San Juan River
Annual Habitat Monitoring 2016

Prepared For:
The San Juan Recovery Implementation Program
United States Fish and Wildlife Service

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Executive Summary

After an above average spring runoff, the San Juan River experienced a dramatic alteration in planform geometry. Habitat features such as new channel bifurcations (secondary channels, island splits and cobble/sand bar channel splits) were built river wide and were extensive. In addition, many new cobble bars were produced in widened areas of the river. In the baseflow time period following runoff, backwater areas increased 240% river-wide compared to 2015 and were the largest in magnitude since January 1996. In the non-canyon reaches of the river, large backwaters were associated with abandoned main channel splits and abandoned secondary channels that had their entrances blocked by large deposits of cobble. Overall, the total wetted area of the non-canyon reaches of the river increased by 4.4% compared to 2015, reversing the trend of losing total wetted area (TWA) at a rate of 1% per year. The increase in habitat complexity may have been a combination of high spring flows (days greater than 5,000 cfs) that created the features and the higher than normal consistent base flows that perpetuated these habitats through the baseflow period.

Introduction

Colorado Pikeminnow (*Ptychocheilus lucius*) and Razorback Sucker (*Xyrauchen texanus*) are two native fish species of the San Juan River listed as endangered in 1967 and 1991 respectively. A major component of the Endangered Species Act is the designation and protection of critical habitat including locations within the geographical area occupied by the species that contain physical or biological features essential to the conservation of the species. These physical or biological qualitites are considered primary constituent elements (USFWS, 1998). There are features within critical habitat that require special management or protection for recovery of the species. These include; space for growth and normal behavior, food, water, or other nutritional or physiological requirements, as well as, cover or shelter, breeding and rearing sites, or other habitats protected from disturbance. These features generally fall into three categories that are considered primary constituent elements: water, physical habitat, and biological environment (Maddux et al. 1993). The US Fish and Wildlife Service determined critical habitat for Colorado Pikeminnow to be from Farmington New Mexico to Neskahi Canyon. Critical habitat for Razorback Sucker is located from Hogback Diversion to Neskahi Canyon.(USFWS, 1998).

Research in the upper Colorado River, Green River, and Yampa River have shown that low velocity type habitats and backwaters were critical to the development of both young-of-year and juvenile Colorado Pikeminnow and Razorback Sucker (Holden 1977; Joseph *et al.* 1977; Tyus and Karp 1989; Tyus and Karp 1990). Most recently, sampling conducted as part of the San Juan River Recovery Implementation Program (SJRIP), indicates both species have reproduced in the San Juan River with early life stages found in low velocity habitats such as backwaters and embayments.

SJRIP is driven by several program guidance documents. The 2012 Monitoring Protocols (SJRRIP 2012) state that the overarching goal for habitat monitoring is to:

> *"Quantitatively document effects of naturally occurring conditions, management actions, and other anthropogenic activities on aquatic habitat availability in the San Juan River. Use this information to recommend appropriate modifications to recovery strategies for Colorado pikeminnow and razorback sucker in the San Juan River."*

In addition, there are statements in the Long Range Plan for specific tasks and objectives. The monitoring objectives relative to habitat are as follows:

1. *Annually, following spring runoff, document abundance and distribution of key habitats and geomorphic features (backwaters, embayments, islands, and total wetted area) that indicate the response of the river channel and habitat to antecedent runoff conditions and specific management actions.*

2. *Track long-term trends of habitat availability.*

3. *Develop relationships between habitat availability and antecedent flow conditions. Use key habitats for this analysis.*

Habitat monitoring (GIS based geometric planforms) started in the San Juan River in 1990 with the initial work being conducted by the Bureau of Reclamation (Pucherelli and Clark 1990). The early mapping in 1990 utilized planform geometry and only looked at total wetted area and backwaters. Data collected in 1992 was expanded to include secondary channels as well as backwaters and embayments (Pucherelli and Goettlicher 1992). The data were taken directly from videography without any field inspections. In the fall of 1992, Ecosystems Research Institute (ERI) started mapping the San Juan River using the river-wide mapping methodologies that included airborne videography, as well as, field mapping. This methodology (planform geometry) was based upon the work of Carter et al (1986) as well as Pucherelli and Clark (1990). This approach allowed the habitat monitoring program to map at a resolution of approximately one meter compared to over two to three meters in past efforts. The field mapping used 40 habitat categories within eight major habitat types. Between 1992 and 2007, river-wide habitat mapping was done 23 times at flows ranging from 479 cfs to 9,453 cfs. During baseflow conditions (<1,500 cfs), the river from river mile 2-180 was mapped 17 times.

In 2011 the San Juan River Recovery Implementation Program revised the habitat monitoring protocols used in the annual SJRIP Monitoring Program (SJRRIP 2012). Those revisions were the result of a workshop held to determine the appropriate habitat monitoring protocols to meet the objectives of the SJRIP Long Range Plan.

Workshop participants, including outside peer reviewers with specific expertise in habitat assessment, combined with the SJRIP Biology Committee members, helped develop the protocols. From 2011 to 2015, habitats in the San Juan River were mapped at baseflows using these protocols (Lamarra and Lamarra, 2011). Specifically, the monitoring focused on backwaters, embayments, islands and the associated side channels.

