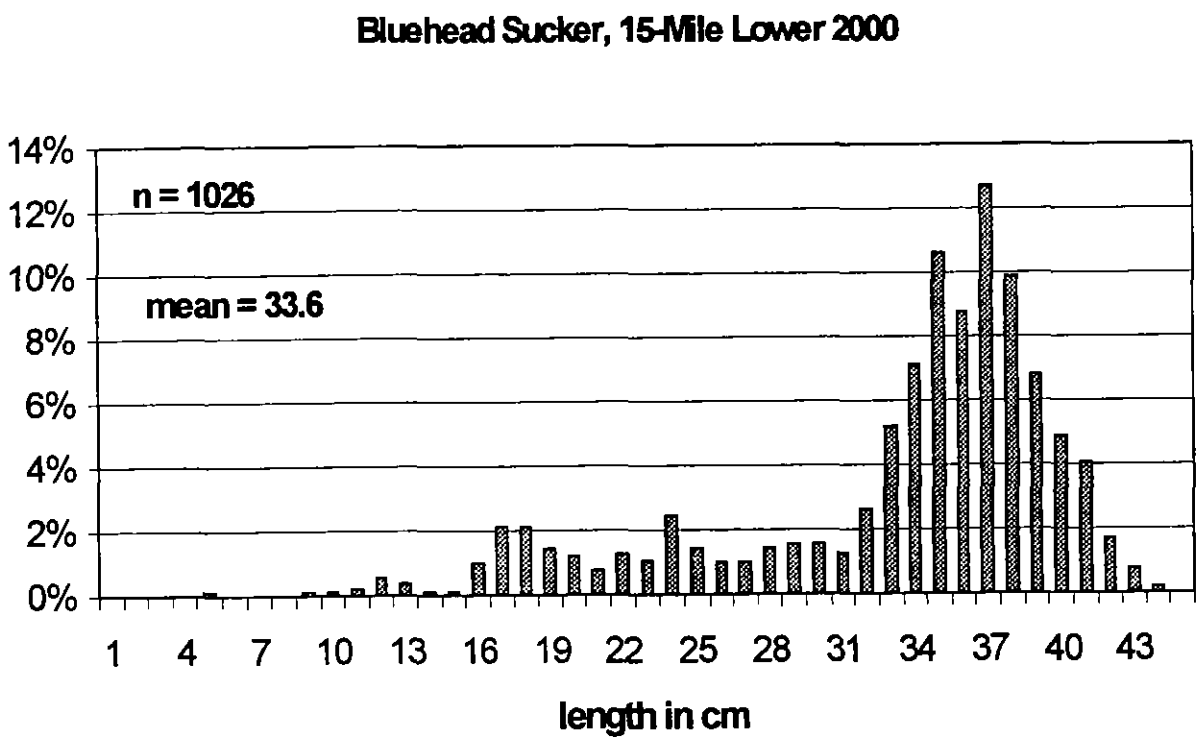


Figure 5. Bluehead Sucker length frequency at the Lower 15-Mile Reach site, August 2000, Colorado River.

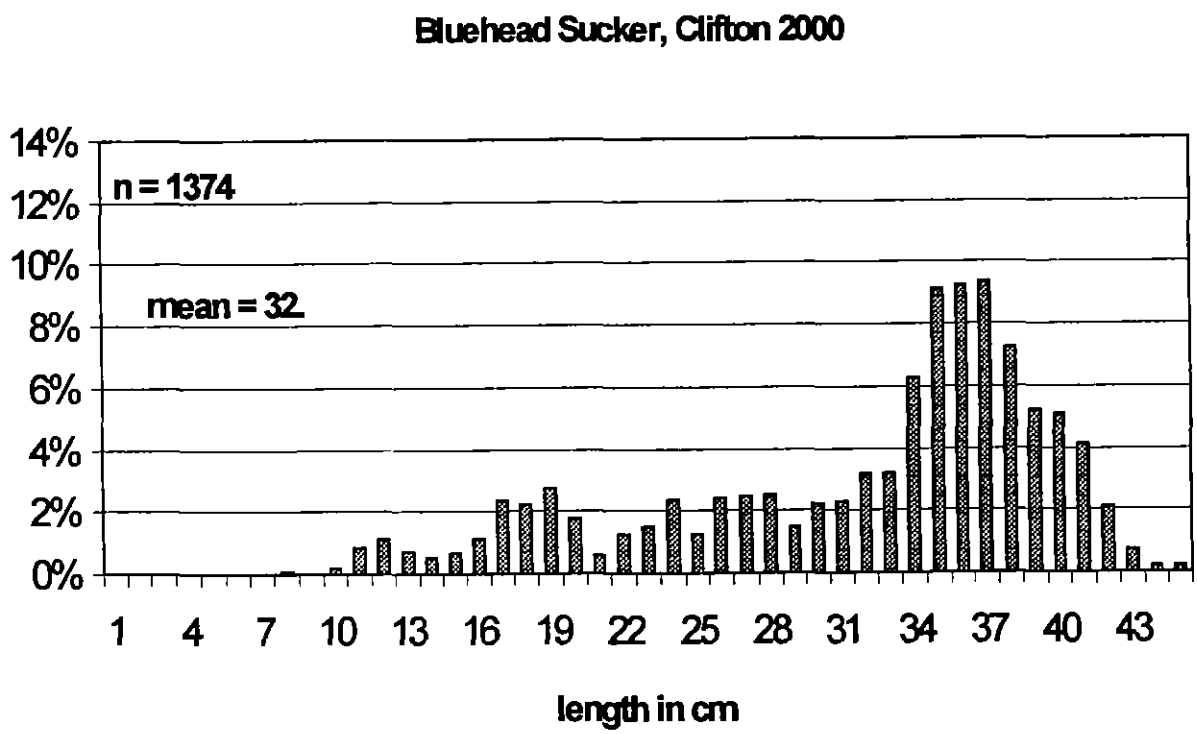


Figure 6. Bluehead Sucker length frequency at the Clifton site, August 2000, Colorado River.

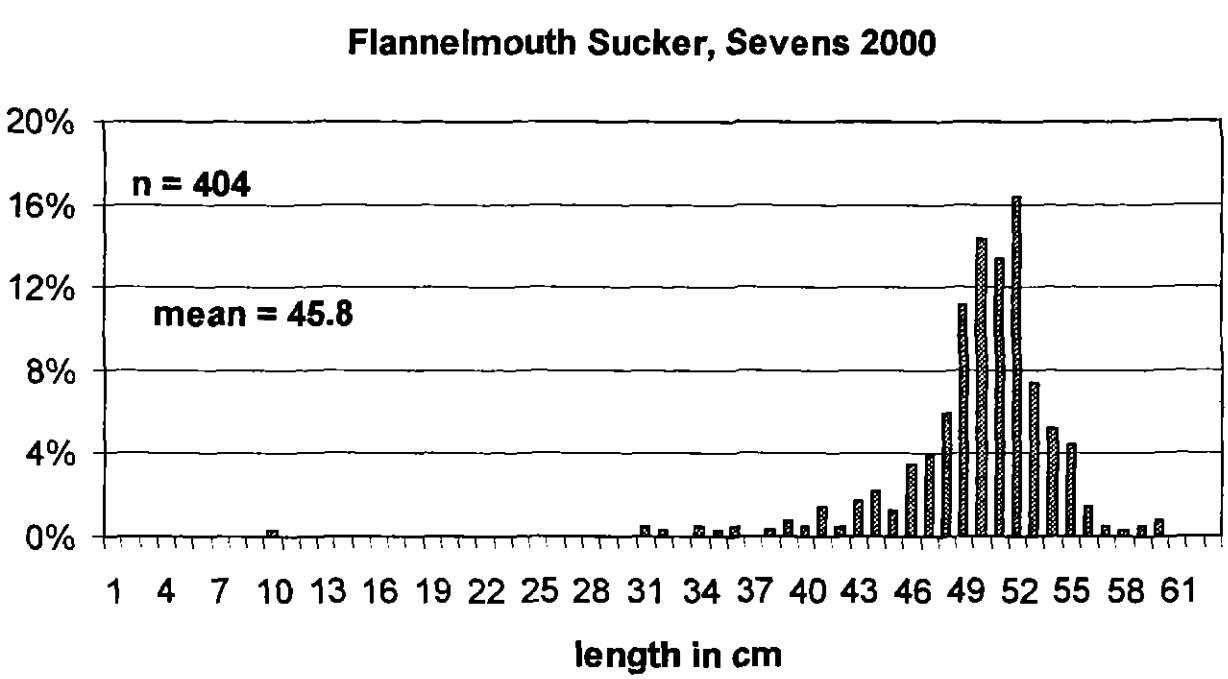


Figure 7. Flannelmouth Sucker length frequency at the Sevens site, September 2000, Yampa River.

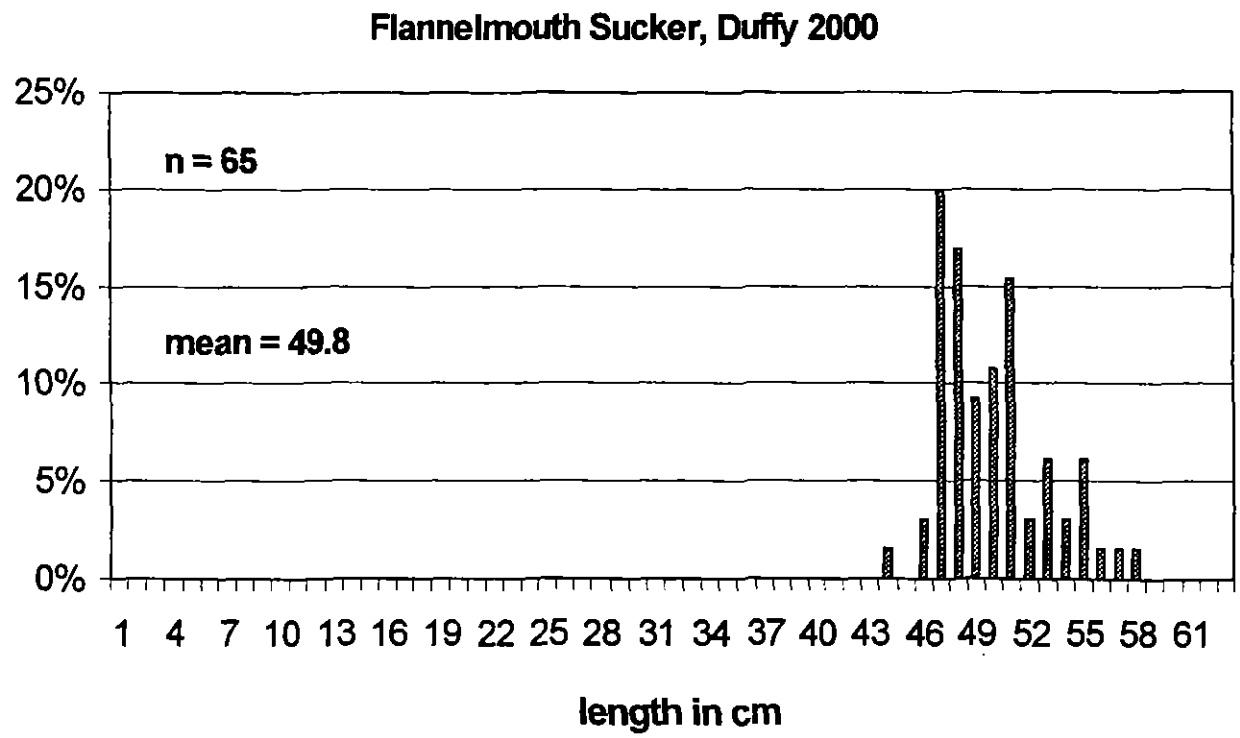


Figure 8. Flannelmouth Sucker length frequency at the Duffy site, September 2000, Yampa River

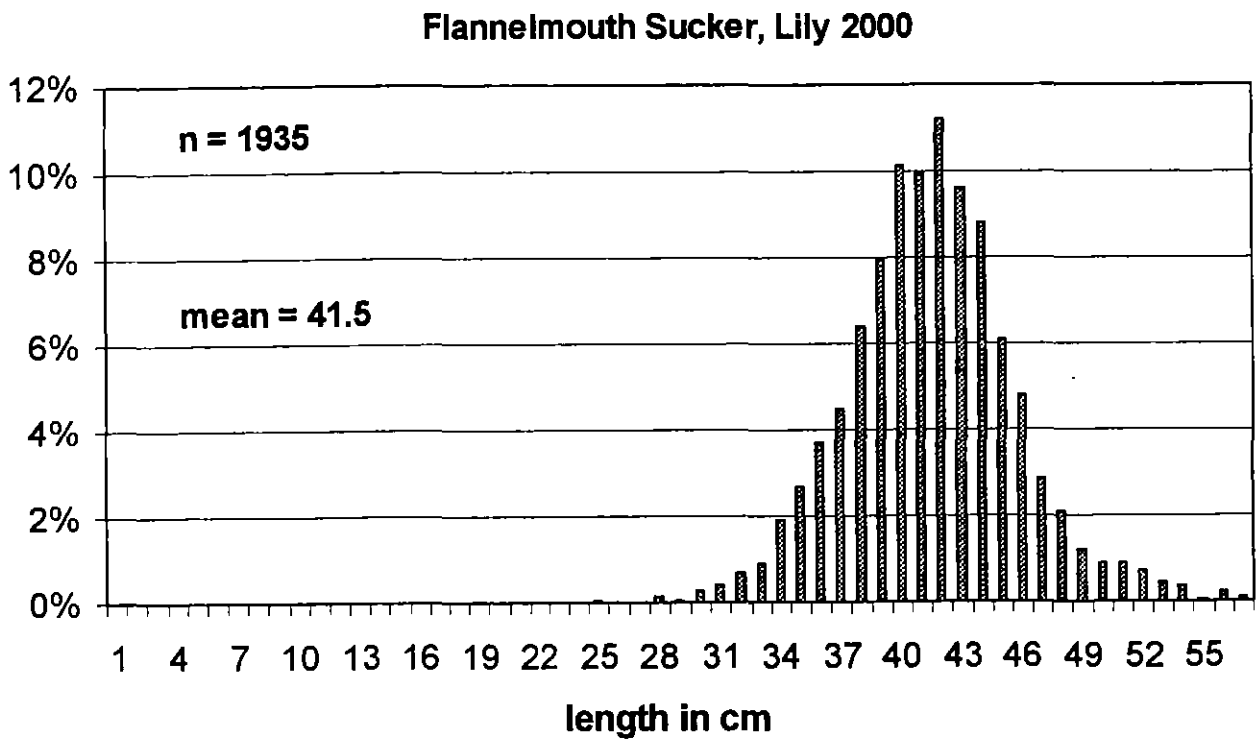


Figure 9. Flannelmouth Sucker length frequency at the Lily Park site, September 2000, Yampa River.

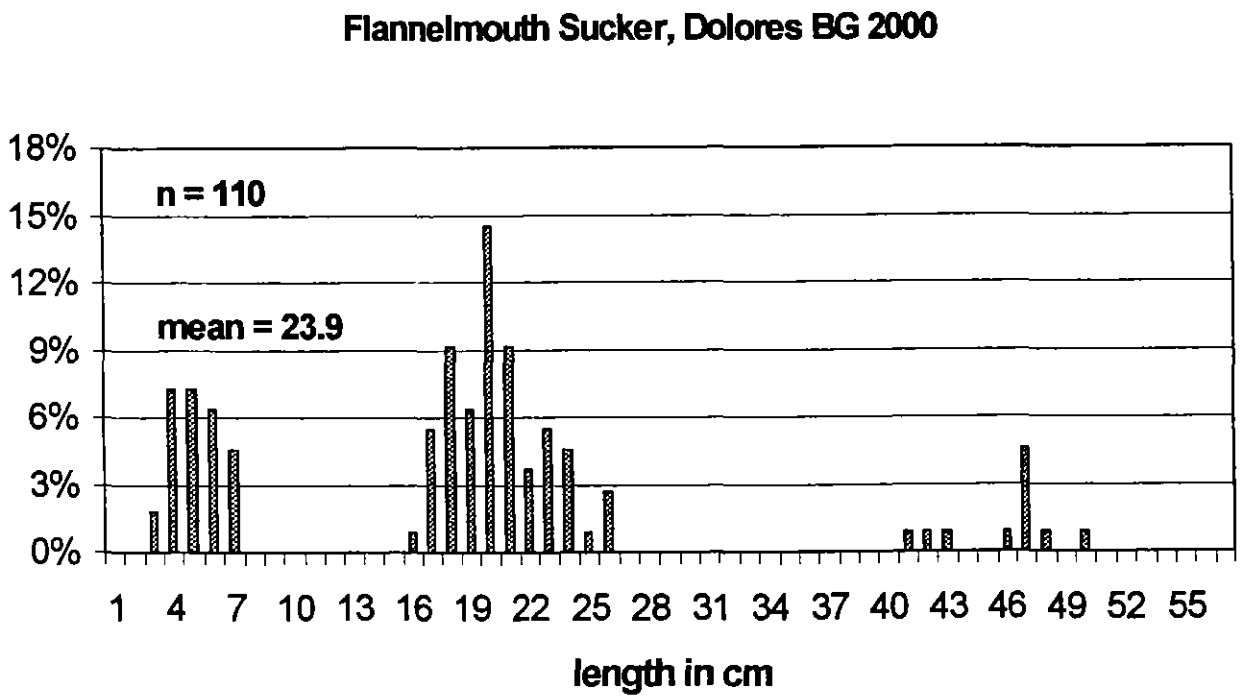


Figure 10. Flannelmouth Sucker length frequency at the Big Gypsum site, July 2000, Dolores River

