Riverine Fish Flow Investigations

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

Period Covered: July 1, 2005 - June 30, 2006

Study Objective: Quantification of habitat availability and instream flows on the Gunnison River and impacts of long term drought on native fish populations in the Dolores River.

INTRODUCTION - *Final draft*

This is the final annual report for Federal Aide project Riverine Fish/Flow Investigations which began in 1998 and presents the 2005 field season data. The project completion report is entitled 'Development, use and validation of a 2D instream flow methodology: Including flow recommendations for the Yampa, Colorado, Gunnison and Dolores Rivers and bankfull flows for the Yampa and Dolores River' **(CDOW Special Report 99?)**

In 1998 the CDOW research section established a project for developing biologically based instream flow recommendations for rivers in the Colorado River Basin. Establishment of instream flows has been a priority management objective for both state (Espegren 1998) and federal agencies concerned with native fish management and recovery (McAda 2003). In spite of cooperative recovery efforts by state and federal agencies there remains a lack of consensus on the most appropriate methodology for quantifying instream flow needs (Anderson and Stewart 2003).

Instream flow methodologies typically use a modeling process that employs a hydraulic model for simulating flow conditions and species habitat suitability indices to represent fish habitat needs. Confidence in a methodology's output is dependent on validation analyses, which can require considerable population sampling effort. Anderson and Stewart (2003) designed a meso-habitat instream flow methodology that used 2D modeling to simulate habitat potential as a function of river discharge. Channel topography was surveyed at six study sites on three rivers. Habitat preferences were determined by correlating species abundance to depths and velocities of different habitat types. The biological basis for the flow recommendations utilized correlations between fish biomass to habitat variables.

Habitat preferences for two native species, bluehead sucker *Catostomus discobolus* and flannelmouth sucker *Catostomus latipinnis*, were identified from populations in the Yampa and Colorado Rivers. Bluehead sucker were highly associated with deep riffle habitats and flannelmouth sucker with deep runs (Anderson and Stewart 2003). The Yampa and Colorado Rivers had similar channel morphology but the Yampa River had much lower summer base flows than the Colorado River. These rivers provided habitat preference information during both low and moderate flow conditions.

Validation of habitat preferences (mean depth and mean velocities) identified from the Yampa and Colorado Rivers using an independent data set would suggest those habitat criteria could be used for predicting native sucker biomass in other rivers or river reaches (Stewart et al

2005). A validation process was initiated in 2004 to determine if bluehead and flannelmouth sucker biomass estimates in the Gunnison River verified model projections made using habitat suitability criteria developed on the Yampa and Colorado Rivers (Anderson and Stewart 2003).

The Gunnison River appeared to be an appropriate system for this validation analysis because of it fish and flow conditions. Burdick (1995) and Osmundson (1999) reported bluehead and flannelmouth sucker were very numerous in the Gunnison River while nonnative predators were very rare. The lack of large predators removed predation as a limiting factor for species abundance. Also the Gunnison River's base flow hydrograph was higher than Colorado River base flows. These factors indicated the Gunnison River retained both high native fish biomass and high habitat availability.

The primary Gunnison River study objective was to develop biologically based instream flow recommendations using the 2D methodology. Secondary objectives were to validate the bluehead and flannelmouth sucker habitat suitability matrices and to collect habitat suitability data for roundtail chub *Gila robusta.*

Bankfull flows and geomorphic properties are appropriate information for some instream flow recommendations. Channel maintenance flows are necessary for maintaining habitats utilized during base flow periods. However biological consequences of a lack of bankfull flow events are difficult to observe and quantify. The Dolores River has experienced severely reduced runoff flows during the recent drought (Anderson 2005). Large changes in the fish community (species composition and native fish biomass) have also been observed during this time period, suggesting a potential cause and effect relationship.

The Dolores River Dialogue (DRD), a local organization, was formed in 2003 to investigate ecological consequences of McPhee Reservoir operations. Wilcox and Richard (2005) concluded that reduction in runoff flows are the primary cause of geomorphic changes downstream of the dam. Because of recently altered runoff flows and channel geomorphology, Anderson (2005) suggested the Dolores Rivers would make a suitable study site for testing hypotheses about linkages between fish population dynamics and geomorphic conditions. Identification of bankfull flow is the first issue to address in a geomorphic analysis. The objective of the Dolores River project was to determine bankfull flow by integrating new channel topography data surveyed up to the floodplain with the channel bed topography collected for 2D flow modeling.

Study Objectives:

1. Establish relationships between native sucker biomass and habitat availability and make instream flow recommendation based on habitat availability modeling.

2. Compare habitat suitability criteria for native sucker on the Gunnison River with those from the Yampa and Colorado Rivers.

3. Identify correlations between habitat availability and roundtail chub abundance.

4. Determine bankfull flow of the Dolores River and examine its role for maintaining channel geomorphology and native fish habitat.

STUDY AREA

Gunnison River

Site locations

The Gunnison River is the largest tributary to the upper Colorado River and its confluence with the Colorado River is located in the City of Grand Junction CO. The Gunnison River from its confluence with the Colorado River upstream to the confluence with the Uncompahgre River has been designated critical habitat for endangered Colorado pikeminnow *Ptychocheilus lucius* and razorback sucker *Xyrauchen texanus* (McAda 2003).

There are two study sites on the Gunnison River. The Delta 2D modeling site extended from the confluence of the Uncompahgre River (RM 56.3) downstream two miles to the county road bridge. Fish were sampled from the 2D modeling site (Delta Station). Fish were also sampled upstream of the 2D site from Confluence Park in Delta to the Uncompahgre River (Delta Above) and below the 2D site from the County road bridge to the State Wildlife Area (Delta Below).

The Escalante 2D modeling and fish sampling locations were the same. Escalante extended from Escalante Bridge (RM 42.7) downstream about 2.5 miles to Hail Mary rapids. The entire Escalante site was located on private property owned by the Escalante Land and Cattle Ranch.

Site Hydrology

The Whitewater gage (USGS 09152500, Gunnison River near Grand Junction) is located near the town of Whitewater. The Gunnison River drainage area at the Whitewater gage is 7,928 mi^2. The mean annual flow for the gage is 2,536 cfs for 1917 to 2004. The Aspinall Unit (Blue Mesa, Morrow Point and Crystal reservoirs) was completed by the United States Bureau of Reclamation (BOR or USBR) between 1966 and 1976. Mean annual flow was little changed by the project, the average mean annual flow from 1917 to 1965 was 2,580 cfs and 2,475 cfs from 1966 to 2004. The average mean annual flow from 1977 to 2004 was 2,564 cfs.

Peak runoff flows were substantially reduced after construction of Blue Mesa Reservoir (1965). The median peak (mean daily) flow from 1917 to 1965 was 15,000 cfs compared to 7,355 cfs from 1966 to 2005 (Whitewater gage). Pitlick (1999) determined bankfull flow to be 14,350 cfs, which was commonly exceeded prior to 1965, but rarely exceeded after 1966 (Figure A2-1).

Minimum flows have been substantially increased after 1965. The Whitewater gage median minimum (mean daily) flow from 1917 to 1965 was 456 cfs compared to 864 cfs from 1966 to 2005 (Figure A2-2).

The Gunnison River drainage area at the USGS Delta Gage (09144250) is 5,626 mi² and is located about 2 miles upstream of the confluence with the Uncompahgre River. The period of record for the Delta gage is from 1977 to the present and the mean annual flow is 1,978 cfs. The Uncompahgre River gage at Delta (09149500) has a drainage area of 1,115 mi². The Uncompahgre River Delta gage period of record is from 1939 to present with a mean annual flow of 301 cfs. Daily flows from these two gages were summed to indicate mean daily flows for both the Delta and Escalante sites. The median peak (mean daily) flow for the Delta and Uncompahgre gages summed was 6,192 cfs (Figure A2-3). The median peak (mean daily) flow at the Whitewater gage was 7,510 cfs for the same period.

The state wide drought that started in 2000 had a large impact on peak and spring runoff flows, which were very low in both 2002 and 2004 (Figures A2-3 and 5). However summer/fall base flows did not fall below 600 cfs except for a brief time in 2002 (Figures A2-4 and 6). Summer/fall minimum mean daily flows for the Delta and Uncompahgre gages summed from 1998 to 2005 were 1,062, 1,303, 1,026, 832, 543, 695, 637 cfs and 897 cfs, respectively (Figure A2-4).

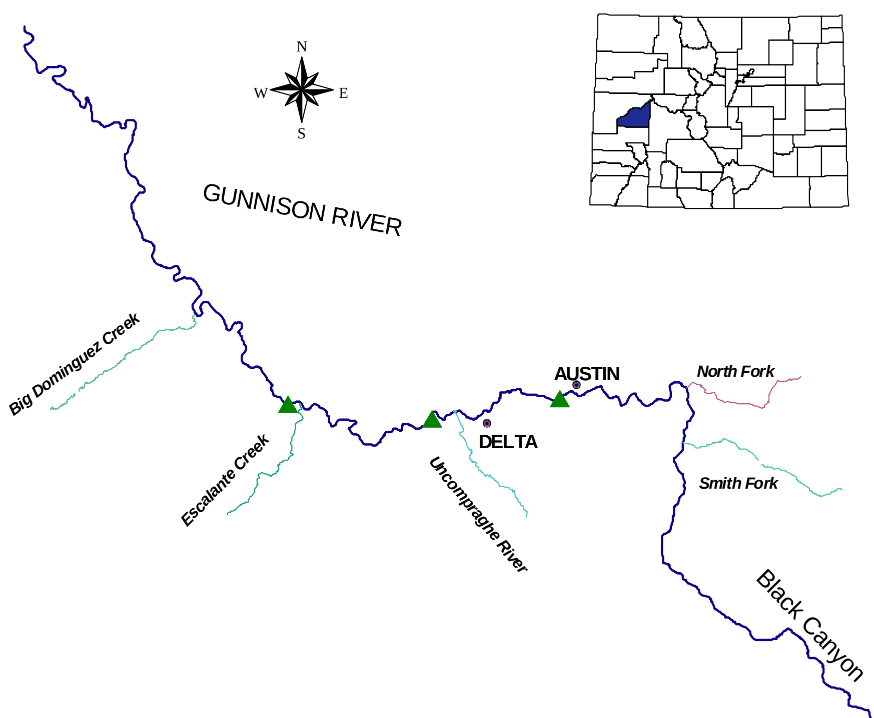

Figure 1. Gunnison River study site locations near Escalante Creek and Delta.

Pitlick et al (1999) reported the mean bankfull width was 73.4 m and mean slope was 0.12% at Whitewater, while the Delta site mean bankfull width was 73 m with a slope of 0.19%, and the Escalante canyon mean bankfull width was 68 m with a 0.12% slope

Dolores River

Site location

The Dolores River headwaters are in the San Juan Mountains of Southwestern Colorado. The river flows northward about 200 miles to its confluence with the Colorado River in Utah. The Dolores River from its mouth upstream to the Bradfield Bridge has a large roundtail chub population, making it potentially important for conservation of this species. Colorado pikeminnow are know to have also resided in the Dolores River (Valdez 1992)

The study site was located in the Big Gypsum Valley. The Big Gypsum site begins at the BLM boat launch and ends just upstream of the county road bridge, 2.2 miles downstream (Figure 5). The site is about 72 river miles downstream from McPhee Reservoir, and about 16 miles downstream of Disappointment Creek. Disappointment Creek is a problematic source of fine sediment input during runoff and storm events.

Site Hydrology

Two canals diverted virtually the entire Dolores River flows (up to approximately 1,400 cfs) from 1886 until 1984 during the irrigation season (April to October). McPhee Dam and Reservoir began storing water in 1985 to provide storage for the Dolores River Project, a system of canals, tunnels, and laterals used to deliver water for irrigation. The Dolores River hydrograph was characterized by very low base flows (about 2 cfs) during the irrigation season prior to McPhee Dam. Since 1985 McPhee Reservoir outflows are usually above 25 cfs. The magnitude and duration of the spring runoff has been heavily reduced after McPhee dam was constructed.

McPhee Reservoir has a storage capacity of 381,000 AF, which is similar to the 30-year average annual Dolores River inflow of 397,000 AF. Total user demand is about 240,000 AF per year. The outflow of McPhee is composed of a volume of water reserved for releases call ‘the fish pool’ which is approximately 29,300 AF (mean annual of about 40 cfs). The inflow that can not be stored or diverted is referred to as ‘the spill’. Since 1985 there have been seven years when demand exceeded the inflow and there was no spill. Spring outflows peaks ranged from 34 to 177 cfs during years with no spill, while inflows ranged from 563 to 2,159 cfs (Table 1). The median inflow and outflow peak after 1985 was 2,941 and 2,009 cfs, respectively. Demand reduces inflow by about 40% during high flow years and by about 85% during dry years (Table 1).

The USGS Bedrock Gage (09169500) has a drainage are of 2,024 mi^2 and is located about 36 miles downstream of the Big Gypsum study site and about 108 miles downstream of McPhee dam. The Dolores River at Bedrock was used to represent flow conditions at the study site. Mean annual stream flow at Bedrock was 516 cfs prior to 1985 and 284 cfs from 1985 to 2004. No effort

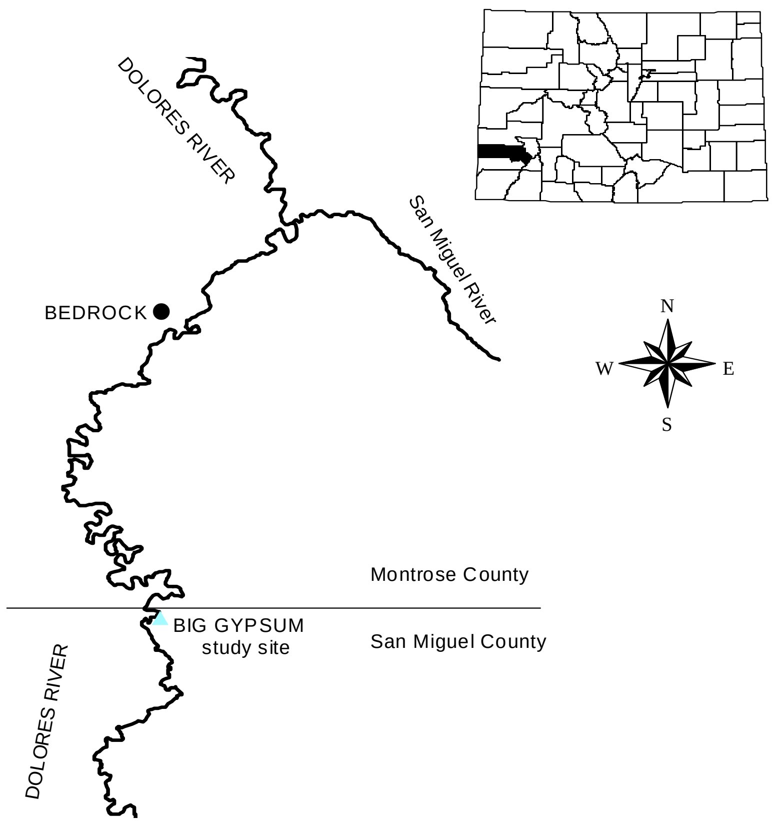

Figure 2. Dolores River study site location in the Big Gypsum Valley.

was made to determine the mean annual flow or minimum natural flows by adjusting for diversions, or reservoir storage which is necessary in order to indicate natural flows since 1886.

The highest annual peak (mean daily) recorded at Bedrock was 8,150 cfs in 1973.   The median annual peak flow for the 32- year Bedrock Gage history was 3,095 cfs (Figure A2-7). Peak and spring runoff flows were eliminated in four years during the drought. Peaks (mean daily flow) for 1998 through 2005 were 3560, 3100, 1170, 522, 54, 323, 307 and 5060 cfs, respectively.

Base flows were also heavily reduced during the drought. Annual minimum (mean daily) flows recorded at the Bedrock Gage for 1998 through 2005 were 21, 32, 25, 24, 1.4, 6.4, 20 and 31 cfs respectively (Figure A2-8).

There were no spring runoff flows below McPhee Reservoir for four consecutive years, 2001 to 2004 (Figure A2-9). The lack of runoff flow meant that more sediment was deposited than transported. The ‘fish pool’ and therefore minimum flows were also reduced in years when the reservoir did not fill (Figure A2-10).

By 2004 fine sediment deposition and channel narrowing were noticeable at the Big Gypsum study site (Wilcox and Richard 2005). Thick deposition layers were evident in pools and runs in the study site.

Table 1. Dolores River inflow and outflow statistics for McPhee Reservoir, 1985 to 2005, data sorted from lowest to highest mean annual outflow*.

YEAR	Mean annual Inflow (cfs)	Mean Annual Outflow (cfs)	Inflow Reduction %	Days of Spill No.	Peak Inflow (cfs)	Peak outflow (cfs)
2002	102	20	80%	0	562	34
2003	272	20	93%	0	1966	42
1990	226	40	82%	0	1374	79
2004	383	42	89%	0	2941	171
2001	352	48	86%	0	2901	168
1996	287	50	83%	0	2159	177
1991	397	71	82%	19	2264	843
1988	361	144	60%	49	2281	1201
2000	341	150	56%	49	2556	1200
1989	362	159	56%	60	2027	1001
1994	405	188	53%	50	2626	2009
1999	574	227	60%	45	3135	3357
1992	483	239	50%	65	3093	3009
2005	693	292	58%	73	5176	4193
1998	531	336	37%	80	3537	3371
1995	778	452	42%	100	4969	3162
1986	847	470	44%	122	4768	4461
1997	841	477	43%	92	4883	3572
1987	760	507	33%	153	4277	3324
1985	845	521	38%	119	4545	3700
1993	828	594	28%	122	5326	4140

METHODS

ELECTROFISHING

Two sites were established on the Gunnison River for characterizing fish and habitat parameters. The fish community was sampled in 2003, 2004 and 2005 and channel surveys were made in 2004. 2D modeling was completed in 2005.

Fish sampling was performed by electro-shocking from a 16-ft Hyside self-bailer raft fitted with a 5PPV Smith-Root electro-fisher, 5000-watt generator and a 6 cable dropper array mounted on a forward boom. The raft was maneuvered by either oars or by a battery powered trolling motor. Two netters caught as many fish as they could during shocker operation. All fish were measured to the nearest millimeter. Mark-Recapture density estimates were made for each study site by marking fish over 15 cm with a hole punch in the tail. The mark was distinctive for each electro-fishing pass.

The Darroch multiple mark method (Everhart and Youngs 1981) with the Chapman (1954) correction was used to calculate population estimates with ninety-five percent confidence intervals.

The 2004 and 2005 Gunnison River bluehead and flannelmouth sucker catch data were also analyzed using the Huggins data type of Program Mark (White and Burnham 1999). This program calculates capture probabilities for each electro-fishing pass and was used to compare catch efficiencies between years.

A total fish estimate was made for all species combined and for individual species. Recapture rates generally varied between species and size-groups. Recapture probabilities were found to vary between species. The high recapture probability group generally included suckers. The low recapture probability group included catfish, carp and predators. The total fish density estimate represented a blend of recapture probabilities, but should produce reliable comparisons of total fish abundance between years when species composition was consistent for that period. Abundance for rare species, those with zero or one recapture, was estimated by dividing the number collected by the recapture probability typical of fish in the lower group.

The z-test, with an alpha of 0.05 (z = 1.96) was used to test for significant differences in density estimates between years at each station (Dr. David Bowden, CSU, pers. communication).

Pit Tags were implanted in bluehead sucker, flannelmouth sucker and roundtail chub in 2005 at both Gunnison River sites for identifying habitat use and fish movements.

In 2003 two passes were made at each site to help establish baseline information relevant to the 2002 drought. Six passes were made in 2004 and seven in 2005. Dates and flows of electro-fishing passes for the Dolores and Gunnison Rivers for the study period are given Table 2.

CHANNEL TOPOGRAPHY SURVEYS

Global Positioning Systems and Sonar

Channel topography was surveyed at Delta and Escalante in May, June, July and September 2004. The 2004 survey used the same technique and equipment as prior study sites (Anderson and Stewart 2003): the RTK GPS Javad Odyssey L1/L2 RTK GPS with Glonass and Multi-path reduction options. The sonar unit was an ODOM Hydrographic Systems, Hydrotrac - Single Frequency, Portable Survey Sounder.

Table 2. Electro-fishing survey dates and mean daily flow on sample day.

Gunnison	**DATE OF ELECTROFISHING**			**FLOW IN CFS**		
Escalante	July	August	Sept	July	August	Sept
2003		25, 28			979, 904	
2004		16, 18, 25, 27	1, 3		919, 1004, 1037, 881	893, 891
2005		1, 3, 8, 11, 15, 17, 22			1011, 1032, 1058, 1440, 1257, 1425, 1053	

Gunnison	**DATE OF ELECTROFISHING**			**FLOW IN CFS**		
Delta	July	August	Sept	July	August	Sept
2003		26, 29			918, 926	
2004		17, 19, 24, 26	2, 9		938, 1035, 944, 841	888, 1254
2005	29	2, 4, 9, 12, 16,18, 23		1143	1032, 964, 1059, 1442, 1306, 1372, 1009	

DOLORES	**DATE OF ELECTROFISHING**		**FLOW IN CFS**	
Big Gypsum	June	July		July
2000		11, 12, 13, 18, 19, 20, 27		52, 53, 55, 58, 53, 53, 52
2001		16, 17, 18, 19, 23		66, 68, 68, 53, 50
2004	21,22,23,29		45, 45, 45, 50	
2005		18, 19, 20, 26		88, 86, 86, 169

The sonar unit logged ten depth readings per second and the RTK GPS logged one position per second. The GPS output was a NMEA GGA string at a rate of 1Hz, while the sonar depth output was at a rate of 10Hz. Data from these instruments were sent to a laptop computer and recorded using the COMLOG software from ODOM Hydrographic.

Bathymetric data were collected in longitudinal runs and cross-sections. The transducer and GPS antenna were mounted vertically. The minimum depth for sonar data was at 75 cm, the transducer needed at least 0.5 m of depth to make a reading and the transducer needed to be mounted about 15 cm below the surface to allow for the pitch and roll of the boat.

Field Surveys

Gunnison River

The Escalante and Delta sites were surveyed with the boat- GPS/sonar technique beginning on May 27th and ending June 11th at flows between 1,097 and 1,969 cfs, much below normal runoff conditions. The reduced flows in 2004 resulted in gaps in the river bed coverage because some areas were too shallow for data collection by the boat- GPS/sonar method. Surveys in shallow areas and along the shorelines were done using the normal walking rover setup, a pole mounted antenna and a TDS Ranger logging shots.

About 46,604 usable bathymetric survey points were collected along a 3.94-km reach at Delta using the boat- GPS/sonar technique. An additional 9,689 waterline and bed shots were obtained between May and November 2004 using the walking method.

About 43,437 usable bathymetric survey points were collected along a 4.38-km reach at Escalante from the boat/sonar method. Waterline and shallow area topographic points were surveyed between May and November 2004 and numbered 6,338.

Big Gypsum, Dolores River

The river channel at Big Gypsum was initially surveyed over a three-day period (May 16, 17, and 18, 2000), using the boat- GPS/sonar method. Waterline shots were made on July 6 and 7, 2000, and on June 13 and 14, 2001 at a flow of about 60 cfs. Another series of water line shots was done in July 2002, when flows were less than 2 cfs.

High flows in 2005 provided an opportunity to survey a series of high flow waterline contours. Waterlines were shot on May 12 and 13, 2005 at flows near 2,160 cfs and again on May 25, 2005 at flows near 4,890 cfs. Additional shots in the floodplain were made on April 5, July 6 and 7, 2005.

Model Calibration

2D modeling was calibrated by taking depth and velocity measurements at known UTM coordinates. Depths were determined with the same equipment used in bathymetry surveys. Velocities were determined with a March McBirney velocity meter or an acoustic Doppler.

The Marsh McBirney Flo-Mate meter readings were taken at 0.6 depth which represents mean water column velocity for a logarithmic velocity profile. The wading rod was held in place for 30 seconds (three 10 second intervals) before recording the velocity reading. The velocity and depth reading were entered in the TDS Ranger as position description. The GPS was then used to log the coordinates of the velocity reading.

At depths > 1m it was not practical to measure velocities with a wading rod, so a Sontek River Surveyor Acoustic Doppler (ADP) was used. The ADP determines water velocities using the Doppler shift principle (the return sound frequency has shifted from the frequency transmitted). The ADP uses three sonar beams to relate the speed and direction of the flow to the speed and direction of the boat in order to compute absolute velocity and direction of the current. The ADP measured velocities in 15 cm vertical increments from the transducer to the river bottom and the boat was held stable for a minimum of 30 seconds to get an average velocity readings. The RTK-GPS antenna was attached to the opposite end of the ADP pole for recording the coordinate.

Sonar Data Management

The GPS/sonar continuously input data when turned on. The GPS and sonar data were reviewed in Excel spreadsheets and a macro deleted unnecessary points so only complete data points were retained. All non-RTK hits, and some apparent false spikes in the sonar data, which can results from pings on fish or woody debris, were eliminated. Depths associated with a GPS position were determined by the linear interpolation of the sonar and GPS time tags. Bed elevation was the GPS antennal elevation minus the length of the transducer rod minus the sonar depth reading. Topographic data were visually examined by creating Triangular Irregular Networks (TIN) in ArcInfo for further refinement.

HYDRAULIC SIMULATION

The 2D modeling was contracted with Utah State University. Craig R. Addley (USU), supervised modeling for the two Gunnison River sites. The USU lab used a 2-dimensional finite volume model, River2D, developed by Peter Steffler (www.river2d.ualberta.ca). The technical description of this model and underlying equations can be found in Steffler, P. and Blackburn, J. (2001). Dr. Addley's lab also performed 2D modeling for four sites in prior years (Anderson and Stewart 2003).

HABITAT DIVERSITY

Habitat diversity as a function of flow was determined by creating 16 meso-habitat categories. Meso-habitats are generally defined as pools, runs, riffles and rapids, and habitats are distinguished by current speed. Pools have low velocities, runs are moderate, riffles have swift currents and rapids are fastest velocities. Pool velocities were zero to 0.15 m/sec, runs were 0.151 to 0.6 m/sec, riffles were 0.61 to 1.5 m/sec and rapids had velocities over 1.51 m/sec. Habitat quality is also a function of depth. Pools and runs were assigned five depth categories, riffles had four and rapids two (Table 3).

These 16 meso-habitat types were mapped for each of the 2D modeled flows. Solution files (2D model output) were imported into ArcInfo and meso-habitat types were based on 1 x 1-meter depth and velocity grids. Meso-habitat area was determined by summing the number of grids. Surface maps of meso-habitat were created either in ArcView or using SMS software.

Shannon's diversity index (Shannon and Weaver 1949) was calculated using the area of 16 meso-habitat types for each of the simulated flows. Several other diversity indices are possibly relevant for quantifying habitat diversity and were evaluated for use in this study by Stewart (2000). Shannon's diversity index is more sensitive to richness than evenness, meaning rare types have a disproportionately large influence on the magnitude of the index. Other indices like the Simpson's diversity index (Simpson 1949) are less sensitive to richness and place more weight on evenness.

A number of studies have shown that habitat diversity is positively correlated with species diversity in aquatic environments (Schlosser, 1982; Shields *et al*., 1994; Eckmann,1995; Katano *et al*., 1998). For this study it was determined the Shannon Diversity index met the goal of defining diversity using richness and evenness. The native fish community was composed of a large number of species and life stages. Some species in the adult life-stage occupied single habitat types and some utilized multiple habitats.

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

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

HABITAT SUITABILITY

Meso-habitat suitability criteria were based on correlations between fish abundance and habitat conditions for river sub-reaches. Biomass estimates were made by sub-reaches (meso-habitats) during electro-fishing surveys. Sub-reaches had the same starting and end points between passes and years. The sum of the area and fish from all sub-reaches summed to 100% of the entire station. Depth and velocity information for each sub-reach was obtained from the 2D model runs that were closest to the flow of the fish sampling period. Fish data and physical habitat data were obtained for about 15 to 20 sub-reaches in each study site.

The biomass, mean depth, and mean velocity for each sub-reach was imported into Sigma Plot and analyzed using a running median function. Sigma Plot was used to create a matrix of biomass as a function of mean depth (x axis) and mean velocity (y axis) at a scale of 0.1 for both depth and velocity. A suitability criterion was associated with each grid.

Four meso-habitat types were defined for bluehead and flannelmouth sucker according the fish abundance: optimal, marginal unsuitable and unusable. Optimal habitat was indicated by high fish biomass and mean depths and velocities of high biomass sites were used to define optimal conditions. Mean depths and velocities associated with zero biomass sub-reaches defined unusable habitat. Unsuitable habitat criteria were from the lowest biomass sub-reaches and equaled about 10% total biomass. Marginal habitat conditions equaled about 30% of the total biomass.