The justification for selecting these habitat parameters (embayments, backwaters, islands and total wetted area), are based on historical observations from the fishery and habitat monitoring programs (Bleisner *et al*. 2007) as reviewed and agreed upon by workshop participants.

The data presented herein are based on the habitat data collected as part of the current annual habitat monitoring program. The SJRIP Biology Committee had expressed an interest in the collection of baseflow 2016 data because the program was expecting an above average water year with concurrent releases from Navajo Dam.

Methods

Aerial imagery of the San Juan River was obtained using a TU-206 Cessna fixed wing aircraft that maintained an altitude above 3,800 feet in order to achieve a 10 centimeter digital 4 band resolution. Images were captured using a UltracamLp high resolution camera. Blue Sky Consulting (BSC) took photographs of the San Juan River on August 14, 2016 while the river was at a flow of 730 cfs measured at the four corners (USGS Station No. 09371010) (Figure 3).

Digital images were imported and post-processed in the laboratory using ESRI Arcmap 10.0, and subsequently overlaid on 2011 geo-referenced National Agriculture Imagery Program (NAIP) county mosaics for the full extent of the river floodplain boundaries. Individual images were already geo-referenced and rectified by the contractor (BSC). The end product was a collection of geo-referenced, high-resolution (10 cm) images of the San Juan River from the confluence of the Animas River to the Clay Hills boat take out (river mile 2) (Figure 1). This initial process of preparing the mapping photos was a similar process to the methods employed by Block (2014) on the Little Colorado River.

The initial total wetted area for the San Juan River was determined by using the vector-editing program within Arcmap and the above-mentioned rectified, high-resolution images from the 2016 images. A vector image of the water's edge was created for each mile and geomorphic reach (Figure 1) in the San Juan River using the polygon function. These vectors were then transformed into an individual mile-specific polygon from which total wetted area could be determined. Islands were delineated (defined as any in-stream, non-wetted structure with at least 50% vegetation coverage), as well as any non-wetted in-stream structures such as sand bars, cobbles bars, or debris piles. These delineated areas were subtracted from the total wetted area to estimate the actual wetted area for each river mile in the system. Island structures were delineated per mile, and uniquely identified as part of the comprehensive data set. Characteristics such as count, area, and perimeter were quantified. Backwater and embayment habitat types were also delineated using the same polygon-editing tool as referenced above, creating a unique vector image for each individual habitat. Both habitat types were considered part of the wetted area.

In addition to the acquisition of new habitat data for 2016, a further effort was undertaken to quantify the number and type of all flowing side channels. Each individual channel split was defined by type and given a unique identifier. Each channel observation was scored as flowing (1) or not flowing (0).

The following definitions of channel types were used in the characterization of channels. Examples of these side channel types can be seen in Figure 2.

> ***Secondary Channel Split*** – A channel (also known as a distributary) that contains less than 50% of the surface area of the river after bifurcation.
> ***Main Channel Split*** – A bifurcation of the main channel that contains approximately 50% of the surface area of the river.
> ***Island Split*** – Channels that dissect islands under various flow conditions.
> ***Cobble/Sand Bar Channel Splits***. Channels that are bifurcated due to the presence of non-vegetated cobble or sand bars.

Various hydrologic parameters were calculated from the hydrograph as gaged at the Four Corners USGS Station No. 09371010 (Table 1). These data points were considered to be antecedent conditions prior to baseflow mapping. Antecedent conditions were calculated for the 2016 baseflow mapping and are compared to the previous 5 years of hydrograph characteristics (2011 to 2015).

Results

Antecedent Conditions

Several hydrograph characteristics for 2016 were similar to the 2015 hydrograph with a maximum flow of 8,480 cfs in 2016 compared to 8,490 cfs in 2015 (Table 1). One antecedent condition that was different between 2015 and 2016 were days greater than 5,000 cfs. In 2015 there were only 14 days greater than 5,000 cfs compared to 36 days in 2016. In addition there were twice as many days (29) in 2016 with flows between 5,000 cfs and 8,000 cfs compared to 2015 (13 days). This difference is also reflected in the volume of runoff (March to July). There was almost 230,000 ac-ft more water in the 2016 spring runoff when compared to 2015 (Table 1).

Total Wetted Area

The total wetted area (TWA) of the stream channel represents the accumulation of all wetted habitats and wetted channels within the river. The TWA is summarized by river reach, canyon and non-canyon reaches and for the entire river (RM 2-180) in Table 2. Data from both 2015 and 2016 are presented. The flow at mapping was almost identical for both years and therefore allowed a direct comparison between 2015 and 2016. In the canyon bound portion of the San Juan River (Reaches 1 and 2), the TWA was reduced by over 160,000 m^2. This represented a 2.8% reduction in TWA between 2015 and 2016, which was similar to the differences in flow at mapping (2.2%). In the non-canyon portion of the San Juan River, there were increases of each reach with the largest gains in Reaches 3 and 4. In total there was an increase in over 450,000 m^2 of

TWA. This represented a 4.4% gain between 2015 and 2016. This gain reversed a trend of losing approximately 1% of the TWA per year (Lamarra and Lamarra 2015).