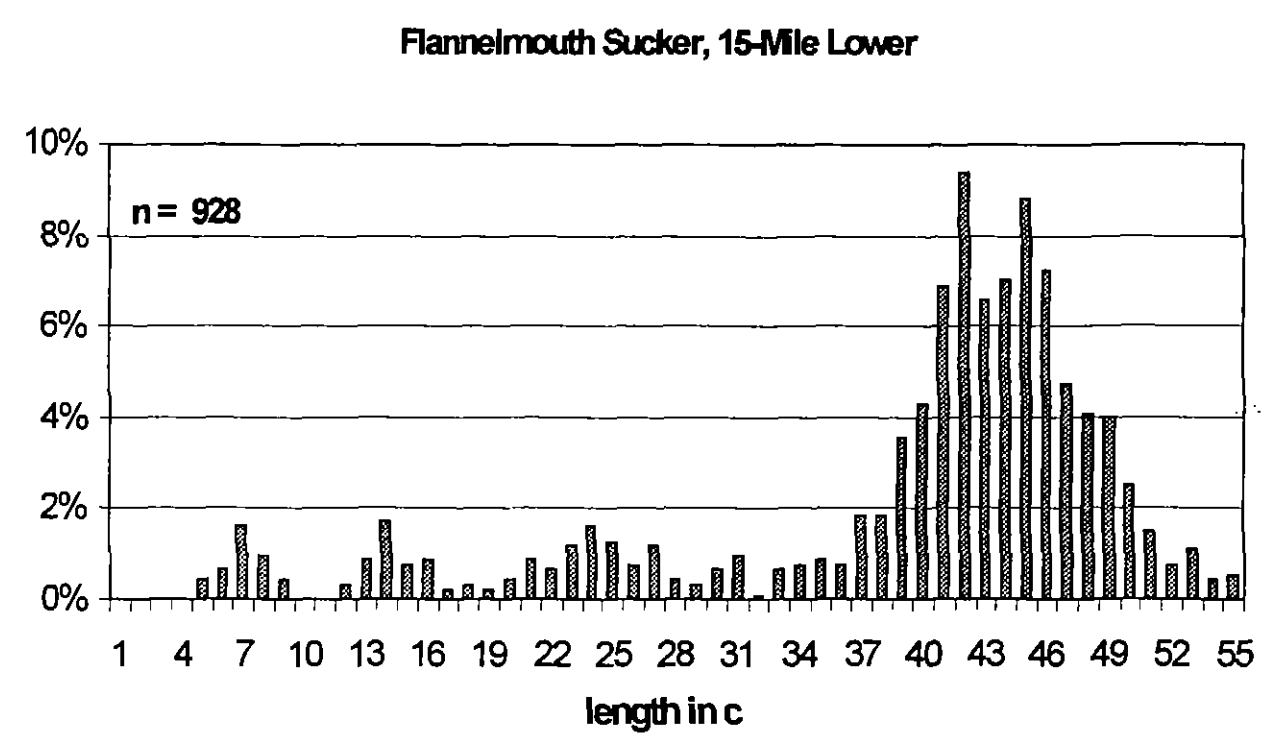


Figure 11. Flannelmouth Sucker length frequency at the Lower 15-Mile Reach, August 2000, Colorado River.

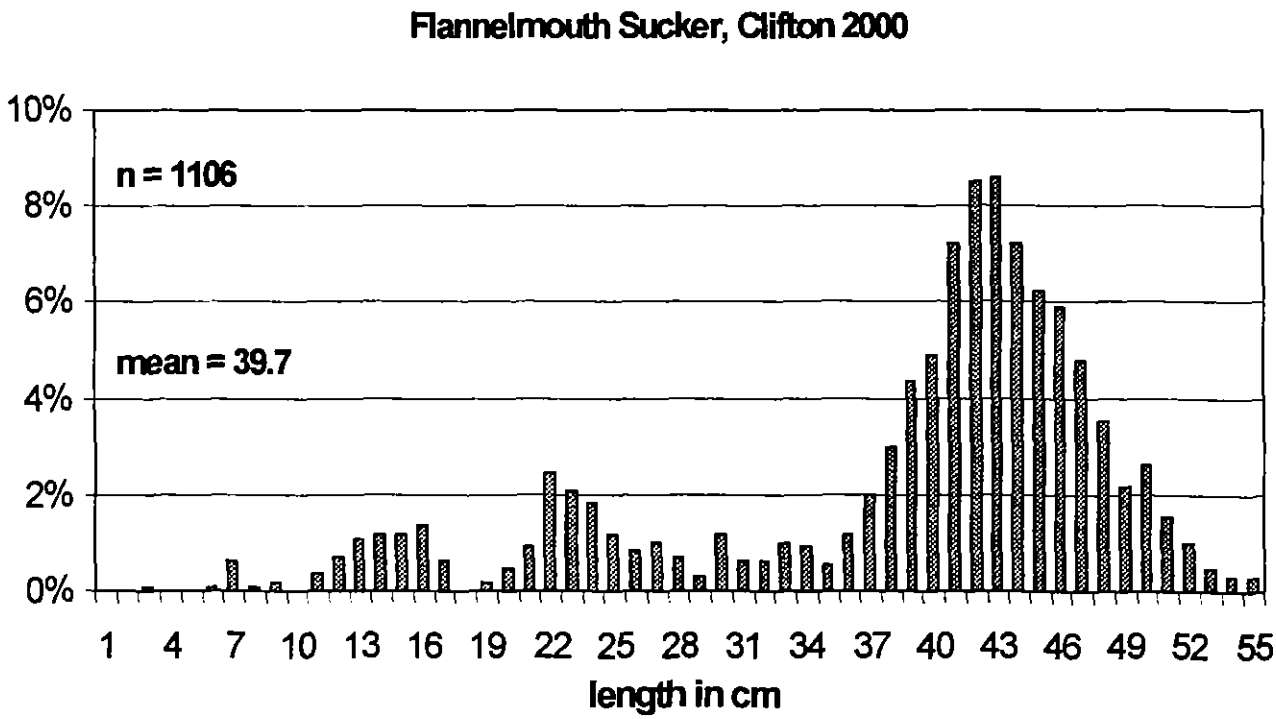


Figure 12. Flannelmouth Sucker length frequency at the Clifton site, August 2000, Colorado River.

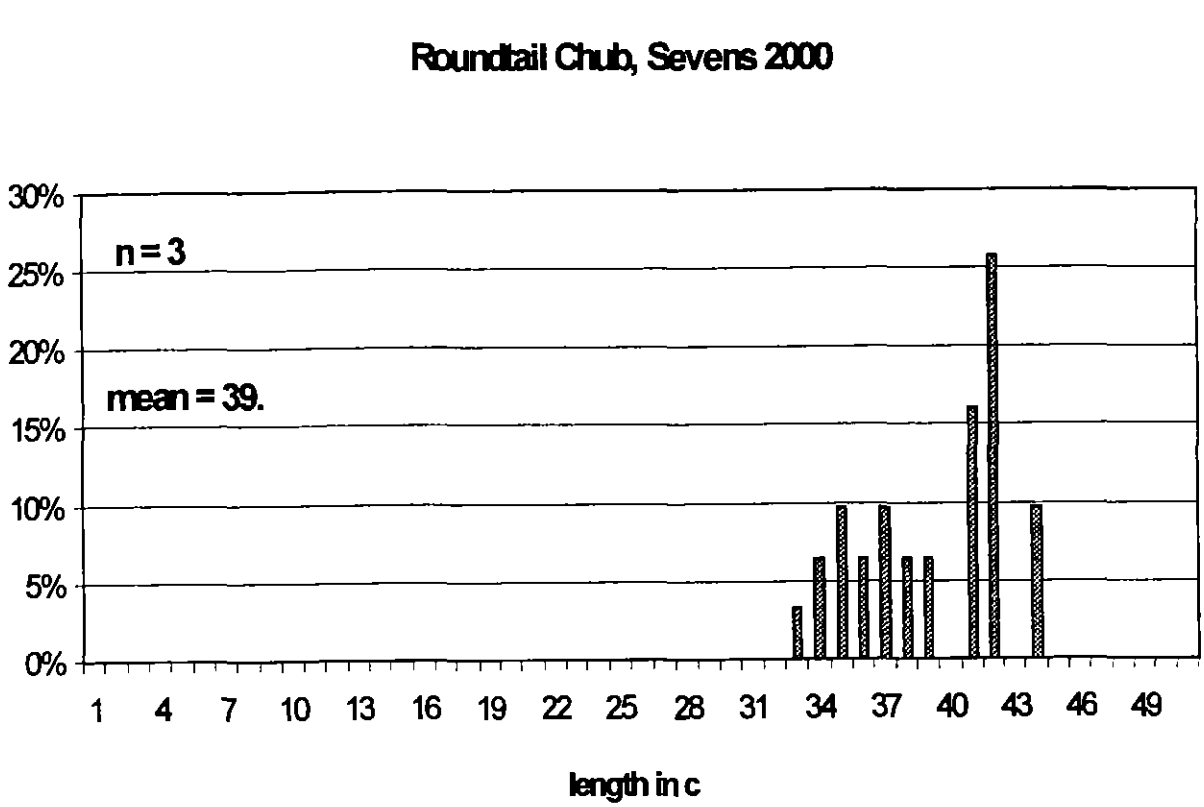


Figure 13. Roundtail Chub length frequency at the Sevens site, September 2000, Yampa River.

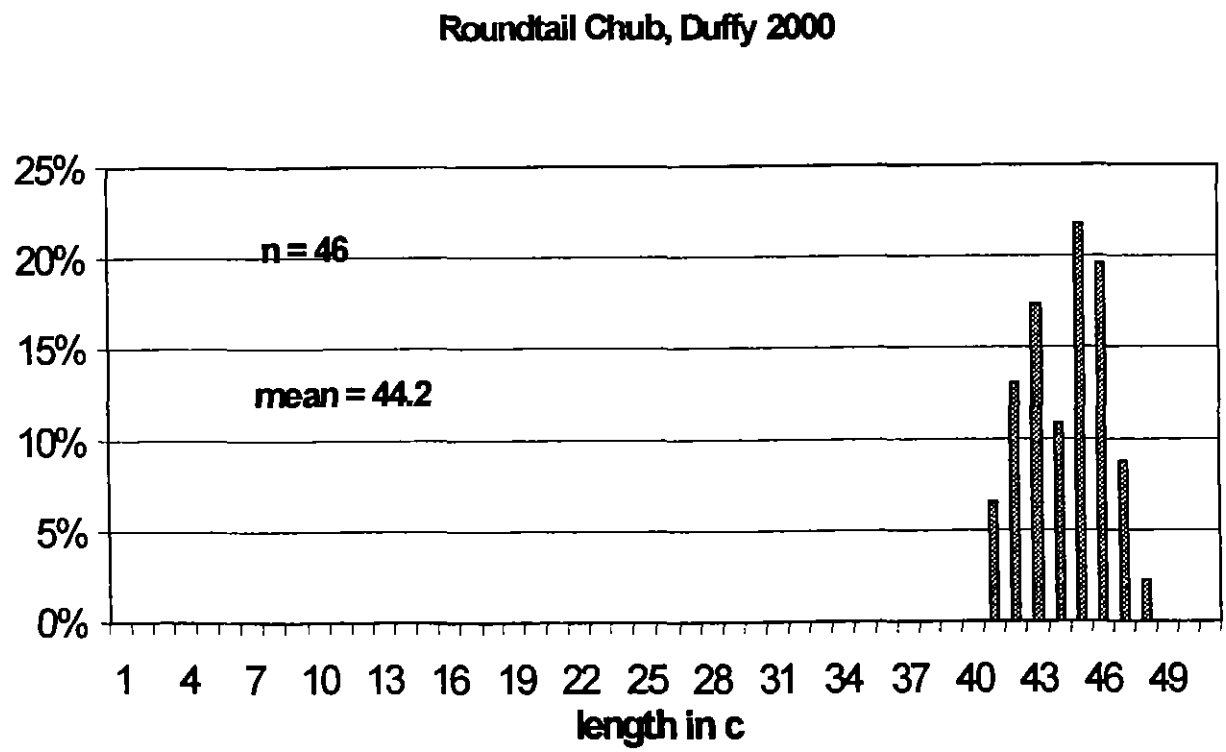


Figure 14. Roundtail Chub length frequency at the Duffy site, September 2000, Yampa River.

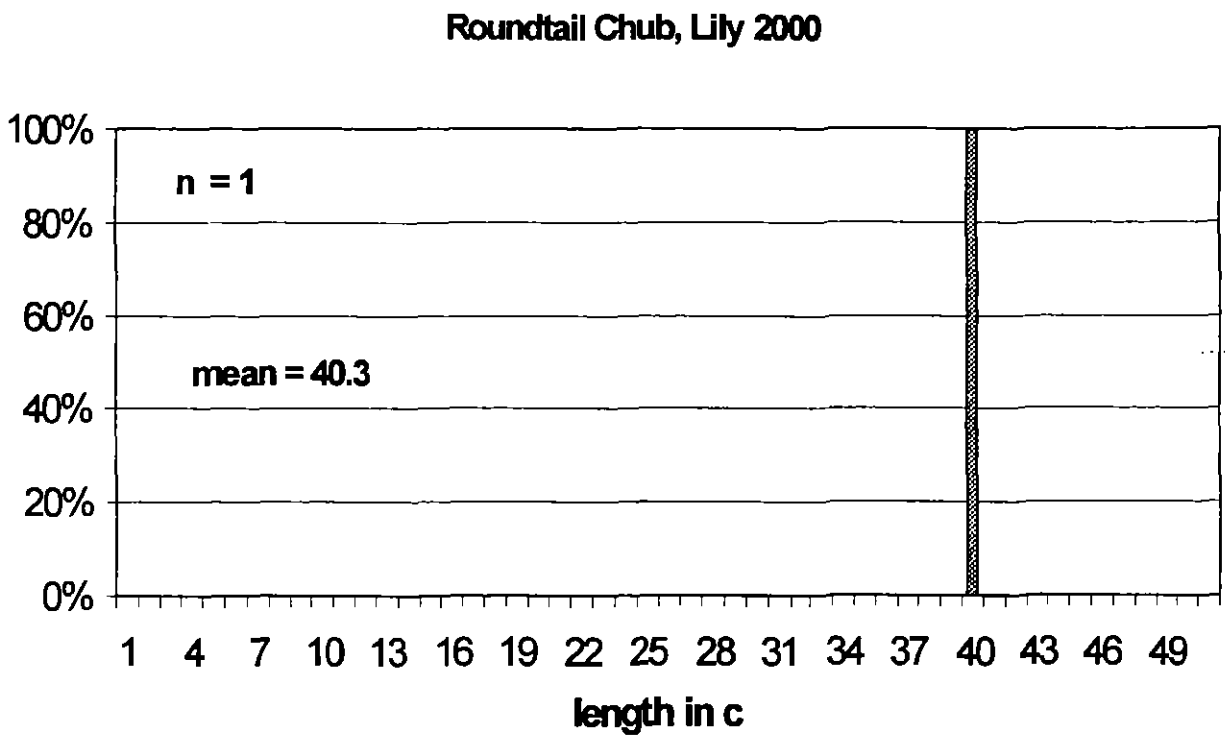


Figure 15. Roundtail Chub length frequency at the Lily Park site, September 2000, Yampa River.

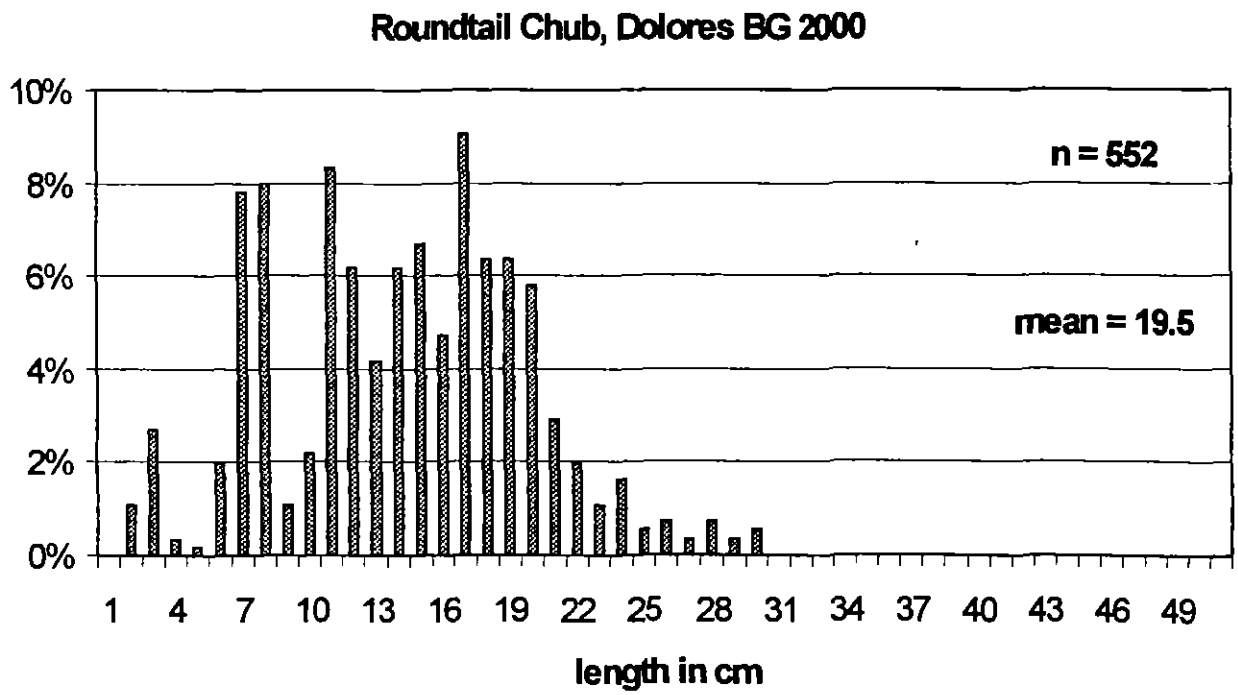


Figure 16. Roundtail Chub length frequency at the Big Gypsum site, July 2000, Dolores River.