Surface area for each meso-habitat type was calculated in ArcInfo for each simulated flow. Surface areas of unusable, unsuitable, marginal and optimal habitats were converted to projected biomass by multiplying surface area times the mean biomass of each habitat type. The relationship between flow and biomass was the basis for instream flow recommendations.

GUNNISON RIVER - Fish and Habitat Data

Gunnison River fish data for 2003, 2004 and 2005 are combined in this report. Length frequency data for 2005 is in Appendix 3, length frequencies for prior years are in that year's annual report. Species composition, density and biomass data are for fish over 15 cm in length. Mean lengths include all fish captured at the site.

FISH DATA

RESULTS

Fish Community

Bluehead sucker was the most common species at Escalante in all three years. Flannelmouth sucker, white sucker and roundtail chub had similar relative abundance between years (Table 4). Flannelmouth sucker was the most common species at Delta in the first two years, but bluehead sucker was most common in 2005. Roundtail chub relative abundance was higher in 2005 at Delta than 2004. Bluehead sucker was the most common species in 1992 and 1993 (Table A1-2 and A1-3).

Native species (fish > 15 cm) comprised 65% and 74% of the Delta catch and 83% and 78% of the Escalante catch in 2004 and 2005, respectively (Table 4). Native species composition for all fish was 53% and 70% at Delta and at Escalante it was 68% and 76% in 2004 and 2005, respectively (Table A1-1).

Fewer small fish (<15 cm) were collected in 2005 (Table A1-1), likely a result of different backwater sampling efforts between years. The most common species less than 15 cm at Delta in 2005 were speckled dace, fathead minnow and white sucker. Fathead minnow were most numerous species in 2004. The most common species less than 15 cm at Escalante in 2005 were roundtail chub, speckled dace and fathead minnow. In 2004 the most common species at Escalante were fathead minnow, bluehead sucker and roundtail chub, respectively (Table A1-1).

Channel catfish, northern pike, and smallmouth bass were not captured at Delta or Escalante. Sand shiners, red shiners, black bullhead, largemouth bass, mottled sculpin, rainbow trout and plains killifish were incidental (Table A1-1).

Mean lengths of flannelmouth sucker, bluehead sucker and roundtail chub were significantly higher at Delta than downstream at Escalante in all years (Table 5). Mean length and the length frequencies indicated that large adult fish were more frequent and numerous at Delta.

Table 4. Species composition (%) for fish >15 cm, Delta (2D site) and Escalante, Gunnison River, 2003, 2004 and 2005.

Gunnison River	Delta			Escalante		
Species	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
Flannelmouth sucker	40.9	40.1	16.3	28.6	20.4	16.0
Bluehead sucker	22.4	20.1	40.5	41.6	48.5	45.9
Roundtail chub	6.2	3.7	16.1	12.5	13.4	15.3
White S. + hybrids	22.7	24.5	19.0	9.6	12.9	17.1
Carp	6.5	9.7	6.0	6.2	3.0	3.0
Brown trout	0.6	0.8	1.4	1.1	1.1	1.7
Rainbow trout	0.1	0.03	0.03	0	0.0	0
Blue-flannel cross	0.6	0.6	0.6	0.2	0.2	0.7
Black Bullhead	0.1	0.03		0.1	0.1	0.2
Razorback sucker			0.1		0.1	0.1
Colorado pikeminnow		0.3			0.1	
% Native species	70.1	64.8	73.6	82.9	82.7	78.0
Sample size	1623	2773	3439	1479	4350	3575

There were a greater frequency and number of small (<22 cm) flannelmouth sucker, bluehead sucker and roundtail chub at Escalante (Table 6). The higher incidence of small fish indicates selectivity and that Escalante had more available juvenile habitat than Delta. The proportion of fish less than 22 cm increased at both sites in 2005, indicating increased Age 1+ bluehead and flannelmouth sucker recruitment that year. Strong year-class recruitment in 2005 would not occur without good 2004 YOY survival.

Table 5. Mean lengths (cm) Delta 2D site and Escalante, Gunnison River, 2003 to 2005.

Species	Delta*			Escalante		
	2003	**2004**	**2005**	**2003**	**2004**	**2005**
Flannelmouth sucker	41.1	44.2	40.2	35.6	37.5	35.5
Bluehead sucker	33.9	34.3	28.6	26.1	27.9	26.7
Roundtail chub	23.7	27.8	23.7	18.3	21.0	22.1
White S. + Hybrids	33.0	29.4	30.4	32.2	29.9	32.8
Carp	37.6	40.8	48.4	39.5	39.9	37.0
Brown trout		24.0	22.5		27.4	28.1

*Delta 2D site only, last year Total Delta was reported.

Table 6. Percent of native fish less than 22 cm in 2004 and 2005, Delta and Escalante.

	Delta		Escalante	
Species	**2004**	**2005**	**2004**	**2005**
Flannelmouth sucker	2.3	13.4	8.9	21.3
Bluehead sucker	7.3	18.4	16.1	30.6
Roundtail chub	35.2	38.1	58.6	57.2

The 2004 and 2005 density estimates were not consistent at Delta for most species. The Delta flannelmouth sucker estimate was 367/ha in 2004 and 258/ha in 2005, the bluehead sucker estimate was 130/ha and 593/ha for 2004 and 2005, respectively. The Delta total fish population estimate doubled in 2005. Carp was the only species for which the density estimate was not significantly different (alpha = 0.05) between years at Delta (Table 7).

Escalante density estimates were generally less in 2005 than 2004: 25% less for flannelmouth sucker and bluehead sucker and 14% less for roundtail chub. The lower 2005 density estimates were significant (alpha = 0.05) for flannelmouth and bluehead sucker but not for roundtail chub or white sucker (Table 7).

Table 7. 2004 and 2005 density estimates for Delta and Escalante, Gunnison River. (The 2004 estimates were adjusted to surface area for the 60 day low flow).

	DELTA		**ESCALANTE**	
	2004	**2005**	**2004**	**2005**
Species	**No/ha**	**no/ha**	**No/ha**	**no/ha**
Total fish	739	1496*	1119	894*
Flannelmouth sucker	367	258*	267	201*
Bluehead sucker	130	593*	502	358*
Roundtail chub	25.0	268*	303	260
White S. + hybrids	153	212*	149	132
Carp	94.4	86.9	75.2	38.3*
Brown trout		6.6	13.6	5.8

*2005 estimate is significantly different (alpha = 0.05) from 2004.

The Delta biomass estimates were very different for 2004 and 2005 (Table 8). The Delta 2004 flannelmouth sucker biomass estimate was 348 kg/ha, which was the highest for any site during the project. The flannelmouth sucker biomass was 213 kg/ha in 2005. The Delta 2004 bluehead sucker biomass estimate was 62 kg/ha. In 2005 bluehead sucker biomass was the highest recorded for any site at 180 kg/ha. Roundtail chub biomass increased at Delta in 2005 while white sucker and carp estimates were similar between years.

Table 8. 2004 and 2005 biomass estimates (model biomass) for Delta and Escalante, Gunnison River. Modeled biomass from 2D modeling suitability curves (Stewart and Anderson 2006).

	DELTA		**ESCALANTE**	
	2004	**2005**	**2004**	**2005**
Species	**kg/ha**	**kg/ha**	**Kg/ha**	**kg/ha**
Total fish	677	674	567	384
Flannelmouth sucker	348 (262)	213 (266)	174 (211)	115 (250)
Bluehead sucker	61.8 (114)	180 (139)	136 (61)	90.5 (91)
Roundtail chub	8.1	40.0	40.0	37.1
White S. + hybrids	80.0	90.4	65.3	64.9
Carp	179	150	142	75.6
Brown trout			3.5	1.6

Biomass estimates at Escalante were less in 2005. The flannelmouth sucker estimate dropped from 174 kg/ha in 2004 to 115 kg/ha in 2005 and bluehead sucker dropped from 136 kg/ha to 91 kg/ha, respectively (Table 8).

<u>Catch rates and recapture probabilities</u>

The large differences for the 2005 estimates were a concern since these data were meant to validate habitat suitability criteria and consistent estimates were anticipated. The Gunnison River catch data was subjected to further analysis because the inconsistency in annual estimates obscured defining the carrying capacity of these sites.

Catch rates are simply the number of fish netted divided by minutes the electro-fisher was in operation. Catch rates can be highly variable between passes, years and sites because sampling effort and catch efficiency (turbidity and netter skill) vary with conditions.

Native sucker catch rates (2.3 - 4.5 fish/min) were highest in 2003 when only two passes were made. The 2004 and 2005 catch rates averaged six and seven passes, respectively. Three of four catch rates were lower in 2005 and suggests reduced catch efficiency that year possibly due to higher more turbid flows (Table 9). In contrast the bluehead sucker catch rate was higher in 2005.

Table 9. Mean electro-fishing catch rates (fish/minute) for the Gunnison River.

Escalante	**2003**	**2004**	**2005**
Bluehead sucker	3.5	3.9	2.6
Flannelmouth sucker	2.3	1.6	0.9
Delta			
Bluehead sucker	2.5	1.5	2.3
Flannelmouth sucker	4.5	2.6	1.0

Bluehead and flannelmouth sucker data were also run using the Huggins data type in Program Mark. Capture probabilities were similar for the 2004 and 2005 Escalante data (bluehead sucker were 3.4% & 3.5%; flannelmouth sucker were 2.8% & 2.2%), which indicates similar catch efficiency between years. At Delta catch probabilities were lower in 2005. The 2004 and 2005 bluehead sucker catch probabilities were 3.7% and 1.9% and the flannelmouth sucker capture probabilities were 2.8% and 1.8%, respectively. Only about 2% of the estimate was caught per pass at Delta in 2005 indicating reduced catch efficiency relative to the prior year and to the Escalante site.

Both the Darroch and Huggins methods assumed closed populations during sampling, which is not likely during a three week sampling period. Migration during the sampling period biases the estimate, but when fish movements at a site are fairly minor and consistent between years, the bias is likely minor and fairly constant between years. Consistent population estimates and catch probabilities between years suggests study site fish emigration was fairly constant. The Delta fish data was not consistent and it was suspected that emigration may have been noticeably different between the 2004 and 2005 surveys.

Pit Tag Results

There were 977 fish implanted with PIT tags in 2005 of which 95 with tags were recaptured. At Delta 272 bluehead sucker were PIT tagged of which 22 were recaptured with a tag and another 15 without a tag (Table 10). At Escalante 274 bluehead sucker were tagged, with 50 tagged fish recaptured and another 16 fish recaptured without a tag. Total recapture of implanted bluehead sucker was 23% at Escalante and 14% at Delta. Recapture rates of implanted flannelmouth sucker and roundtail chub were somewhat higher at Escalante than Delta (Table 10).

Table 10. PIT Tag implant and return data for Delta and Escalante, 2005.

	DELTA 2005			**ESCALANTE 2005**		
	Bluehead sucker	**Flannelmouth Sucker**	**Roundtail chub**	**Bluehead sucker**	**Flannelmouth sucker**	**Roundtail chub**
Number tagged	272	149	78	274	145	59
Recovered tags	22	7	4	50	8	4
Recovered fish*	15	4	2	16	7	2
Total recaptures	37	11	6	63	15	6
% recaptured	13.6%	7.4%	7.7%	23.0%	10.3%	10.2%
% with lost tag	40.5	36.4	33.3	24.2	46.7	33.3

*Recovered fish were fish that had been tagged, but on recapture a tag was not recorded.

The location of each PIT tagged fish was compared for time of capture versus recapture. There was a stronger tendency for downstream movement of bluehead sucker at Delta than at Escalante. Eleven of 22 (50%) bluehead sucker were collected from a downstream sub-reach, eight were taken in the same general area and three taken from an upstream location (Table 11). At Escalante 14 of 50 (28%) tagged bluehead sucker were collected at a downstream location, 31 were from the same area and 5 had moved upstream. The higher tendency for downstream movement at Delta could explain the different recapture probabilities at the two sites.

Fish were collected from above and below the Delta site in both 2004 and 2005 to give an indication of movements in or out of the study site. No fish marked in the 2D site were recaptured upstream in 2004. There was more effort in 2005, but four marked fish were collected upstream which suggested fish were more mobile in the higher flow year (Table 12).

Flannelmouth sucker, marked in the 2D site, had a higher frequency of below station recapture than bluehead sucker in both 2004 and 2005 (Table 12). It appeared that below station flannelmouth sucker recapture frequency was similar in 2004 and 2005, but a higher proportion of marked fish left the study site in 2005 because fewer fish were marked. It also appeared that a higher proportion of bluehead sucker left the study site in 2005. These data along with the PIT tag return data indicate study site emigration was higher in 2005 than 2004.

Table 11. Capture versus recapture location for PIT Tagged fish, 2005, Gunnison River.

Delta					
Species	Recovered	Down	Same	Up	% down
Bluehead sucker	22	11-3*	8	3	50%
Flannelmouth sucker	7	4-1*	2	1	57%
Roundtail chub	4	0	2	2	0%
Escalante					
Species	Recovered	Down	Same	Up	% down
Bluehead sucker	50	14	31	5	28%
Flannelmouth sucker	8	3	3	2	38%
Roundtail chub	4	1	2	1	25%

*3 bluehead sucker and 1 flannelmouth recaptured downstream of the study site.

The emigration bias could inflate the Delta bluehead sucker population estimate if marked fish had a much higher frequency of leaving the study site than unmarked fish. In spite of increased emigration in 2005, the Delta bluehead sucker catch rates were higher in 2005.

The flannelmouth sucker emigration bias appeared fairly similar between years and could deflate the estimate if total catch rates were reduced. Flannelmouth sucker catch rates were reduced in 2005 and emigration is suspected of having a higher impact on the 2005 estimate.

Table 12. Marked fish recaptured above, within and below the Delta study site in 2004 and 2005.

	Bluehead		Flannelmouth		Roundtail chub		White sucker	
	2004	2005	2004	2005	2004	2005	2004	2005
Section above the 2D study site								
1. Marked above station	10	23	26	27	5	10	40	55
2. Catch above station	26	113	49	109	1	24	41	104
3. Above-Mark Recap	1	0	2	0	0	1	5	0
4. Station-Mark Recap	0	1	0	1	0	0	0	2
2D study site								
5. Marked in station	533	1375	1027	490	87	500	614	573
6. Recap inside station	52	68	73	19	7	21	58	36
Section below the 2D study site								
7. Marked below station	91	62	45	72	2	8	1	15
8. Catch below station	103	253	99	135	3	11	37	66
9. Below-Mark recap	3	1	1	3	0	0	0	0
10. Station-Mark recap	1	8	7	9	0	0	0	5
% 2D study site fish recaptured downstream								
Line 10 ÷ Line 5	0.19%	0.58%	0.68%	1.84%	0%	0%	0%	0.87%
Line 10 ÷ Line 8	1.0%	3.2%	7.1%	6.7%	0%	0%	0%	7.6%

DISCUSSION

There were large differences in species composition, size structure and density between Delta and Escalante. Differences in species composition, size structure and density were also found on the Colorado River where juvenile fish were more prevalent in Debeque Canyon than upstream sites (Anderson 1997). Both Escalante and Debeque Canyons had higher proportions of juvenile fish, indicating these canyon reaches had higher nursery habitat availability and may be important sites for native fish recruitment. Differences in fish community structure in the canyon reach were attributed to differences in habitat availability, which was confirmed by 2D modeling at Escalante and Delta. The Escalante and Delta 2D modeling data could be used for determining juvenile flannelmouth and bluehead sucker habitat suitability criteria in the same way it was done for adults.

The flannelmouth and bluehead sucker biomass estimates were the primary objective of the fish sampling efforts, since these estimates were needed to validate habitat suitability criteria (Stewart et al 2005). Biomass estimates are a measure of a site's physical carrying capacity as limited by habitat quality and quantity. When flows and habitat are stable between years then carrying capacity is also expected to be stable.

Biomass estimates were fairly consistent between years for the Yampa and Colorado Rivers (Anderson 2004). Biomass estimates were not consistent at Delta between 2004 and 2005. The 2005 bluehead sucker biomass was extremely high relative to 2004. The 2D model projected bluehead sucker biomass to be about 60 kg/ha higher than the 2004 estimate and about 60 kg/ha less than the 2005 estimate. The average of these two years approximated the predicted value. The fact that bluehead sucker estimates were so much different between years suggested one or both of those estimates was not indicative of the long-term carrying capacity.

Large differences in density and biomass between years can naturally happen in years of exceptional recruitment and 2005 appeared to be a high recruitment year for bluehead sucker. Numbers of juvenile sized (12 to 28 cm) bluehead sucker were much higher in 2005 at both Delta and Escalante than in 2004. Numbers of juvenile size bluehead sucker were much lower in 2004 than observed in surveys in 1992 and 1993 by the USFWS (Burdick 1996).

High recruitment years for trout have been associated with low spring runoff flows that improved YOY annual survival and growth rates (Nehring and Anderson 1993). High recruitment for native sucker has been associated with high spring runoff flows (Burdick 1995). Perhaps the very low runoff flows of 2002 suppressed bluehead sucker year class strength in 2002. Runoff was normal in 2003 and a strong 2003 year class would explain improved recruitment in 2005.

Bluehead sucker were observed spawning in early May 2005 in Dominguez Creek (Escalante Canyon) on the ascending limb of the hydrograph. Reproductive success is likely associated with habitat conditions during the runoff. Runoff was high in 2005. If reproductive success was also high in 2005, there should be more bluehead sucker in 2006 or 2007.

Exceptional recruitment is less likely to occur in years when adult fish are at carrying capacity or when all available niches are occupied. When habitats are at saturation, surplus recruitment is expected to migrate or occupy marginal habitats, but not be permanently assimilated.

If the 2004 bluehead sucker biomass was below carrying capacity, then habitats would be available. Bluehead sucker biomass was lower than modeled in 2004.

Another condition that would promote strong recruitment is a real increase in carrying capacity due to increased habitat availability. Bluehead sucker prefer deep riffle habitats, which increases with increasing base flows. In 2005 habitat conditions were ideal for strong recruitment due to increased base flows. During the 2004 fish sampling there were certain side channel riffles that were too shallow to sample, but at the higher 2005 flows, large numbers of bluehead sucker were collected from flowing side channels and around shallow bars.

Catch rates (fish per minute) were much higher in 2005 than 2004 and this is a clear indication of strong recruitment at Delta in 2005. Also higher emigration from the study site could have bolstered the 2005 estimate somewhat.

We suggest the discrepancy in annual biomass estimates for bluehead sucker at Delta is explained by a rapid increase in biomass due to very strong recruitment between 2004 and 2005. The best way to verify that is to sample Delta in 2006, but that is not planned. Therefore the average of the two estimates is likely a better estimate of carrying capacity than either year.

The non-overlapping 2004 and 2005 Delta flannelmouth sucker biomass estimates were also troublesome in terms of validating suitability criteria used in 2D modeling. Instead of the desirable consistency in biomass estimates, the flannelmouth estimate was much higher in 2004 than 2005.

During low to moderate flows (300 to 1000 cfs) flannelmouth sucker occupied run habitats with moderate velocities and average depths of near one meter (Anderson 2003). Gunnison River base flows are high. Flows during the 2005 sampling period were higher and more turbid than in 2004, averaging 1,360 cfs in 2005 and 980 cfs in 2004. At the higher 2005 discharges the availability of moderate velocity habitats may have been spatially different than in 2004.

Shallow runs may become less suitable as flannelmouth sucker habitat at higher discharges since velocities increase with discharge. At some increasing flow deeper pools may possess velocities in preferred range. Indeed, it appeared that flannelmouth sucker were occupying deeper habitats in 2005.

Fish are less vulnerable to electroshock when occupying habitats over 1.5 m depth. Capture effectiveness is further reduced during turbid sampling conditions when fish have to break the surface in order to be seen and netted. This would explain the lower catch rates and the total number of flannelmouth collected in 2005, but these conditions should not influence recapture probabilities if the close-population assumption or if emigration was constant between years.

It appeared that although emigration was fairly constant, it was a factor for the lower 2005 estimate. There was a higher proportion of marked fish downstream of the study site in 2005 than in 2004. Downstream movement also appeared to be higher at Delta than it was at Escalante in 2005 based on PIT tag recoveries.

Flannelmouth sucker appeared to be sedentary during a radio telemetry study at Corn Lake in 2000 (Byers et al. 2000). In this study six of six flannelmouth sucker were location in the 2D site when flows were fairly low and stable in late September and October 2000. A follow-up telemetry study was made at the 2D site in August 2001. Two of five radio- tagged flannelmouth sucker were not located after release and suspected of leaving the 2D site (Rees and Miller 2001). Flows during August 2001 were higher and more turbid than in 2000.

The lower flannelmouth sucker 2005 biomass estimate appears to be explained by fish switching to deeper habitats at higher base flows, which reduced sampling effectiveness and also inflated emigration. To verify this scenario another year of sampling is required. But since 2003 and 2004 catch rates were similar and we suspect the 2005 biomass estimate was biased low, the 2004 flannelmouth sucker biomass estimate appears more reliable.

The roundtail chub biomass estimate and catch rates were higher at Delta in 2005 than in 2004. There appears to be a simple explanation for this inconsistency. During daylight roundtail chub reside in deep pools that are less vulnerable to sampling, but during night or during turbid conditions chub move to shallower habitats. Therefore catch efficiency for roundtail chub was better in 2005 than 2004 due to turbid conditions.

Also the higher 2005 flows may have influenced roundtail chub to select eddy habitats over main channel pools due to circulating currents in eddies. Stunned fish float on the surface longer in eddies and are easier to net. The fact that the 2005 Delta roundtail chub estimate was similar to the Escalante estimates strongly indicates it was more reliable than the 2004 estimate.

Escalante was also sampled for two years for the purpose of establishing reliable biomass estimates to validate habitat suitability criteria and model projections. The bluehead and flannelmouth sucker biomass estimates at Escalante were lower in 2005 and the drop was similar for both species.

The explanation for reduced flannelmouth sucker biomass at Delta in 2005 also can be applied to Escalante. The higher 2005 flows resulted in flannelmouth sucker switching to deeper habitats possessing suitable velocities and emigration had a negative bias on the biomass estimate and catch rates. At Escalante it is also suspected that the 2004 flannelmouth sucker estimate was a more reliable index of carrying capacity.

The biggest contradiction with the Gunnison River fish data was that bluehead sucker biomass increased at Delta but decreased at Escalante in 2005. The higher 2005 catch rate data suggested Delta biomass increased in 2005 as a result of strong recruitment and increased habitat in the higher flow year, but that was not applicable for bluehead sucker at Escalante.

At Escalante catch efficiency was similar between years suggesting recruitment was not better in 2005 compared to 2004. The modeling data indicated that Escalante Canyon appeared to have better juvenile fish habitat and the catch data indicated juvenile bluehead abundance was high in both 2004 and 2005.

If Escalante biomass was at or near its habitats ‘carrying capacity’ in 2004 then the 2005 estimate should have been similar. The different catch and emigration rates between years resulted in either a 2004 estimate that was high or a 2005 estimate that was low. Because of the uncertainty in how these factors influenced the estimates it is likely the average of the two years is better than either year for representation of carrying capacity.

Native species were 79% of fish collected by electrofishing in 1992 and 1993 and white sucker species composition was much lower (Burdick 1995) than in this study. The increase in white sucker could be associated with altered spring flows.

2D HABITAT MODELING

RESULTS AND DISCUSSION

Habitat Composition

The Gunnison River sites had narrower wetted widths than the Colorado and Yampa Rivers (Table 13). A narrower channel on the Gunnison River could indicate channel downsizing has occurred due to reduced spring peak flows after construction of the Aspinall project. In general narrower rivers have either lower width/depth ratios or higher mean velocities, both positive attributes for maintaining fish habitat during low flow conditions.

Bed slope of the Delta and Escalante sites was 0.16% and 0.09%, respectively (Table 13). Pitlick (1999) reported Delta and Escalante slopes averaged 0.19% and 0.12%, respectively.

Bed slopes are directly related to mean velocity. Mean velocities at a typical flow of 1,000 cfs were 0.69 and 0.52 m/sec at Delta and Escalante, respectively (Table 13). Delta had the highest mean velocity of all sites and mean velocity at Escalante was also high relative to other sites.

The steeper gradient and higher mean velocity at Delta resulted in a very a high proportion of riffle/rapid habitat (64%) at Delta. In contrast riffle/rapid habitat made up only 39% of the area at Escalante (Table 14). Run habitats types were 23% at Delta and 42% at Escalante, indicating substantial differences in habitat composition for these two sites. Substantial differences were also found in the demographics of each sites fish assemblage.

Riffle habitat area was positively correlated with native sucker biomass and density (Anderson and Stewart 2003). The Gunnison River had high levels of both native sucker biomass and riffle habitats. The deep riffle habitat type was associated with bluehead sucker habitat and Delta had the highest area of deep riffle habitat (Table 14) and bluehead sucker biomass (Anderson and Stewart 2006, report B).

Fish body size also appeared to be a function of habitat composition. A general observation made throughout the project was that fish body size tended to be proportional with their habitat’s velocity. Also, larger fish were more common in the larger volume base flow rivers. The Dolores River had very limited swift current habitats and the fish were small (Anderson and Stewart 2006, Dolores River section of this report). Large-sized adult native sucker were very common in the

Colorado River where riffle/rapid habitat types were very common. The Yampa River at Lily Park was intermediate for fish size and availability of swift water habitats.

Size of flannelmouth and bluehead sucker differed for Delta and Escalante site, as did habitat composition. Large adult flannelmouth sucker (over 45 cm) and bluehead sucker (over 35 cm) were more common at Delta where deep riffle habitat were more common. At Escalante fish less than 26 cm and the lower velocity run habitats were more common (Table 14).

At similar flows the Gunnison, Colorado and Yampa Rivers had similar availability of riffle habitats. At 250 cfs riffle habitats were about 6 to 7% for both Delta and Escalante, very similar to the Yampa and Colorado rivers.

At similar flows the fact that the Gunnison, Colorado and Yampa Rivers have similar habitat composition strongly suggests these rivers fish communities would be more alike. The abundance and therefore the impacts (predation, competition and hybridization) of non-native species also appear to be related to habitat availability and flow conditions (Anderson and Stewart 2006, report B).

Availability of 16 meso habitat types (pools, runs and riffles) varied with flow (Fgure A3-3) and Shannon Diversity peaked at 600 cfs at Delta and at 800 cfs at Escalante (Figures A3- 4). This habitat diversity indicator suggests that flows in the vicinity of 600 to 800 cfs would support the widest variety of habitats and niches utilized by native species and life stages.

Table 13. Physical attributes of each study site (mean velocity, length, mean width, surface area at modeled flows).

	Delta	**Escalante**	**Clifton**	**Corn Lake**	**Duffy**	**Lily**	**Sevens**	**Big Gyp**
Mean annual flow	**2,564 cfs**		**2,817 cfs**		**1,546 cfs**			**284 cfs**
Length (km)	3.9	4.4	4.2	3.9	2.1	3.1	2.9	3.3
Percent slope	0.16%	0.09%	0.20%	0.16%	0.06%	0.20%	0.05%	0.15%
Typical base cfs	1000	1000	1000	1000	250	250	250	50
*Mean vel. (m/s)	0.69	0.52	0.44	0.54	0.39	0.51	0.38	0.28
*Mean width (m)	42	44	59	50	68	57	60	21
*Mean depth (m)	0.81	1.02	0.76	0.82	0.53	0.6	0.6	0.46
Width/depth ratio	52	43	77	61	128	94	100	46
Flow (cfs)	Area (ha/km)							
50						4.2	4.3	2.0
60					5.1	4.2	4.5	2.1
100	3.2	3.3	3.9	2.9	5.5	4.2	4.9	2.1
200	3.6	3.7	4.7	4.2	6.0	4.8	5.4	2.3
400	4.0	4.1	5.3	4.7	6.5	5.4	5.8	2.4
500	4.1	4.3	5.5	4.9	6.6	5.5	5.9	2.5
800	4.4	4.7	6.2	5.3		5.9	6.2	
1000	4.6	4.9	6.5	5.3		6.0		
1400	4.8	5.1	7.0	5.8		6.3		
2000	5.2	5.5	7.6	6.2		6.7		

Insert Table 14, here.   It is a landscape page.

HABITAT and FLOW RELATIONSHIPS

The final process of 2D modeling was to produce a curve for projected bluehead sucker biomass as a function of discharge. The relationship was based on significant correlations for biomass to habitat availability and then determining habitat as a function of discharge (Stewart and Anderson 2006).

The curve for bluehead sucker biomass to discharge peaked at about 1,000 cfs. Flows over 1,400 cfs resulted in deceasing habitat which suggested negative impacts to bluehead sucker abundance could result with long term excessive flows (Figure 3).

The inflection points of both the Delta and Escalante curves were at 600 cfs. The curves for both Delta and Escalante indicate that habitat and projected biomass would rapidly drop if long term (over 2 years) flows were less than 400 cfs.