Island Count and Area

Quantifying the Island complexes in the San Juan River is part of the Habitat Monitoring program because islands represent a surrogate for habitat complexity in the river (Bliesner and Lamarra 1999). In 2016, there was 8.482 million m^2 of surface area in 199 islands between RM 68 to 180. Reach 5 had the highest count (65) and area (4.53 million m^2). Reach 6 had the lowest island area (655,624 m^2 in 38 islands). Although there was a net gain of 55 islands and 542,924 m^2 of area from 2015 to 2016, not all reaches responded the same. Reaches 3 and 6 had large gains in island area and count, while Reaches 4 and 5 had losses in area with only small gains in counts. This pattern is the result of increases in the number of newly inundated secondary channels in Reaches 3 and 6 in 2016 and the loss of main channel bifurcations (Table 3).

Backwater and Embayment Habitats

As noted previously, backwaters and embayments are considered important low velocity habitats for the early life stages of several endangered species in the San Juan River. Because of their importance to the rare fish in the San Juan River, the densities of backwaters and embayments are tracked as part of the annual habitat monitoring program. Functionally, low velocity habitats (backwaters and embayments) are produced by different mechanisms in the canyon bound river reaches compared to the non-canyon portion of the San Juan River. In the canyon, low velocity type habitats are associated with the mouths of dry washes and debris fans. In addition, Reach 1 (River miles 2-16) has large amounts of ephemeral sand bars and associated backwaters. In the non-canyon portion of the San Juan River (Reaches 3 to 6), backwater type habitats are associated with temporally non-flowing secondary channels and main-stem cobble/sand bars.

In 2016, the amount of backwater type habitats was high throughout the entire river. The total surface area (94,001 m^2) and count (394) represented the highest densities since January 1996 (Figure 4). Compared to just 2015, the largest surface area gains occurred in the non-canyon portion of the river (Table 4). Reaches 3 to 6 had an increase in backwater area of 46,735 m^2 and an increase of 109 backwaters. This change in backwater area was a 270% increase compared to 2015. In the canyon bound section of the river, there was an increase of 8,537 m^2 of backwater area represented in 77 new backwaters. The increase was a 175% from the 2015 canyon backwater densities.

Channel Bifurcation Types

In the San Juan River, there are several types of channel splits (bifurcations) that have been monitored because changes in the type and densities of channel bifurcations can represent indications of channel change (complexity or simplification). Compared to 2015, the densities of the four channel types in 2016 had differences in all reaches of the river (Table 5). Secondary channel splits (channels that contain less than 50% of the river flow) increased in Reaches 3 (6 new channels) and 5 (2 new channels) Reaches 4 and 6 did not have changes in flowing channels in 2016 compared to 2015. However, main channel splits (each channel contains approximately 50% of the flow) had only one new main channel split from 2015 to 2016. Island splits are associated with the dissection of islands by the river. Island splits also increased in densities in 2016 compared to 2015. A total of 14 new island dissections (38 to 52) occurred throughout the non-canyon river with the highest in Reaches 5 and 6 (Table 5). A similar spatial pattern was found in the changes to cobble/sand bar splits between 2015 and 2016. These channels bifurcations are characterized by recent depositions within the main channel and are not long in length. In total, 12 new cobble/sand bar splits were developed in 2016 compared to 2015. This is consistent with the observations that the 2016 antecedent hydrologic conditions resulted in major planform changes in the San Juan River with large movement of cobble substrates and the deposition of numerous debris piles within the channel. Compared to 2015, there were a total of 35 new channel splits documented as part of the 2016 Habitat Monitoring program.

Discussion

The results of the 2016 Habitat Monitoring program indicated extensive changes in the planform geometry of the San Juan River channels. Observation after spring runoff showed that in many areas, the channel had widened and new cobble bars had been deposited within the main channel (Figures 5 and 6). Also, under baseflow conditions, large backwaters and embayments were observed in association with abandoned main channel splits (Figure 7) and abandoned secondary channels (Figure 8). In many cases, these channels were not flowing at 730 cfs due to large deposits of cobble at the upstream bifurcations. The number and sizes of the backwaters created in 2016 were greater than 2015. In 2015, only 3 backwaters were greater than 1,000 m^2 compared to 16 in 2016. In terms of surface area, 43% of the total areas of backwaters in 2016 were located in backwaters greater than 1,000 m^2 compared to 14% in 2015 (Figure 9).

The exact mechanisms are still unclear, however, comparing the differences in the flow patterns between 2016 and the previous 5 years when habitat features and richness were in decline does allow strong inferences.

One important difference was the characteristics of the spring runoff volume during 2016. The total volume was 230,000 ac-ft greater than the 2011 and 2015 runoff volume with 100,000 ac-ft more water in the descending hydrograph compared to the previous five years. The higher flows were sustained above the 5,000 cfs flow range resulting in 36 days of high flows compared to just 12 days in 2011 and 14 days in 2015. This increased magnitude and duration of flows in 2016 could have reshaped the main and secondary channels in the San Juan River. Previous studies (Holden 2000) had shown that sustained flows above 5,000 cfs would flush sand and silt from the bottoms of secondary channels primarily in Reach 3. As shown in Table 4, Reach 3 had the largest gain in backwater area and contributed almost 50% of the gain observed in the non-canyon area of the river. Sustained flows between 5,000 and 8,000 cfs also were shown to mobilize cobble substrates in the San Juan River (Bliesner and Lamarra 1999). The large increase in newly created cobble/sand bar channel splits in 2016 (Table 5), verifies that large quantities of cobble were eroded and re-deposited.