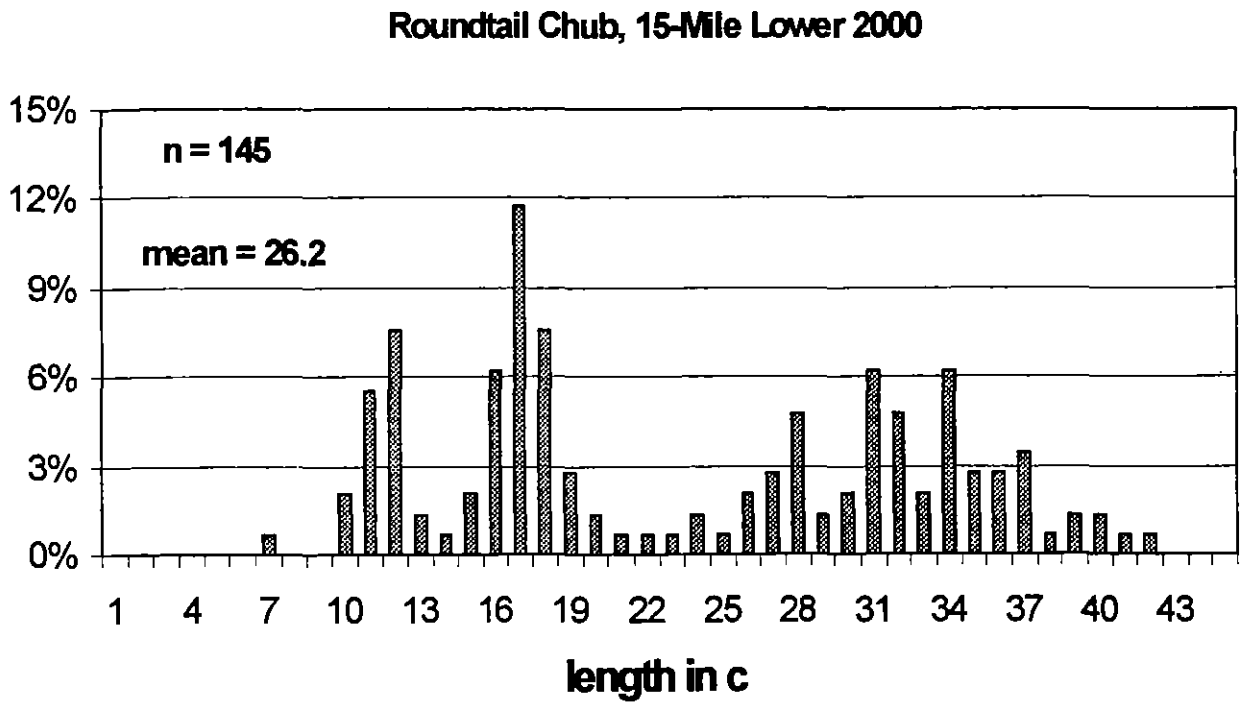


Figure 17. Roundtail Chub length frequency at the Lower 15-Mile Reach site, August 2000, Colorado River.

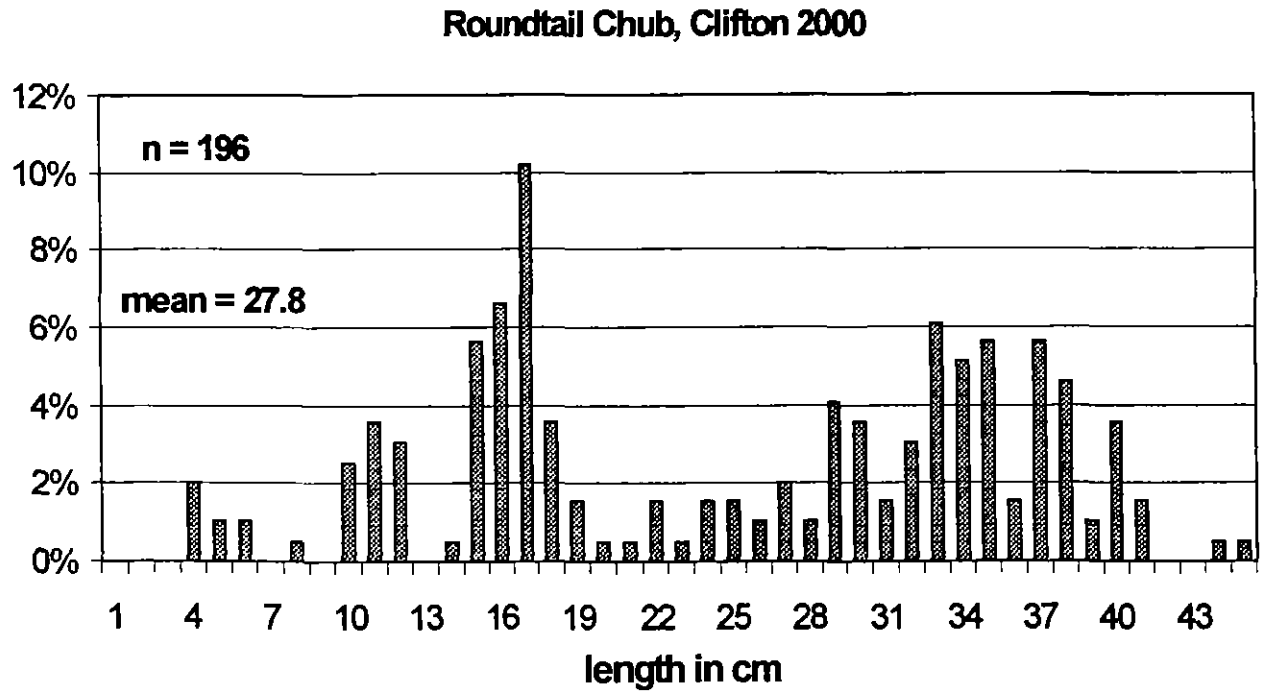


Figure 18. Roundtail Chub length frequency at the Clifton site, August 2000, Colorado River.

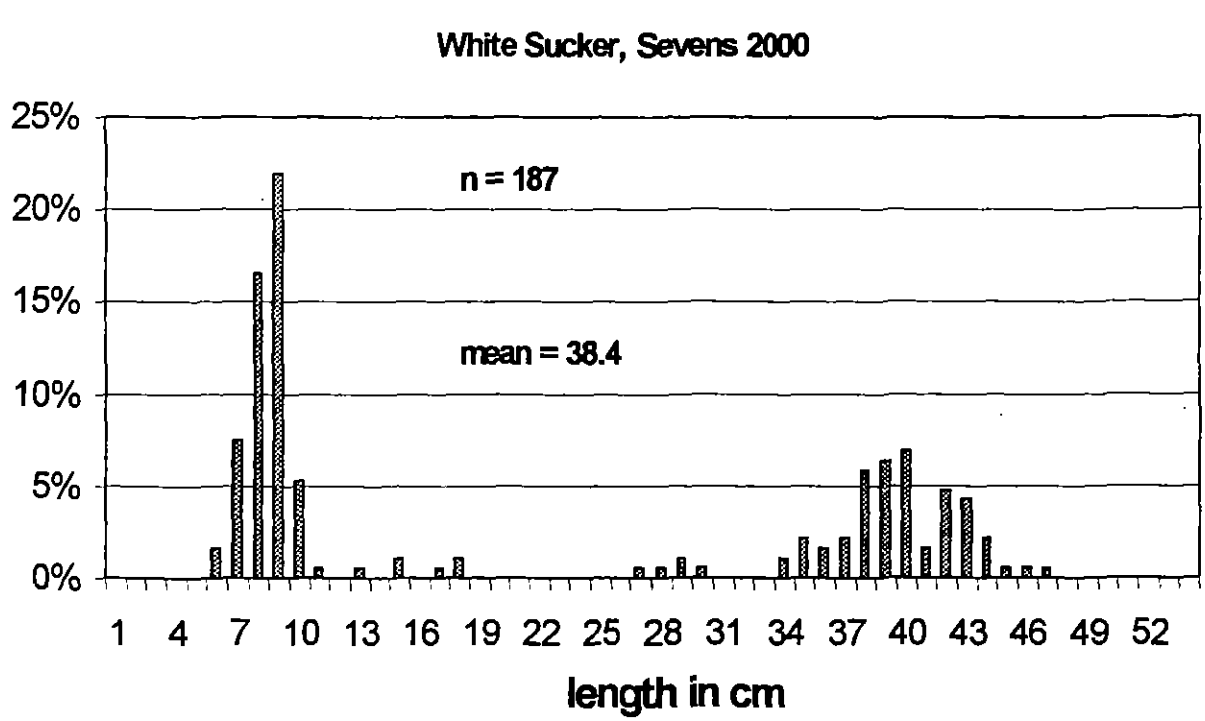


Figure 19. White Sucker length frequency at the Sevens site, September 2000, Yampa River.

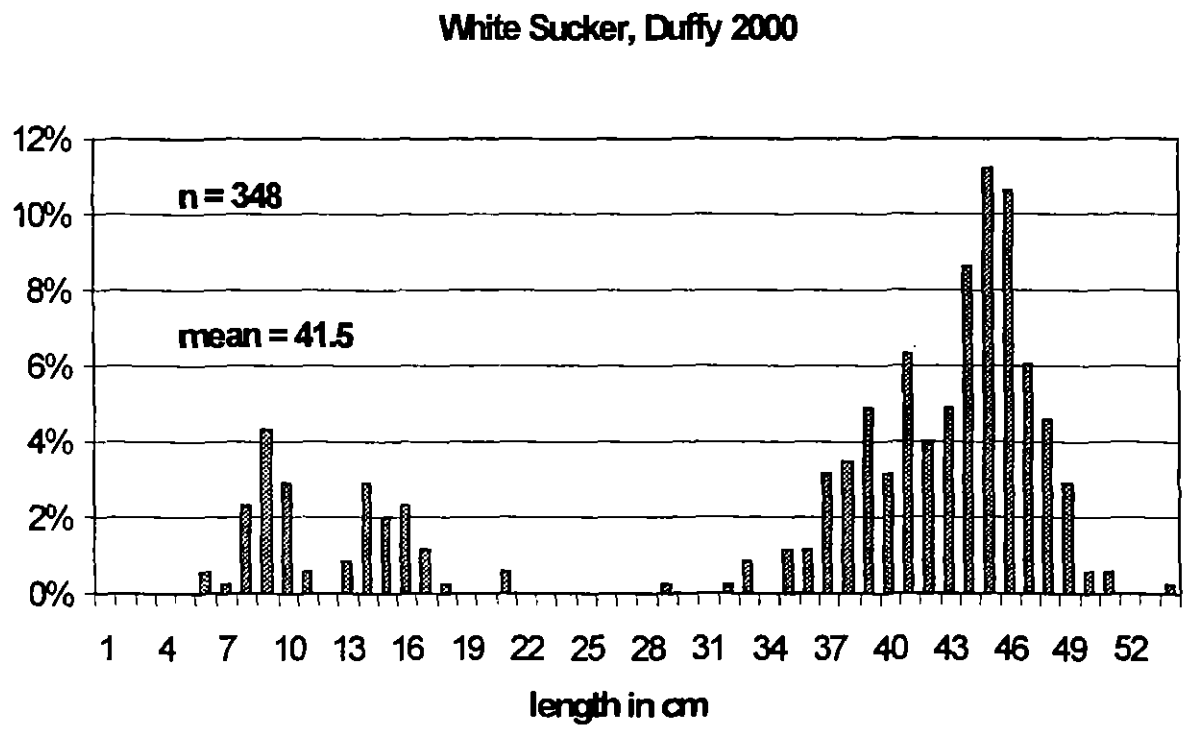


Figure 20. White Sucker length frequency at the Duffy site, September 2000, Yampa River.

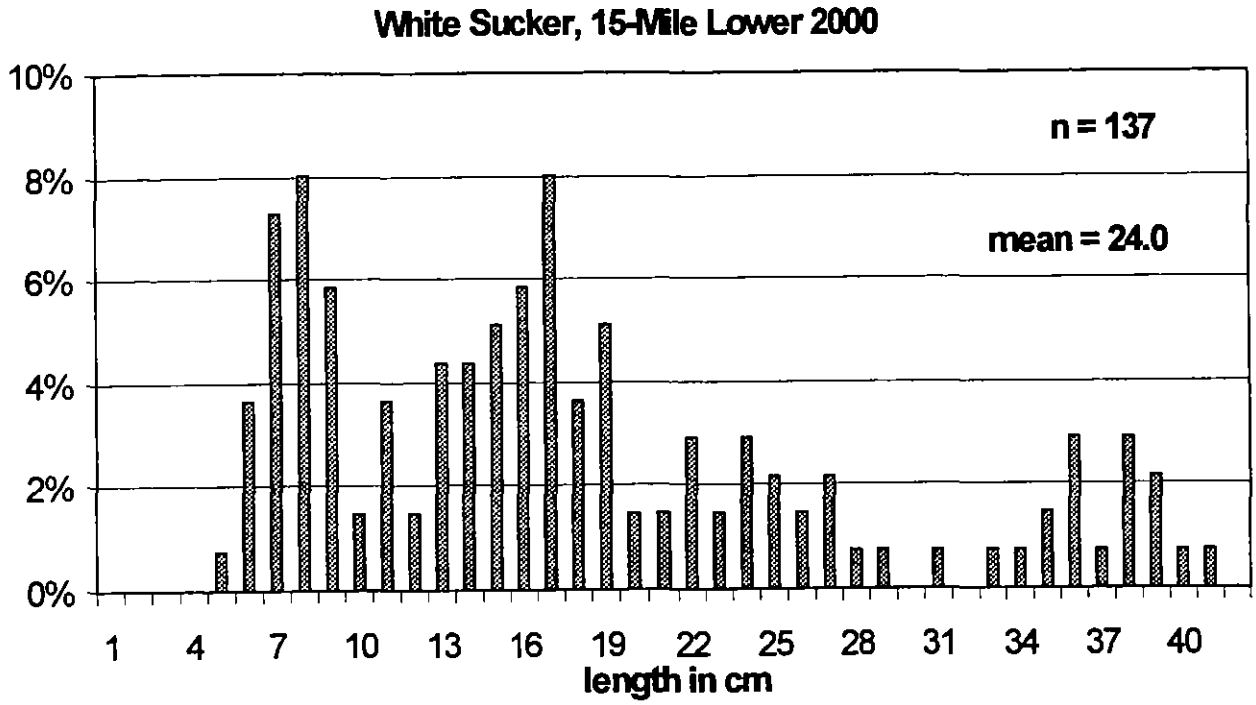


Figure 21. White Sucker length frequency at the Lower 15-Mile Reach site, August 2000, Colorado River

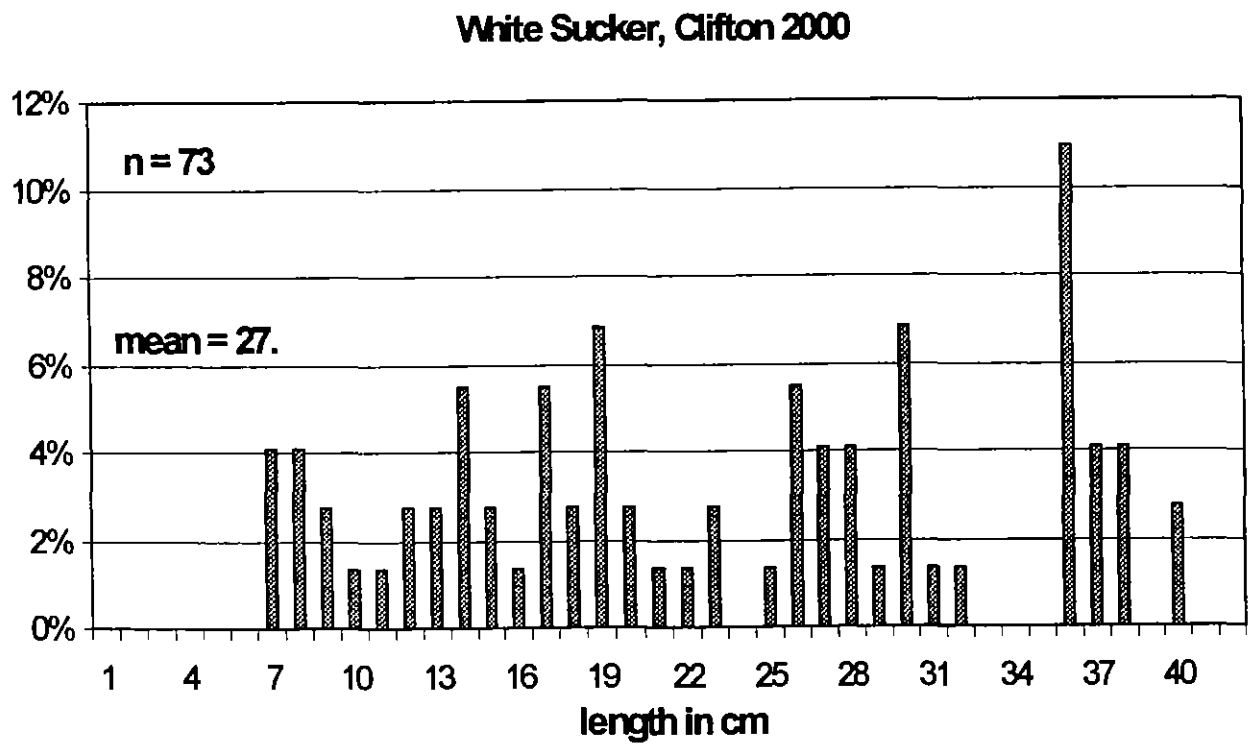


Figure 22. White Sucker length frequency at the Clifton site, August 2000, Colorado River.