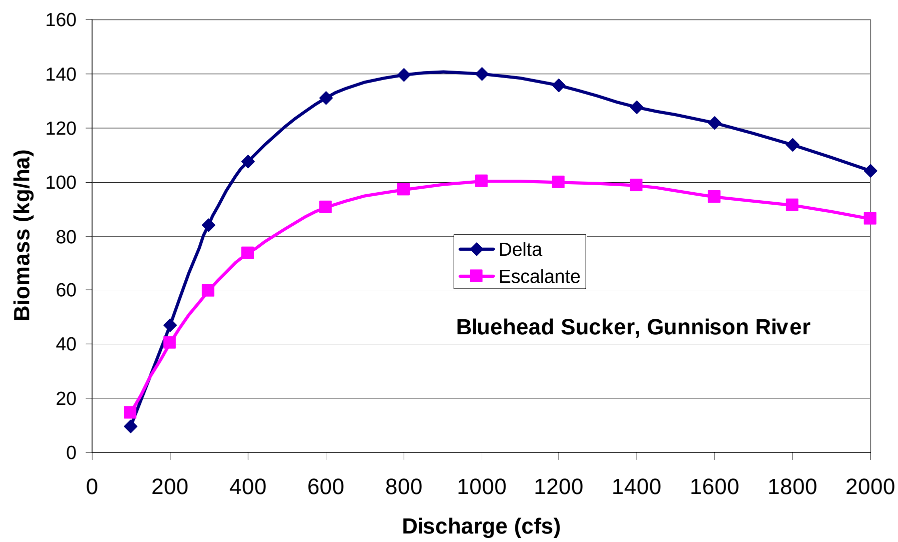

Figure 3. Modeled bluehead sucker biomass (kg/ha) as a function of discharge, Delta and Escalante, Gunnison River.

Maximum bluehead sucker biomass was modeled at flows near 1,000 cfs at both Delta and Escalante. About 95% of maximum remained at 700 cfs and 91% of maximum remained at 600 cfs (Figure 4). This modeling suggests that base flows over 600 cfs are sufficient to maintain the existing bluehead sucker biomass.

Adult flannelmouth sucker habitat suitability criteria from the prior study were valid for the Gunnison River and the correlation of flannelmouth sucker with discharge was significant (Stewart and Anderson 2006).

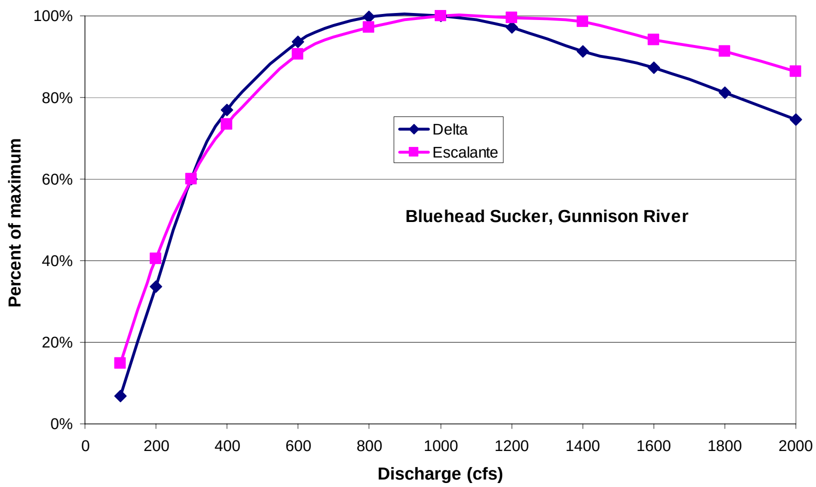

Figure 4. Percent of maximum bluehead sucker modeled biomass as a function of discharge, Delta and Escalante, Gunnison River.

Projected flannelmouth sucker biomass peaked between 600 to 800 cfs at Delta and 1,000 to 1,400 cfs at Escalante. The inflection point for the flannelmouth sucker curve was at 600 cfs at Delta and at both 600 and 900 cfs at Escalante. The flannelmouth sucker biomass curve indicated reduced abundance when flows exceed 1,000 cfs at Delta and 1,400 cfs at Escalante. Flannelmouth sucker abundance rapidly dropped when flows are less than 400 cfs (Figure 5).

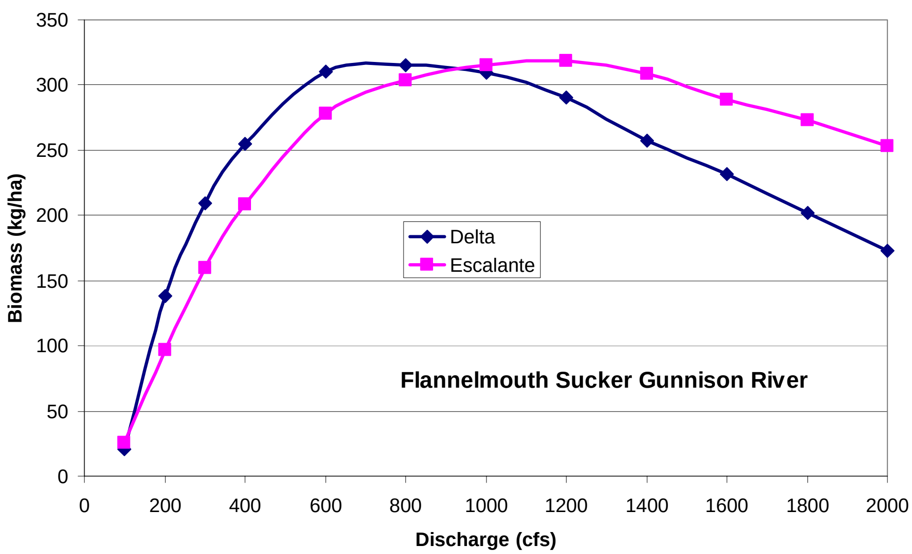

Figure 5. Modeled flannelmouth sucker biomass (kg/ha) as a function of discharge, Delta and Escalante, Gunnison River.

Maximum projected flannelmouth sucker biomass peaked near 1000 cfs at Delta and Escalante, very similar to bluehead sucker. About 98% of maximum biomass was retained at 600 cfs at Delta and 87% at Escalante (Figure 6). This modeling suggests that base flows over 600 cfs are sufficient to maintain existing flannelmouth sucker biomass.

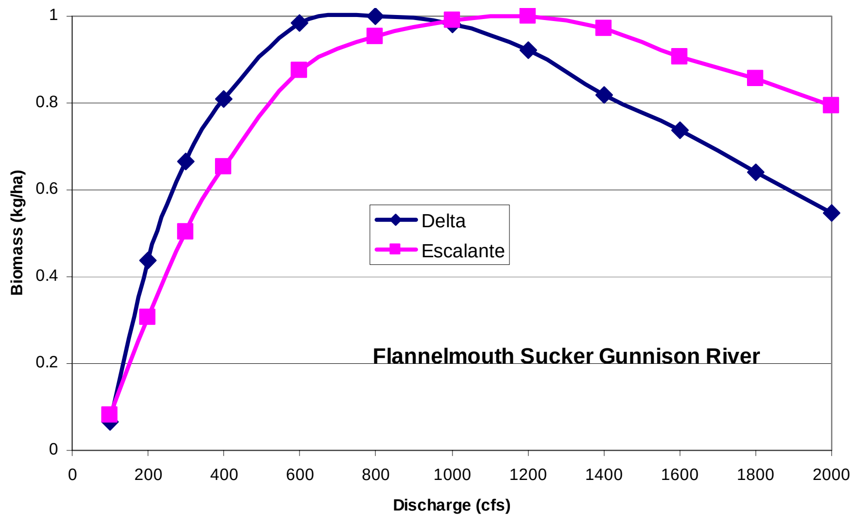

Figure 6. Percent of maximum flannelmouth sucker modeled biomass as a function of discharge, Delta and Escalante.

INSTREAM FLOW RECOMMENDATIONS

Base flow Recommendation

The instream flow recommendation for the Gunnison River is 600 cfs.

The 600 cfs recommendation is based primarily on 2D modeling results that identified inflection points for bluehead and flannelmouth sucker biomass as a function of discharge. The 2D modeling indicated that about 90% of the projected maximum bluehead and flannelmouth sucker biomass would be maintained at 600 cfs.

The 600 cfs recommendation is supported by the Shannon habitat diversity values that were highest at flows of 600 to 800 cfs. The maximum Shannon diversity suggests that habitat types required by other species and younger life stages of native species would also be available at a 600 cfs base flow.

The fish surveys in 2004 and 2005 provided empirical support that base flows in those years (900 to 1,200 cfs) were maintaining fry and juvenile native fish habitat availability. Typically fry and nursery habitat availability are expected to be maximized at a low base flows since they prefer shallow low-velocity habitats.

Spring or Channel Maintenance flow recommendation

The 2D modeling was not applied for developing a spring or channel maintenance flow since there is little promise of relating peak flows or recurrence of bankfull flows with biologically based metrics. Bankfull flows are directly related to sediment transport and therefore channel maintenance. Channel maintenance flows are necessary to maintain channel geomorphology and habitats used by fish during base flow periods.

Pitlick (1999) identified bankfull flow to be 14,500 cfs for the Gunnison River, but flows have not been that high since 1995 (10 years). In 2002 the mean daily peak flow was 1,464 cfs and it was 2,769 cfs in 2004. Reduced reproductive success for native species is a potential negative consequence in years with low runoff flows. However native sucker biomass remained high in the study period and immediate impacts due to the low 2002 and 2004 spring runoff flows were detected. Excessive sedimentation or channel deterioration was not observed during the 2003, 2004 and 2005 fish and habitat surveys.

The mean annual peak since 1965 has been about 6,000 cfs. If 6,000 cfs has been functional for sediment transport equilibrium in the last 40 years then it should be continue to be functional in the future. However, base flows have been quite high since 1965 (1,000 to 1,200 cfs) and base flows are certainly capable of transporting fine sediment from riffles and runs. Spring runoff or flushing flows may need to be higher than 6,000 cfs to maintain current sediment transport rates if base-flows drop to the 600 cfs or less over the long term

The recommendation is to strive to maintain an average peak of 6,000 cfs for a spring peak flow. Sediment transport studies are needed to establish accurate sediment transport rates at the current hydrograph and potentially altered hydrographs.

DOLORES RIVER

Dolores River fish data for 2000, 2001, 2004 and 2005 are contained in this report. Length frequency data for 2005 is in Appendix 3, length frequencies for prior years are in that year's annual report. Species composition, density and biomass data are for fish over 15 cm in length. Mean lengths include all fish captured at the site.

Fish Sampling

RESULTS

Native fish relative abundance, for fish >15 cm, varied from 43 to 87% for the four years with data, with the lowest in 2004 and the highest in 2001 (Table 15). Flannelmouth sucker was the most common fish collected in 2001 and 2005 (55 and 59%, respectively), but was only 2% in 2004. Bluehead sucker composition ranged from 0% in 2005 to 6% in 2001. Roundtail chub ranged from 25 to 55% and was the most common species in 2000. Black bullhead was the most common species in 2004 (45%), but was uncommon prior to 2002.

Table 15. Species composition (%) for fish over 15 cm (n) at Big Gypsum, Dolores River.

Dolores River	**Big Gypsum fish > 15 cm**			
Species	**2000**	**2001**	**2004**	**2005**
Flannelmouth sucker	15.7 (79)	55.0 (309)	2.4 (10)	59.1 (286)
Bluehead sucker	2.2 (11)	6.2 (35)	1.2 (5)	0 (0)
Roundtail chub	54.7 (275)	25.8 (145)	39.5 (166)	24.8 (120)
Channel catfish	16.7 (84)	9.1 (51)	5.2 (22)	5.0 (24)
Black bullhead	5.0 (25)	0.5 (3)	44.5 (187)	9.5 (46)
Carp	3.4 (17)	2.0 (11)	7.1 (30)	1.4 (7)
Green sunfish	2.0 (9)	1.4 (8)	0	0.2 (1)
Brown trout	0.6 (3)			
Native species	72.6	87.0	43.1	80.5
Sample size	503	562	420	484

The Big Gypsum study site has been unlike other project study sites in that larger native fish have been uncommon. Total fish relative abundance may be a better than fish >15 cm because a large proportion of native fish were smaller than 15 cm at Big Gypsum.

Total fish relative abundance includes the Non Native Cyprinids (NNC; i.e. red shiner, sand shiner and fathead minnow), which were not target species for this project. Fish less than 15 cm occupy shallow low-velocity habitats that generally not suitable for adult native fish. Native fish occupy shallow habitats as fry, but availability of small fish habitat is generally not limiting or a factor concerning instream flow recommendations. Even though attempts were made to net all stunned fish, sampling NNC habitats (<16 cm depth) was not quantitative and NNC numbers were likely undercounted in most years.

Native species composition ranged from 53% to 81% for total fish collected (Table 16). NNC were the most abundant group in the 2001 and 2005 sample. NNC were less common in 2004, and only a few were collected in 2000. The differences in NNC abundance between years could result from sampling variability more than changes in abundance. Because NNC were undercounted, native species composition is likely higher than in reality.

Roundtail chub was the most common species collected in 2000 and 2004, the third most common in 2001 and ranked fifth in 2005. Flannelmouth sucker was the second most numerous species in 2001 and 2005, years when NNC were most common. Bluehead sucker were common in 2001, but rare in all other years. Speckled dace were common in all years, ranging from 14 to 19% of the total catch (Table 16).

Number of fish caught each year was highly variable. Flannelmouth sucker numbered 580 in 2001 and 514 in 2005, but only 25 in 2004 (Table 16). There were 383 bluehead sucker in 2001, but only 5 and 4 in 2004 and 2005, respectively. There were 197 black bullhead caught in 2004, but few in prior years. More roundtail chub, channel catfish and green sunfish were caught in the first two years than in 2004 and 2005.

Table 16. Species composition (%) for total fish (n) at Big Gypsum, Dolores River.

Dolores River	**Big Gypsum total fish**			
Species	**2000**	**2001**	**2004**	**2005**
Flannelmouth sucker	10.2 (109)	20.8 (580)	3.3 (25)	28.3 (514)
Bluehead sucker	1.0 (11)	12.3 (343)	0.7 (5)	0.2 (4)
Roundtail chub	51.2 (552)	18.3 (512)	30.2 (228)	12.3 (224)
Channel catfish	8.1 (87)	2.2 (62)	3.0 (22)	1.3 (24)
Black bullhead	2.5 (27)	0.5 (14)	25.8 (197)	2.5 (46)
Carp	1.7 (18)	0.4 (11)	4.1 (30)	2.2 (40)
Green sunfish	4.0 (43)	1.5 (42)	3.8 (27)	1.5 (27)
Pumpkinseed		0.4		
Speckled dace	18.1 (195)	13.5 (378)	18.3 (140)	19.2 (349)
Red shiner	2.8 (30)	28.1 (784)	8.2 (61)	14.1 (257)
Sand shiner	0.1 (1)	1.8 (49)	1.2 (9)	16.9 (308)
Fathead minnow	2.4 (1)	0.4 (10)	1.4 (11)	1.4 (25)
NNC -nonnative cyprinids	3 (32)	30.3 (843)	10.8 (81)	32.4 (590)
Brown trout	0.3 (3)			
Native species	80.5	64.9	52.5%	60.0%
Sample size	1078	2795	755	1818

The total density estimate (fish over 145 mm) and estimates of flannelmouth sucker and roundtail chub were highest in 2005 (Table 17). The number of recaptures in 2005 was much less than in prior years, which inflated the 2005 estimates relative to the number marked. The bluehead sucker estimate was zero in 2005 and the black bullhead estimate was less in 2005 than in 2004.

Flannelmouth sucker estimates were significantly different (@ = 0.05) between all years (Table 18). Roundtail chub estimates were not significantly different (@ = 0.05) between years, except between 2000 and 2004.

Table 17. Density estimates for 2000, 2001, 2004 and 2005 at Big Gypsum, Dolores River.

Dolores River	Big Gypsum density fish/ha			
Species	**2000 (n)**	**2001 (n)**	**2004 (n)**	**2005 (n)**
Total fish	119.7	154.3	115.5	283.8
Flannelmouth sucker	20.0	76.	3.2	149.6
Bluehead sucker	1.6	6.5	1.0	0
Roundtail chub	53.3	43.9	34.6	78.4
Channel catfish	40.7	31.2	8.7	28.8
Black bullhead	8.1	0.9	61.0	16.1
Carp	8.7	3.2	8.3	2.9

Table 18. Significant differences (alpha = 0.05) in density estimate between years.

Dolores River	Significant difference (sd) in Big Gypsum density estimates.					
Species	**2000/2001**	**2000/2004**	**2000/2005**	**2001/2004**	**2001/2005**	**2004/2005**
Total fish	sd		sd	sd	sd	sd
Flannelmouth sucker	sd	sd	sd	sd	sd	sd
Bluehead sucker	sd		sd	sd	sd	sd
Roundtail chub		sd				
Channel catfish		sd				
Black bullhead	sd	sd		sd	sd	sd
Carp						

Big Gypsum had poor total fish biomass (fish >15 cm). Total fish biomass was highest in 2000 due to more channel catfish and carp biomass that year. Total biomass was lowest in 2004 for all species except black bullhead and carp (Table 19). Biomass estimates for flannelmouth sucker, bluehead sucker, and roundtail chub were very low relative to other rivers.

Table 19. 2000, 2001 2004 and 2005 biomass estimates for Big Gypsum, Dolores River.

Dolores River	Big Gypsum biomass kg/ha			
Species	**2000**	**2001**	**2004**	**2005**
Total fish	41.9	19.2	22.3	27.9
Flannelmouth sucker	4.2	3.2	0.4	6.6
Bluehead sucker	0.2	0.6	0.1	0
Roundtail chub	3.0	2.4	1.6	5.2
Channel catfish	16.3	10.3	3.2	10.9
Black bullhead	0.6	0.1	2.8	0.9
Carp	17.5	2.6	14.2	4.4

Mean lengths were highest in 2000 for all species except for roundtail chub and channel catfish. Larger sized flannelmouth sucker, bluehead sucker and roundtail chub were collected in 2000, but were absent in 2001, 2004 and 2005. Most of the carp collected in 2005 were yearling size (10 to 13 cm), producing the low mean length that year (Table 20).

Table 20. Fish mean lengths at Big Gypsum, Dolores River.

Dolores River	Mean length in cm (n)			
Species	**2000**	**2001**	**2004**	**2005**
Flannelmouth sucker	18.8 (109)	14.2 (580)	11.1 (25)	14.9 (514)
Bluehead sucker	23.6 (11)	12.1 (343)	22.5 (5)	12.2 (4)
Roundtail chub	14.1 (552)	10.9 (512)	15.9 (228)	14.6 (224)
Carp	50.3 (18)	35.2 (11)	49.6 (30)	17.4 (40)
Channel Catfish	28.7 (87)	25.8 (62)	32.1 (22)	32.4 (24)
Black Bullhead	21.1 (27)	13.6 (14)	17.7 (197)	19.2 (46)
Green Sunfish	13.0 (43)	9.6 (42)	9.3 (27)	11.6 (27)

Length frequencies indicate year-class strength and recruitment, which vary between years due to flows or other environment conditions. Flannelmouth sucker had three length frequency modes in 2000, one for YOY, and one each for juvenile and adults. In 2001 the YOY mode was present but most fish were in a yearling mode, indicating good recruitment of the 2000 year-class. In 2004 both YOY and age 1+ flannelmouth sucker were rare, indicating poor recruitment from the 2002 and 2003 year-class. Flannelmouth sucker from 13 to 18 cm were numerous in 2005, indicating good recruitment from 2004. Since YOY flannelmouth sucker were not observed at Big Gypsum in 2004, the fish collected in 2005 must have migrated to the area from either upstream (Dove Creek area) or downstream (Slick Rock Canyon) spawning sites.

There were no YOY bluehead suckers collected in any of the four years indicating no local reproduction. A fairly high number of Age1+ bluehead suckers were collected in 2001, but not in 2000, 2004 and 2005. The strong 2000 year-class observed at Big Gypsum in 2001 must have resulted from migration to the area.

Roundtail chub appear to have had local reproduction in all years except 2004. YOY and Age1+ roundtail chub were collected in both 2000 and 2001. The main difference in length frequencies between these years was there was more fish >20 cm in 2000. Fish less than 12 cm were rare in 2004, likely due to a poor 2003 year-class.

Length frequencies were highly variable for most nonnative species between years. Small carp were uncommon in 2000 and 2001, but were very common in 2005, indicating reproduction was improved. Black bullhead numbers and mean size also increased in 2004 indicating the drought had positive impacts for this species.

DISCUSSION

Valdez et al. (1992) reported no significant changes in species composition between 1990-91 surveys and similar surveys made ten year earlier by Valdez et al. (1982). Dr. Valdez concluded the ichthyofaunal community remained relatively stable over that ten year period. The fish community was dramatically altered at Big Gypsum between 2000 and 2004 and the most likely cause was reduced flows.

In 2004 there had not been a flushing flow since 1999, allowing sediment from Disappointment Creek to accumulate for five years. In addition to sedimentation problems, year-round base flows were very low in 2002 and 2003.

The most notable differences between the fish community in 2004 from 2000 and 2001 were increased numbers of black bullhead and decreased numbers of flannelmouth sucker. Black bullhead is strongly associated with backwater or other low velocity habitats. The fact that black bullhead was the most common species in 2004 strongly indicated that habitat availability was composed primarily of low velocity pools that were favorable to bullhead, but not native species.

The low numbers of flannelmouth sucker collected in 2004 confirmed habitats had been altered during the drought period. Adult flannelmouth sucker prefer runs with velocities of about 0.4 to 1.0 ft/sec (Anderson and Stewart 2003). These habitats were very rare in 2002 and 2003 when flows were 2 to 20 cfs. Larger flannelmouth sucker were also rare after 2002. The fact that juvenile flannelmouth sucker (12 to 18 cm) were common indicates habitat suitable for small fish was available.

The low number of bluehead sucker in 2004 and 2005 was attributed to absence of quality riffle habitat after the 2002 low flows.

Reduced biomass of roundtail chub and channel catfish was also found in 2004. Both roundtail chub and channel catfish are predators and both species utilize pool habitats and forage in runs or riffles. Reduced biomass for these species would happen if their forage potential had been impacted. Invertebrate production is generally highest in riffle habitats, and riffles appeared degraded or more silted after 2002.

Recruitment of flannelmouth sucker, bluehead sucker and roundtail chub was variable between years. Roundtail chub YOY were collected in all years except 2004, the year with the most sedimentation and also the year with the highest black bullhead density. It is possible that the large black bullhead abundance in 2004 had negative impacts on roundtail chub abundance, either by predation or competition.

Flannelmouth sucker YOY were collected in 2000 and 2001 indicating reproductive success in those years. No flannelmouth sucker YOY were collected in 2004 and 2005. This suggests there were suitable spawning sites at Big Gypsum prior to 2002 but not in 2004 or 2005.

Flannelmouth sucker spawning at Big Gypsum probably occurs in April (Dan Kowalski, DOW, personal comm.). Flannelmouth sucker spawning in 2005 would have been prior to the runoff and therefore prior to flushing flows in May and June. The collection of YOY flannelmouth at Big Gypsum in 2006 would provide supporting data that flannelmouth sucker spawning habitat had been degraded in 2004 and 2005.

Age1+ sized flannelmouth sucker were abundant in 2005, even though no YOY were collected in 2004. Sedimentation problems are not apparent in the Dolores River upstream of Disappointment Creek. Adult flannelmouth sucker and bluehead sucker were common from Bradfield Bridge to Dove Creek prior to 2002 (Japhet and Nehring, CDOW, personal comm.) and spawning was confirmed in this reach in 2006 by Dan Kowalski (CDOW, personal comm.).

The Age1+ flannelmouth sucker at Big Gypsum in 2005 likely originated from upstream of Disappointment Creek. Slick Rock Canyon could also be a nursery area. Canyon Reaches with moderate gradients on the Gunnison and Colorado Rivers have been identified as good nursery habitats.

There were no YOY bluehead sucker collected at Big Gypsum. Age1+ bluehead sucker were abundant in 2001, but were rare in 2004 and 2005. Bluehead sucker are presumed to spawn upstream of Disappointment Creek and migrate to Big Gypsum.

Valdez et al. (1992) reported large differences in abundance for bluehead sucker between his 1990 and 1991 surveys. The wide swings in bluehead sucker abundance could be due to variability in recruitment or migration between years. In 2004 and 2005 either bluehead sucker recruitment was lacking or migrating fish did not find Big Gypsum to be suitable habitat. Bluehead sucker was the most sensitive species to drought flows on the Yampa River (Anderson 2006).

The very high runoff flows of 2005 appeared to have scoured pools and runs and flushed riffles. The maximum depth of one pool surveyed at Big Gypsum pre and post 2005 runoff increased by 7.5 ft (David Graf, DOW, personal comm.). Also water clarity was good during the 2005 fish sampling. Deeper and less turbid conditions in 2005 may have been related to the poor recapture of marked fish in 2005.

Total fish biomass at Big Gypsum was very poor compared to the Yampa, Colorado and Gunnison Rivers (Anderson 2005). Natural base flows appear to be in the range of 60 to 70 cfs. Habitat modeling projected that base flows of near 150 cfs would be required in order to generate similar habitat availability as found on the Colorado and Gunnison Rivers (Anderson and Stewart 2003).

White sucker were not collected at Big Gypsum. The presence of white sucker would likely have a negative impact on native sucker due to hybridization, as witnessed on other rivers.

Roundtail chub and speckled dace appear to be more drought-resistant than the native sucker. However, roundtail chub are more vulnerable to predation from channel catfish, black bullhead both currently in the community.

Black bullhead abundance decreased in 2005, but was still higher than in 2001 and 2002. Conversely channel catfish density increased in 2005. Reduced flow appeared to explain the increased black bullhead abundance in 2004, therefore reduced flows further impact native species by exacerbating negative interactions with nonnative fish.

The pre- and post-McPhee dam annual hydrographs have been much different, with the pre-having a high frequency of flushing flows (3,000 to 5,000 cfs) but low annual base flows (two to five cfs). These conditions appear to have been more conducive for native fish than those observed in recent years. In the pre-McPhee period riffles and pools were scoured nearly every year, which helped to maintain habitats used by native fish during the irrigation season. In recent drought years sediment accumulated in riffles and pools, resulting in a net loss of habitat quality that was not compensated by somewhat higher reservoir releases.

The Dolores River has been dewatered since 1886 (BLM 1990). Native fish have had to contend with reduced flows for a long time. In general small sized fish are better fit to survive drought while large fish are more flood-resistant. The small size of flannelmouth sucker, bluehead sucker and roundtail chub at Big Gypsum may be a consequence of long term drought-like flow conditions in the Dolores River.

It appears that the three native fish species (roundtail chub, flannelmouth and bluehead sucker) mature at younger ages and smaller sizes than typical for other river systems. Small size and early maturity suggest a hypothesis that low flow habitat conditions have been selecting for these traits.

The Dolores River fish data demonstrates that roundtail chub and flannelmouth can survive and adjust to long-term low flow conditions, albeit in very low abundance. However bluehead sucker have just barely survived the current drought and urgent surveys are needed to establish the status of this species. It is rather doubtful that bluehead sucker could expand in abundance downstream of McPhee dam under the current flow regimen (2000 to present). Certain nonnative fish have increased during the recent drought which will likely impose additional negative responses by the native fish community.

DOLORES RIVER – BANKFULL FLOW STUDY

Introduction

Bankfull flows are often included with instream flow recommendations. Bankfull flow is the flow and fills the channel up to the elevation of the floodplain. Typically bankfull flow is the most effective flow of sediment transport and channel maintenance.

Determination of bankfull flow at Big Gypsum was contracted with Dr. Gigi Richard of Mesa State University. Dr. Richard was provided channel bed topography from the 2D modeling and floodplain surveys.

Dr. Richard's methods and findings are presented in the Project Completion Report (CDOW Special Report 99).

Results and Discussion

In a prior study the Bureau of Land Management (BLM 1990) estimated bankfull flow to be about 2,300 cfs. It was expected that Dolores River channel geomorphic characteristics should not change significantly if a flow of 2,000 cfs was maintained over a 7-day period, on average every other year. At about 1,000 cfs it was considered likely that stream width and depth would be reduced as much as 30 percent (BLM 1990).

The bankfull flow at Big Gypsum determined by this project was near 2,800 cfs (Richard and Anderson 2006).

SUMMARY

The Gunnison River was surveyed for fish and habitat for the purpose of validating flannelmouth and bluehead sucker habitat suitability criteria made in the prior study (Anderson and Stewart 2003). The validation analysis was presented in the project completion report (Stewart and Anderson 2006).