A second, and equally important, characteristic of the flows experienced by the San Juan River in 2016 were the reduction in the number of low flow days during baseflow conditions. For the antecedent conditions related to flows, 2016 had the fewest days of flows less than 500 cfs, days less than 750 cfs, and total days between 500 and 1,000 cfs when compared to the previous 5 years (Table 1). Lamarra and Lamarra (2015) demonstrated that the reduction of habitat features such as island counts and the number of channel bifurcations, were significantly related to the increase in the number of low flow days. Due to low numbers of low flow days, the concurrent higher flows in 2016 would have prevented many channel bifurcations from filling in with sand and becoming abandoned.

Additional possible mechanisms that may have also played a role in the creation of habitats and complexity in the San Juan River in 2016, are the timing of flows from Navajo Reservoir. Due to flooding concerns, the flows were reduced for a short period of time after reaching a maximum discharge. This resulted in a pulsed release pattern rather than a continuous high flow release. This pattern may have affected the entrainment and movement of bed sediments. A second possible mechanism may have been back to back moderate to high flow years that could have worked in concert to reverse the temporal trend of channel simplification that was documented in 2015 (Lamarra and Lamarra 2015).

In summary, total wetted area, backwater type habitats, island counts and area, the density of secondary channels, island split channels and cobble/sand bar split channels had dramatic increases in 2016. The increase in habitat complexity may have been a combination of high spring flows (days greater than 5,000 cfs) that created the features and the lack of low flows that perpetuated these habitats through the baseflow period.

Conclusions

Based on the results presented, we conclude the 2016 spring runoff was successful in the San Juan River experienced a dramatic alteration in planform geometry. Habitat features such as new channel bifurcations (secondary channels, island splits and cobble/sand bar channel splits) were built river-wide and were extensive. In addition, many new cobble bars were produced in widened areas of the river. In the baseflow time period following runoff, backwater areas increased 240% river-wide and were the largest in magnitude since January 1996. In the non-canyon reaches of the river, large backwaters were associated with abandoned main channel splits and abandoned secondary channels that had their entrances blocked by large deposits of cobble. Overall, the total wetted area of the non-canyon reaches of the river increased by 4.4%, reversing the trend of losing TWA at a rate of 1% per year.

Recommendations

The period 1993 to 1995 represented a series of wet years in the San Juan Basin that culminated in baseflow backwater and embayment densities reaching a maximum surface area not seen in the river system since that period. In 2015 and 2016, the San Juan River experienced above average flows with 2016 having more days above 5,000 cfs compared to the hydrology over the last 10 years. 2017 is expected to be an above average water year with snow packs exceeding 125% of normal. At the time of writing the BOR is expecting to have approximately 50 days of 5,000 cfs releases from Navajo Reservoir. This would result in higher flows compared to 2016. Given the geomorphic planform changes that have occurred in the San Juan River in the last two years, it is recommended that the San Juan River be re-photographed and mapped as in 2016 to further document the changes in habitat resulting in multiple sequential wet years similar to the 1993-95 periods.