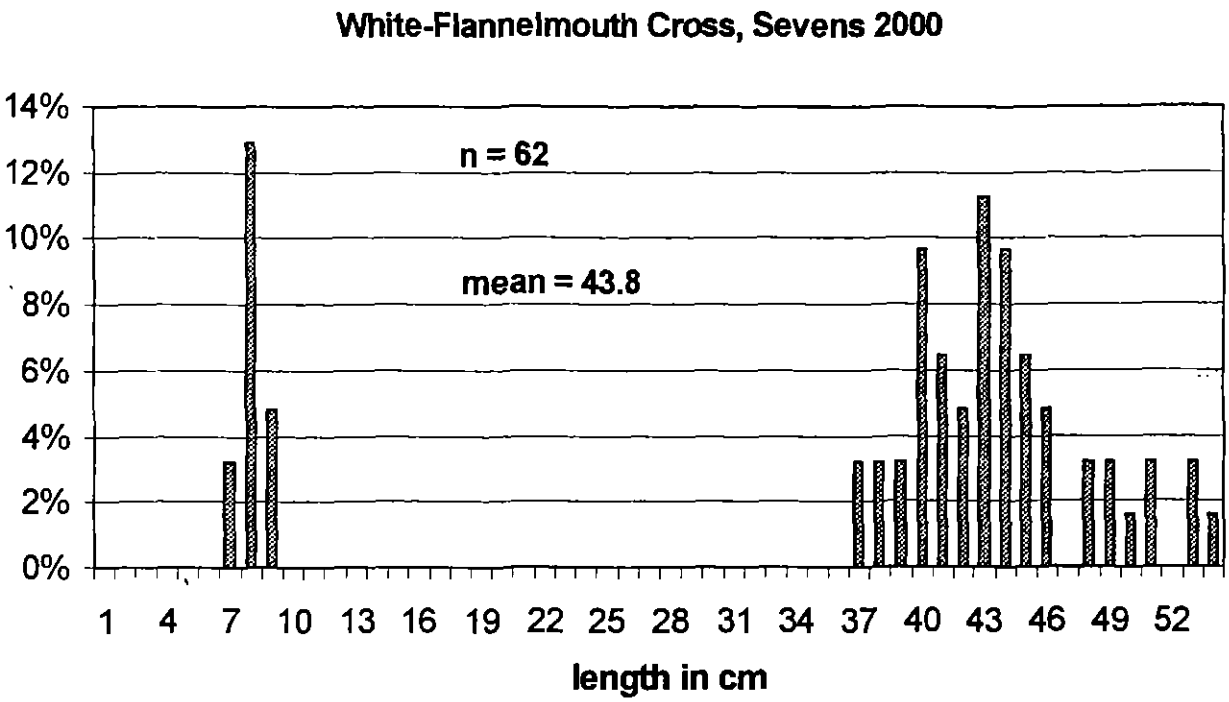


Figure 23. White-Flannelmouth Cross length frequency at the Sevens site, September 2000, Yampa River.

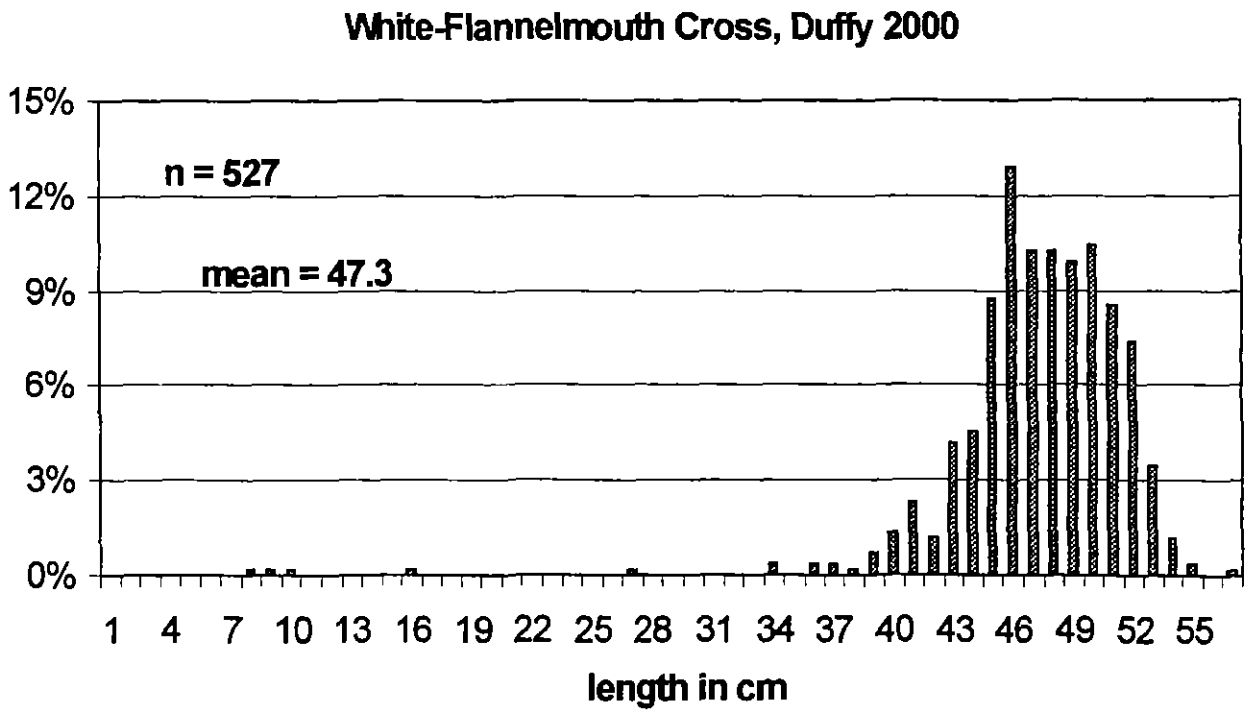


Figure 24. White-Flannelmouth Cross length frequency at the Duffy site, September 2000, Yampa River.

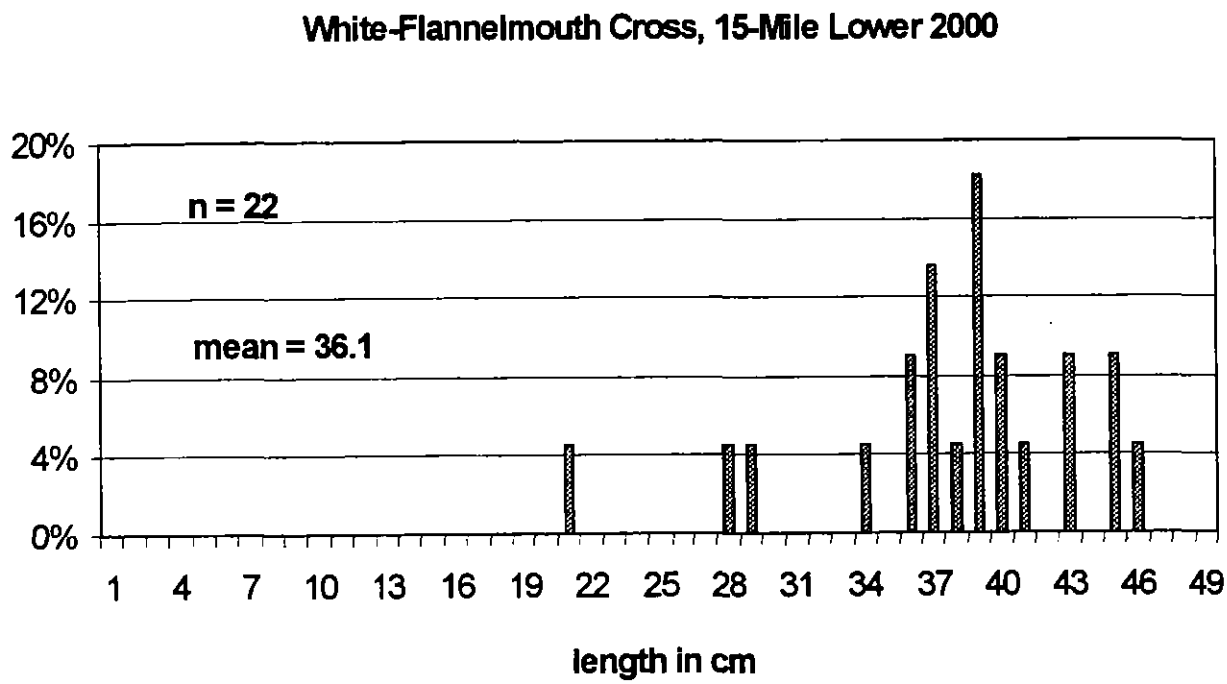


Figure 25. White-Flannelmouth Cross length frequency at the Lower 15-Mile Reach site, August 2000, Colorado River.

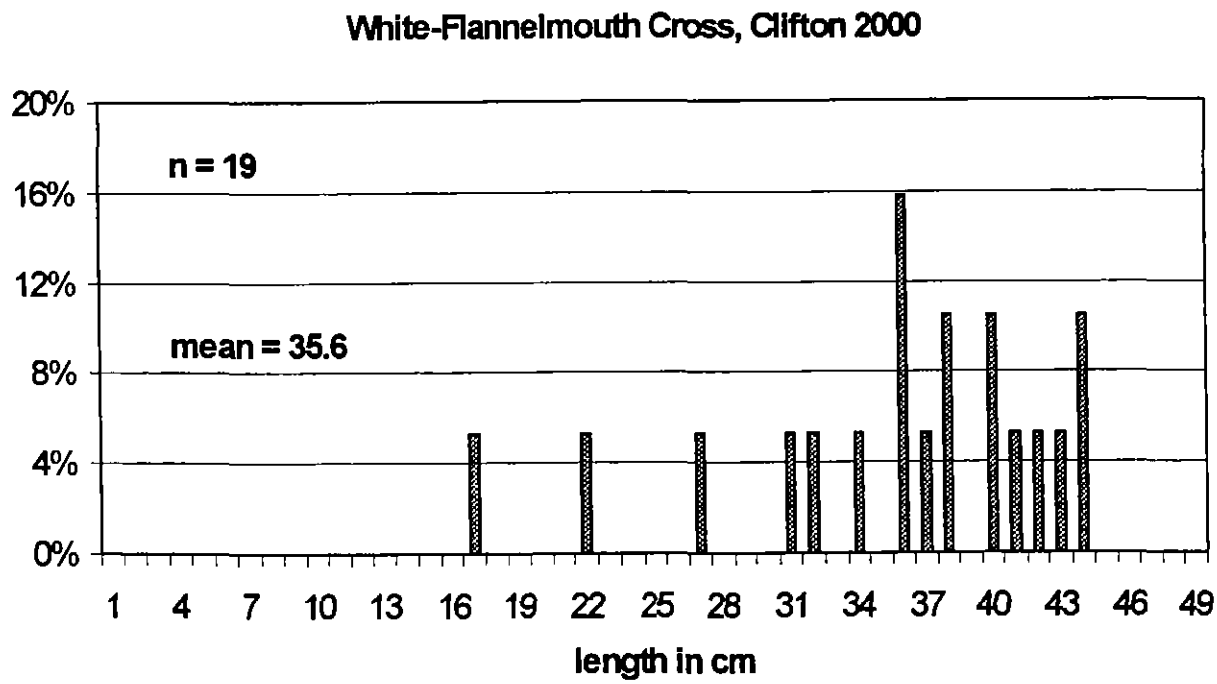


Figure 26. White-Flannelmouth Cross length frequency at the Clifton site, August 2000, Colorado River.

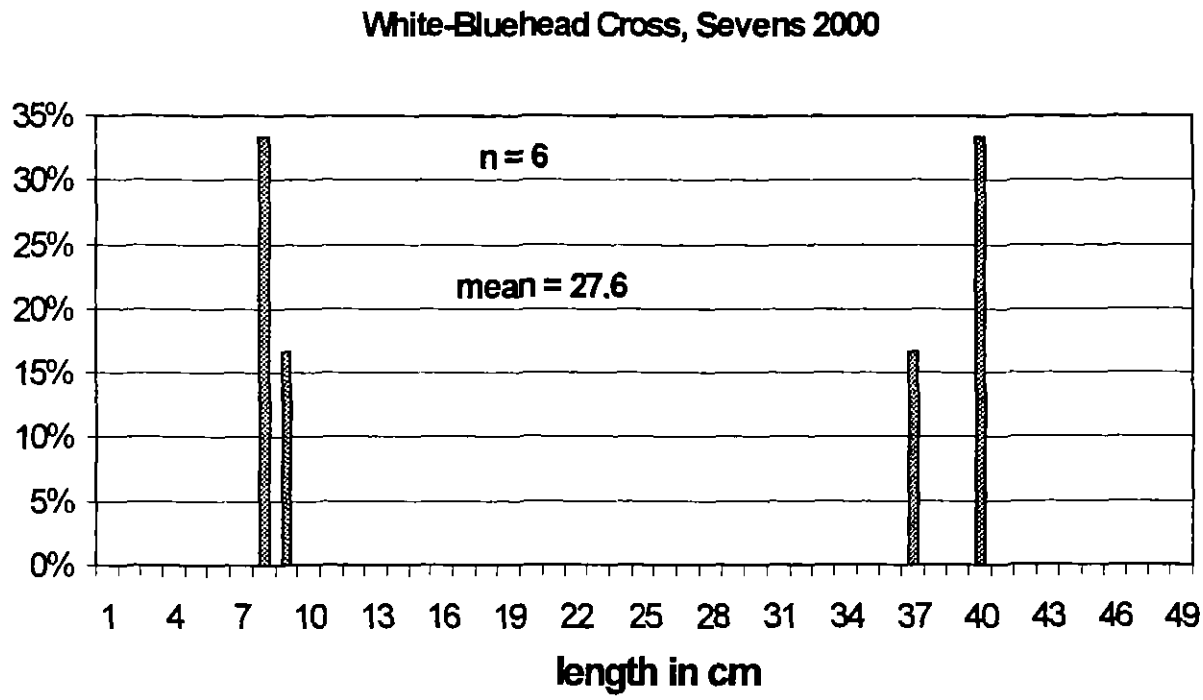


Figure 27. White-Bluehead Cross length frequency at the Sevens site, September 2000, Yampa River.

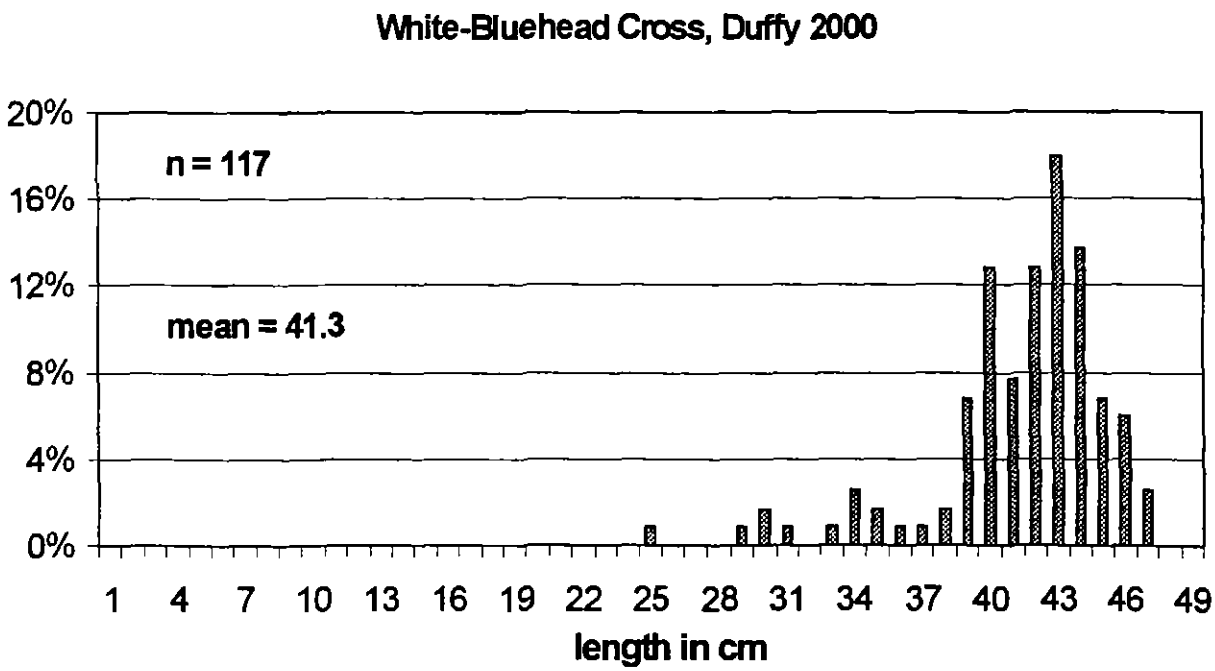


Figure 28. White-Bluehead Cross length frequency at the Duffy site, September 2000, Yampa River.