The Gunnison River has had a highly reduced spring runoff hydrograph and a highly increased base flow hydrograph following construction of the Aspinall project in 1965. There was no spring runoff in either 2002 or 2004. Potential consequences of poor runoff flows include reduced native sucker reproductive success and increased white sucker reproductive success. White sucker were more common in 2003 to 2005 than 12 years ago in 1992 and 1993.

The Gunnison River did not experience low base flows during the drought period of 2000 to 2004 and therefore alterations to the fish biomass due to low flow impacts were not expected.

Flannelmouth and bluehead sucker biomass was high on the Gunnison River. Habitat analysis identified that Delta had the highest availability of both adult flannelmouth and bluehead sucker in its usual flow range (1,000 to 1,200 cfs). Juvenile native sucker abundance and habitat was higher at Escalante than at Delta.

The flannelmouth and bluehead sucker density and biomass estimates were widely different for 2004 and 2005. Because of the widely different estimates, the catch data were subjected to further analysis. Catch rates and capture probabilities were compared between years (2004 & 2005) and between sites (Escalante and Delta).

The PIT tag study demonstrated there was more downstream fish movement at Delta than at Escalante in 2005. Recaptures of marked fish below the Delta study site indicated higher study site emigration in 2005 than 2004. Higher emigration in 2005 could have biased the 2005 estimates.

The higher bluehead sucker density estimate at Delta in 2005 appeared related to increased recruitment and increased emigration. Bluehead sucker recruitment was high in 2005 indicating there was a strong 2003 age class. Higher flows during the 2005 sampling period appeared to alter fish behavior and appeared responsible for the higher emigration that year.

The lower bluehead sucker estimate at Escalante in 2005 was mainly attributed to the influence of higher emigration in 2005. The Escalante bluehead sucker population was fairly stable during the study period. Recruitment appeared to be normal in both 2004 and 2005. The average of the 2004 and 2005 bluehead sucker estimates was accepted as the better indicator of bluehead sucker carrying capacity than either years estimate alone.

The lower 2005 flannelmouth sucker biomass estimates appeared related to altered fish behavior during high flow periods. At higher flows flannelmouth sucker switch to deeper habitats in order to locate preferred velocities. Flannelmouth sucker in deeper water are not as susceptible to capture by electrofishing. Thus, the higher 2005 base flows resulted in reduced catch rates. Flannelmouth sucker emigration was higher in 2005 compared to 2004. Fewer fish were available for capture in 2005. We considered the 2004 biomass estimate for flannelmouth sucker to be the more reliable estimate of carrying capacity.

Habitat composition information was presented for the Delta and Escalante sites. The Gunnison River instream flow recommendation of 600 cfs was based on 2D habitat modeling, Shannon Diversity and empirical fish data.

The Dolores River experienced extreme reductions for both the spring and base flow hydrographs during the recent drought period (2000 to 2005). Disappointment Creek continued to input sediment but fines were not diluted or flushed for four straight years. Accumulation of sediment appeared to be a major cause for poor fish productivity at the Big Gypsum study site.

The Big Gypsum native fish community was much altered in 2004 compared to 2000.

High flows in the spring of 2005 flushed a lot of sediment from the Big Gypsum site. In 2005 flannelmouth sucker yearlings were abundant, but these fish were not locally produced. Small flannelmouth sucker migrated to the Big Gypsum, probably from upstream spawning sites. Roundtail chub were less numerous in 2004 and 2005 than prior to 2002. Bluehead sucker were very rare in 2004 and 2005 and that was directly attributed to lack of habitat availability during low flows.

The Dolores River appears to be an ideal site to study impacts of reduced spring flows on the aquatic community (fish and invertebrate abundance). In five of the last six years (2001, 2002, 2003, 2004 and 2006) spring runoff was captured in the reservoir and outlet flows ranged from about 150 cfs in the spring to 30 cfs during winter. Flows were as low as 2 cfs for most of 2002.

Dolores River native fish have had a long time to adapt to reduced flows. The small size of flannelmouth sucker, bluehead sucker and roundtail chub appears to be a consequence of long-term low flows. It also appears that the three native fish species (roundtail chub, flannelmouth and bluehead sucker) mature at younger ages and smaller sizes than typical in larger rivers.

The Dolores River data clearly demonstrates that roundtail chub and flannelmouth can survive low flow conditions, albeit in very low abundance, as long as nonnative fish are not a negative factor. However bluehead sucker have just barely survived the current drought and it is rather doubtful that bluehead sucker abundance can increase downstream of McPhee dam if current flow regimens (2000 to present) continue.

RECOMMENDATIONS FOR FUTURE RESEARCH

1. Simplify the use of 2D modeling as a methodology for instream flow recommendations. Bluehead sucker and flannelmouth sucker habitat criteria have been determined to be valid and do not need to be reanalyzed in future studies. Another way to simplify is to compare results of cross-section methods to 2D results at established study sites. The much simpler cross-section methods would be more acceptable for instream flow recommendations if assumptions were validated. The current study sites have both the necessary fish and habitat

data to validate assumptions implicit in many cross-section methods. Another suggestion is to modify IFIM to accept meso habitat criteria, which is more biologically appropriate.

2. The Dolores River flows have been severely reduced since 2000. This is a rare site to perform geomorphic studies to establish functional relationship between magnitude and duration of bankfull flow with biological metrics. One or two study sites need to be added to the Dolores River, upstream near Dove Creek or the Bradfield area to assist in recommending flow management from McPhee dam.

3. The White River is a potential site for 2D modeling for instream flow recommendations using established habitat suitability criteria. The hydrograph of the White River has not been as dramatically altered and would provide another river that has both habitat and native fish data. 2D modeling could be useful for evaluating impacts of smallmouth bass, since both native fish biomass and smallmouth bass abundance tend to balance with habitat conditions. Smallmouth bass have not been a major problem on the 15-Mile Reach of the Colorado River, and the hypothesis is that higher base flows and lower temperatures tend to suppress smallmouth bass habitat and abundance. Since the White River has relatively higher base flows than the Yampa River it might be less vulnerable to being overrun by smallmouth bass.

4. Precision on habitat use by species and life stage could be greatly improved using video cameras mounted on the front of the fish-sampling raft. In this project, bluehead and flannelmouth sucker habitat use was based on average conditions of large meso habitats. Video cameras linked with the GPS could pinpoint areas of high catch rates versus areas of low catch rates and eliminate the need for mark and recapture estimates. In this project the number of meso habitats was based on habitat distribution, the number of riffles, runs and pools in a station, and averaged about 20 per site. The video recorded method would base meso habitats on fish concentrations and would result in a more precise description of habitat preference.

5. The video/GPS method would be more appropriate for determining habitat suitability criteria for endangered species and for problematic nonnative species. Presently there is not a lot of data that is useful for integrating abundance of rare fish to habitat and flow metrics.

6. Larger reaches of critical habitat could be mapped. Ten to 20 mile river sections could be mapped for habitat availability and that would provide a basis for relating differences in fish abundance by river reach. Availability of spawning and nursery areas (Debeque and Escalante Canyons) could be identified and prioritized if determined to be potentially limiting.

7. 2D modeling was also found to be a valuable tool for evaluating stream improvement projects. Channel modifications could be modeled and evaluated during the project design phase.

ACKNOWLEDGEMENTS

I greatly appreciated the cooperation of landowners on the Gunnison River. Mike Zeaman of the CDOW provided access to the Gunnison River at the State Wildlife Area near Delta. Dick Miller graciously granted access to the Gunnison River on the Escalante Ranch and his foreman Kent Davis was very helpful. I also appreciate effort of the 2005 field crew Greg Stewart and Paul Minchoff. Rachel Dougherty assisted with PIT tagging. I thank Dr. Gary White for guidance with the Program Mark. I am very grateful for the interest and encouragement from the CWCB's Randy Seaholm and Michelle Garrison.

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APPENDIX ONE

Fish composition table.

Table A1-1. Species composition for total fish collected in 2004 and 2005, Gunnison River (Delta 2D site).

Gunnison River	Delta- total	Delta- total	Escalante –total	Escalante –total
Species	**2004**	**2005**	**2004**	**2005**
Flannelmouth sucker	29.4	15.0	16.4	14.9
Bluehead sucker	15.0	36.1	39.0	42.9
Roundtail chub	3.2	15.2	11.9	15.9
Colorado pikeminnow	0.2	0	0.1	0
Razorback sucker	0	0.1	0.1	0.05
Bluehead X Flannelmouth	0.4	0.5	0.2	0.6
Speckled dace	4.8	4.5	1.6	1.9
Mottled sculpin	0.03	0	0	0
White S. + hybrids	22.2	18.6	11.2	16.1
Carp	9.2	5.3	3.5	4.0
Brown trout	0.7	1.3	0.9	1.5
Fathead minnow	13.6	2.1	12.9	1.4
Green sunfish	0.7	1.0	1.0	0.4

Black bullhead	0.03	0	0.1	0.1
Shiner species	0.1	0.2	1.2	0.1
Plains killifish	0.2	0	0	0
Largemouth bass	0	0.1	0.02	0
Native species	53.1	71.4	67.6	76.2
Sample size	3,856	3,959	5,808	4,021

Table A1-2. Species composition (%) collected by electro-fishing from Delta and for 1992 and 1993 in Reach 5 (Burdick 1995). Reach 5 is from Escalante Bridge to Hartland Diversion Dam. 1992 are pooled collections made in April, June, July and October. 1993 are pooled collection made in April/May, June/July, and September/October. Juvenile size: 60-300 (BHS, WHS) 60-410 (FMS), 60-260 (RTC). Adult size: >300 (BHS, WHS), >410 (FMS), >260 (RTC).

Delta and Reach 5, Burdick 1995	**R5-1992**	**R5-1993**	**D-2003**	**D-2004**	**D-2005**
Common name	Total	Total	Total	Total	Total
Flannelmouth sucker	27.95	29.67	39.15	36.64	16.35
Bluehead sucker	43.89	44.44	21.47	18.71	39.39
Colorado pikeminnow	0.00	0.00	0.00	0.26	0.00
Roundtail chub	7.82	7.20	6.90	4.05	16.52
White sucker	9.57	5.73	15.45	19.52	16.30
White x Flannelmouth	0.29	1.53	5.09	6.03	2.26
White x Bluehead	0.47	1.38	1.81	1.82	1.35
White + hybrids	10.32	8.64	22.35	27.37	19.90
Carp	7.75	7.51	8.78	11.48	5.78
Bluehead x flannelmouth	0.00	0.04	0.53	0.55	0.58
Northern pike	0.12	0.04	0.00	0.00	0.00
Brown trout	1.08	1.40	0.70	0.88	1.40
Rainbow trout	0.98	1.04	0.06	0.03	0.03
Razorback sucker	0.00	0.00	0.00	0.00	0.06
Black bullhead	0.09	0.00	0.06	0.03	0.00
Total (n)	6648	4500	1709	3084	3633

	R5-1992	R5-1993	D-2003	D-2004	D-2005		R5-1992	R5-1993	D-2003	D-2004	D-2005
Species	Juvenile	Juvenile	Juvenile	Juvenile	Juvenile		Adult	Adult	Adult	Adult	Adult
FMS	35.65	42.45	39.49	27.13	11.98		21.59	22.73	38.98	40.04	20.43
BHS	43.47	38.85	12.68	13.19	43.07		44.25	47.48	25.67	20.68	35.96
CPM	0.00	0.00	0.00	0.99	0.00		0.00	0.00	0.00	0.00	0.00
RTC	9.94	9.16	12.68	6.78	25.44		6.07	6.14	4.15	3.08	8.19
WWS	8.28	4.30	20.83	35.14	15.40		10.63	6.51	12.88	13.95	17.13
WXF	0.27	1.77	0.72	1.23	0.51		0.30	1.41	7.17	7.74	3.88
WXB	0.50	1.26	2.72	1.85	0.57		0.44	1.44	1.38	1.80	2.07
WS+Xs	9.05	7.33	24.28	38.22	16.49		11.37	9.36	21.43	23.49	23.09
CCP	0.80	0.00	8.88	10.85	0.51		13.49	11.59	8.73	11.70	10.69
BXF	0.00	0.06	0.54	0.62	0.57		0.00	0.03	0.52	0.53	0.59
NOP	0.00	0.00	0.00	0.00	0.00		0.22	0.07	0.00	0.00	0.00
BNT	0.67	1.90	1.27	2.22	1.94		1.43	1.13	0.43	0.40	0.90
RBT	0.27	0.25	0.18	0.00	0.00		1.57	1.47	0.00	0.04	0.05
RZS	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.11
BBH	0.17	0.00	0.00	0.00	0.00		0.03	0.00	0.09	0.04	0.00
(n)	3007	1583	552	811	1753		3641	2917	1157	2273	1880

Table A1-3. Species composition (%) collected by electro-fishing from Delta and for 1992 and 1993 in Reach 4 (Burdick 1995). Reach 4 is from Bridgeport to Escalante Bridge. 1992 are pooled collections made in April, June, July and October. 1993 are pooled collection made in April/May, June/July, and September/October. Juvenile size: 60-300 (BHS, WHS), 60-410 (FMS), 60-260 (RTC), 70-250 (CCP), 100-250 (RBT, BNT), 50-250 (BBH), 60-400 (RZS). Adult size: >300 (BHS, WHS), >410 (FMS), >260 (RTC), >250 (CCP, RBT, BNT, BBH), >400 (RZS).

Escalante and Reach 4, Burdick 1995	**R4-1992**	**R4-1993**	**E-2003**	**E-2004**	**E-2005**
Common name	Total	Total	Total	Total	Total
Flannelmouth sucker	**34.69**	**35.85**	26.27	19.66	15.54
Bluehead sucker	**42.22**	**40.52**	39.55	47.37	44.61
Colorado pikeminnow	**0.00**	**0.13**	0.00	0.08	0.10
Roundtail chub	**16.77**	**13.05**	17.75	13.98	16.57
White sucker	**1.43**	**1.81**	5.98	9.45	13.21
White X flannelmouth	**0.19**	**0.65**	1.57	2.36	1.76
White X bluehead	**0.51**	**0.73**	1.21	1.41	1.76
White sucker + hybrids	**2.13**	**3.20**	8.76	13.22	16.73
Carp	**3.05**	**5.66**	6.40	4.21	4.01
Rainbow trout	**0.35**	**0.22**	0.00	0.00	0.00
Brown trout	**0.73**	**1.12**	0.97	1.05	1.58
Bluehead x flannelmouth	**0.06**	**0.26**	0.18	0.21	0.65
Black bullhead	**0.00**	**0.00**	0.12	0.13	0.16
Razorback sucker	**0.00**	**0.00**	0.00	0.08	0.05
Total (n)	**3148**	**2315**	1656	4750	3862

	R4-1992	R4-1993	E-2003	E-2004	E-2005		R4-1992	R4-1993	E-2003	E-2004	E-2005
Species	Juvenile	Juvenile	Juvenile	Juvenile	Juvenile		Adult	Adult	Adult	Adult	Adult
FMS	**34.59**	**39.39**	24.88	19.59	17.35		**34.82**	**33.26**	28.84	19.79	12.72
BHS	**49.80**	**44.69**	42.43	50.61	49.53		**32.33**	**37.45**	34.20	41.57	36.95
CPM	**0.00**	**0.00**	0.00	0.13	0.17		**0.00**	**0.22**	0.00	0.00	0.00
RTC	**14.65**	**13.06**	23.21	17.56	21.34		**19.53**	**13.03**	7.60	7.57	9.14
WWS	**0.39**	**0.41**	4.55	6.99	6.72		**2.78**	**2.85**	8.64	13.86	23.31
WXF	**0.17**	**0.71**	0.19	0.62	0.21		**0.22**	**0.60**	4.15	5.46	4.17
WXB	**0.11**	**0.20**	0.37	1.02	1.06		**1.02**	**1.12**	2.76	2.11	2.85
WS+Xs	**0.67**	**1.33**	5.11	8.63	7.99		**4.02**	**4.57**	15.54	21.43	30.33
CCP	**0.06**	**0.00**	3.44	2.43	2.08		**6.95**	**9.81**	11.92	7.40	7.02
RBT	**0.00**	**0.20**	0.00	0.00	0.00		**0.80**	**0.22**	0.00	0.00	0.00
BNT	**0.22**	**1.02**	0.84	0.92	1.02		**1.39**	**1.20**	1.21	1.29	2.45
BXF	**0.00**	**0.31**	0.09	0.07	0.51		**0.15**	**0.22**	0.35	0.47	0.86
BBH	**0.00**	**0.00**	0.00	0.07	0.00		**0.00**	**0.00**	0.35	0.23	0.40
RZS	**0.00**	**0.00**	0.00	0.00	0.00		**0.00**	**0.00**	0.00	0.23	0.13
Total (n)	**1781**	**980**	1077	3047	2352		**1367**	**1335**	579	1703	1510

APPENDIX TWO

Hydrographic Records

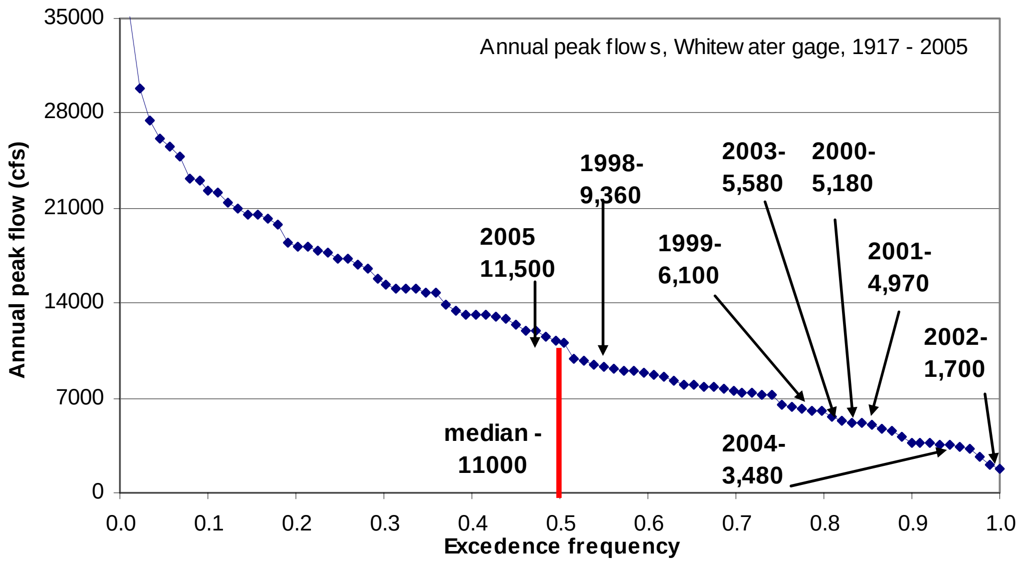

Figure A2-1. Exceedance probability values for annual peak flows, Whitewater Gage period of record (1917-2005), Gunnison River.

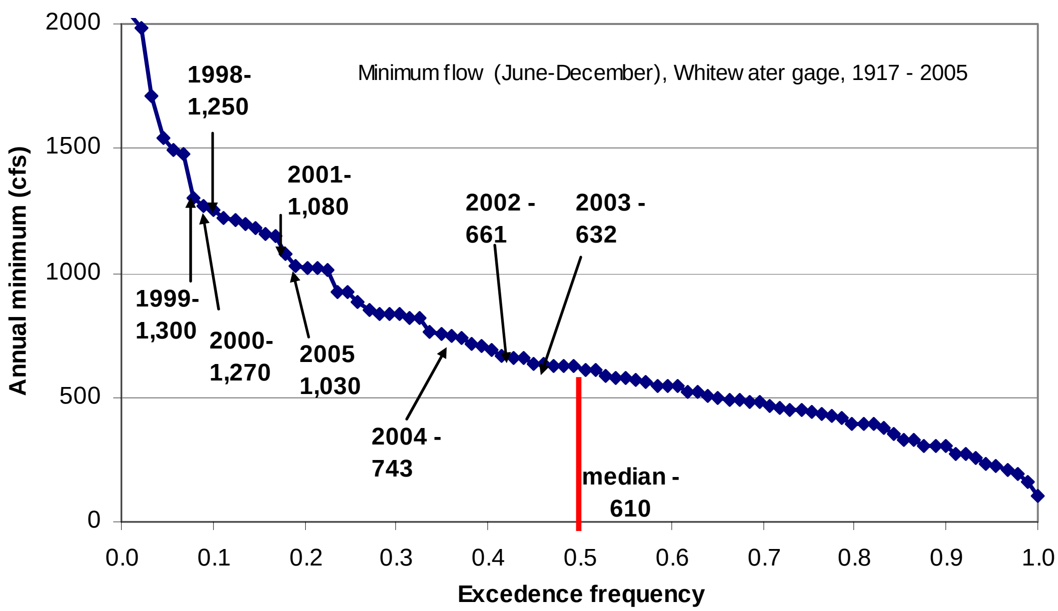

Figure A2-2. Exceedance probability values for annual minimum flows, Whitewater Gage period of record (1917-2005), Gunnison River.

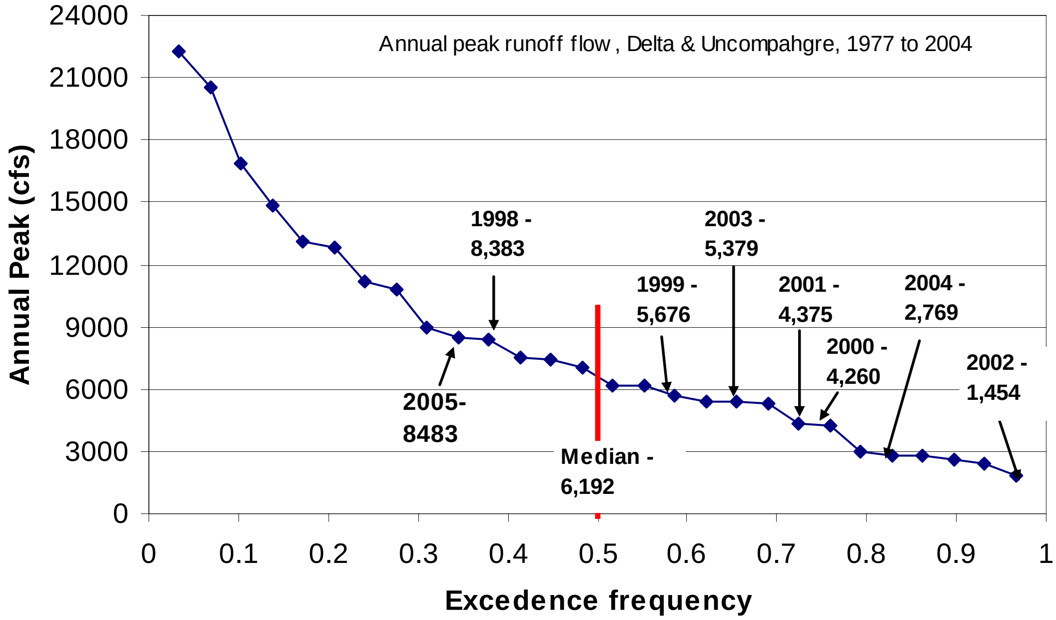

Figure A2-3. Exceedance probabilities for annual peak flows, Delta and Uncompahgre gages summed period of record (1977-2005), Gunnison River.

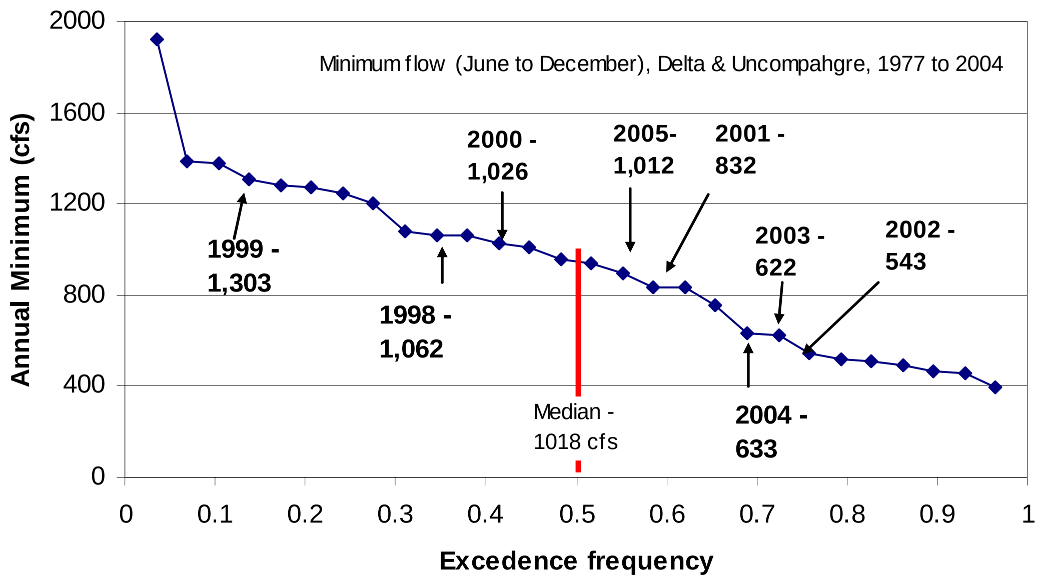

Figure A2-4. Exceedance probabilities for minimum flows (June 1 to December 31) Delta and Uncompahgre gages summed period of record (1977 to 2005), Gunnison River.

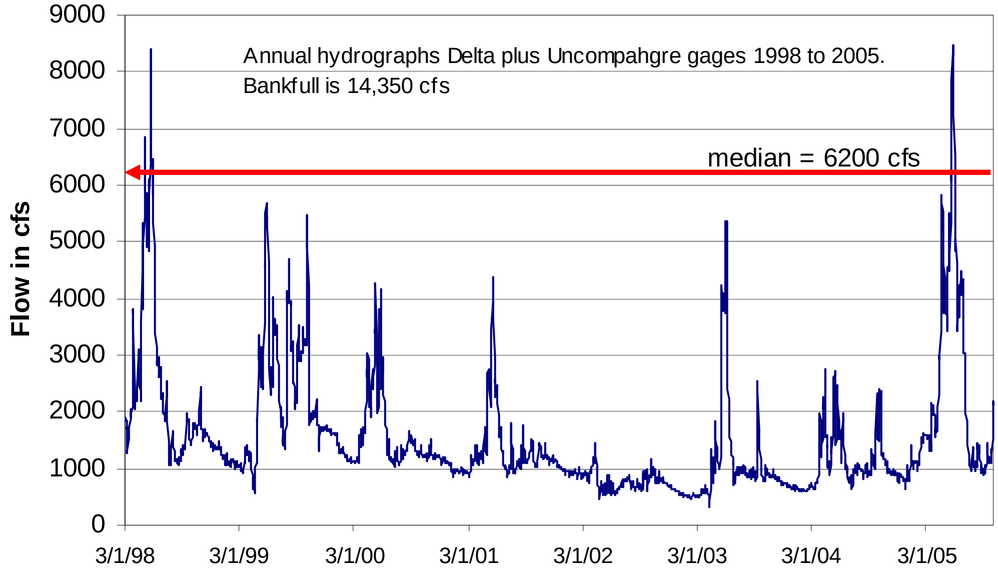

Figure A2-5. Annual hydrographs Delta and Uncompahgre gages summed, 1998-2005, Gunnison River.

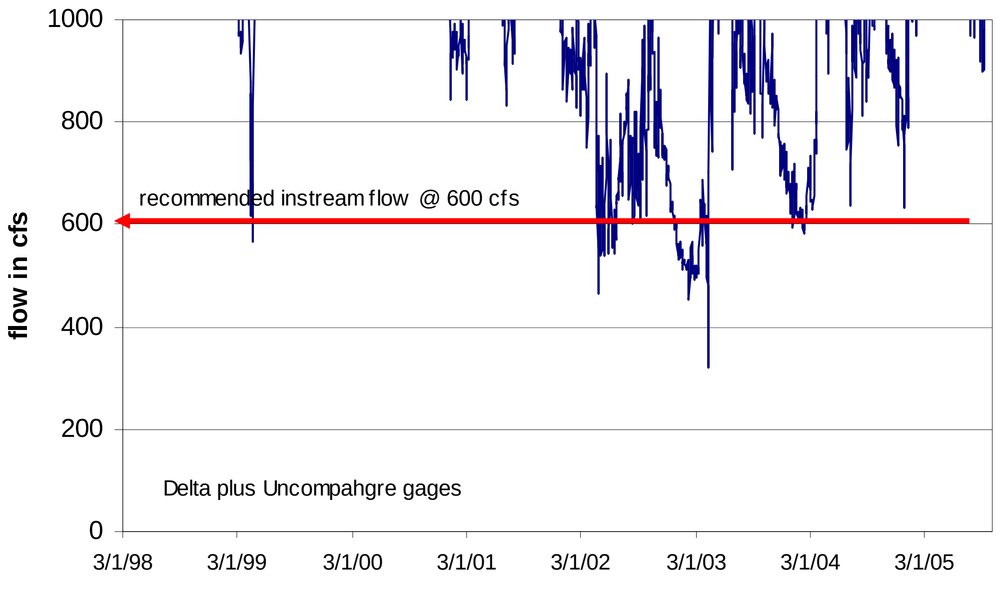

Figure A2-6. Below 1000 cfs annual hydrograph, Delta and Uncompahgre Gages summed, 1998-2005, Gunnison River.