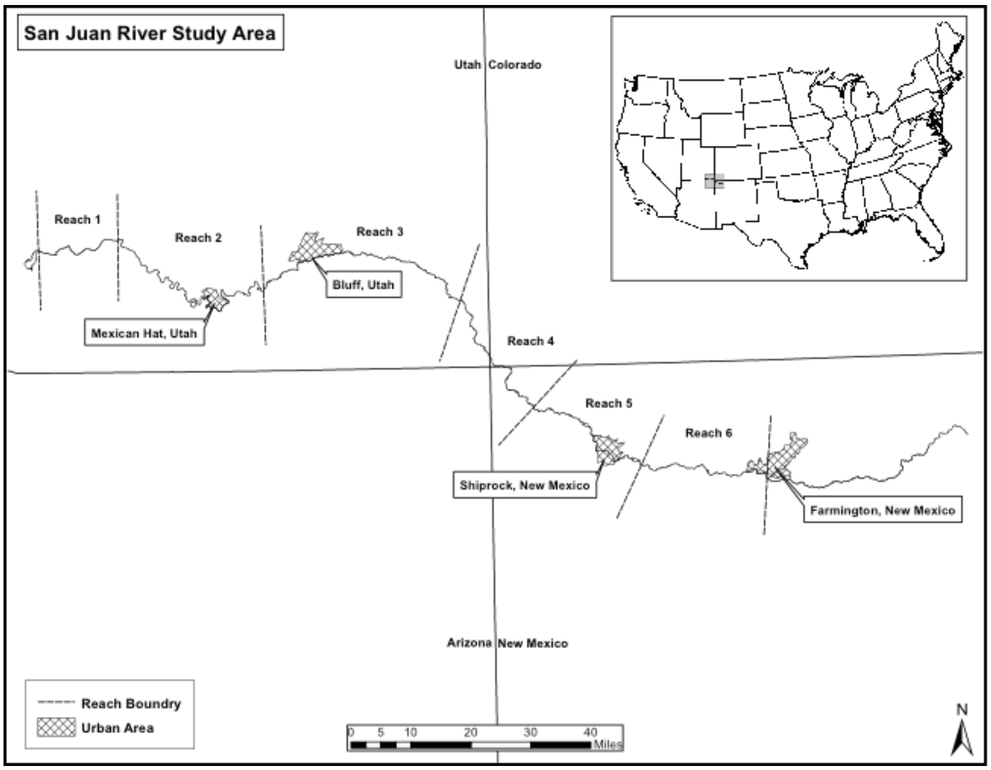


Figure 1: A location map of the San Juan River study area.