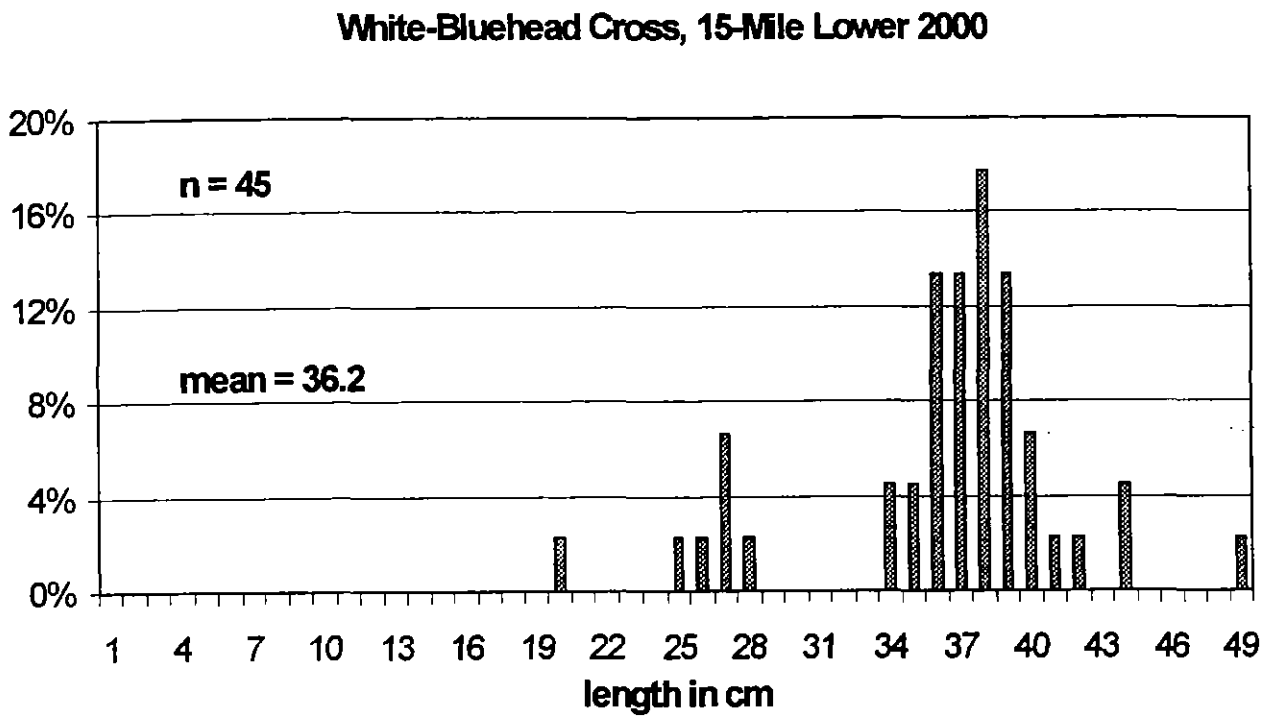


Figure 29. White-Bluehead Cross length frequency at the Lower 15-Mile Reach site, August 2000, Colorado River.

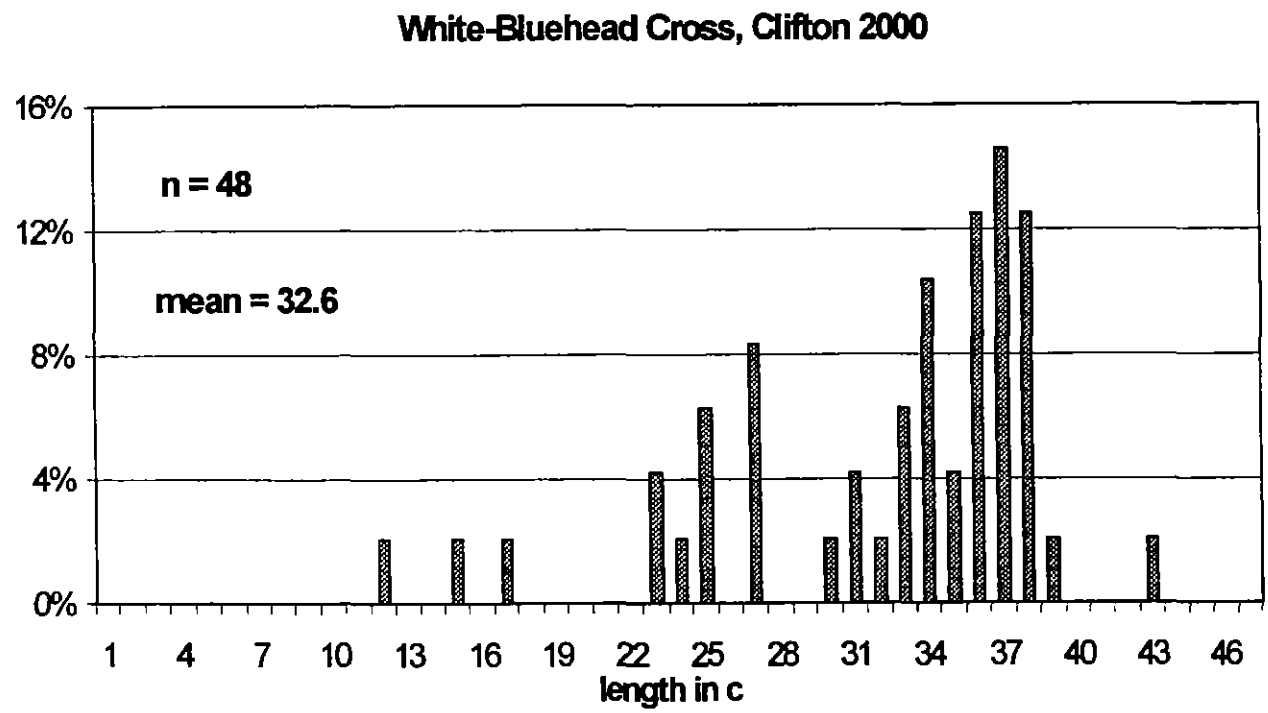


Figure 30. White-Bluehead Cross length frequency at the Clifton site, August 2000, Colorado River.

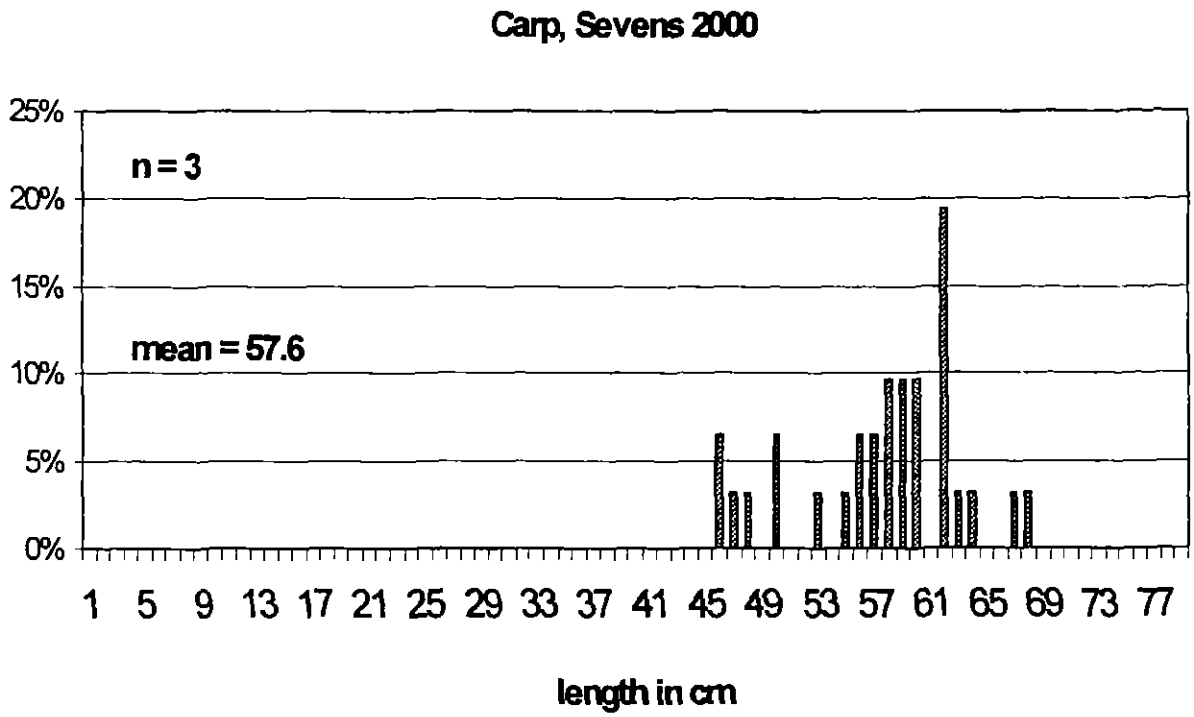


Figure 31. Carp length frequency at the Sevens site, September 2000, Yampa River.

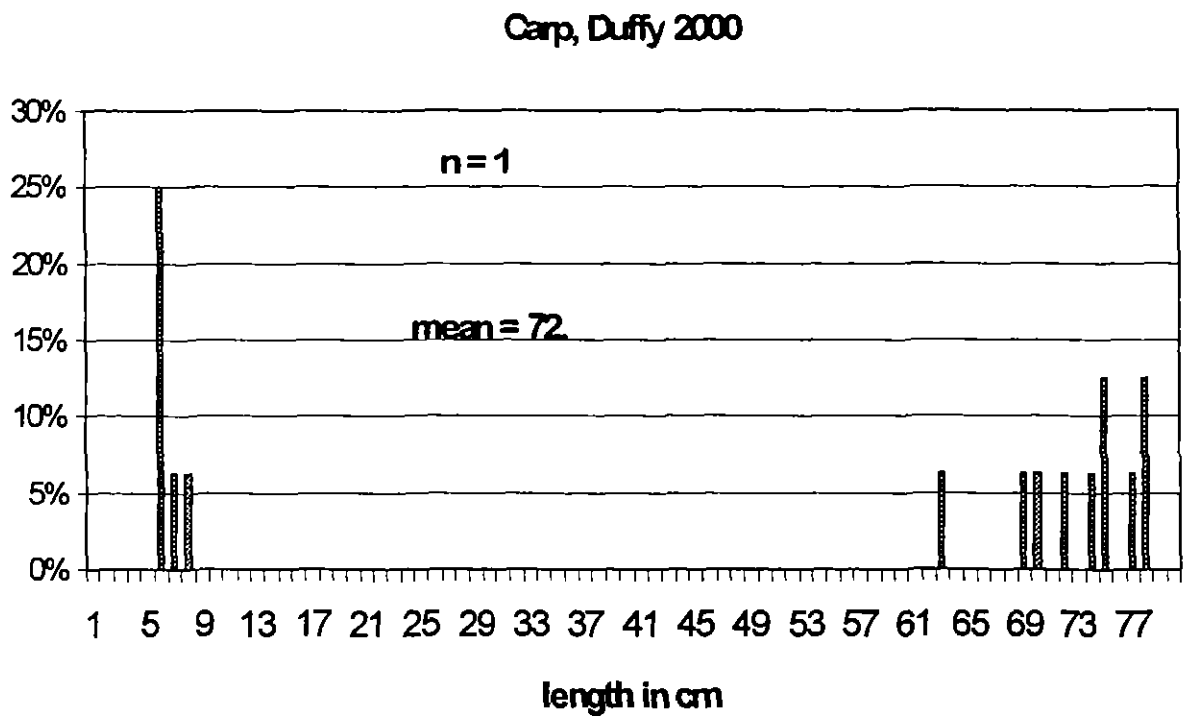


Figure 32. Carp length frequency at the Duffy site, September 2000, Yampa River.

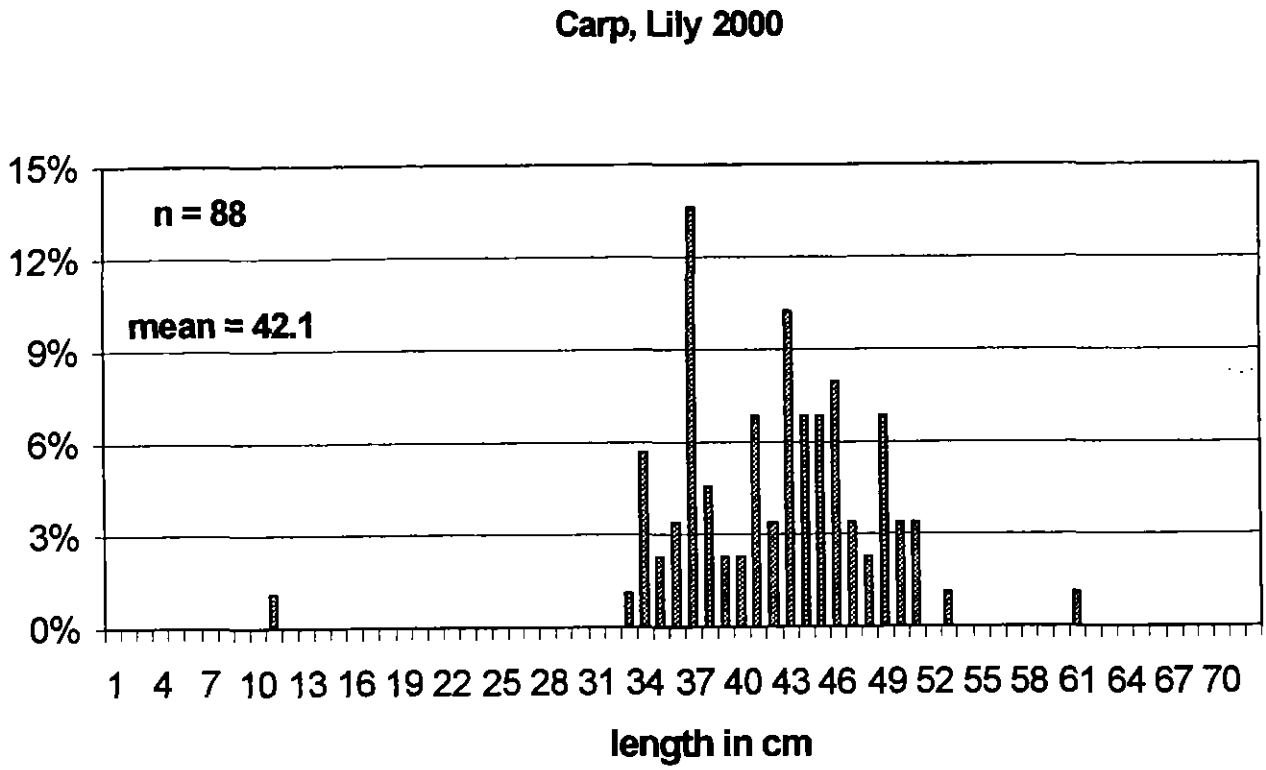


Figure 33. Carp length frequency at the Lily Park site, September 2000, Yampa River.

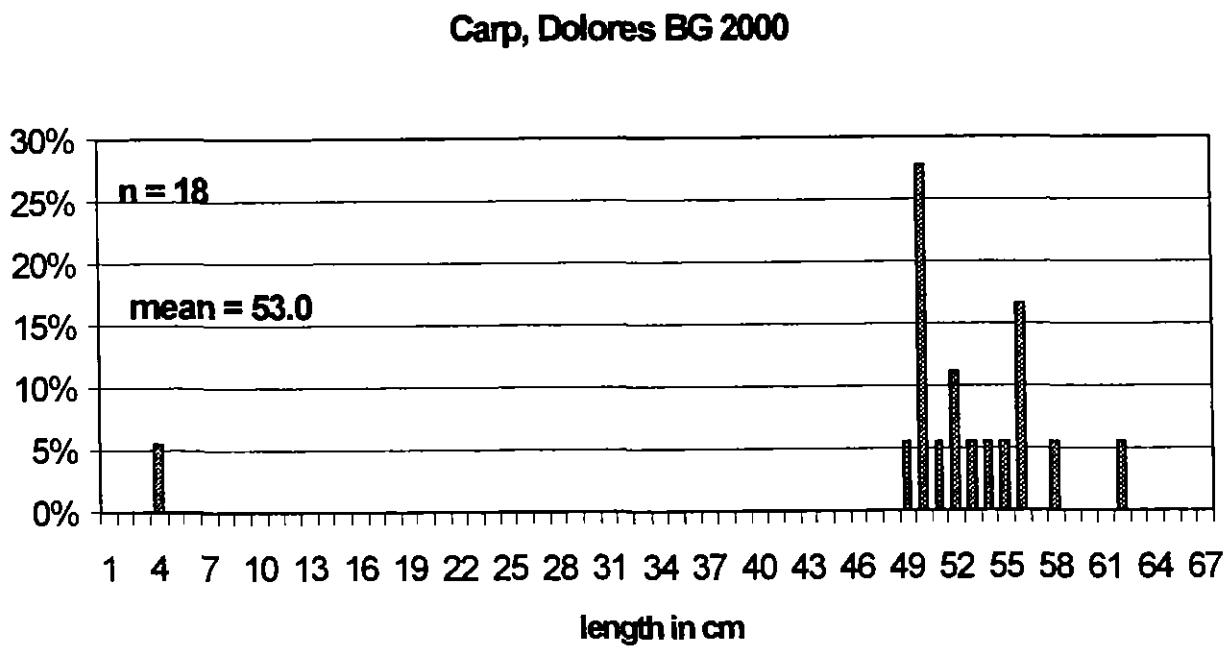


Figure 34. Carp length frequency at the Big Gypsum site, July 2000, Dolores River.

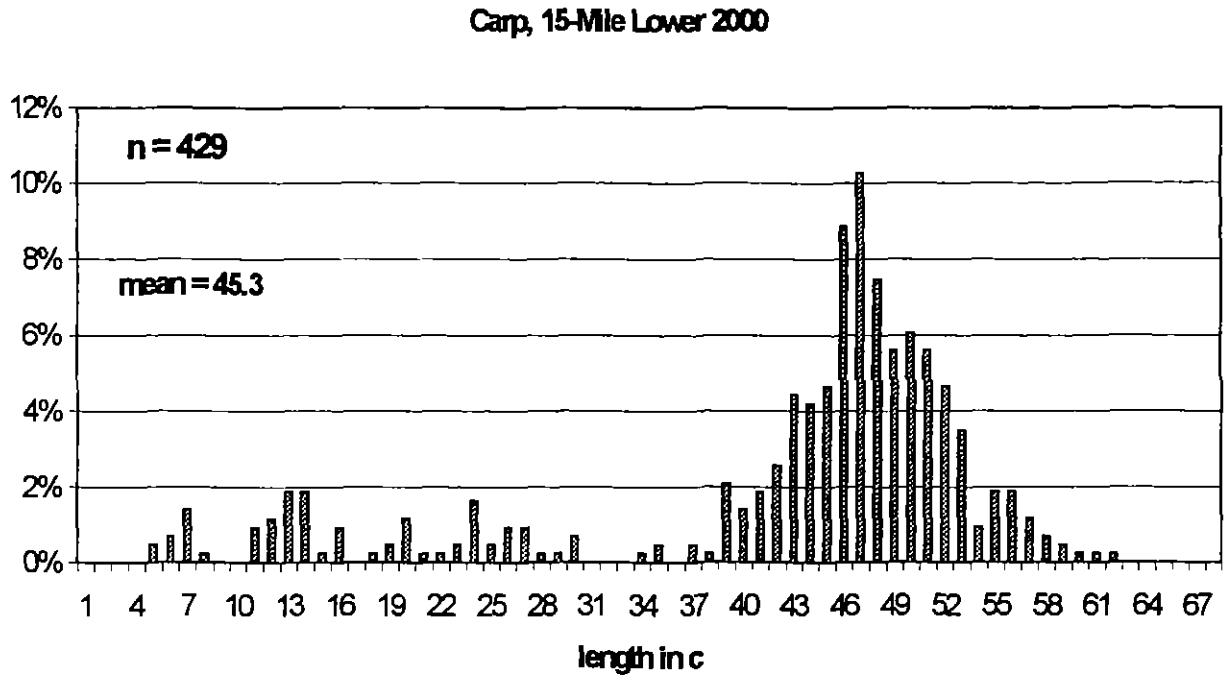


Figure 35. Carp length frequency at the Lower 15-Mile Reach site, August 2000, Colorado River.