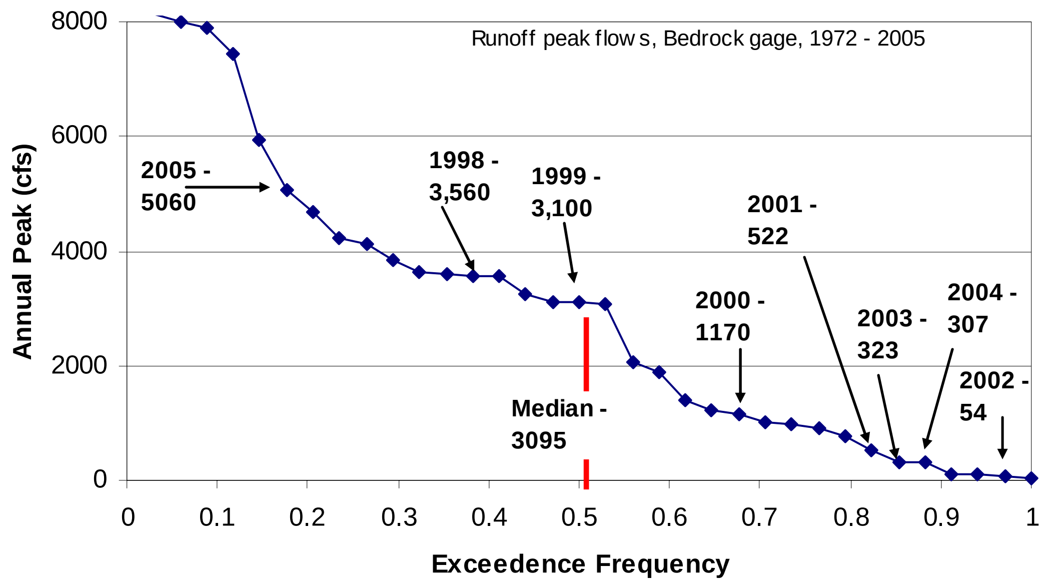

Figure A2-7. Exceedance probabilities for annual peak flows, Bedrock Gage period of record (1972-2005), Dolores River.

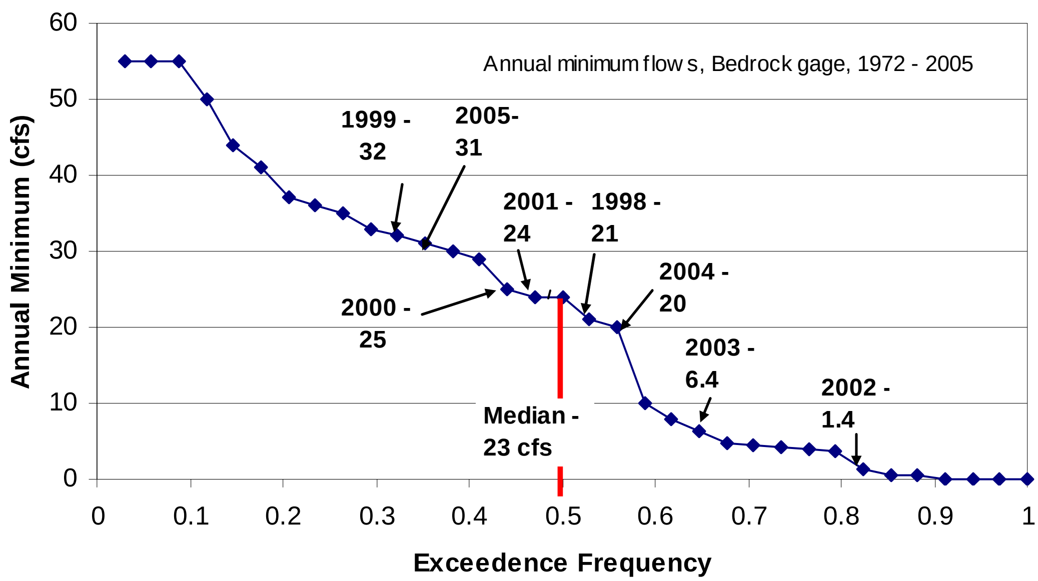

Figure A2-8. Exceedance probability values for annual minimum flows, Bedrock Gage period of record (1972 to 2004), Dolores River.

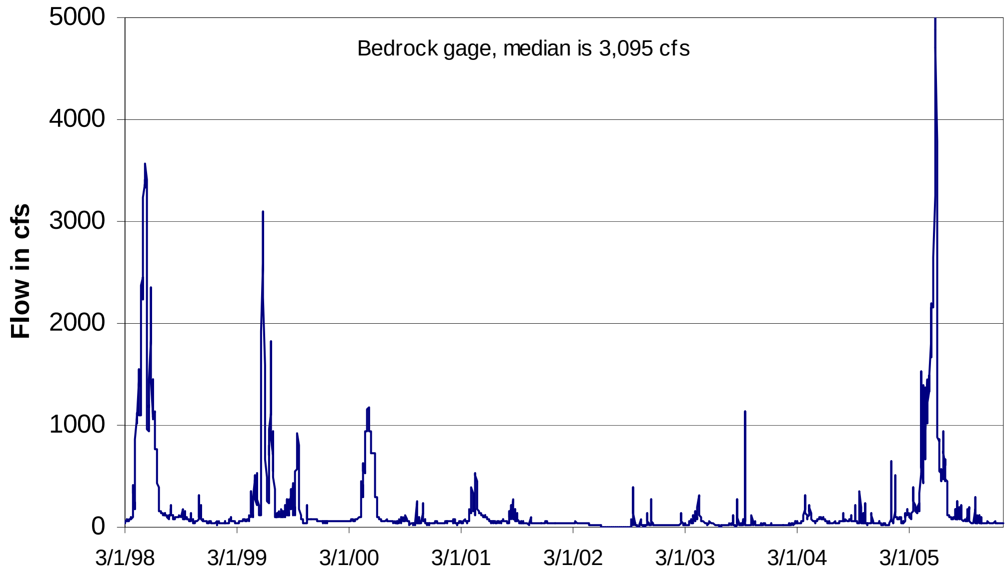

Figure A2-9. Annual hydrograph from 1998 – 2004, Bedrock Gage, Dolores River.

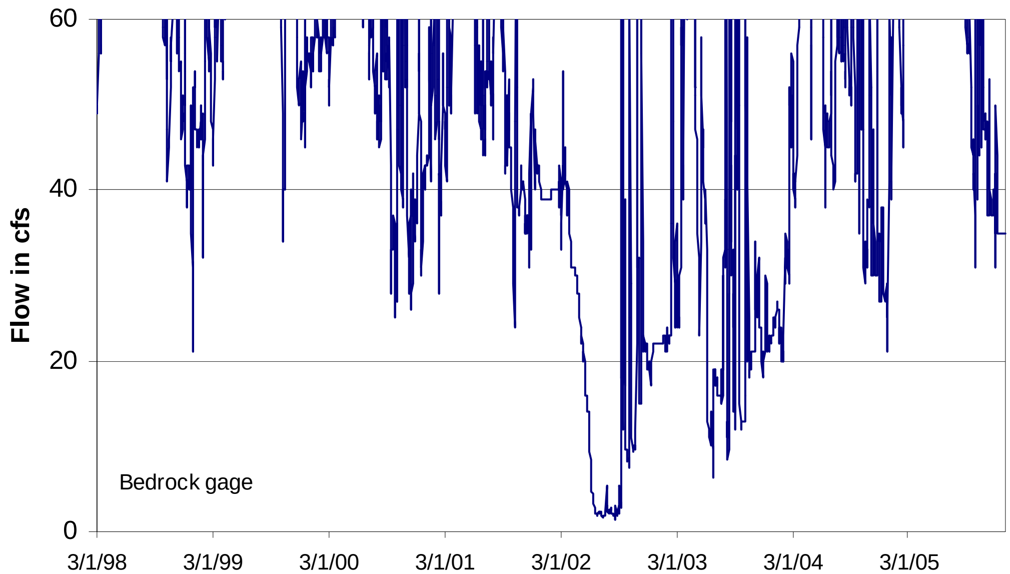

Figure A2-10. Below 60 cfs annual hydrograph from 1998-2004, Bedrock Gage, Dolores River.

APPENDIX THREE

Length Frequency Histograms

*Delta has three histograms per species:

Delta (Station) 2004 = 2D site only in 2004
Delta (Station) 2005 = 2D site only in 2005
Delta (total) 2005 = Fish from all locations and corresponds to the Delta 2004 in Anderson (2005).

Table A3-1. Length frequency histograms for fish collected in the Gunnison and Dolores Rivers in 2005.

Figure A3-1. Bluehead Sucker – Delta (station)*, Gunnison River, August-September 2004.
Figure A3-2. Bluehead Sucker – Delta (station)*, Gunnison River, August 2005.
Figure A3-3. Bluehead Sucker - Delta (total)*, Gunnison River, August 2005.
Figure A3-4. Bluehead Sucker - Escalante, Gunnison River, August 2005.
Figure A3-5. Bluehead Sucker – Big Gypsum, Dolores River, July 2005.
Figure A3-6. Flannelmouth Sucker – Big Gypsum, Dolores River, July 2005.
Figure A3-7. Flannelmouth Sucker – Delta (station), Gunnison River, August-September 2004.
Figure A3-8. Flannelmouth Sucker – Delta (station), Gunnison River, August 2005.
Figure A3-9. Flannelmouth Sucker – Delta (total), Gunnison River, August 2005.
Figure A3-10. Flannelmouth Sucker – Escalante, Gunnison River, August 2005.
Figure A3-11. Bluehead-Flannelmouth Hybrid – Delta (station), Gunnison River, August-September 2004.
Figure A3-12. Bluehead-Flannelmouth Hybrid – Delta (station), Gunnison River, August 2005.
Figure A3-13. Bluehead-Flannelmouth Hybrid – Delta (total), Gunnison River, August 2005.
Figure A3-14. Bluehead-Flannelmouth Hybrid – Escalante, Gunnison River, August 2005.
Figure A3-15. Roundtail Chub – Delta (station), Gunnison River, August-September 2004.
Figure A3-16. Roundtail Chub - Delta (station), Gunnison River, August 2005.
Figure A3-17. Roundtail Chub – Delta (total), Gunnison River, August 2005.
Figure A3-18. Roundtail Chub – Escalante, Gunnison River, August 2005.
Figure A3-19. Roundtail Chub – Big Gypsum, Dolores River, July 2005.
Figure A3-20. White Sucker – Delta (total), Gunnison River, August 2005.
Figure A3-21. White Sucker – Delta (station), Gunnison River, August-September 2004.
Figure A3-22. White Sucker – Delta (station), Gunnison River, August 2005.
Figure A3-23. White Sucker, Escalante, Gunnison River, August 2005.
Figure A3-24. White-Flannelmouth Hybrid – Delta (total), Gunnison River, August 2005.
Figure A3-25. White-Flannelmouth Hybrid – Delta (station), Gunnison River, August 2004.
Figure A3-26. White-Flannelmouth Hybrid - Delta (station), Gunnison River, August 2005.
Figure A3-27. White-Flannelmouth Hybrid – Escalante, Gunnison River, August 2005.
Figure A3-28. White-Bluehead Hybrid – Delta (total), Gunnison River, August 2005.
Figure A3-29. White-Bluehead Hybrid – Delta (station), Gunnison River, August-September 2004.
Figure A3-30. White-Bluehead Hybrid – Delta (station), Gunnison River, August 2005.
Figure A3-31. White-Bluehead Hybrid – Escalante, Gunnison River, August 2005.
Figure A3-32. White Sucker and Hybrids – Delta (total), Gunnison River, August 2005.
Figure A3-33. White Sucker and Hybrids – Delta (station), Gunnison River, August-September 2004.
Figure A3-34   White Sucker and Hybrids – Delta (station), Gunnison River, August 2005.
Figure A3-35. White Sucker and Hybrids – Escalante, Gunnison River, August 2005.
Figure A3-36. Carp – Delta (total), Gunnison River, August 2005.
Figure A3-37. Carp – Delta (station), Gunnison River, August-September 2004.
Figure A3-38. Carp - Delta (station), Gunnison River, August 2005.
Figure A3-39. Carp – Escalante, Gunnison River, August 2005.
Figure A3-40. Carp – Big Gypsum, Dolores River, July 2005.
Figure A3-41. Channel Catfish, Big Gypsum, Dolores River, July 2005.
Figure A3-42. Brown Trout – Delta (total), Gunnison River, August 2005.
Figure A3-43. Brown Trout – Delta (station), Gunnison River, August-September 2004.
Figure A3-44. Brown Trout – Delta (station), Gunnison River, August 2005.
Figure A3-45. Brown Trout – Escalante, Gunnison River, August 2005.
Figure A3-46. Green Sunfish – Delta (total), Gunnison River, August 2005.
Figure A3-47. Green Sunfish – Delta (station), Gunnison River, August-September 2004.
Figure A3-48. Green Sunfish – Delta (station), Gunnison River, August 2005.
Figure A3-49. Green Sunfish – Escalante, Gunnison River, August 2005.
Figure A3-50. Green Sunfish – Big Gypsum, Dolores River, July 2005.
Figure A3-51. Black Bullhead – Big Gypsum, Dolores River, July 2005.

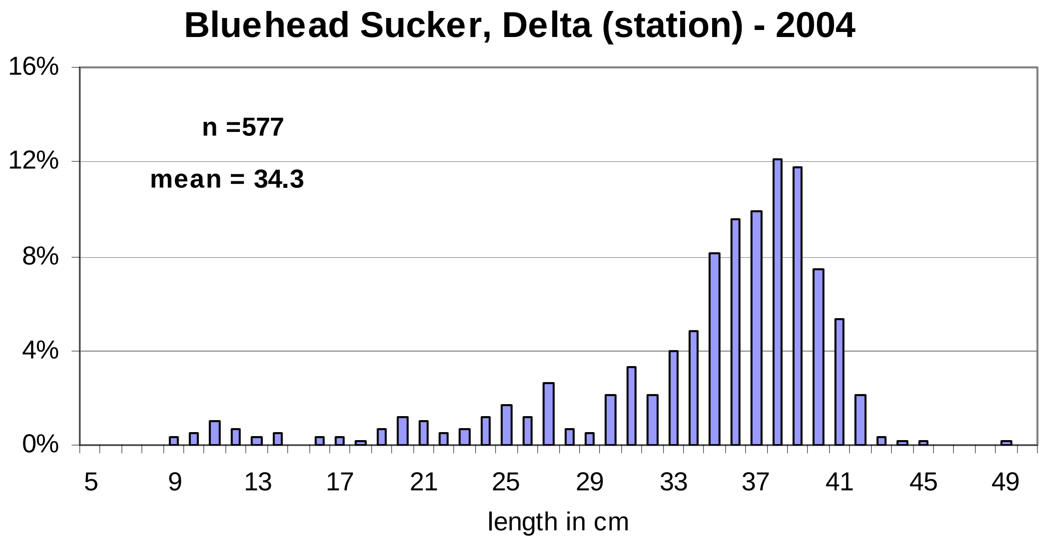

Figure A3-1. Bluehead Sucker – Delta (station), Gunnison River, August-September 2004.

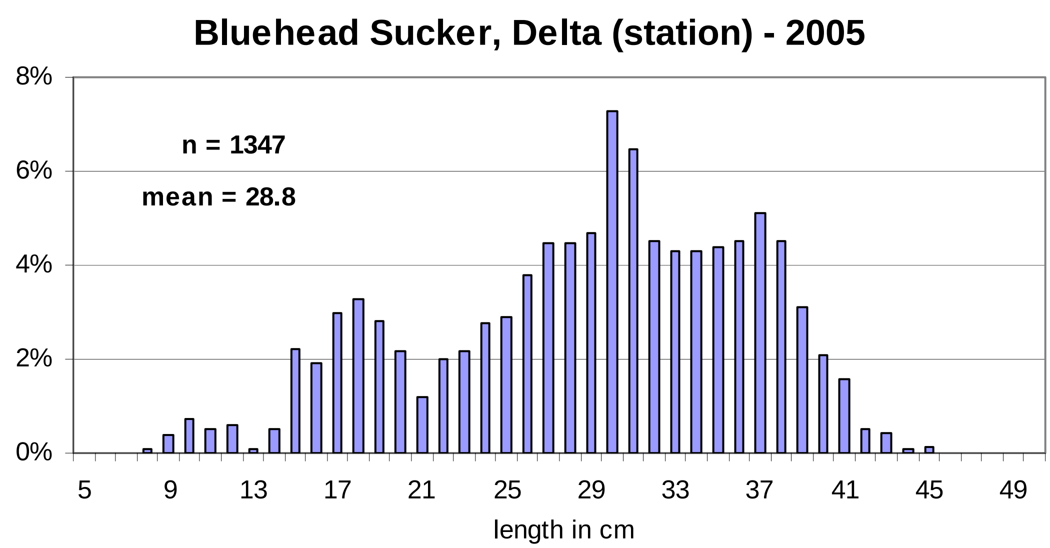

Figure A3-2. Bluehead Sucker – Delta (station), Gunnison River, August 2005.

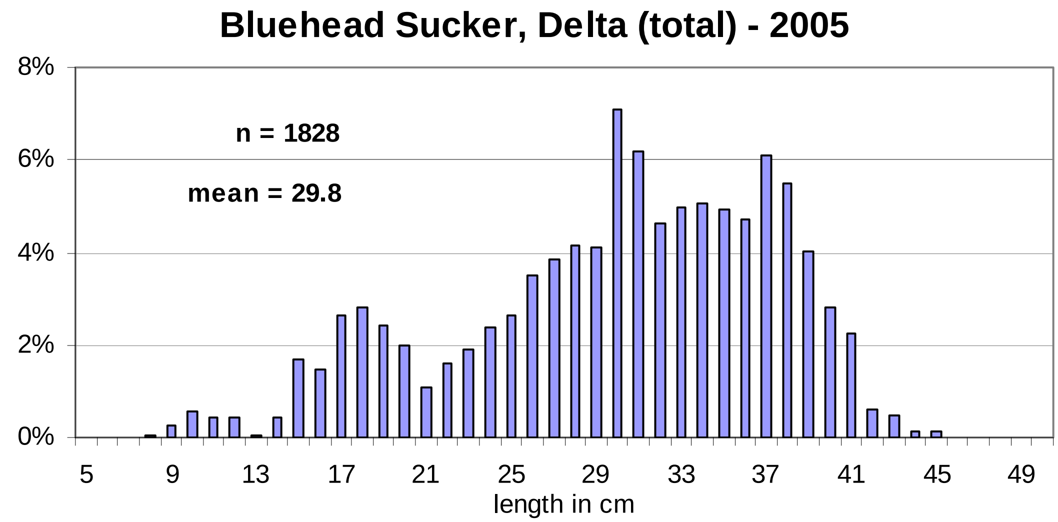

Figure A3-3. Bluehead Sucker - Delta (total), Gunnison River, August 2005.

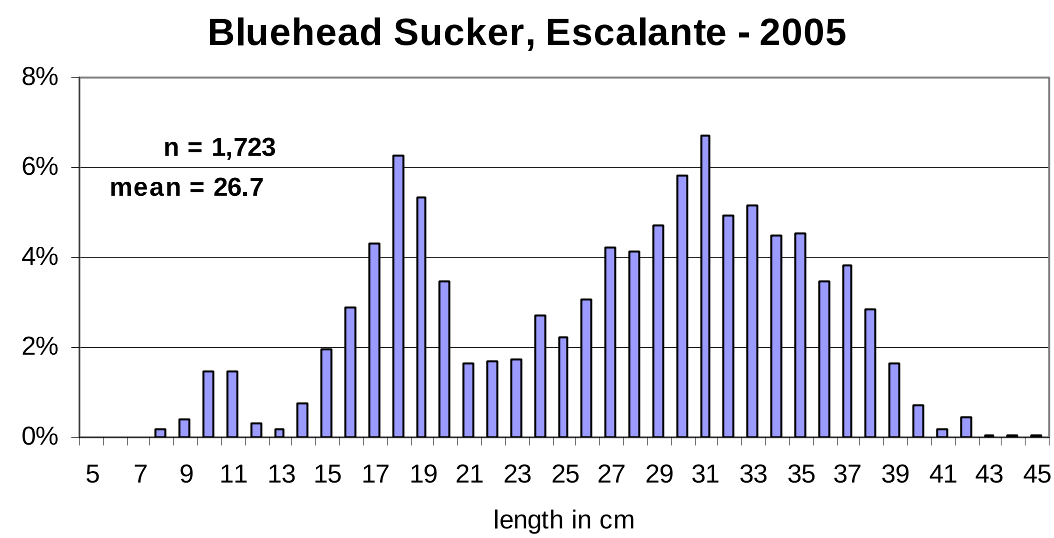

Figure A3-4. Bluehead Sucker - Escalante, Gunnison River, August 2005.

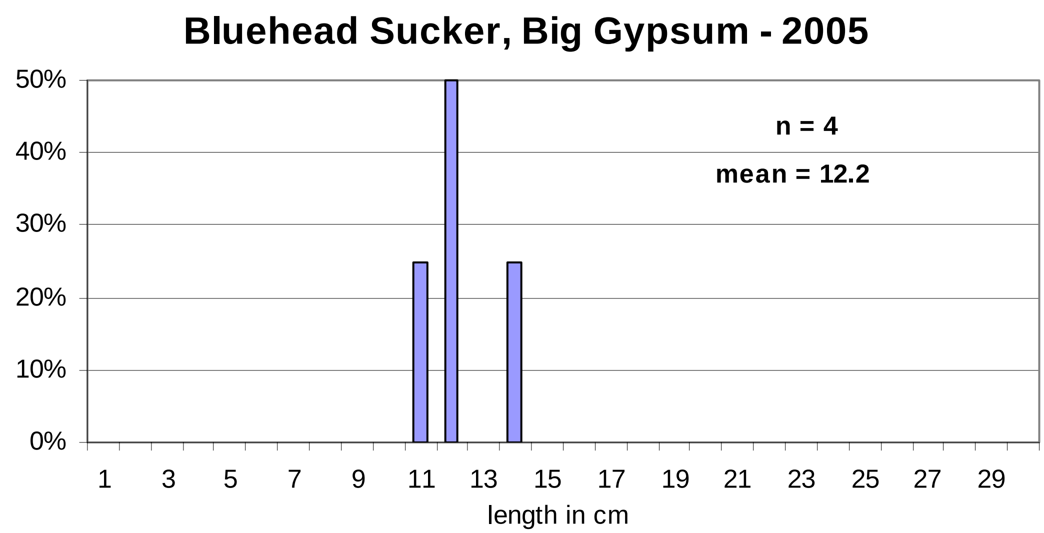

Figure A3-5. Bluehead Sucker – Big Gypsum, Dolores River, July 2005.

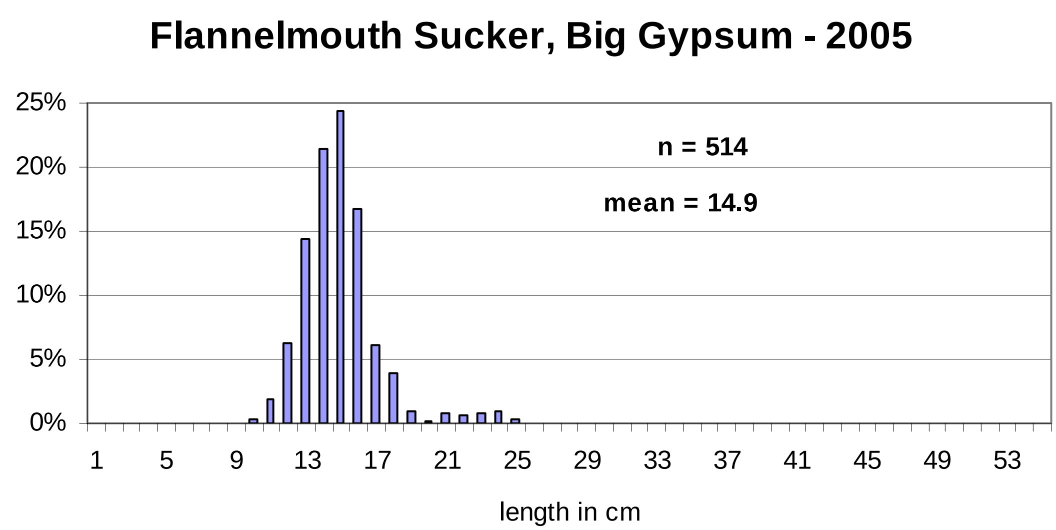

Figure A3-6. Flannelmouth Sucker – Big Gypsum, Dolores River, July 2005.

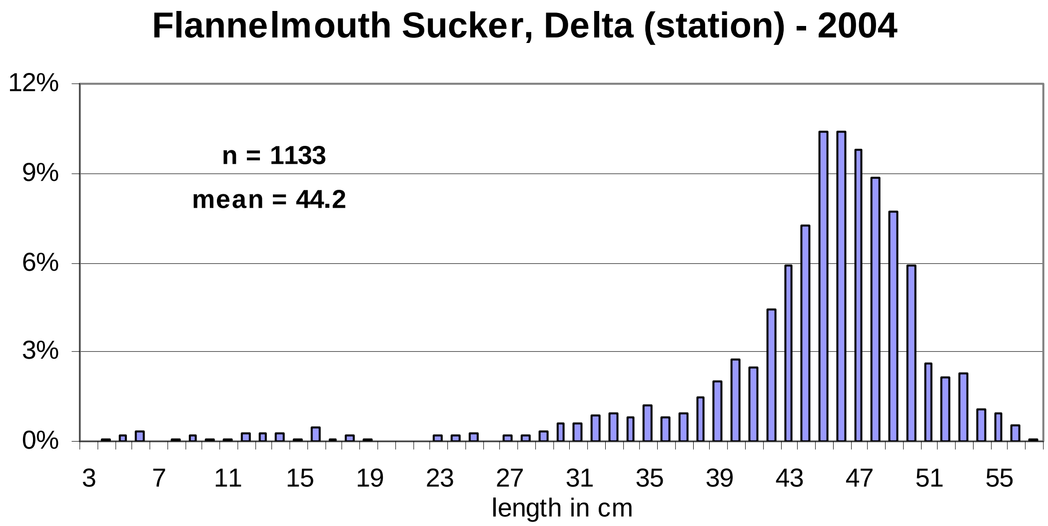

Figure A3-7. Flannelmouth Sucker – Delta (station), Gunnison River, August-September 2004.

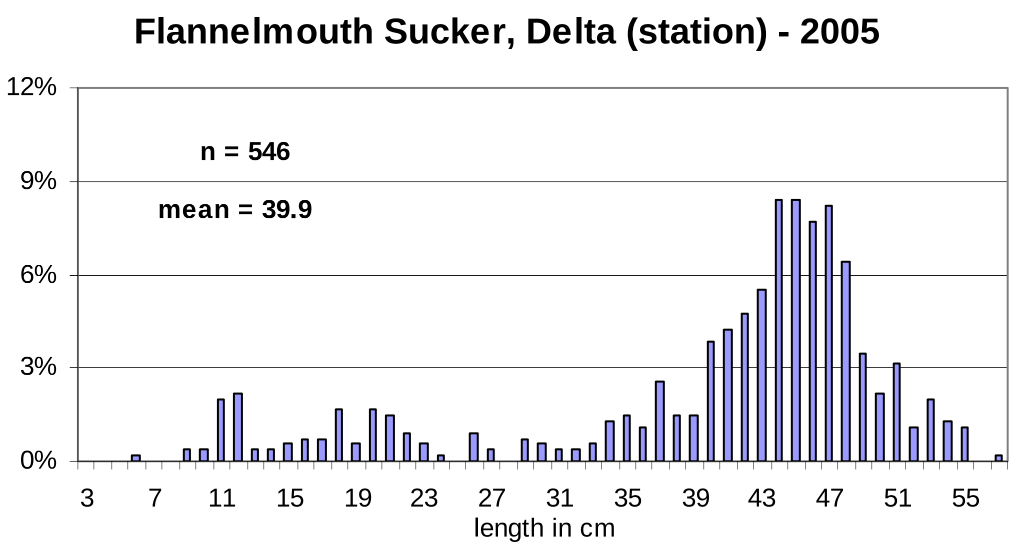

Figure A3-8. Flannelmouth Sucker – Delta (station), Gunnison River, August 2005.