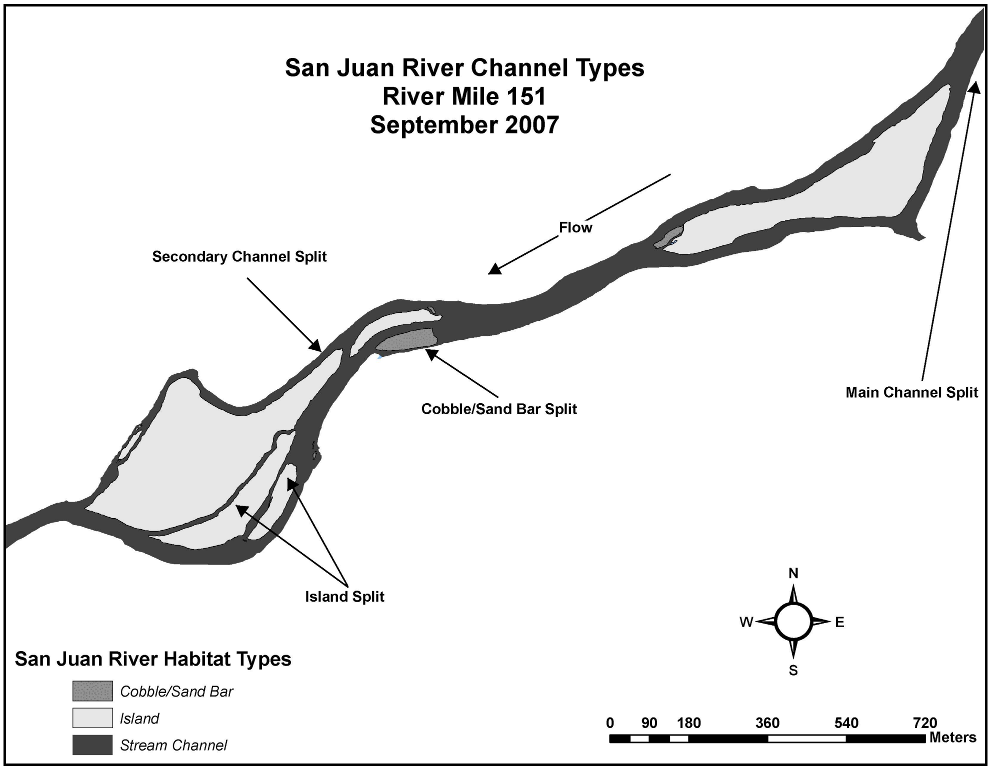


Figure 2: An example of channel bifurcation types in the San Juan River

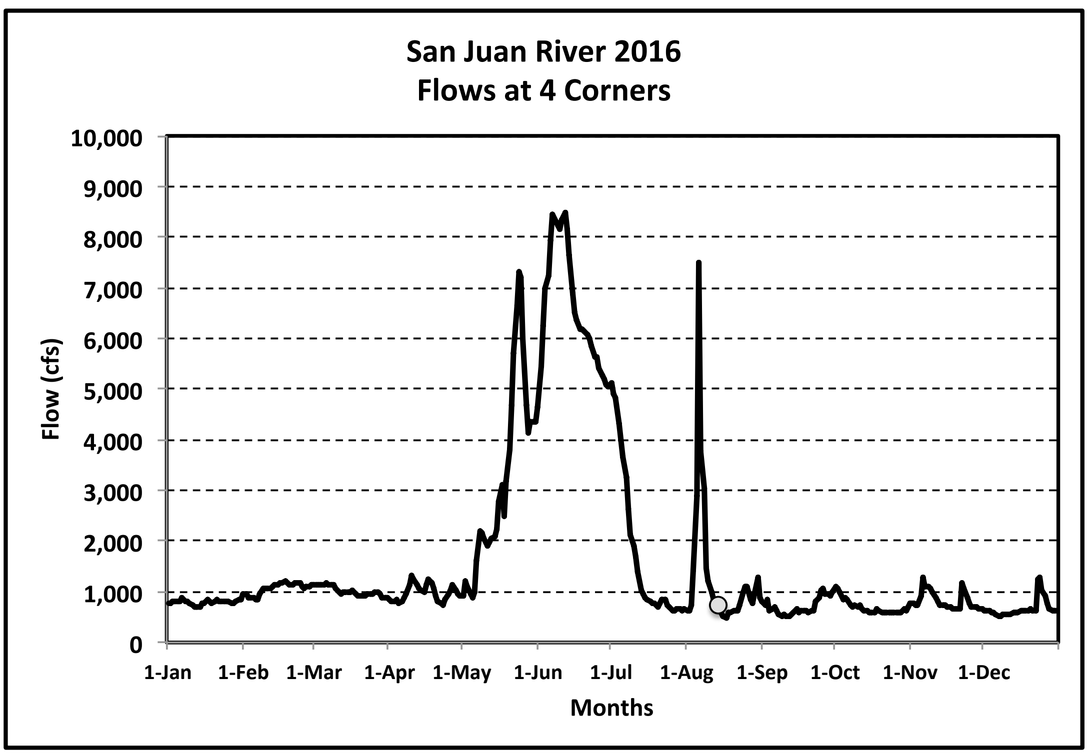


Figure 3: The hydrograph of the San Juan River at the 4-Corners gage (USGS Station No. 09371010) for 2016. The gray dot signifies when aerial images were taken of the river.

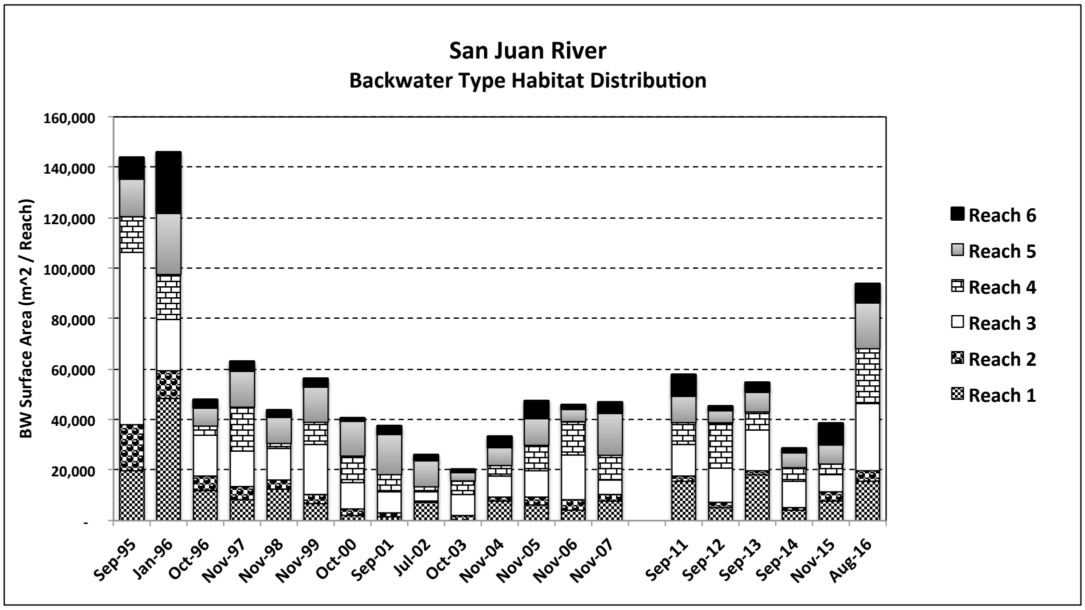


Figure 4: The temporal distribution of backwater type habitats in the San Juan River during baseflow conditions (<1,500 cfs). Data are in m² / reach.

Table 1: A summary of the antecedent flow conditions in the San Juan River from 2011 to 2016 based on the 4-Corners gage.

Hydrograph Characteristics at 4-Courners Gage

Antecedent Condition	2011	2012	2013	2014	2015	2016
Peak Runoff (cfs)	8,980	5,680	2,140	4,890	8,490	8,480
Runoff (Mar-July af)	545,803	388,502	223,358	189,779	585,358	816,094
Total Runoff (Annual af)	871,147	674,917	632,705	721,912	939,320	1,179,646
Peak Date	13-Jun	25-May	20-May	3-Jun	12-Jun	12-Jun
Days > 10,000 cfs	0	0	0	0	0	0
Days > 8,000 cfs	7	0	0	0	1	7
Days > 5,000 cfs	12	6	0	0	14	36
Days > 2,500 cfs	27	10	0	23	38	58
Days BT 500 & 1,000	255	278	253	251	232	220
Days BT 750 & 1,000	157	79	45	79	77	110
Days BT 1,000 & 1,500	37	52	33	46	55	75
Days BT 1,500 & 2,000	22	18	17	10	14	5
Days BT 2,000 & 2,500	11	2	2	10	16	7
Days BT 5,000 & 8.000	5	6	0	0	13	29
Days < 500	12	5	46	25	9	1
Days < 750	110	204	254	197	155	111
Days < 1000	267	283	299	276	241	221
Days < 1500	304	335	332	322	296	296
Days < 2000	326	353	349	332	310	301
Days < 2500	336	355	365	342	327	308
Maximum Daily Flow (cfs)	8,980	5,680	8,440	4,890	8,490	8,480
Minimum Daily Flow (cfs)	399	461	259	354	405	484
Assending RO (Mar 1-May 31) af	172,226	281,708	145,112	187,047	187,744	316,697
Decending RO (June 1-July 31) af	373,577	106,793	78,246	188,716	391,761	499,397

Table 2: The comparison of Total Wetted Areas (TWA) in the San Juan River during baseflows for 2015 and 2016.