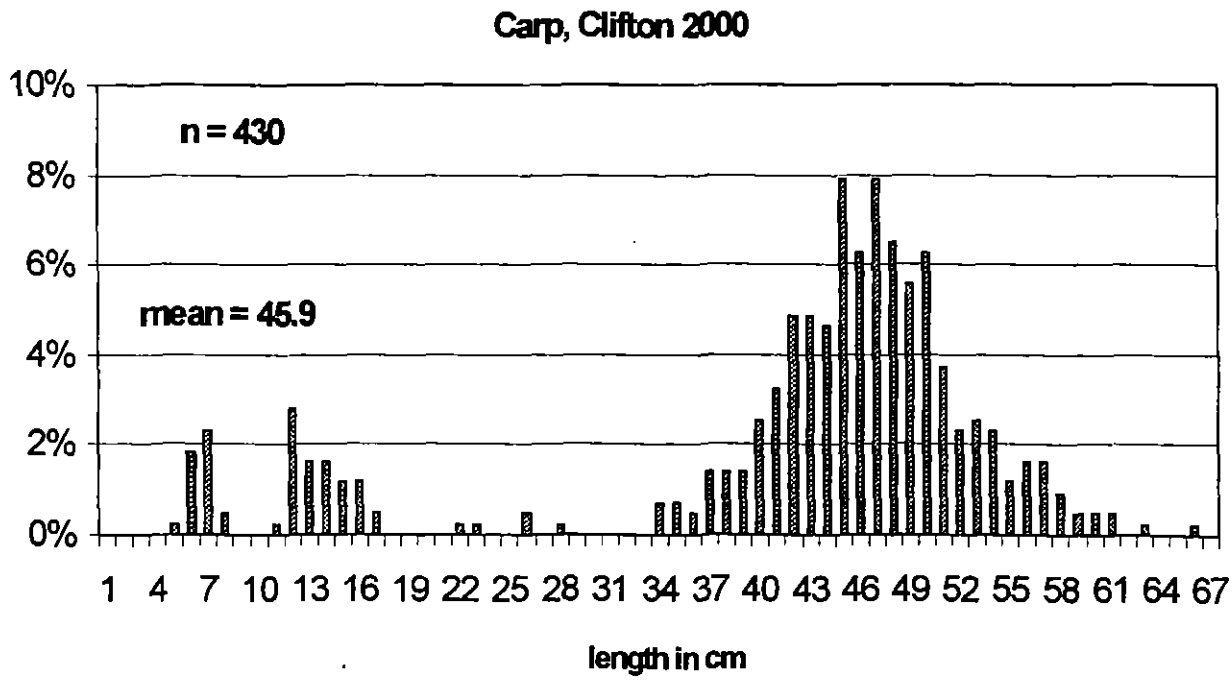


Figure 36. Carp length frequency at the Clifton site, August 2000, Colorado River.

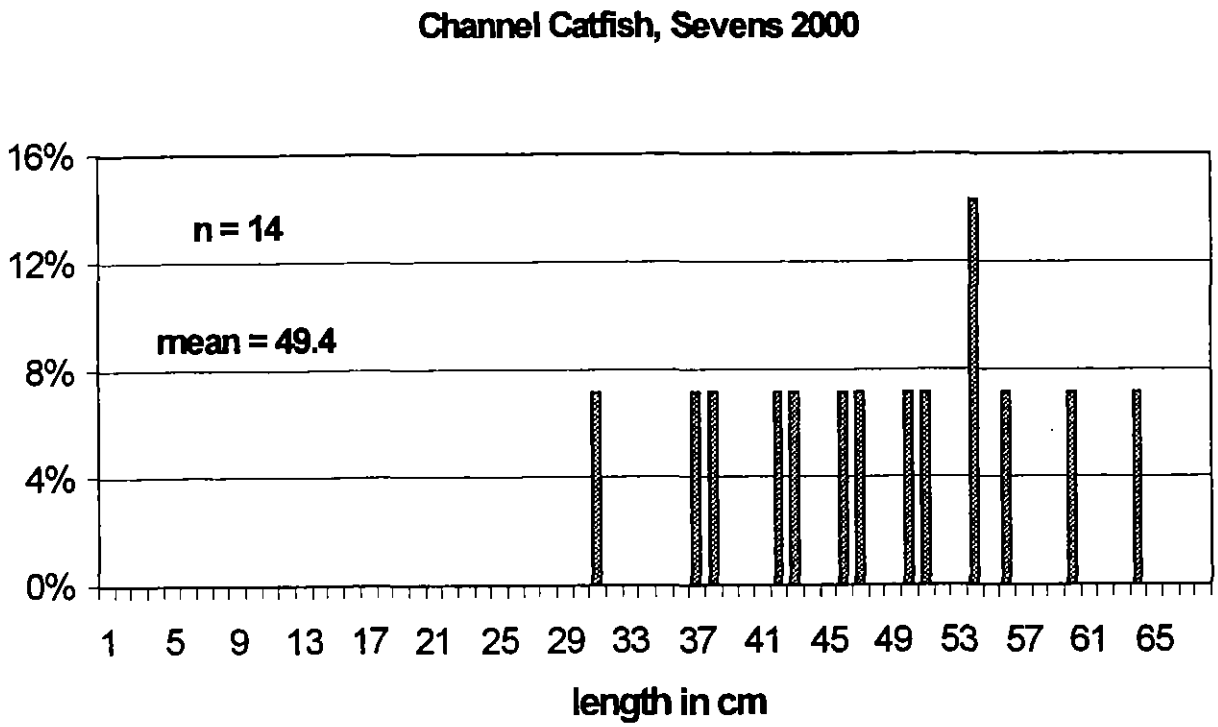


Figure 37. Channel Catfish length frequency at the Sevens site, September 2000, Yampa River.

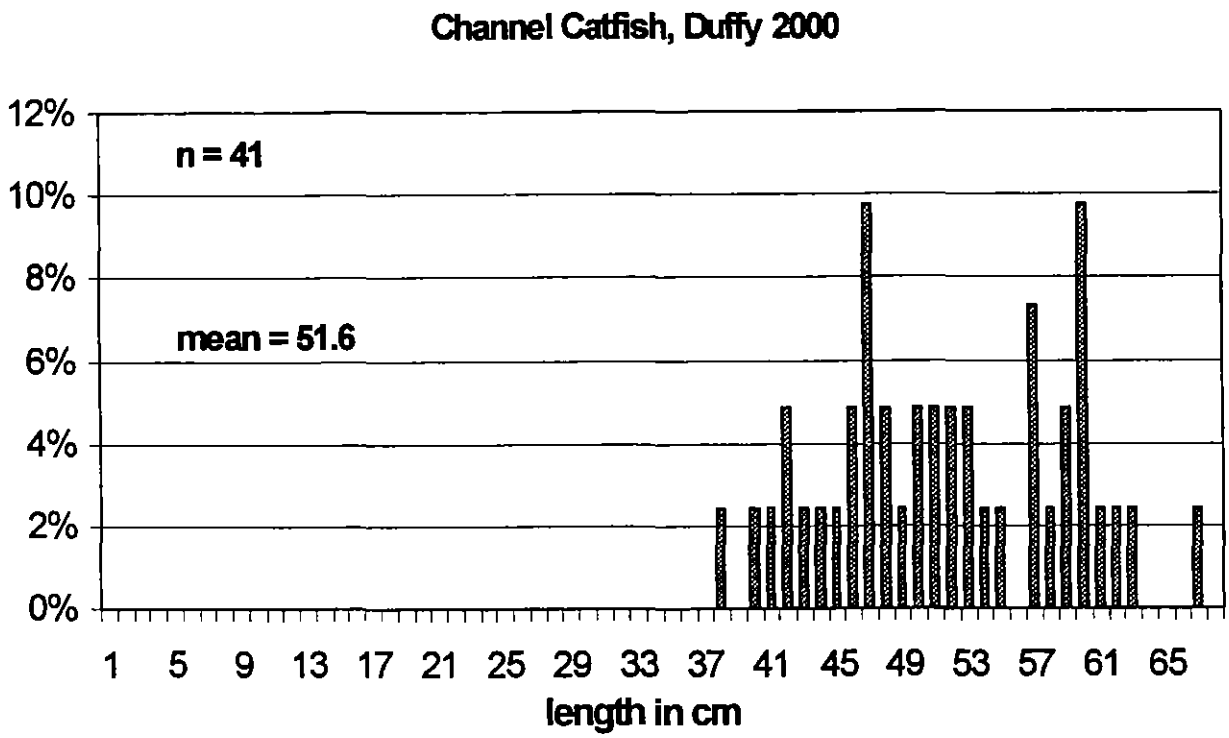


Figure 38. Channel Catfish length frequency at the Duffy site, September 2000, Yampa River.

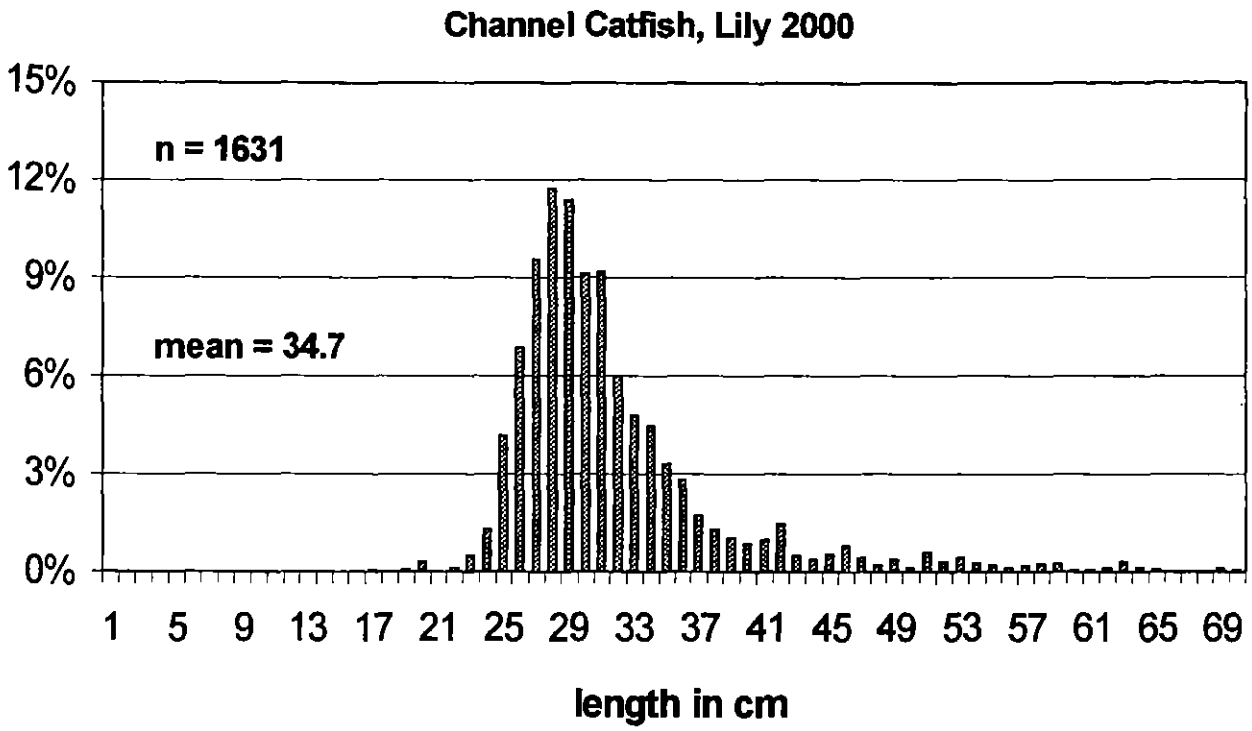


Figure 39. Channel Catfish length frequency at the Lily Park site, September 2000, Yampa River.

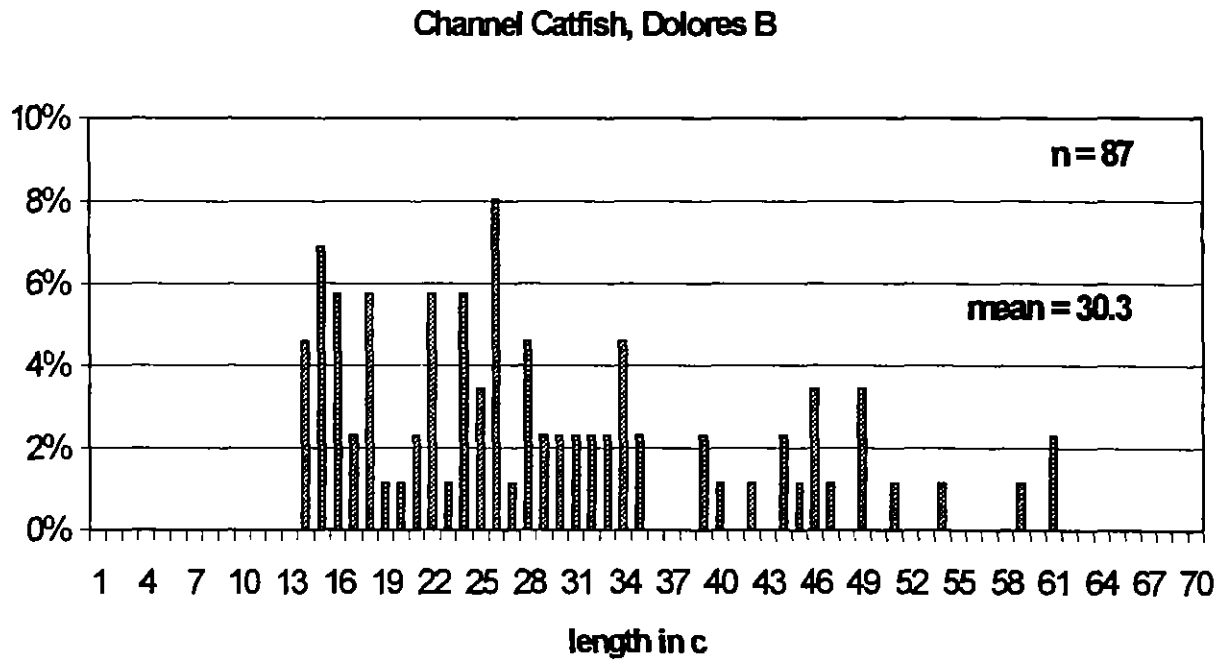


Figure 40. Channel Catfish length frequency at the Big Gypsum site, July 2000, Dolores River.

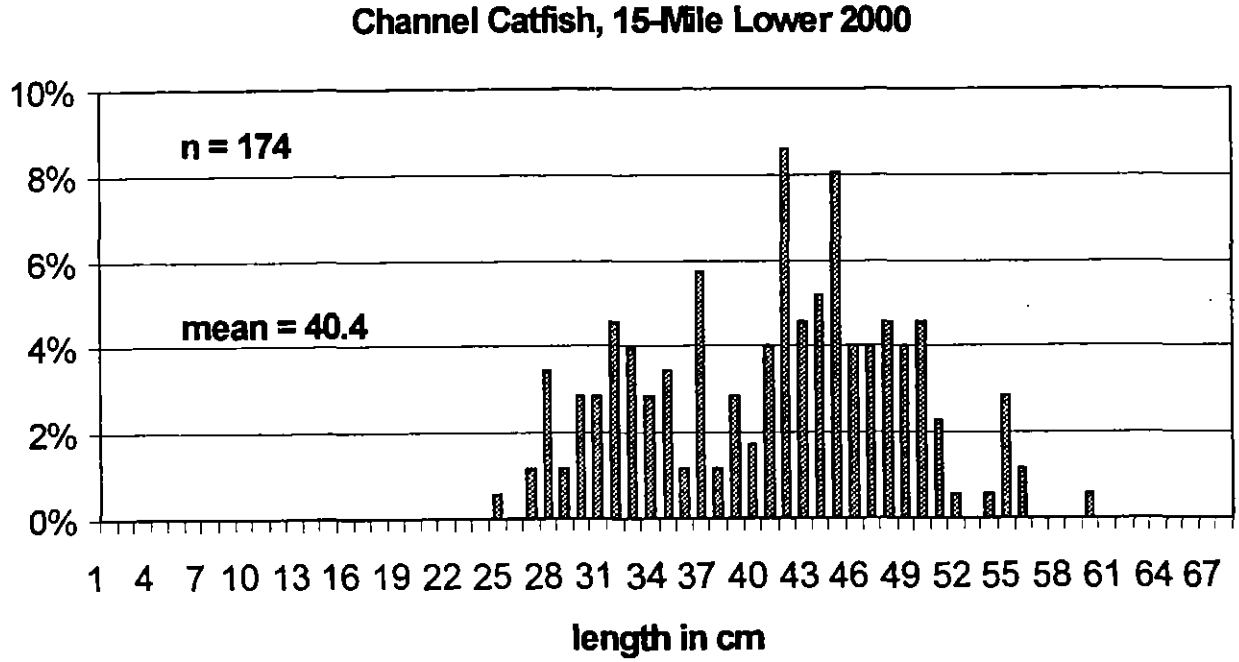


Figure 41. Channel Catfish length frequency at the Lower 15-Mile Reach site, August 2000, Colorado River.