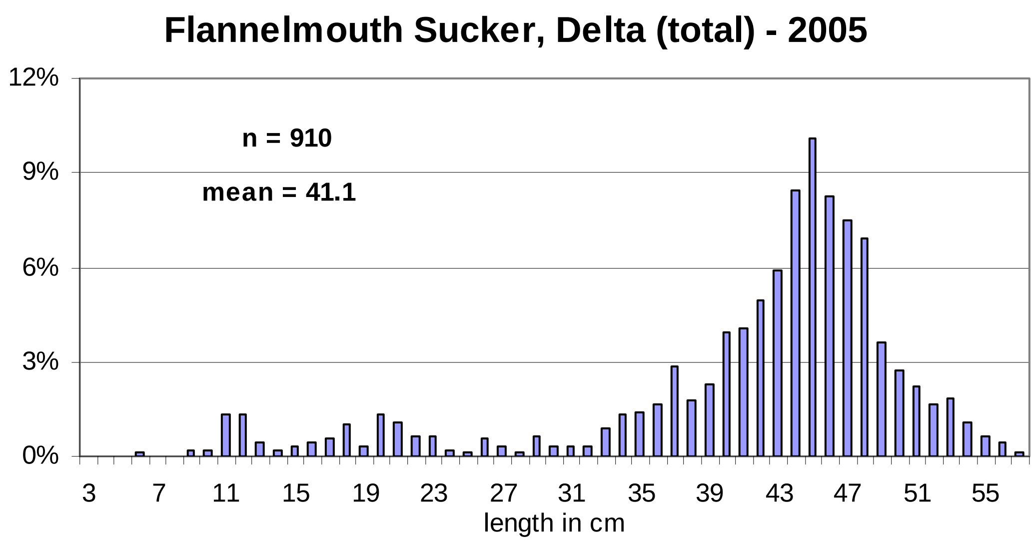

Figure A3-9. Flannelmouth Sucker – Delta (total), Gunnison River, August 2005.

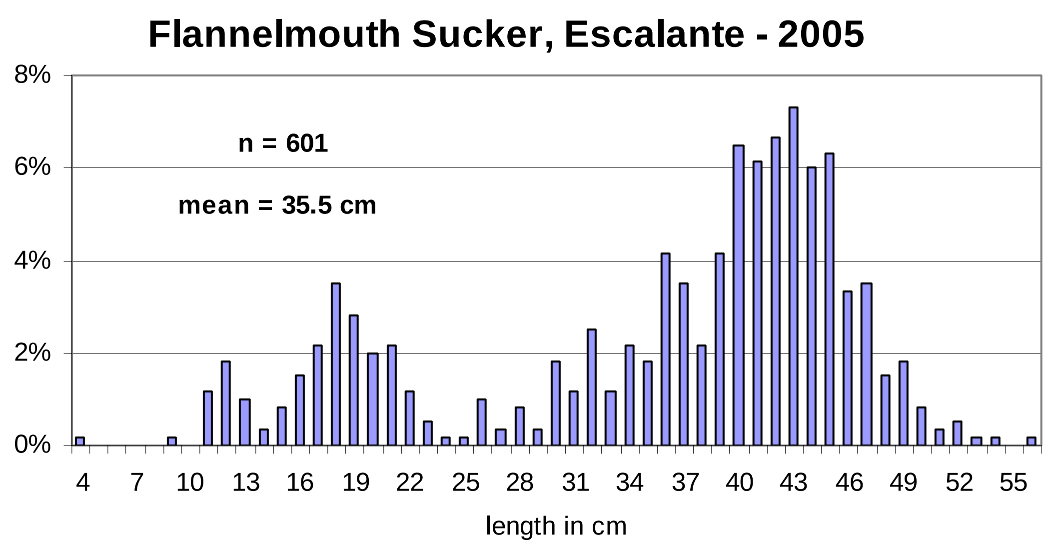

Figure A3-10. Flannelmouth Sucker – Escalante, Gunnison River, August 2005.

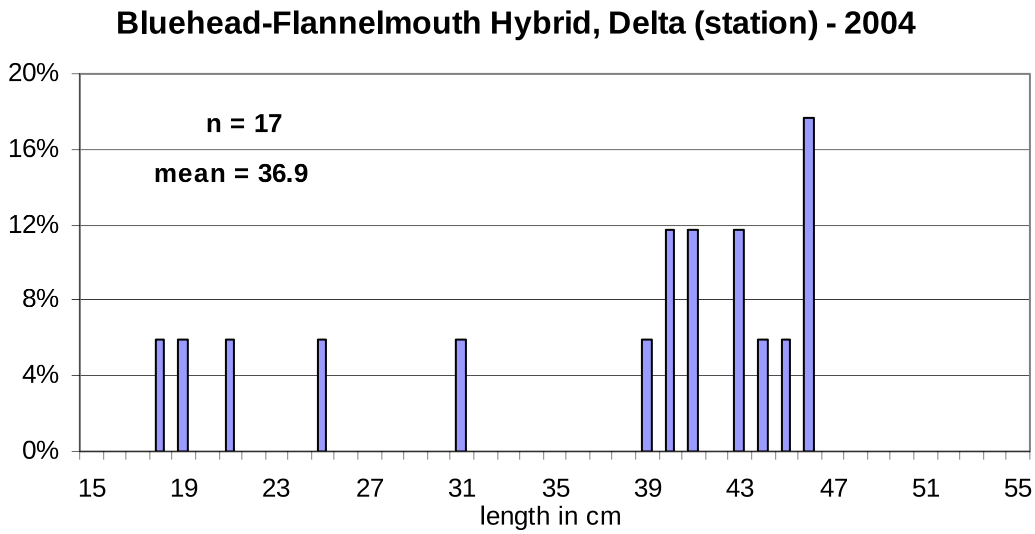

Figure A3-11. Bluehead-Flannelmouth Hybrid – Delta (station), Gunnison River, August-September 2004.

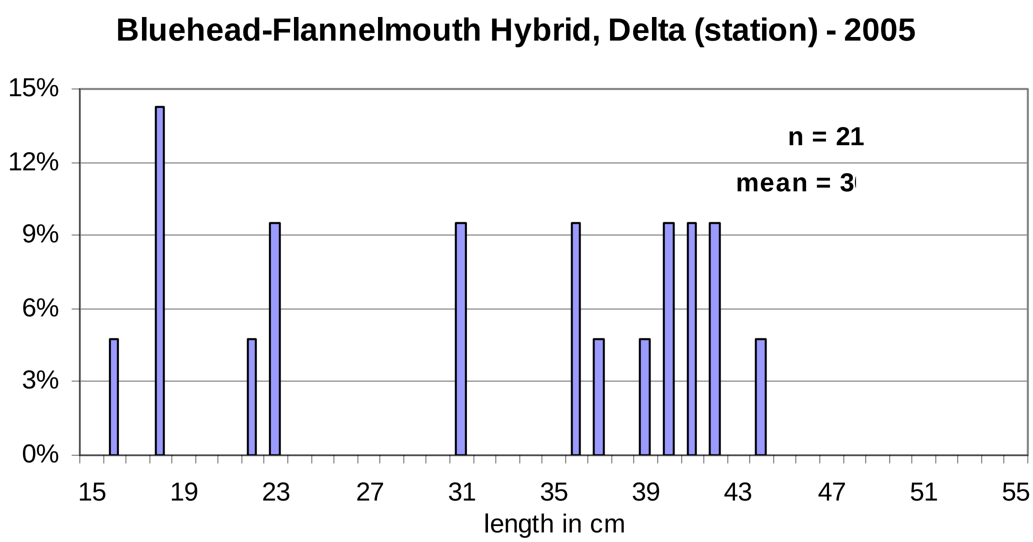

Figure A3-12. Bluehead-Flannelmouth Hybrid – Delta (station), Gunnison River, August 2005.

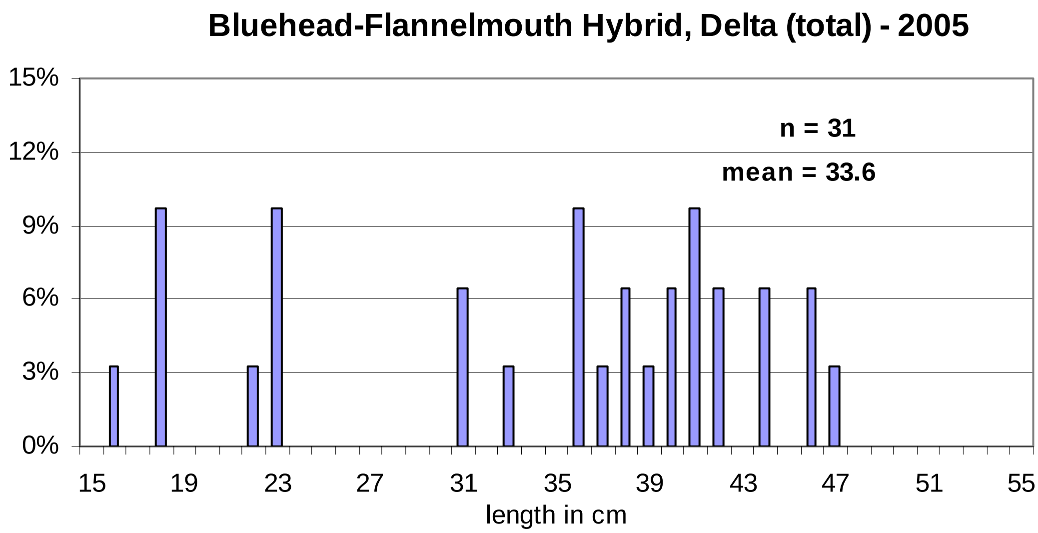

Figure A3-13. Bluehead-Flannelmouth Hybrid – Delta (total), Gunnison River, August 2005.

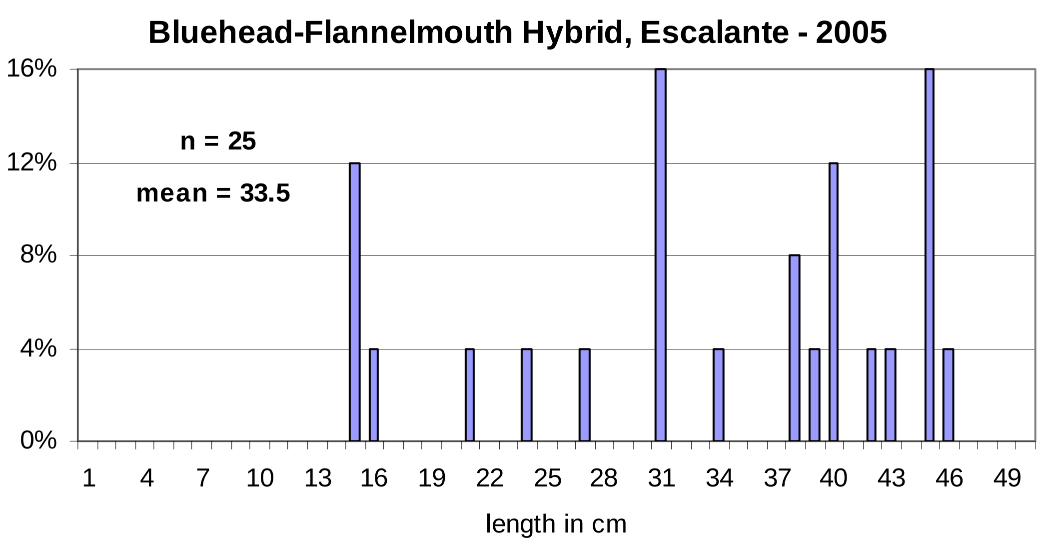

Figure A3-14. Bluehead-Flannelmouth Hybrid – Escalante, Gunnison River, August 2005.

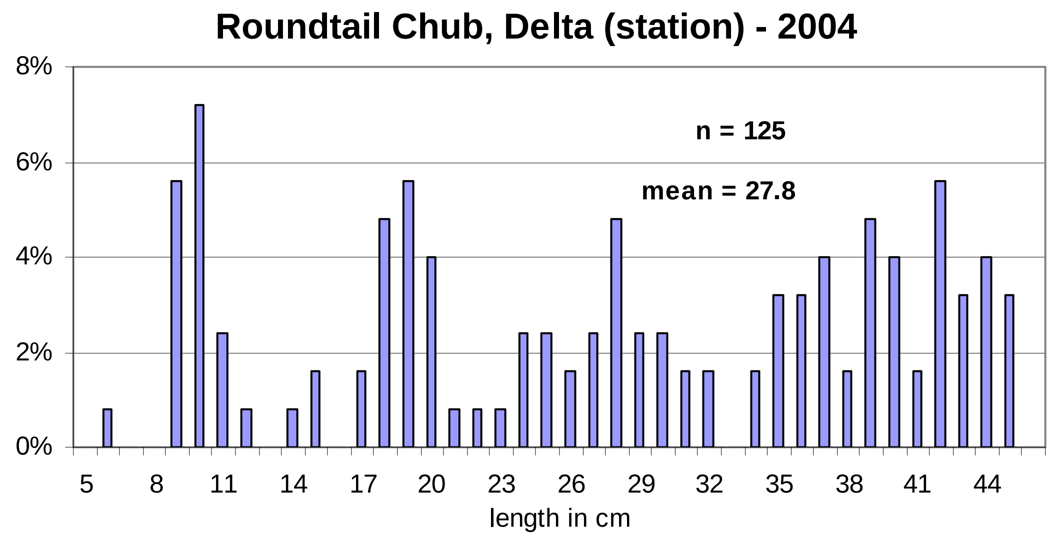

Figure A3-15. Roundtail Chub – Delta (station), Gunnison River, August-September 2004.

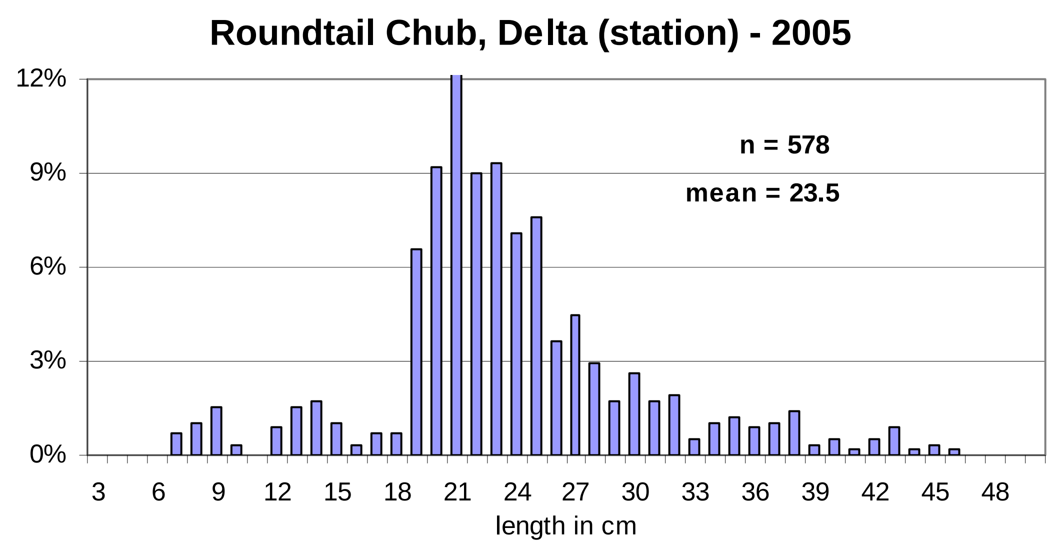

Figure A3-16. Roundtail Chub - Delta (station), Gunnison River, August 2005.

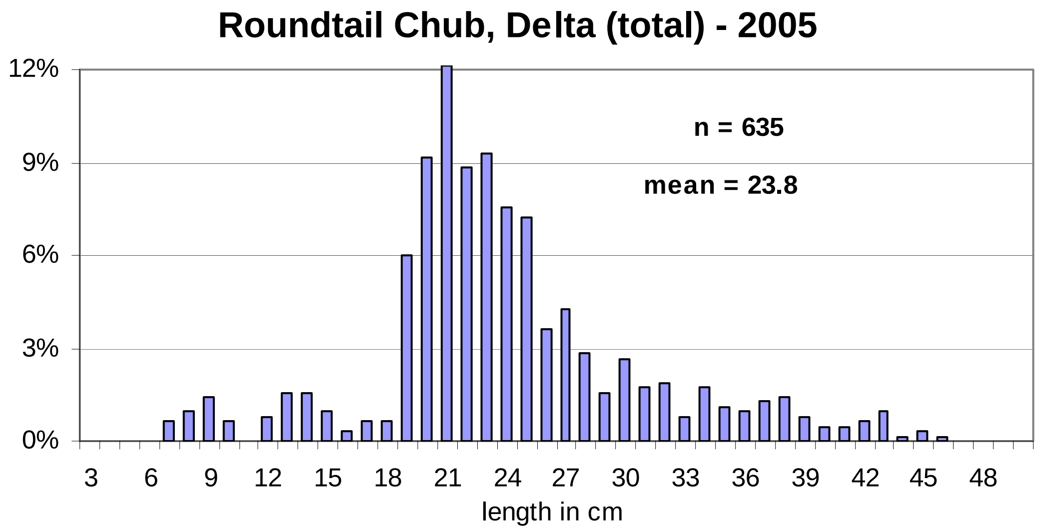

Figure A3-17. Roundtail Chub – Delta (total), Gunnison River, August 2005.

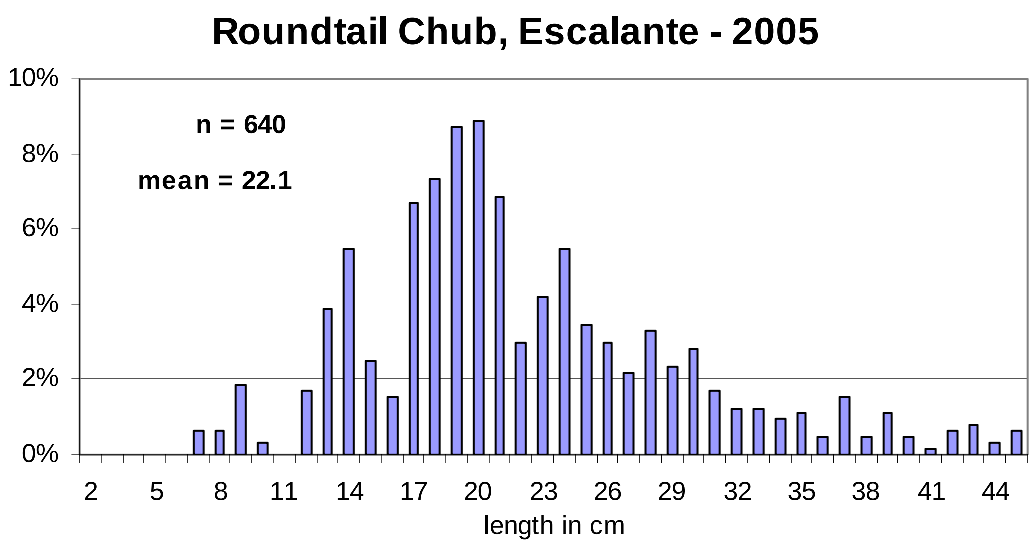

Figure A3-18. Roundtail Chub – Escalante, Gunnison River, August 2005.

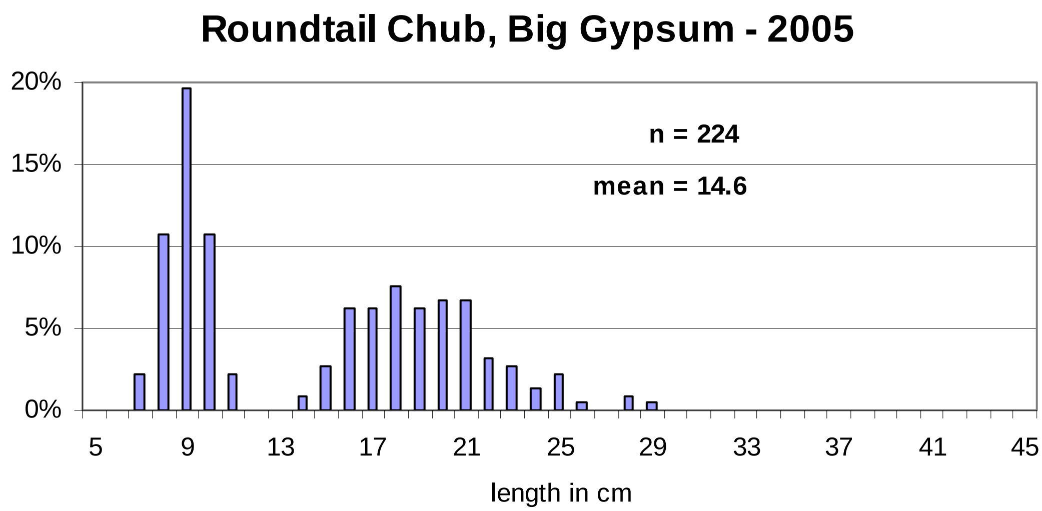

Figure A3-19. Roundtail Chub – Big Gypsum, Dolores River, July 2005.

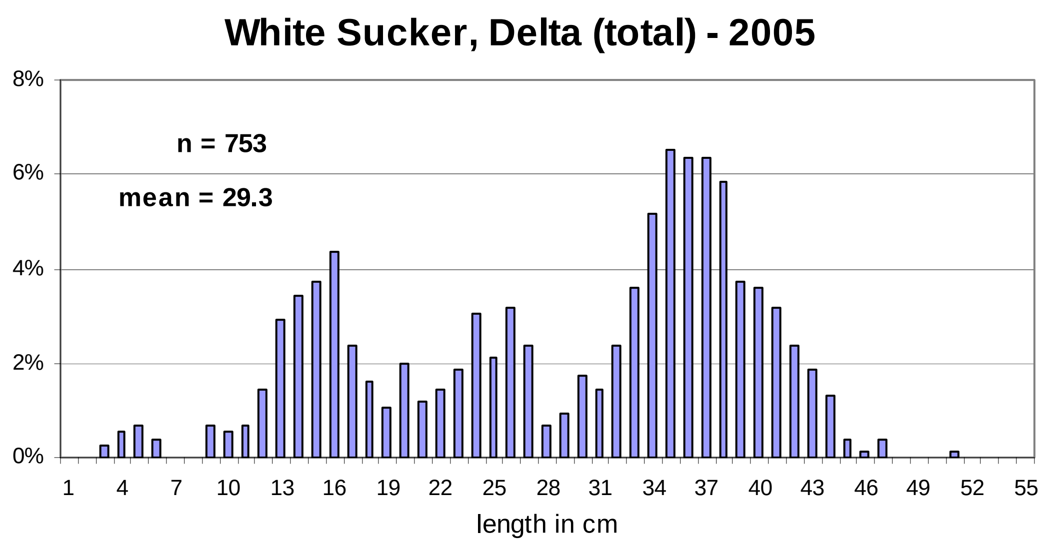

Figure A3-20. White Sucker – Delta (total), Gunnison River, August 2005.

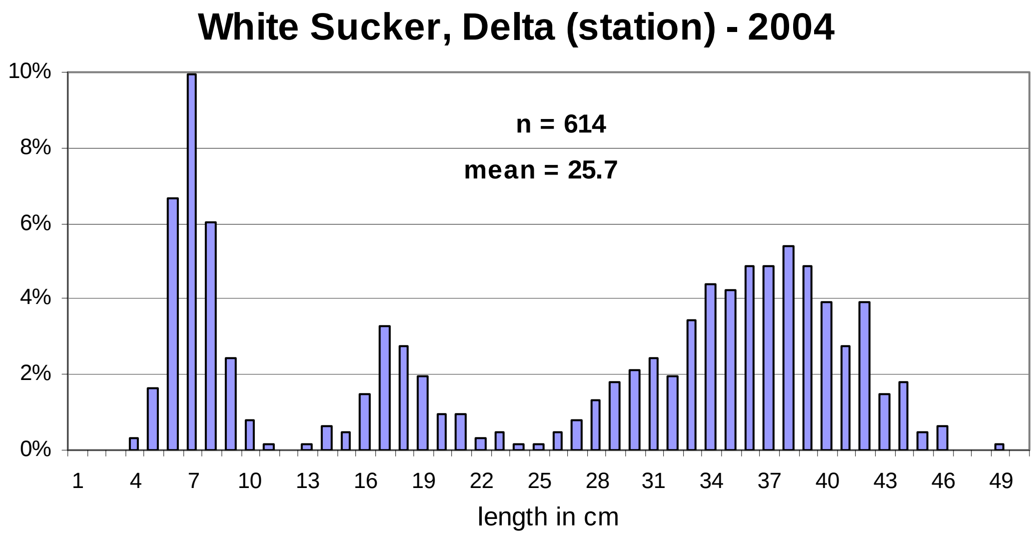

Figure A3-21. White Sucker – Delta (station), Gunnison River, August-September 2004.

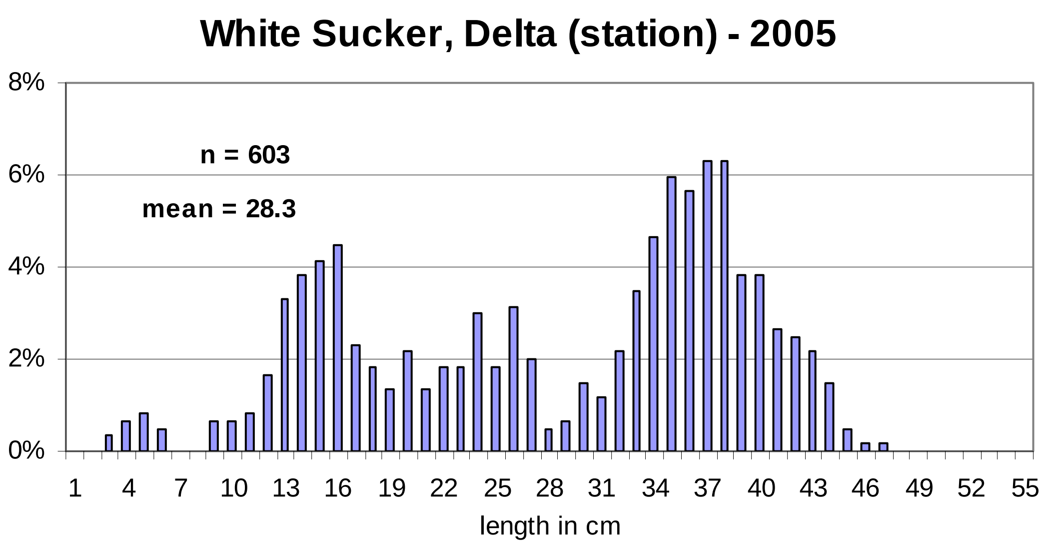

Figure A3-22. White Sucker – Delta (station), Gunnison River, August 2005.

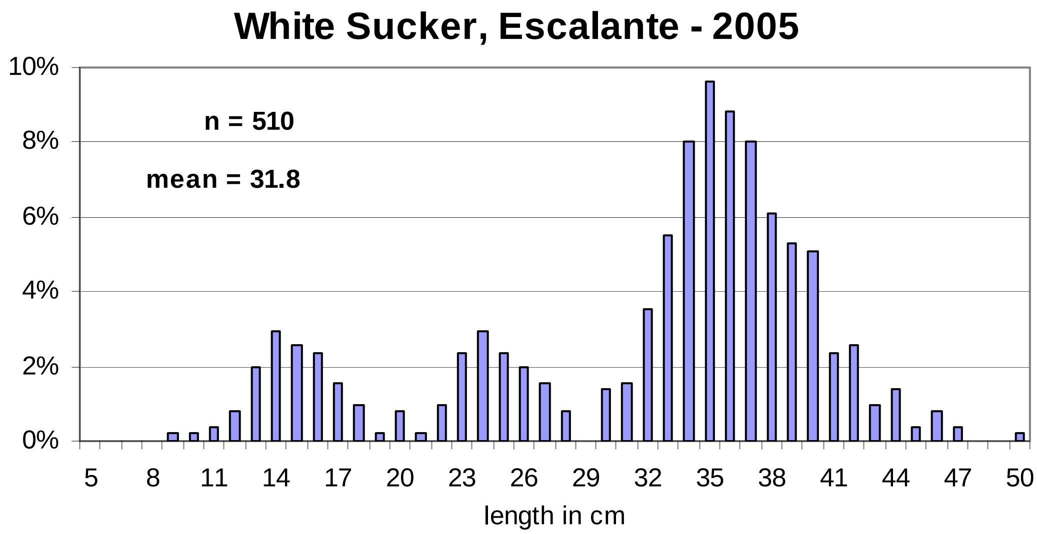

Figure A3-23. White Sucker, Escalante, Gunnison River, August 2005.