REACH	RIVER MILES	Nov-15	Aug-16	Difference (2015-16)
		YEARS		
1	2-16	2,039,165	1,999,597	-39,568
2	17-67	3,795,063	3,674,051	-121,012
3	68-105	3,569,930	3,760,698	190,768
4	106-130	2,371,517	2,446,947	75,431
5	131-154	2,191,584	2,309,093	117,509
6	155-180	2,043,307	2,109,804	66,498
Canyon	2-67	5,834,228	5,673,649	-160,579
Non-Canyon	68-180	10,176,337	10,626,543	450,205
River Total	2-180	16,010,565	16,300,191	289,626
Flow at Mapping		750 cfs	730 cfs	

Table 3: The comparison of Island area (above) and count (below) at baseflows in the San Juan River between 2015 and 2016.

REACH	RIVER MILES	YEARS Nov-15	Aug-16	Difference (2015-16)
1	2-16			
2	17-67			
3	68-105	1,072,712	1,586,880	514,168
4	106-130	1,801,503	1,708,457	-93,046
5	131-154	4,601,579	4,531,692	-69,887
6	155-180	463,934	655,624	191,690
Canyon	2-67	-	-	0
Non-Canyon	68-180	7,939,730	8,482,654	542,924
River Total	2-180	7,939,730	8,482,654	542,924
Flow at Mapping		750 cfs	730 cfs	

REACH	RIVER MILES	YEARS Nov-15	Aug-16	Difference (2015-16)
1	2-16			
2	17-67			
3	68-105	27	58	31
4	106-130	32	38	6
5	131-154	62	65	3
6	155-180	23	38	15
Canyon	2-67	0	0	0
Non-Canyon	68-180	144	199	55
River Total	2-180	144	199	55

Table 4: The comparison of backwater type habitat area (above) and count (below) at baseflows between 2015 and 2016.

REACH	RIVER MILES	YEARS: Nov-15	YEARS: Aug-16	Difference (2015-16)
1	2-16	7,737	15,728	7,991
2	17-67	3,500	4,046	546
3	68-105	7,191	26,538	19,347
4	106-130	3,953	21,785	17,832
5	131-154	8,020	18,192	10,172
6	155-180	8,328	7,713	-616
Canyon	2-67	11,237	19,774	8,537
Non-Canyon	68-180	27,492	74,227	46,735
River Total	2-180	38,729	94,001	55,272
Flow at Mapping		750 cfs	730 cfs	

REACH	RIVER MILES	YEARS: Nov-15	YEARS: Aug-16	Difference (2015-16)
1	2-16	14	83	69
2	17-67	24	32	8
3	68-105	83	124	41
4	106-130	56	55	-1
5	131-154	20	68	48
6	155-180	11	32	21
Canyon	2-67	38	115	77
Non-Canyon	68-180	170	279	109
River Total	2-180	208	394	186

Table 5: The comparison of flowing channel types in the San Juan River at baseflows between 2015 and 2016.

		Type 1 (Secondary)			Type 2 (MC Split)			Type 3 (Isl Split)			Type 4 (Co/Sa Bar Split)			Total Channels		
REACH	RIVER MILES	Nov-15	Aug-16	Difference (2015-16)	Nov-15	Aug-16	Difference (2015-16)	Nov-15	Aug-16	Difference (2015-16)	Nov-15	Aug-16	Difference (2015-16)	Nov-15	Aug-16	Difference (2015-16)
1	2-16															
2	17-67															
3	68-105	17	23	6	8	8	0	10	13	3	40	42	2	75	86	11
4	106-130	16	16	0	8	8	0	10	11	1	32	34	2	66	69	3
5	131-154	15	17	2	10	11	1	16	21	5	27	30	3	68	79	11
6	155-180	6	6	0	19	19	0	2	7	5	21	26	5	48	58	10
Canyon	2-67															
Non-Canyon	68-180	54	62	8	45	46	1	38	52	14	120	132	12	257	292	35
River Total	2-180	54	62	8	45	46	1	38	52	14	120	132	12	257	292	35
Flow at Mapping		750 cfs	730 cfs													