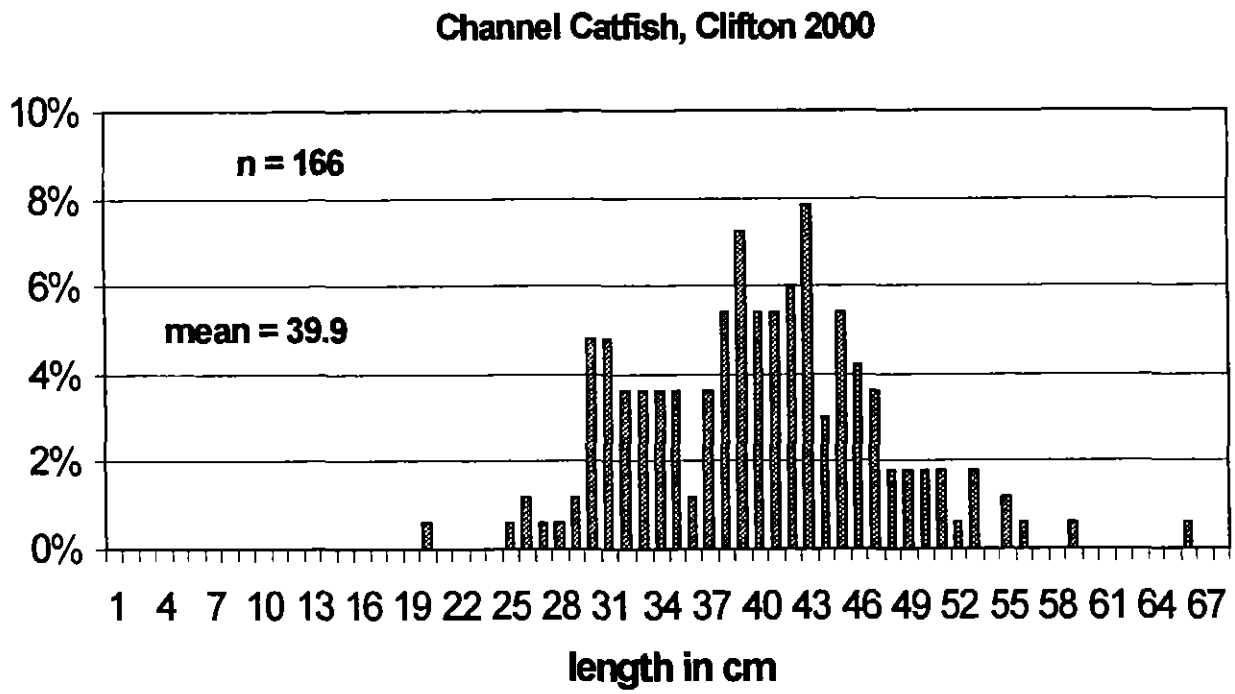


Figure 42. Channel Catfish length frequency at the Clifton site, July 2000, Colorado River.

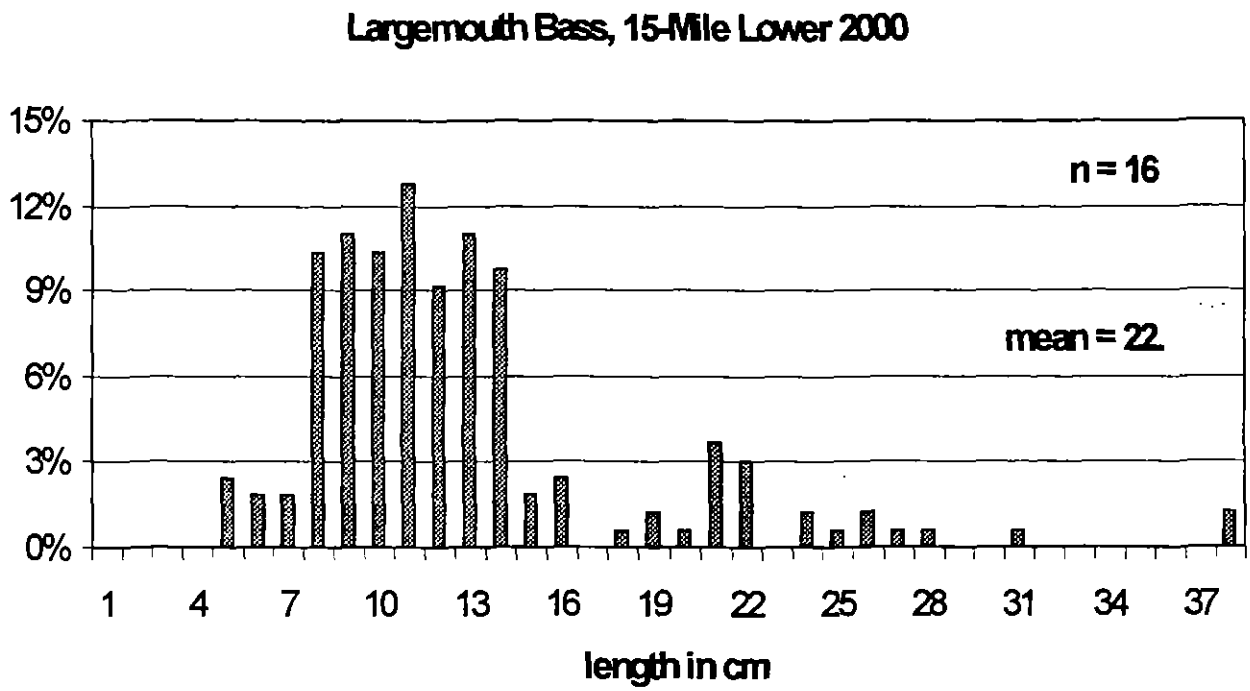


Figure 43. Largemouth Bass length frequency at the Lower 15-Mile Reach site, August 2000, Colorado River.

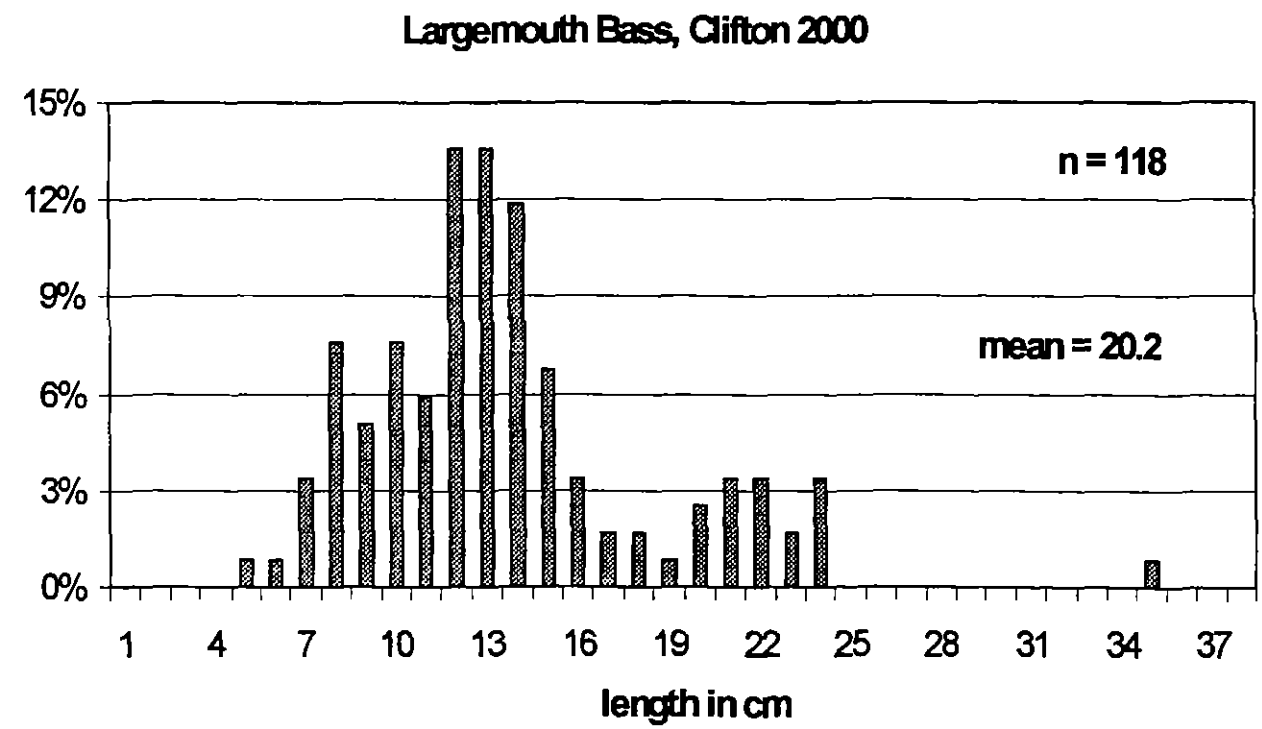


Figure 44. Largemouth Bass length frequency at the Clifton site, August 2000, Colorado River.

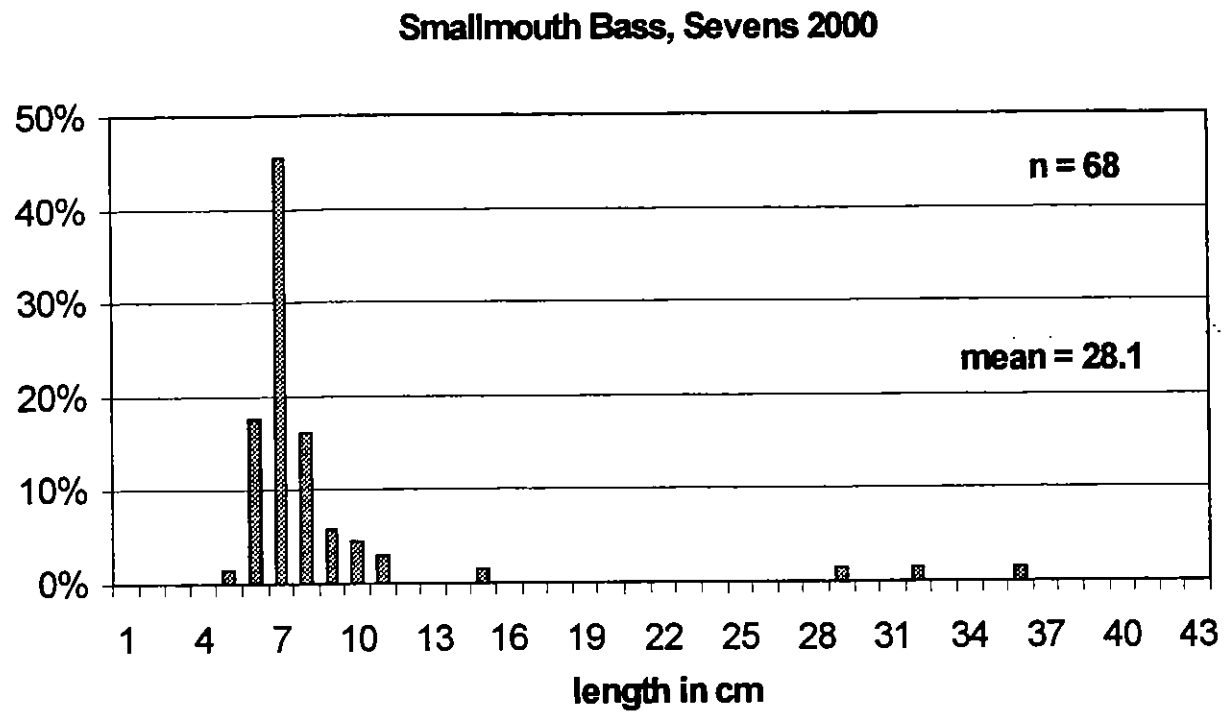


Figure 45. Smallmouth Bass length frequency at the Sevens site, September 2000, Yampa River.

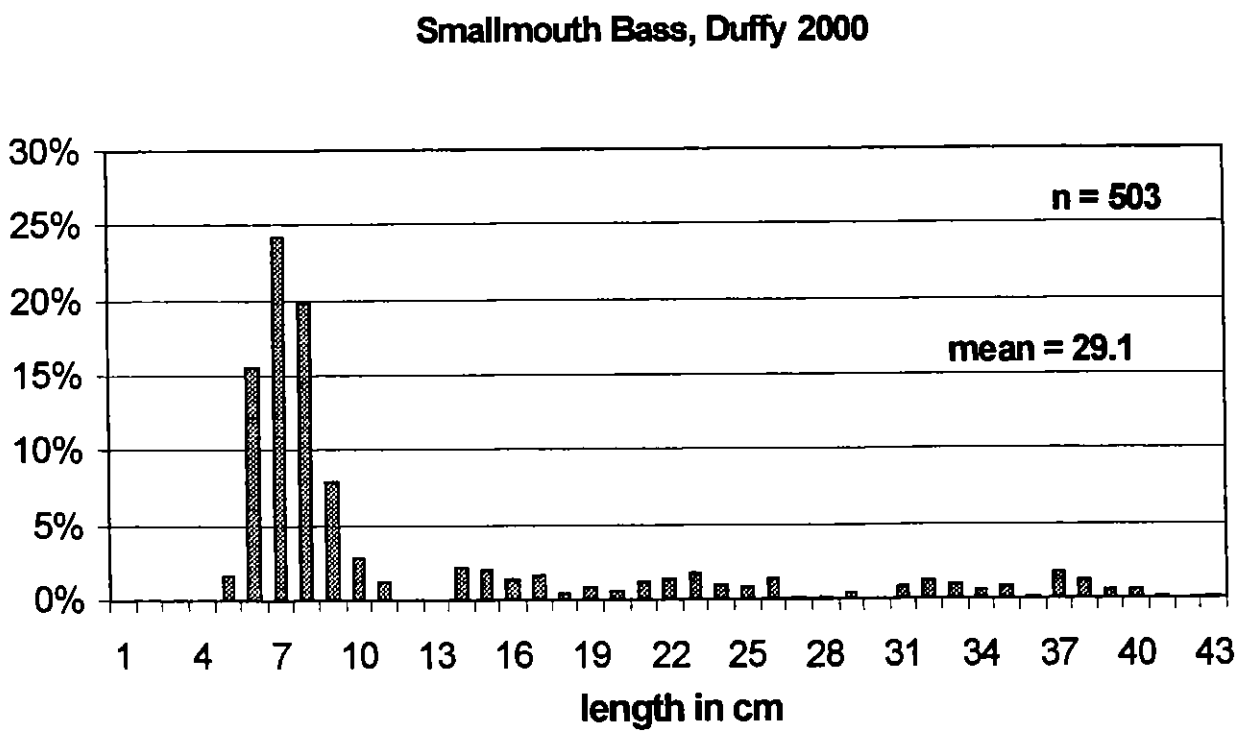


Figure 46. Smallmouth Bass length frequency at the Duffy site, September 2000, Yampa River.

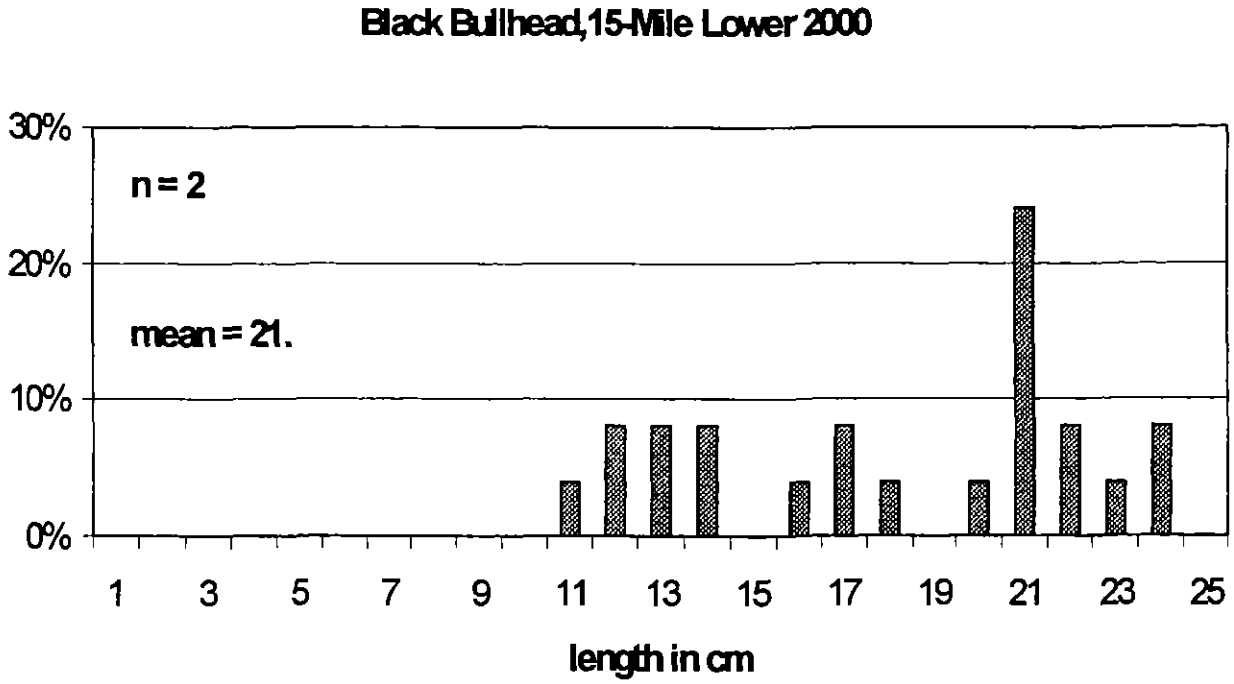


Figure 47. Black Bullhead length frequency at the Lower 15-Mile Reach site, August 2000, Colorado River.