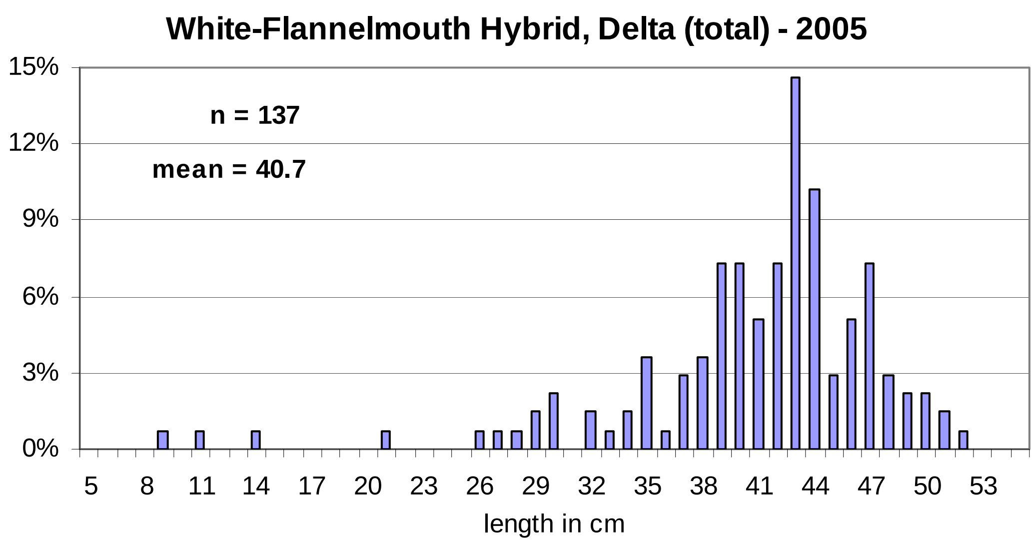

Figure A3-24. White-Flannelmouth Hybrid – Delta (total), Gunnison River, August 2005.

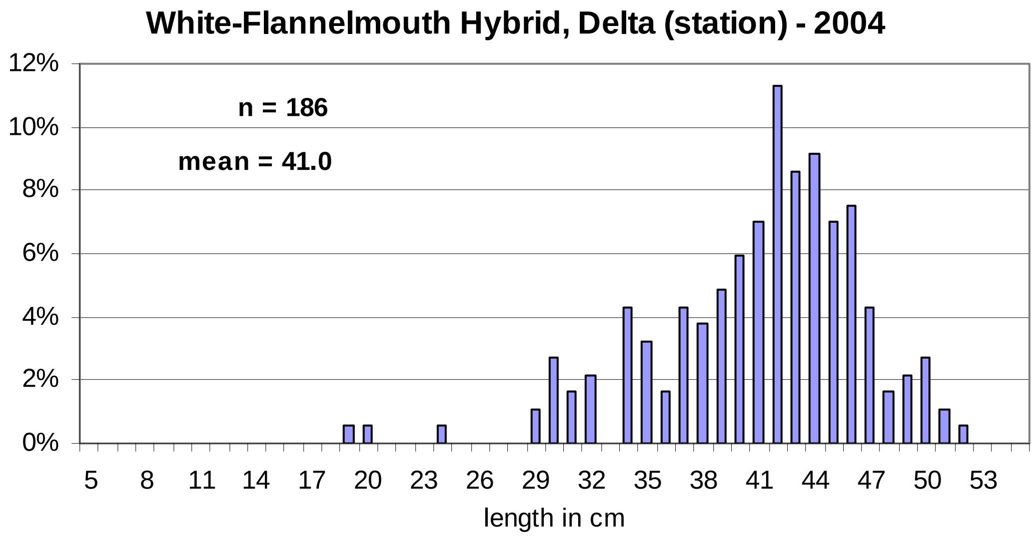

Figure A3-25. White-Flannelmouth Hybrid – Delta (station), Gunnison River, August-September 2004.

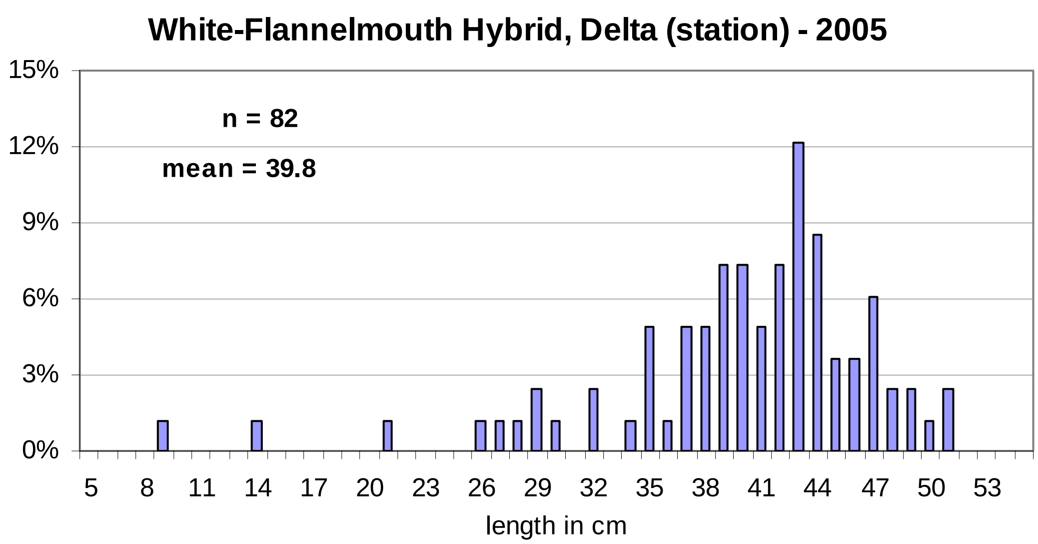

Figure A3-26. White-Flannelmouth Hybrid - Delta (station), Gunnison River, August 2005.

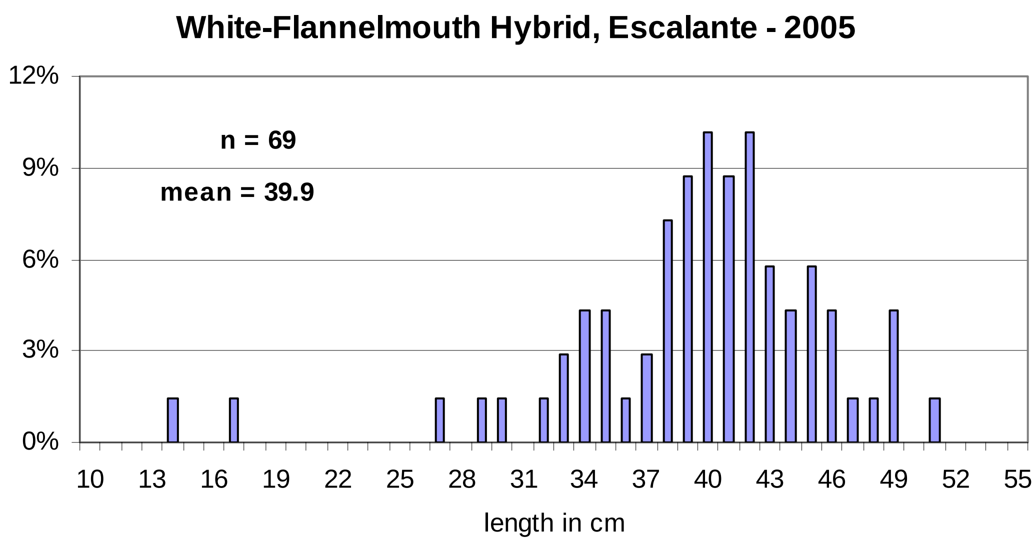

Figure A3-27. White-Flannelmouth Hybrid – Escalante, Gunnison River, August 2005.

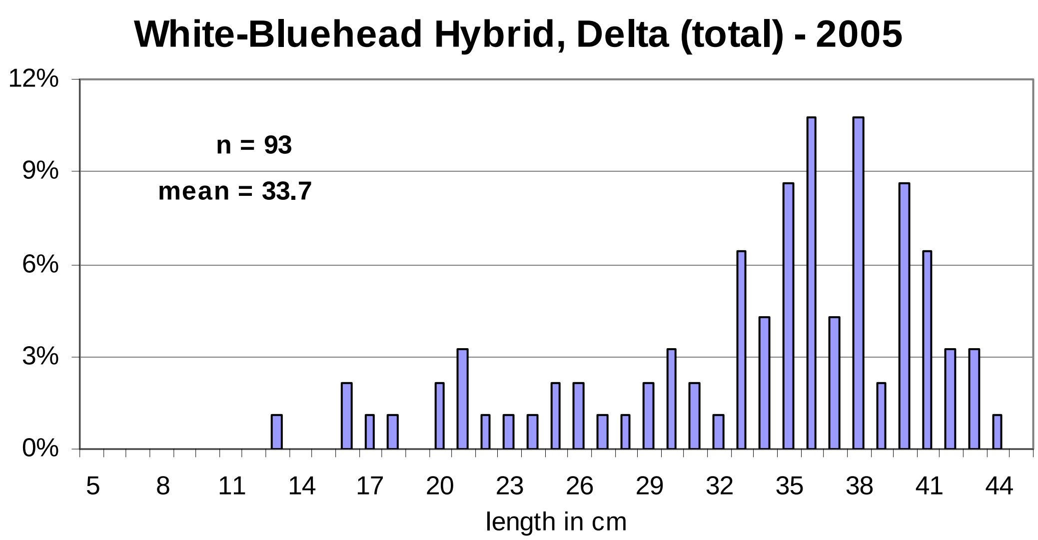

Figure A3-28. White-Bluehead Hybrid – Delta (total), Gunnison River, August 2005.

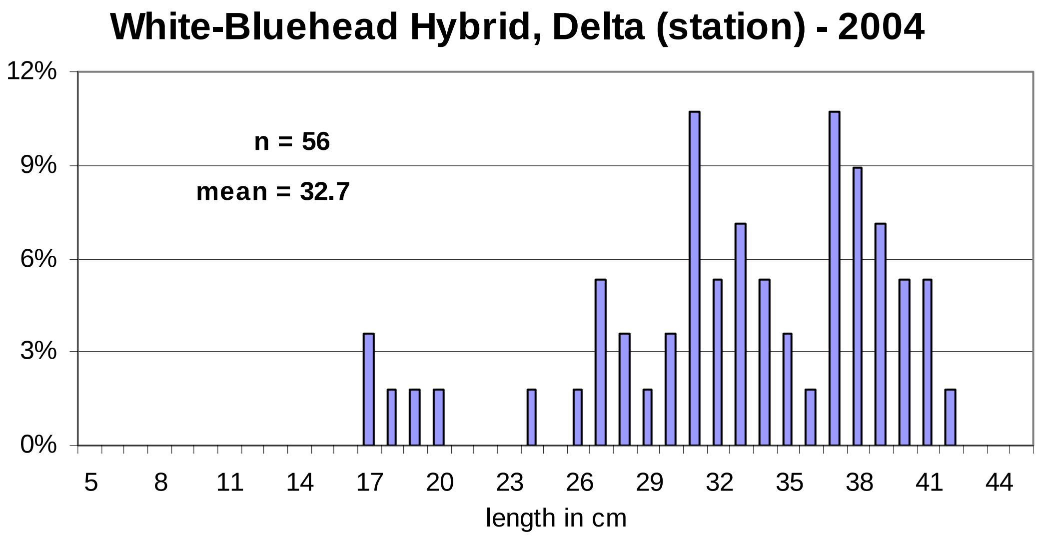

Figure A3-29. White-Bluehead Hybrid – Delta (station), Gunnison River, August-September 2004.

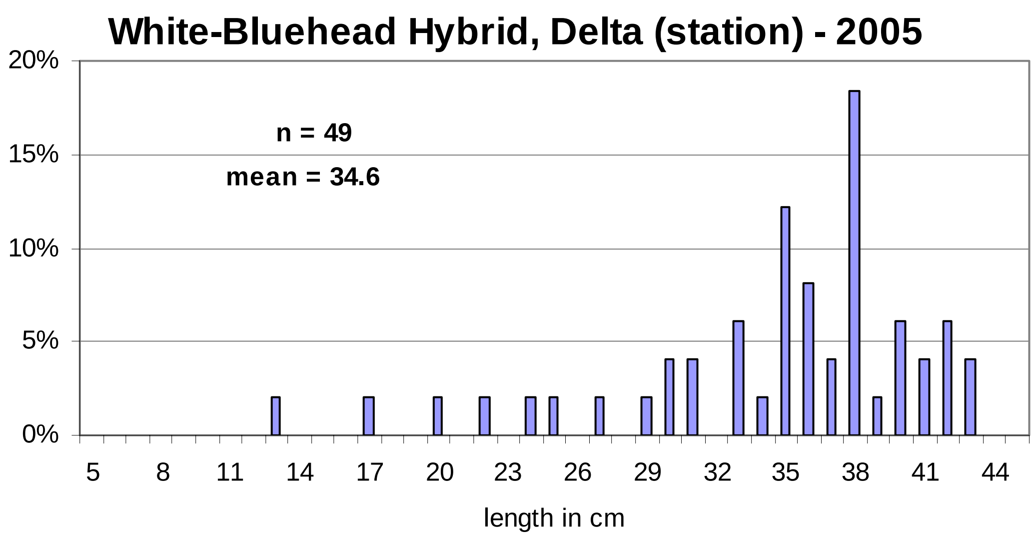

Figure A3-30. White-Bluehead Hybrid – Delta (station), Gunnison River, August 2005.

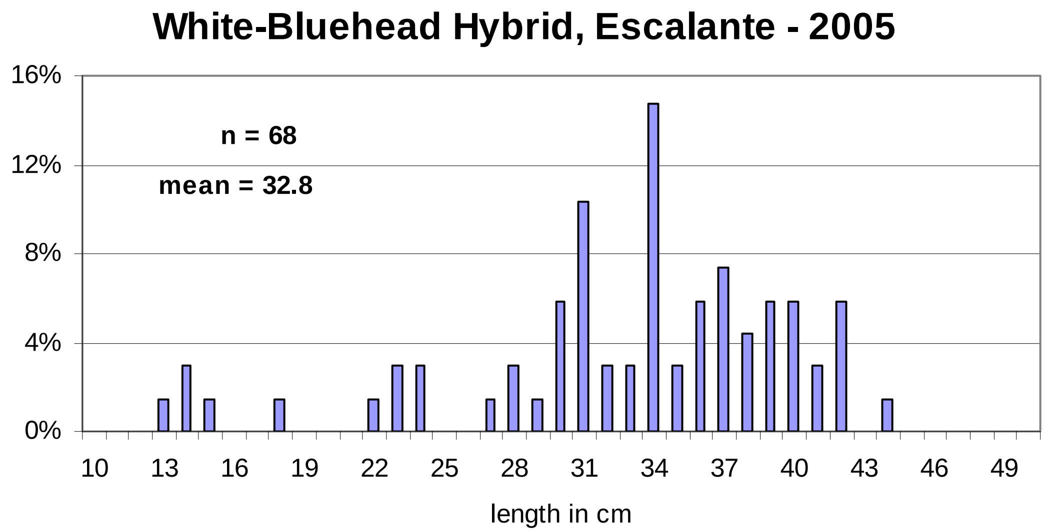

Figure A3-31. White-Bluehead Hybrid – Escalante, Gunnison River, August 2005.

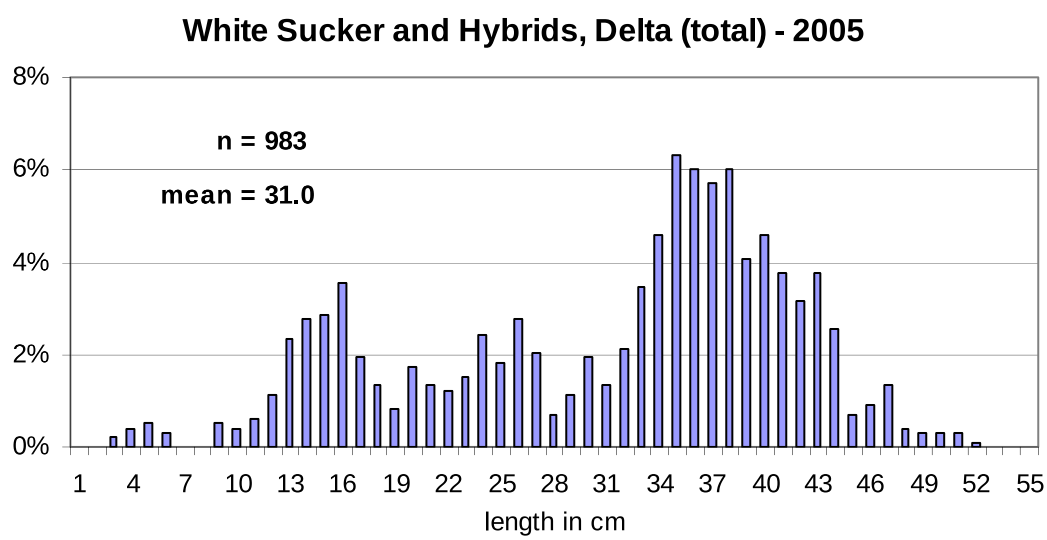

Figure A3-32. White Sucker and Hybrids – Delta (total), Gunnison River, August 2005.

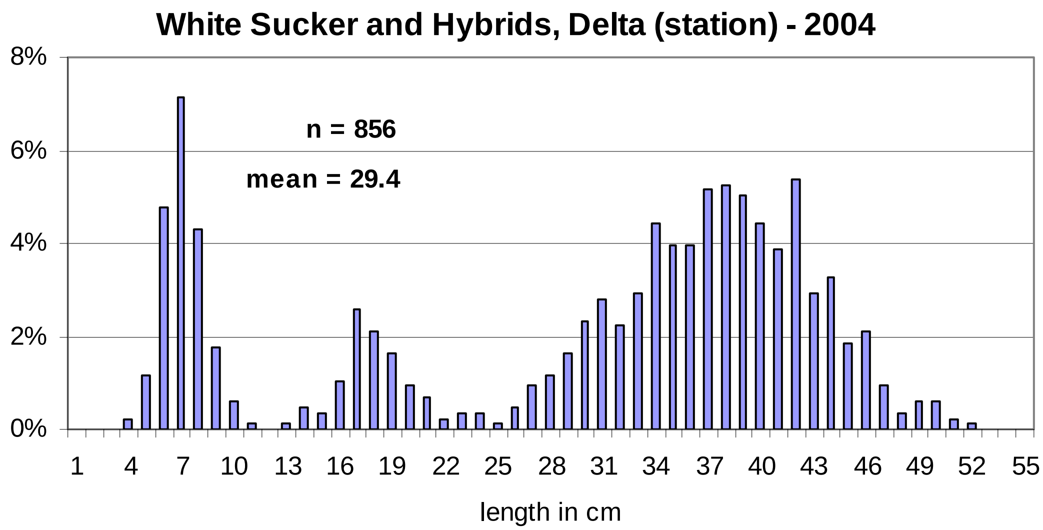

Figure A3-33. White Sucker and Hybrids – Delta (station), Gunnison River, August-September 2004.

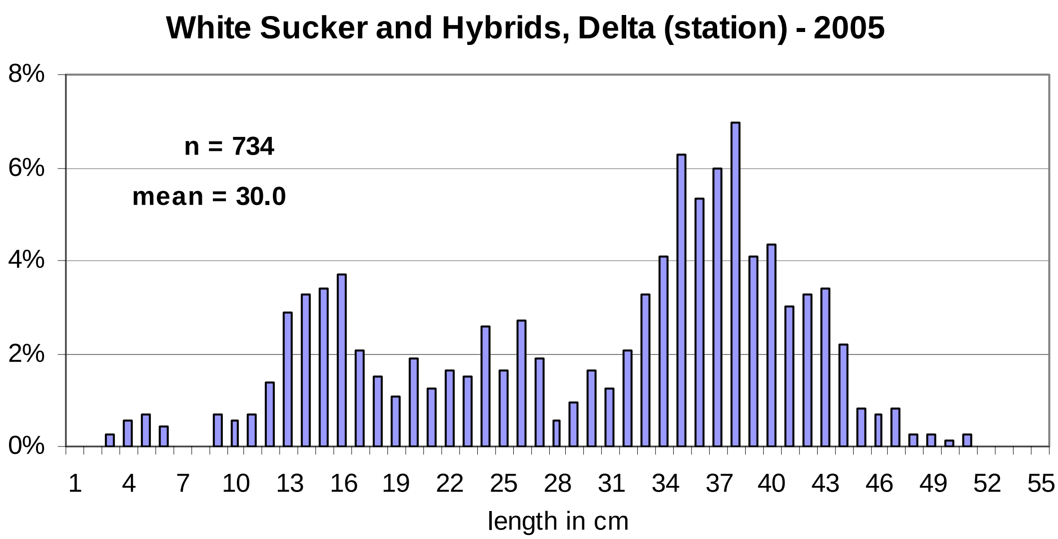

Figure A3-34. White Sucker and Hybrids – Delta (station), Gunnison River, August 2005.

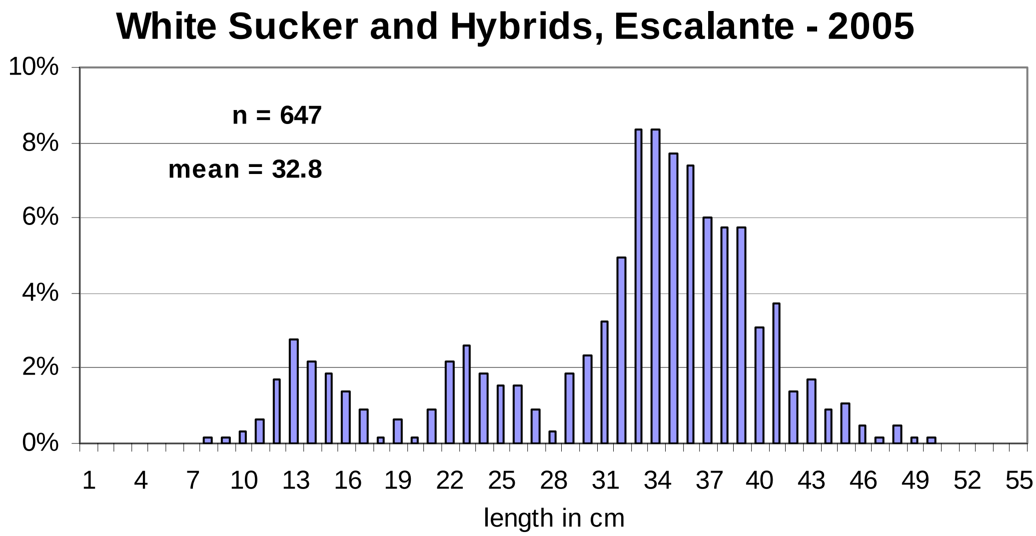

Figure A3-35. White Sucker and Hybrids – Escalante, Gunnison River, August 2005.

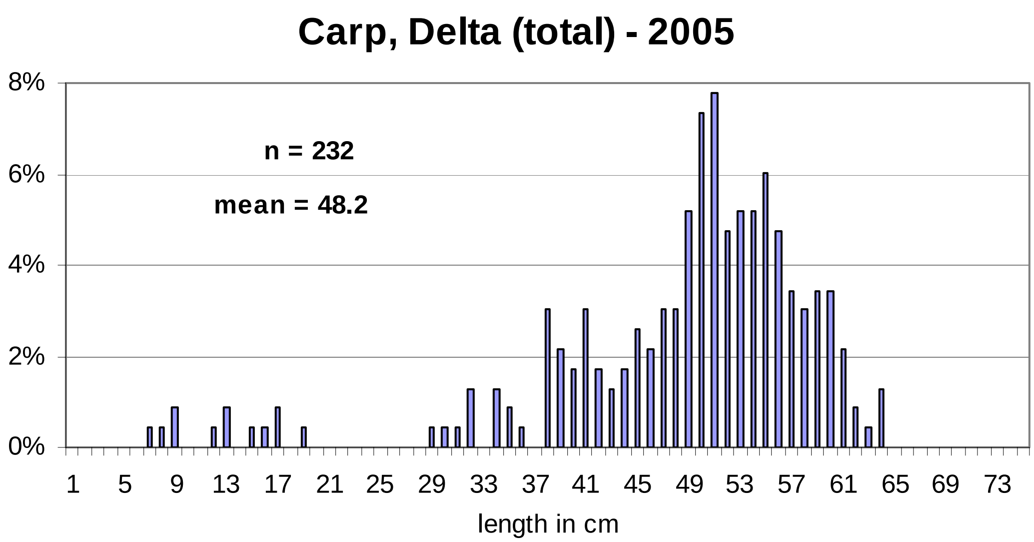

Figure A3-36. Carp – Delta (total), Gunnison River, August 2005.

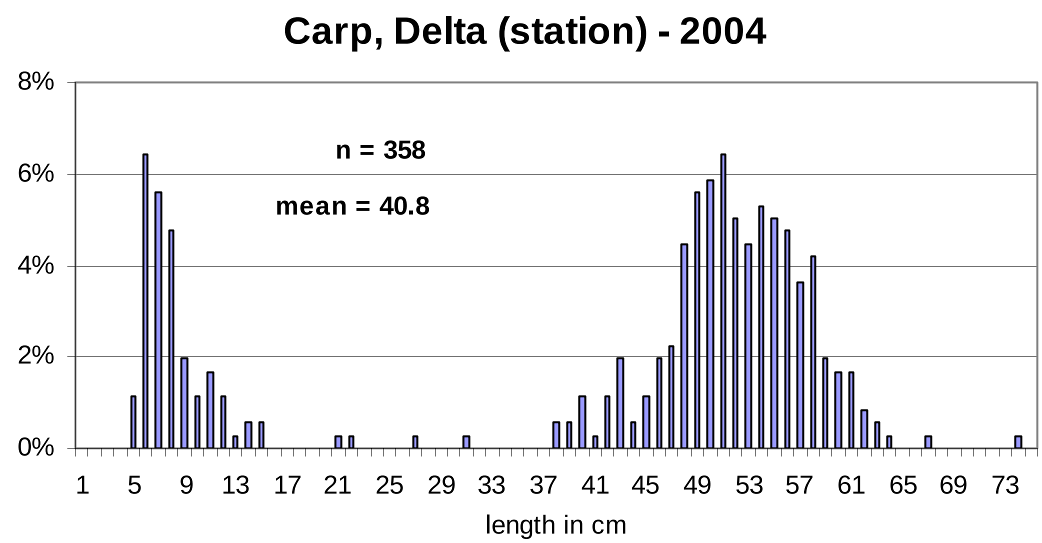

Figure A3-37. Carp – Delta (station), Gunnison River, August-September 2004.

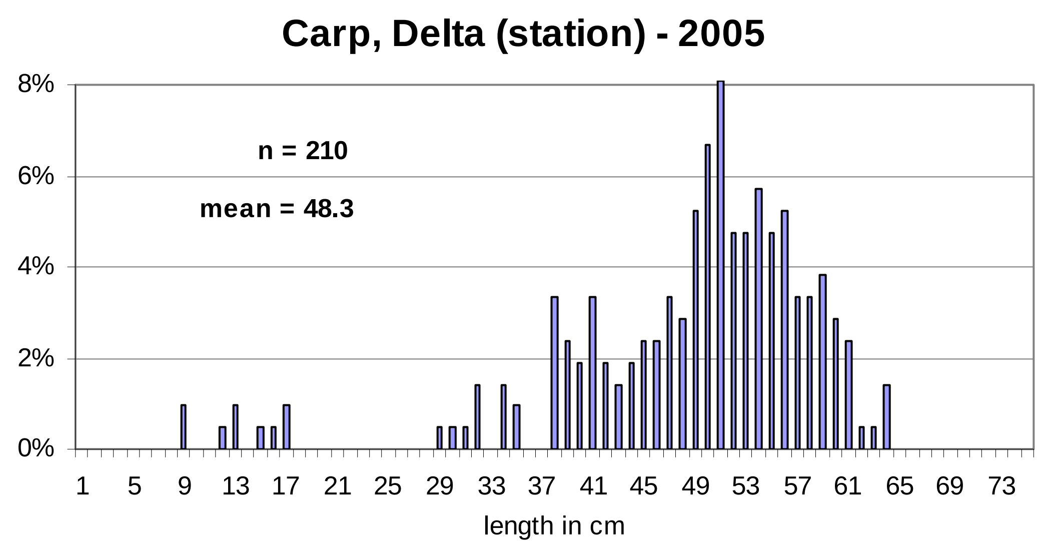

Figure A3-38 Carp - Delta (station), Gunnison River, August 2005.

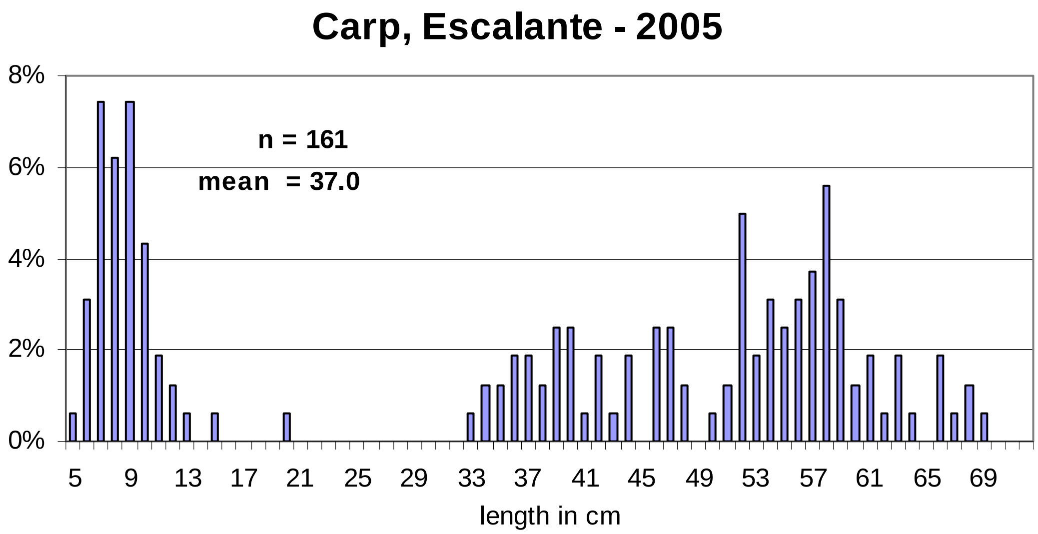

Figure A3-39. Carp – Escalante, Gunnison River, August 2005.

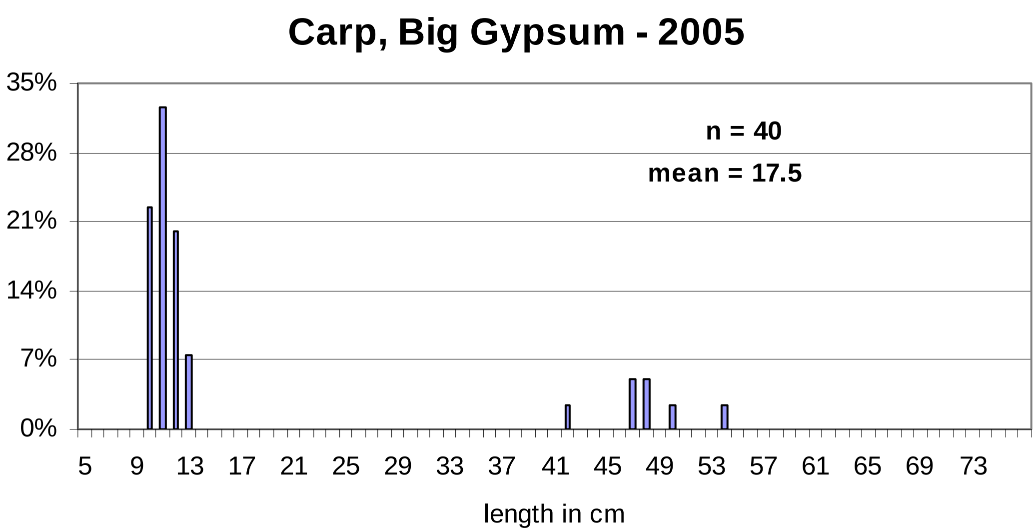

Figure A3-40. Carp – Big Gypsum, Dolores River, July 2005.

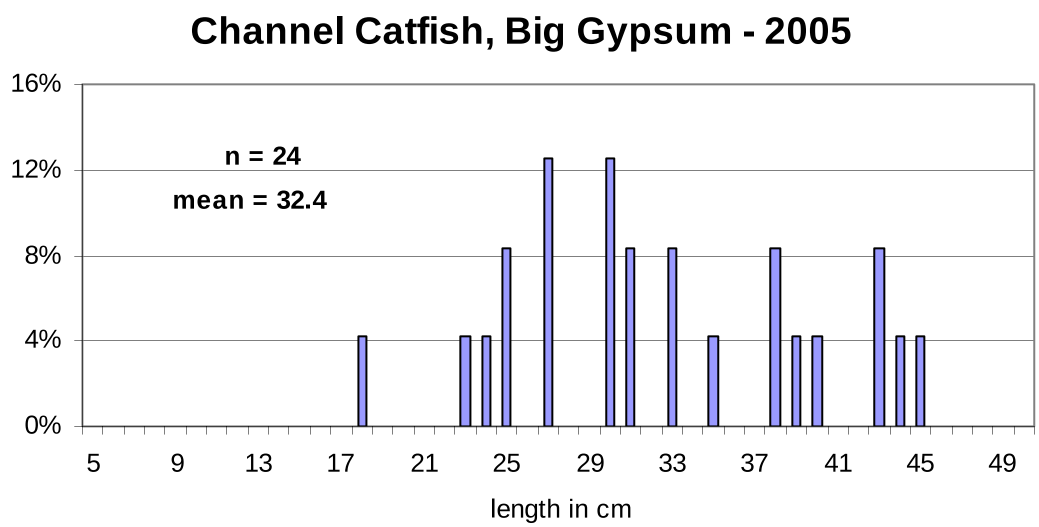

Figure A3-41. Channel Catfish, Big Gypsum, Dolores River, July 2005.

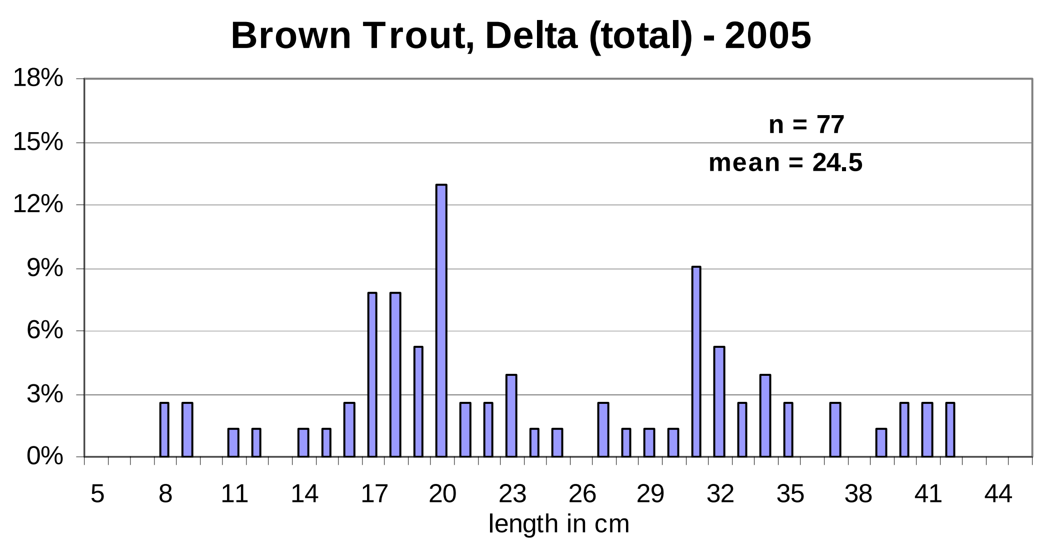

Figure A3-42 Brown Trout – Delta (total*), Gunnison River, August 2005.

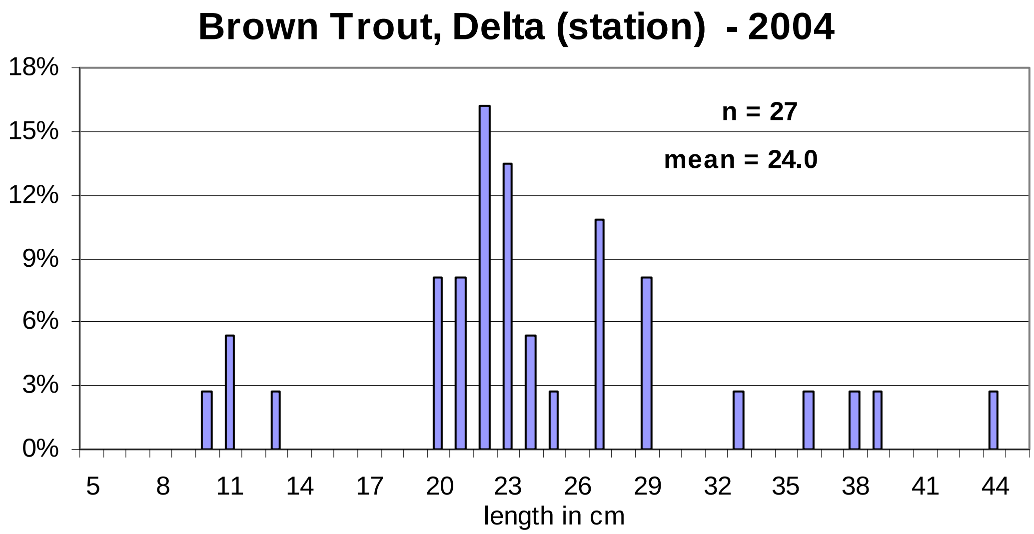

Figure A3-43. Brown Trout – Delta (station), Gunnison River, August-September 2004.

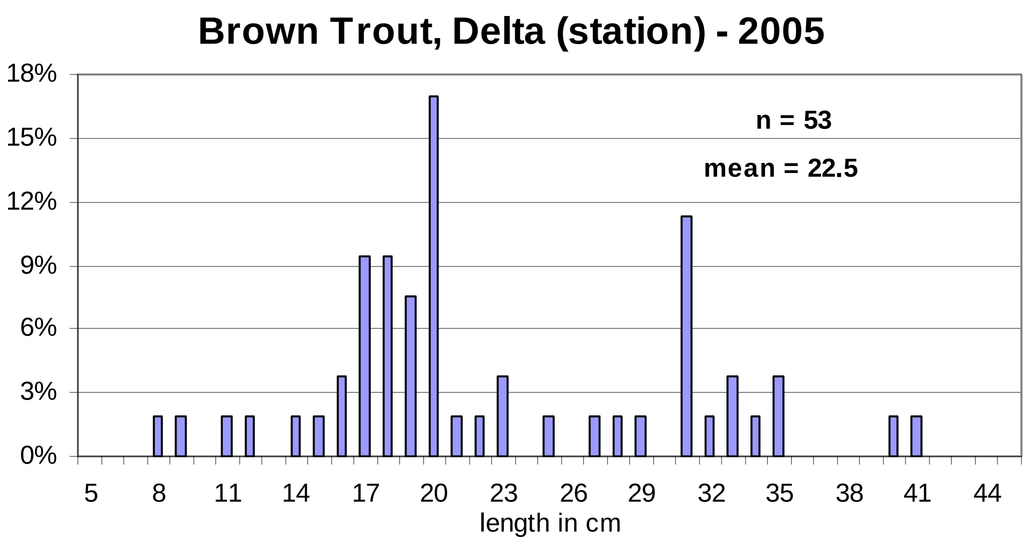

Figure A3-44. Brown Trout – Delta (station), Gunnison River, August 2005.

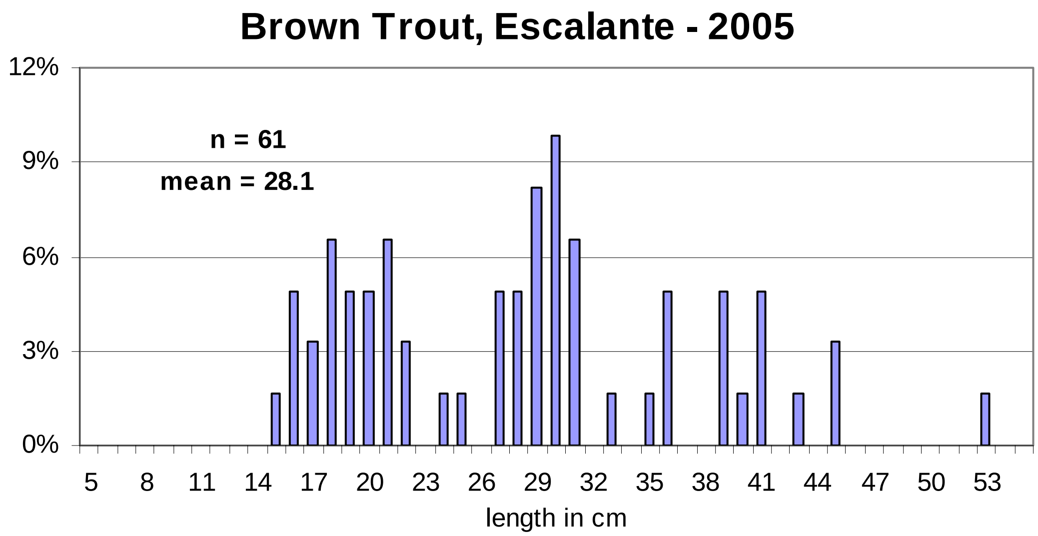

Figure A3-45. Brown Trout – Escalante, Gunnison River, August 2005.

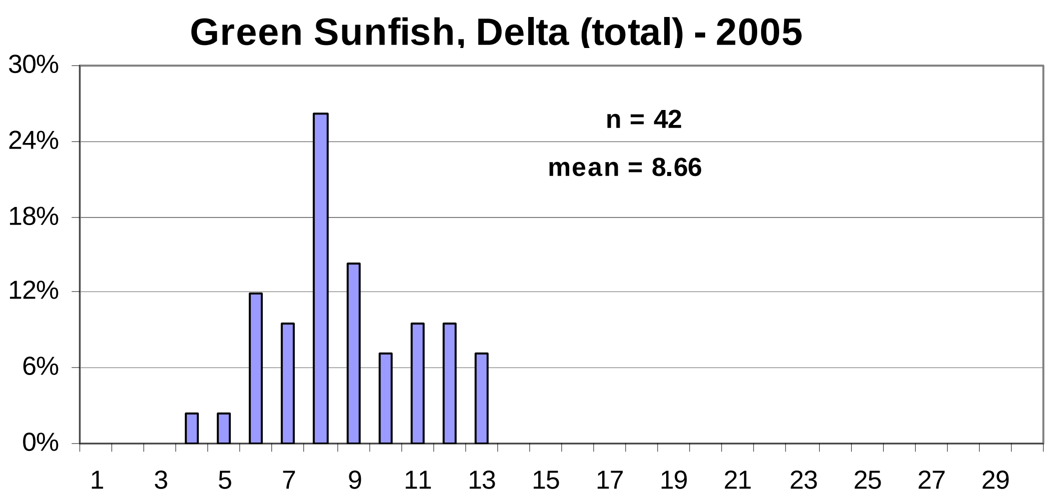

Figure A3-46 Green Sunfish – Delta (total*), Gunnison River, August 2005.

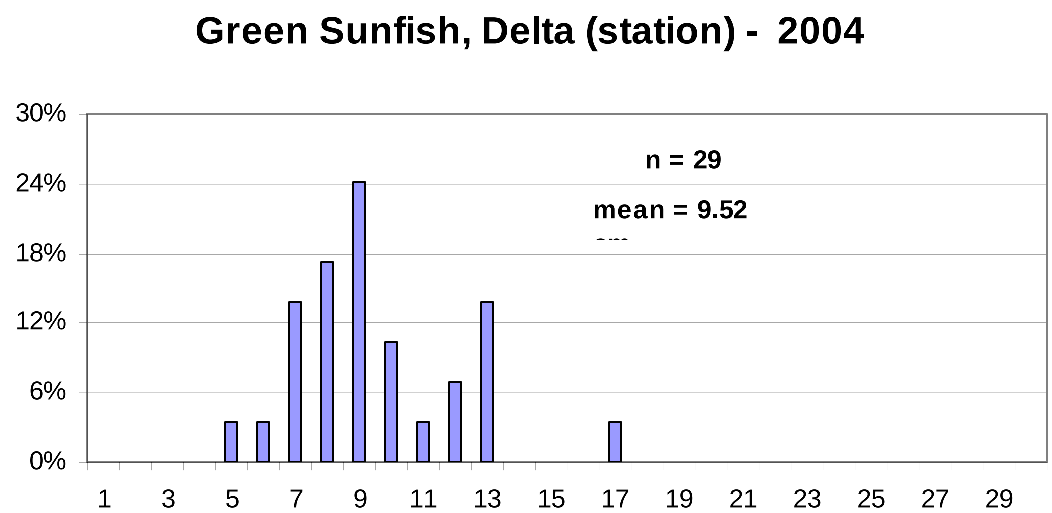

Figure A3-47. Green Sunfish – Delta (station), Gunnison River, August-September 2004

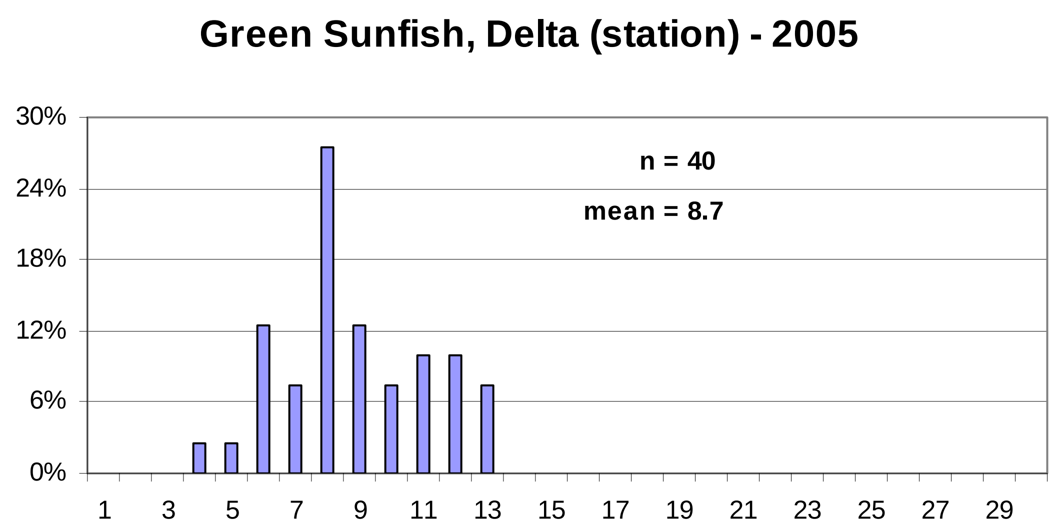

Figure A3-48. Green Sunfish – Delta (station), Gunnison River, August 2005.

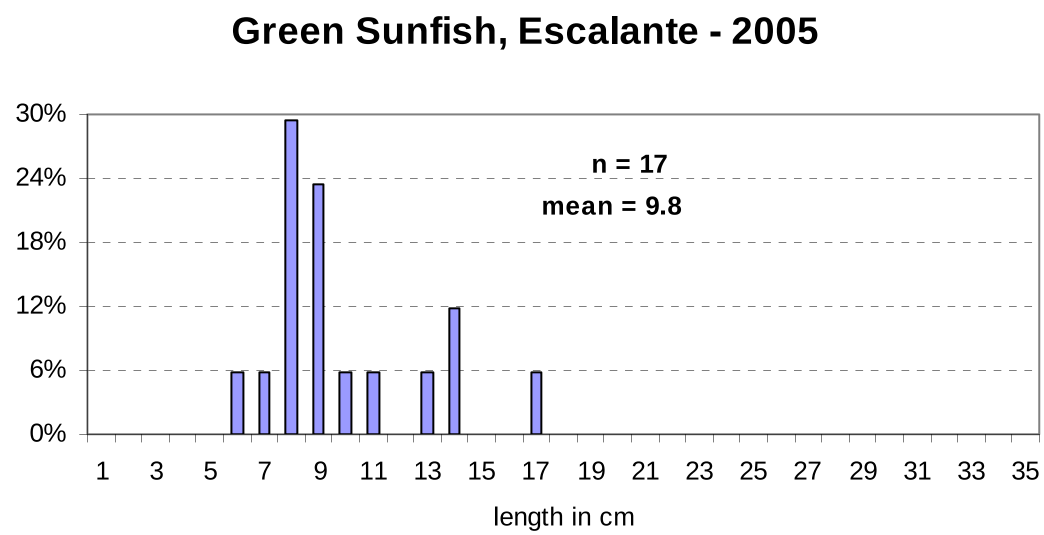

Figure A3-49. Green Sunfish – Escalante, Gunnison River, August 2005.

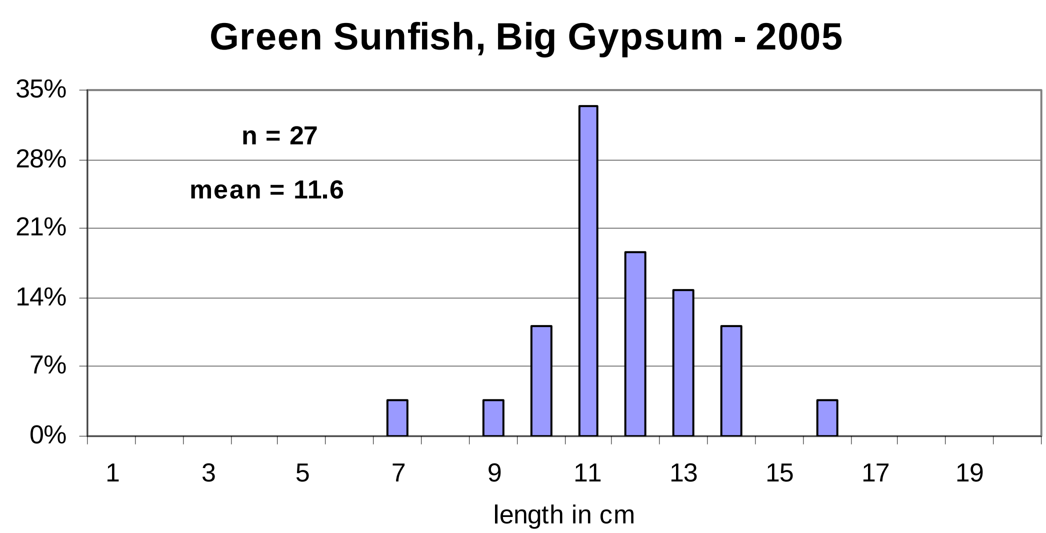

Figure A3-50. Green Sunfish – Big Gypsum, Dolores River, July 2005.

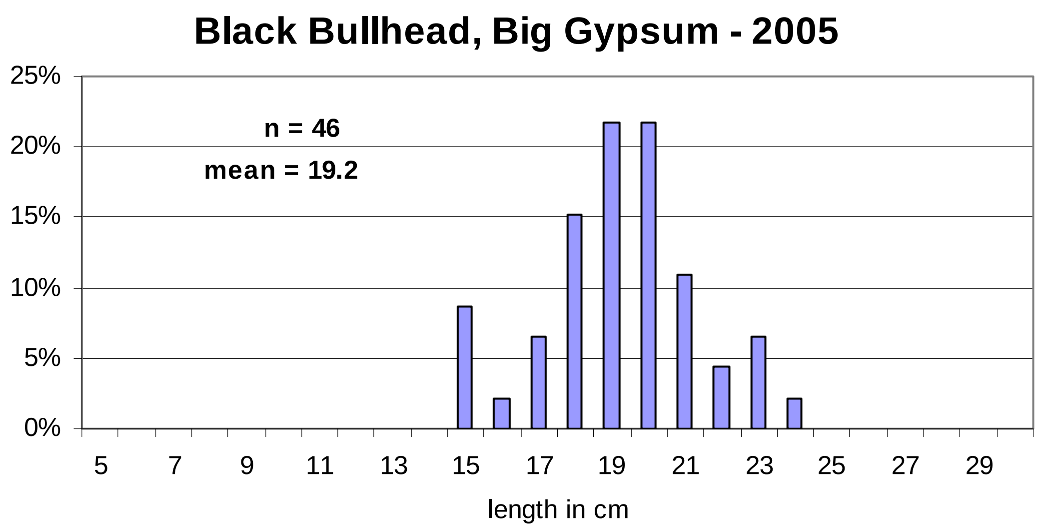

Figure A3-51. Black Bullhead – Big Gypsum, Dolores River, July 2005.

Appendix 4

Habitat composition

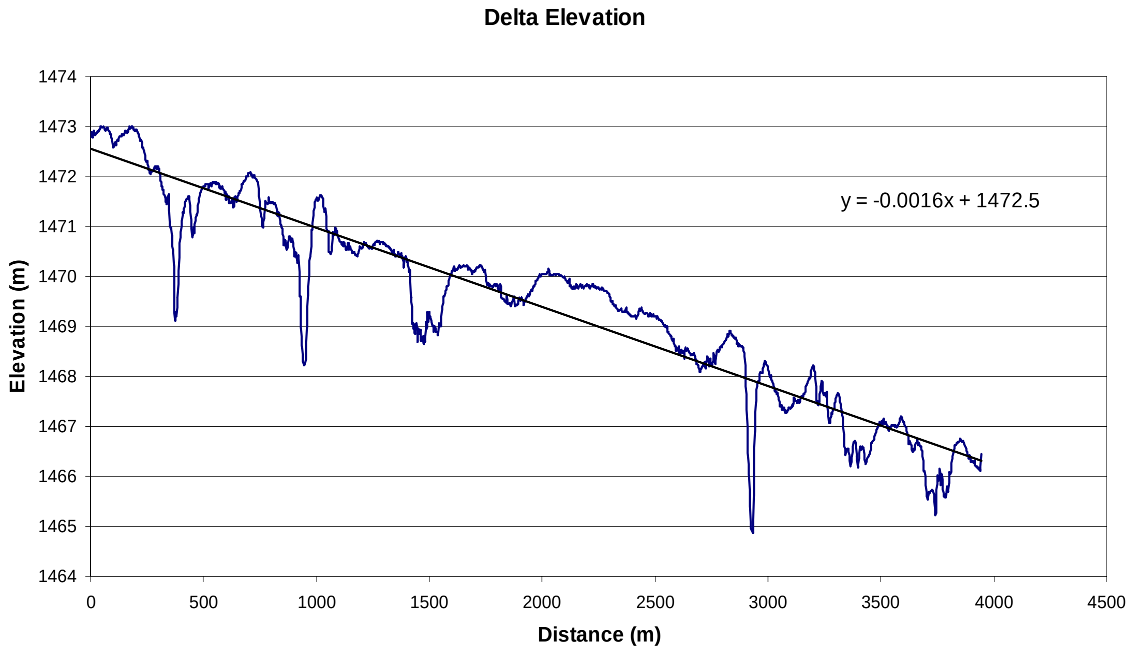

Figure A4-1. Longitudinal profile for Delta, Gunnison River.

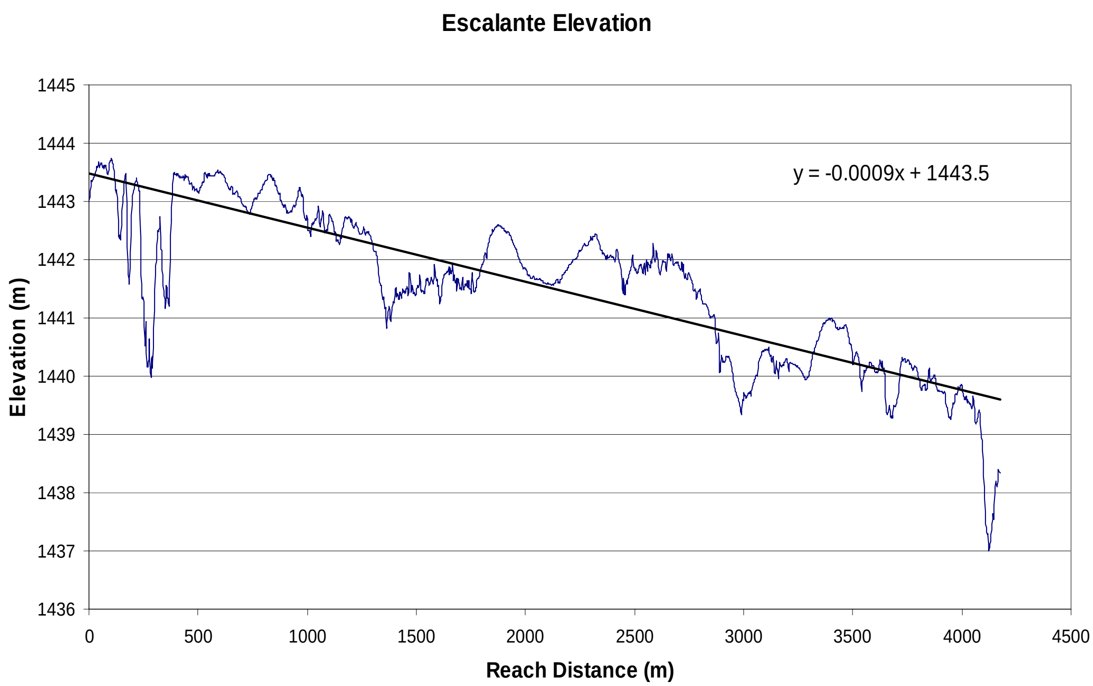

Figure A4-1. Longitudinal profile for Escalante, Gunnison River.

Last Page.   Landscape format.

Insert mesohabitat figures, and make this page in color.