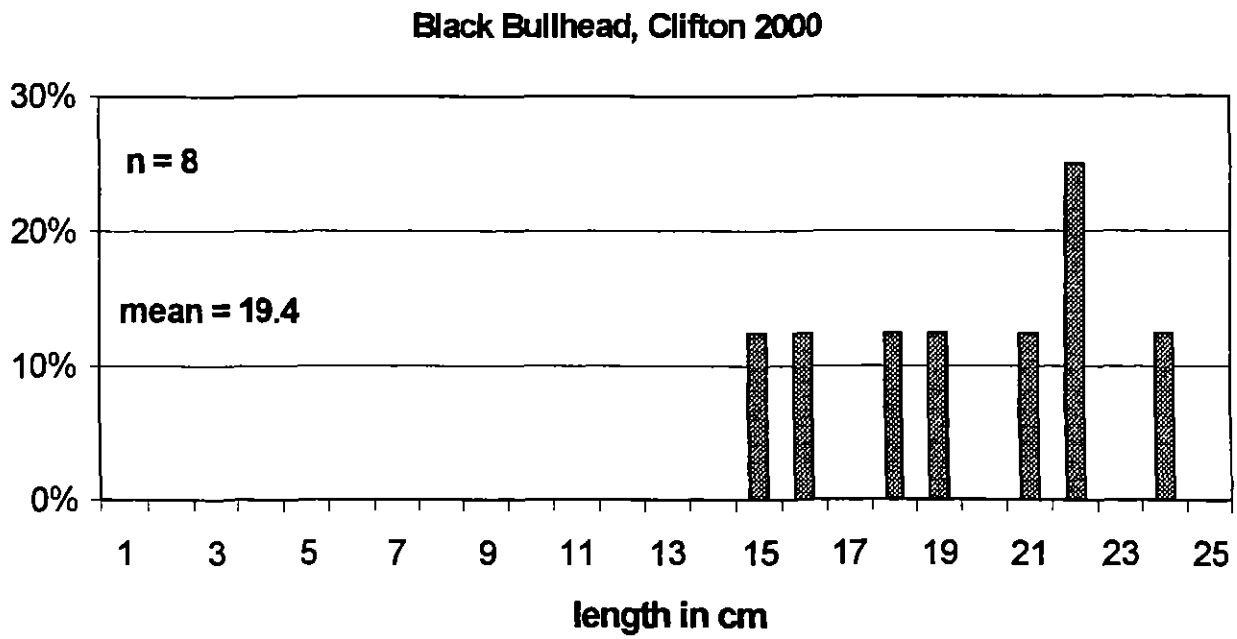


Figure 48. Black Bullhead length frequency at the Clifton site, August 2000, Colorado River.

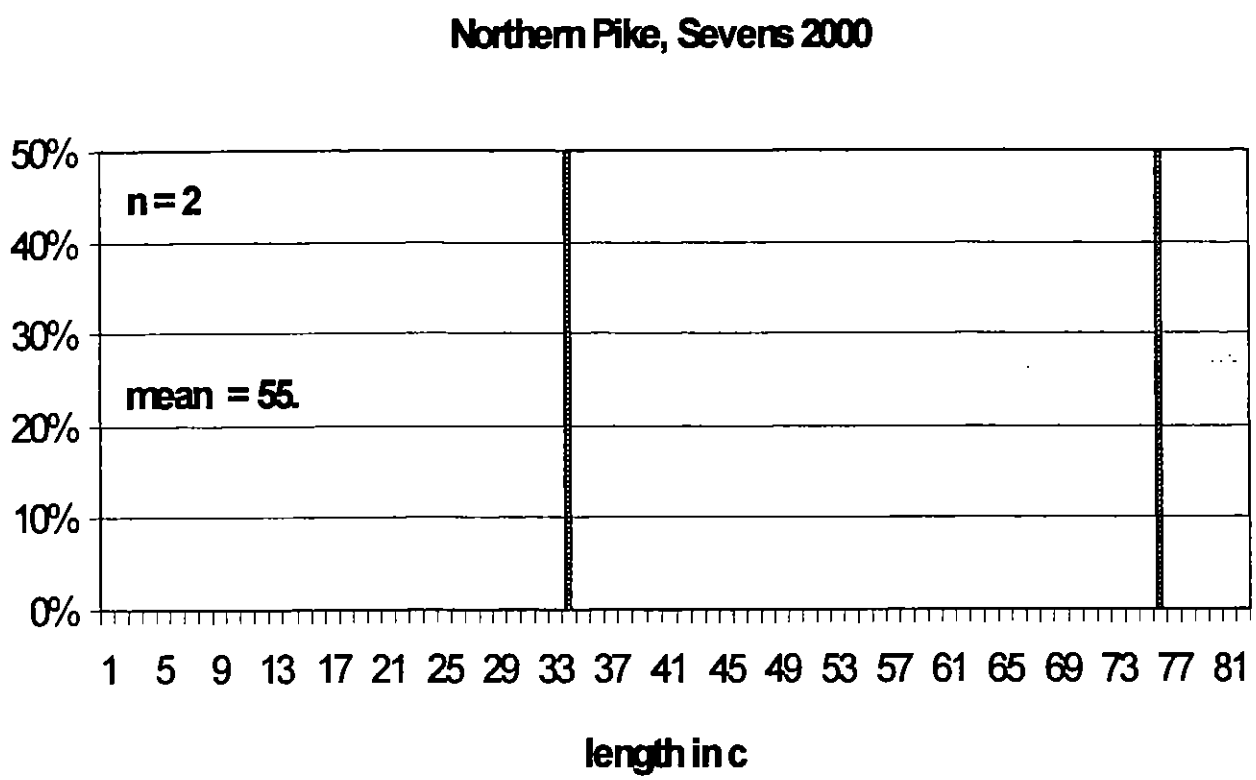


Figure 49. Northern Pike length frequency at the Sevens site, September 2000, Yampa River.

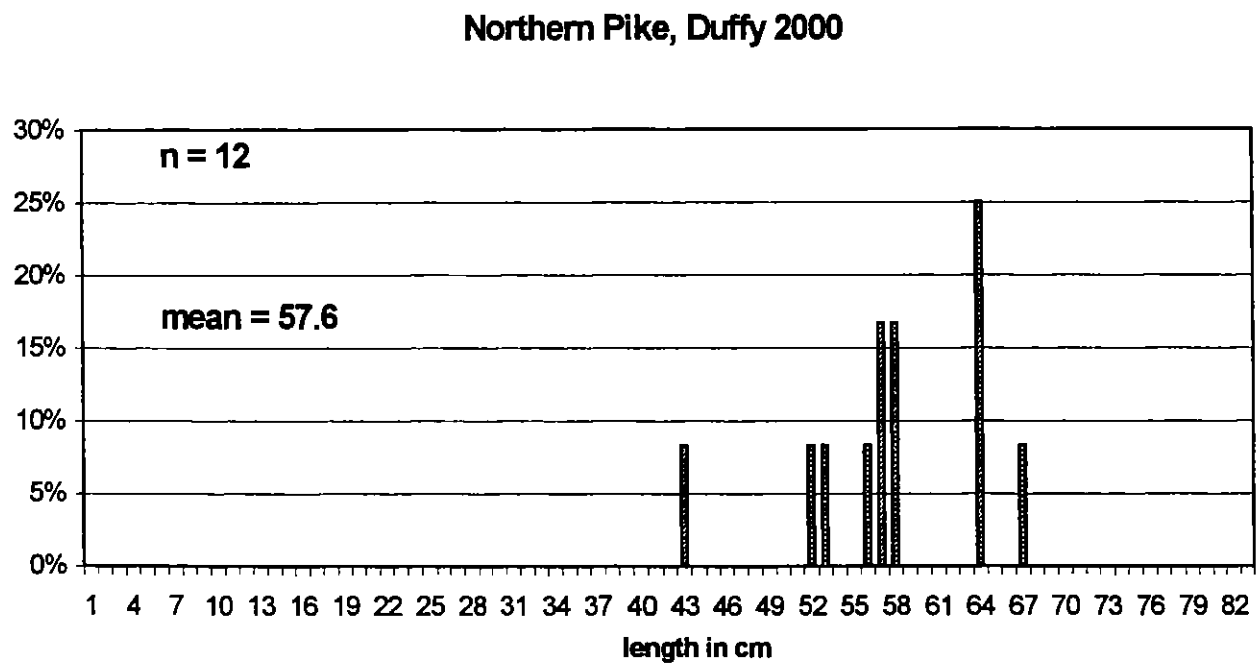
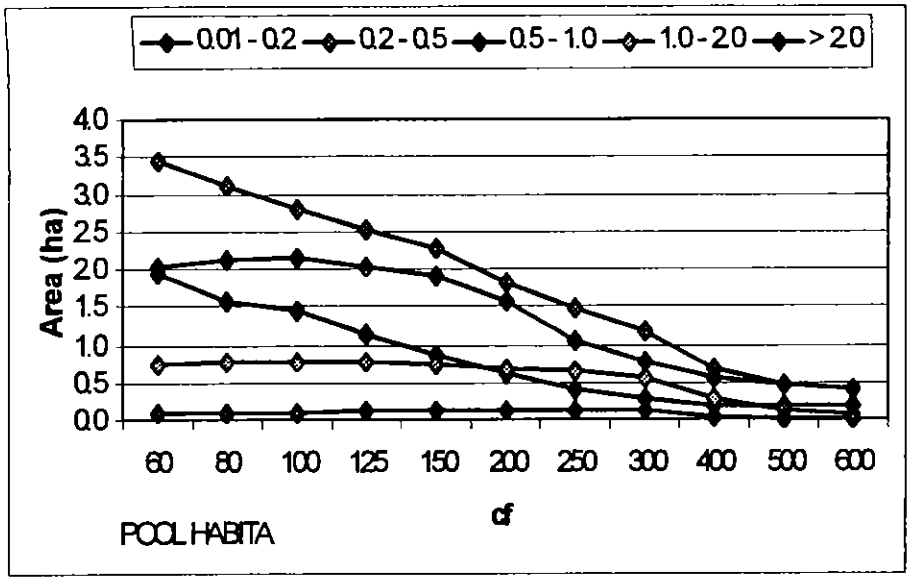
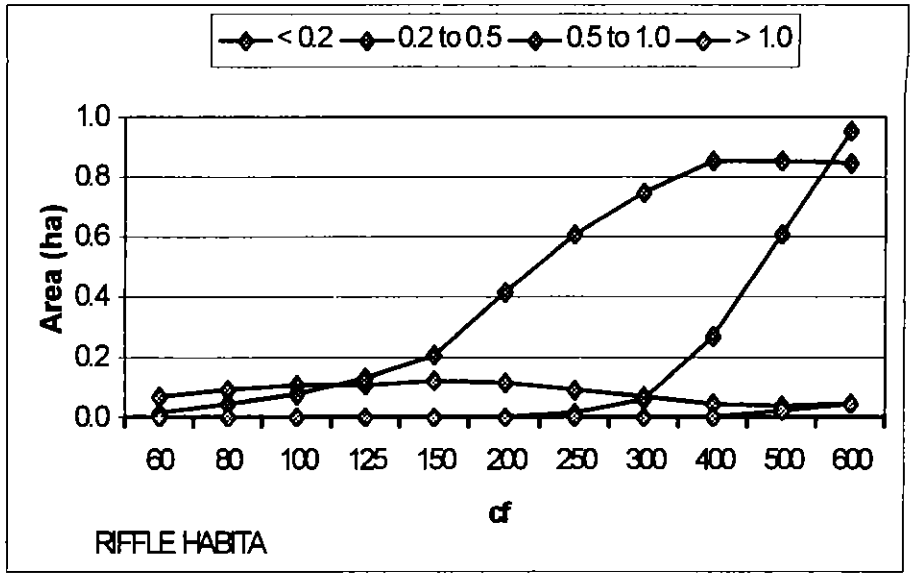


Figure 50. Northern Pike length frequency at the Duffy site, September 2000, Yampa River.





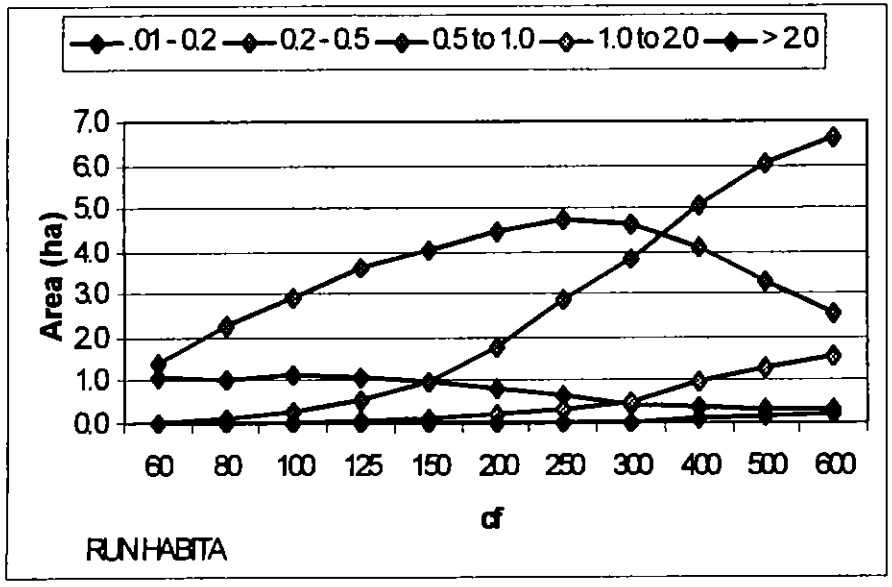


Figure A51. Habitat area for flow between 600 and 1800 cfs on the Duffy study site on the Yampa River for four main habitat types:

POOL (velocity < 0.15 m/s)
RUN (velocity.15 TO 0.6 m/s)
riffles (VELOCITY 0.6 TO 1.5 m/s)
RAPIDS (velocity >1.5 m/s), depths in meters in legend

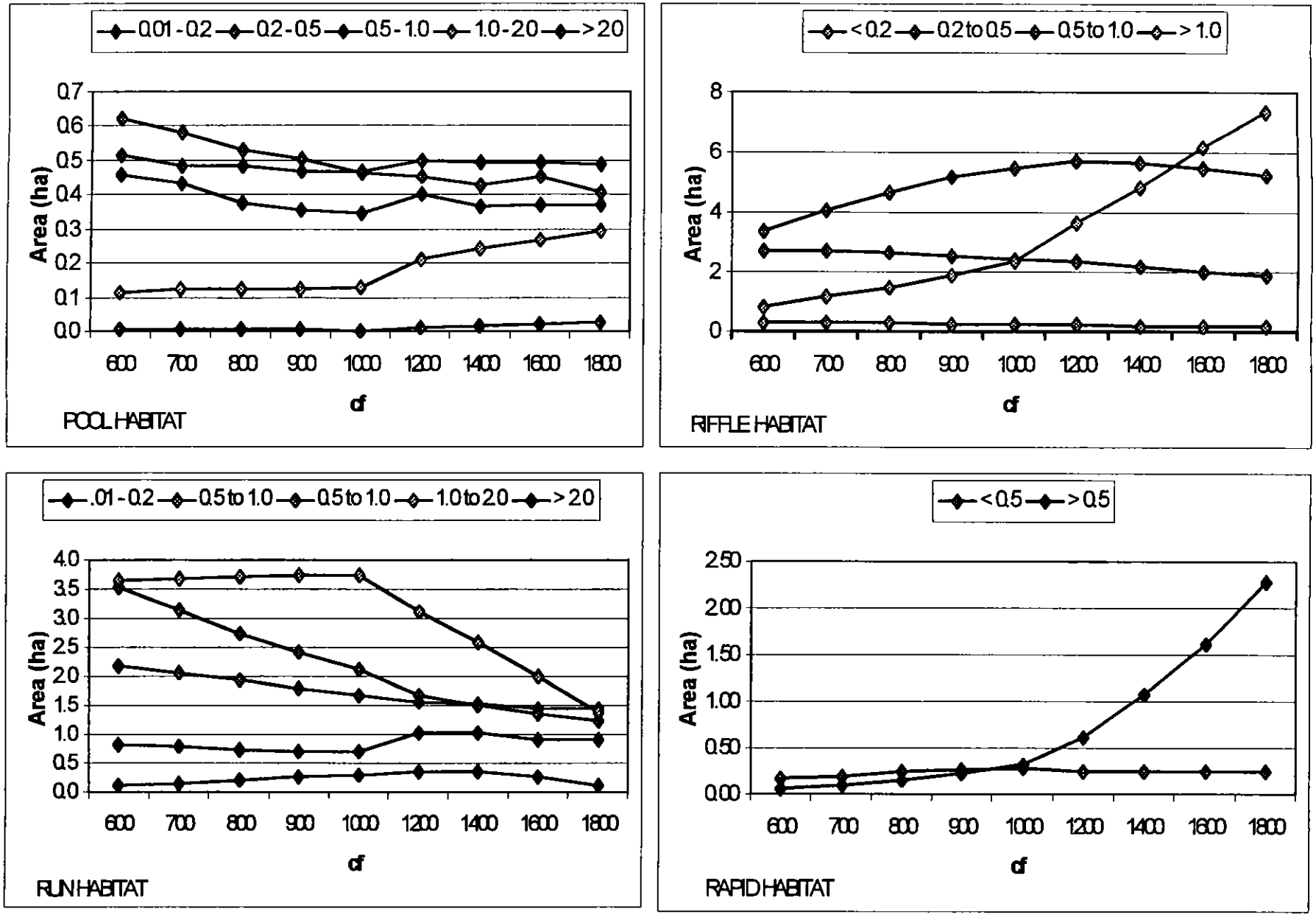


Figure A52. Habitat area for flow between 600 and 1800 cfs on the Corn Lake study site on the Colorado River in the 15-Mile reach for four main habitat types:
POOL (velocity < 0.15 m/s); RUN (velocity.15 TO 0.6 m/s); riffles (VELOCITY 0.6 TO 1.5 m/s) and RAPIDS (velocity >1.5 m/s), depths in meters in legend.