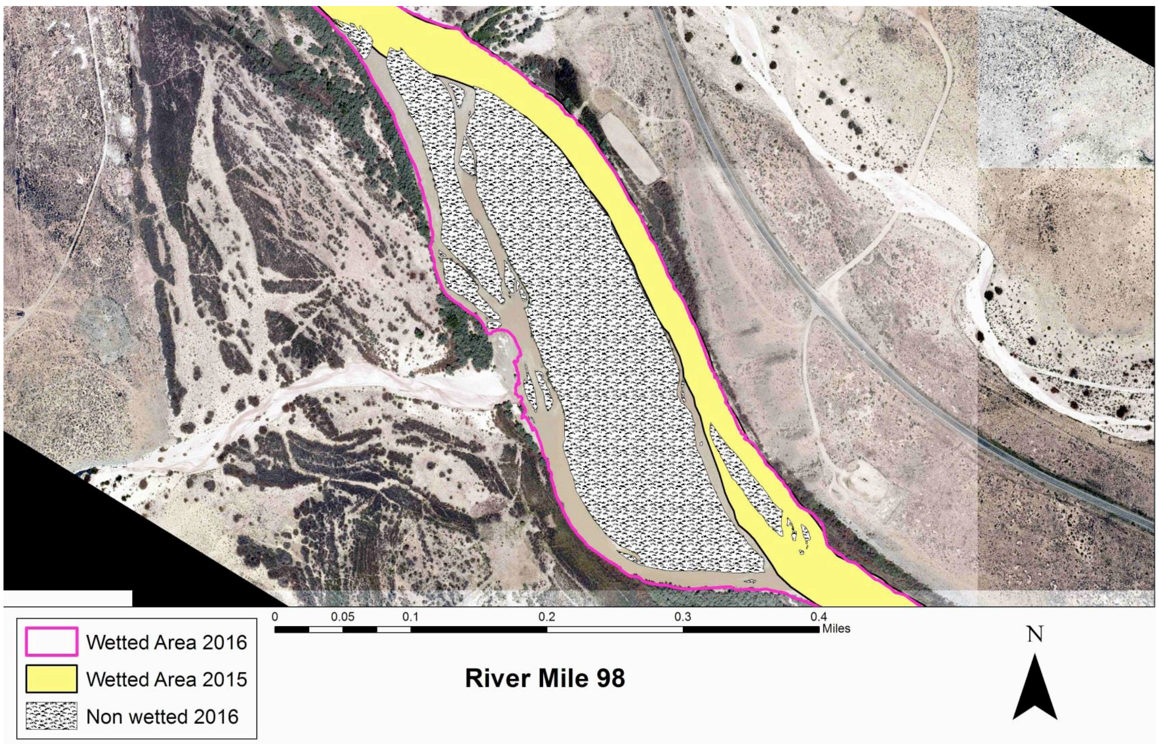


Figure 5: An example of a widened channel and a new cobble bar at River Mile 98 in the San Juan River in 2016.

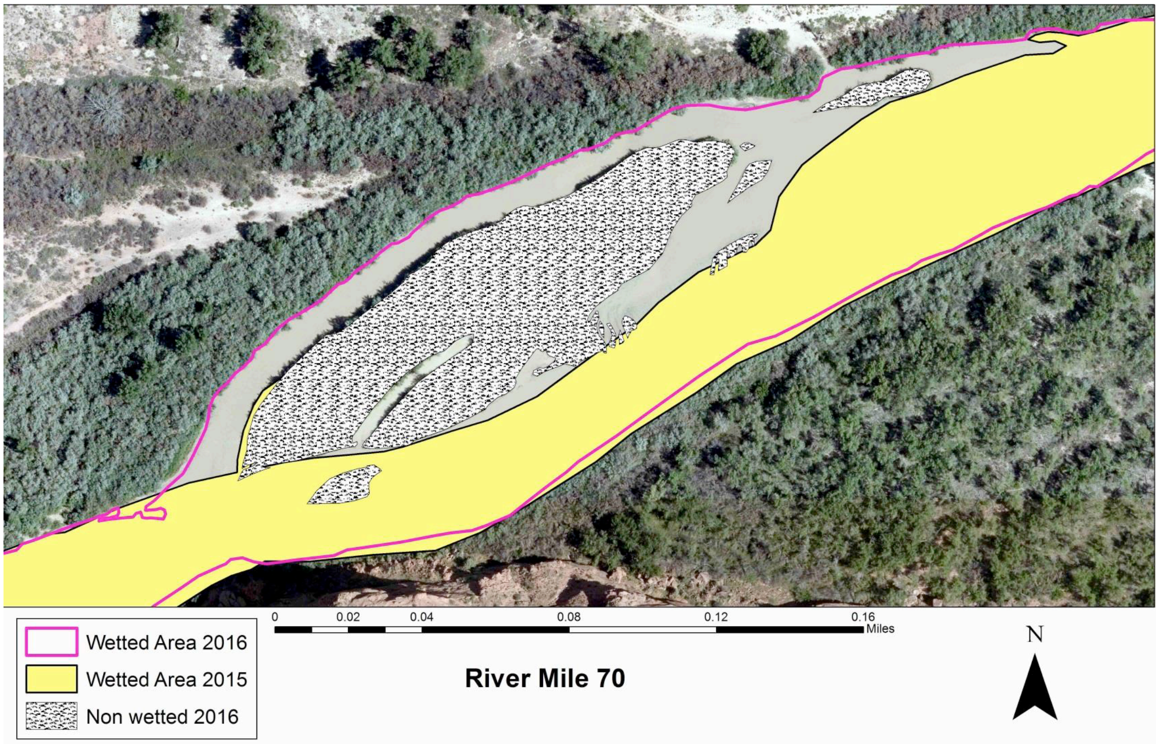


Figure 6: An example of a widened channel and a new cobble bar at River Mile 70 in the San Juan River in 2016.

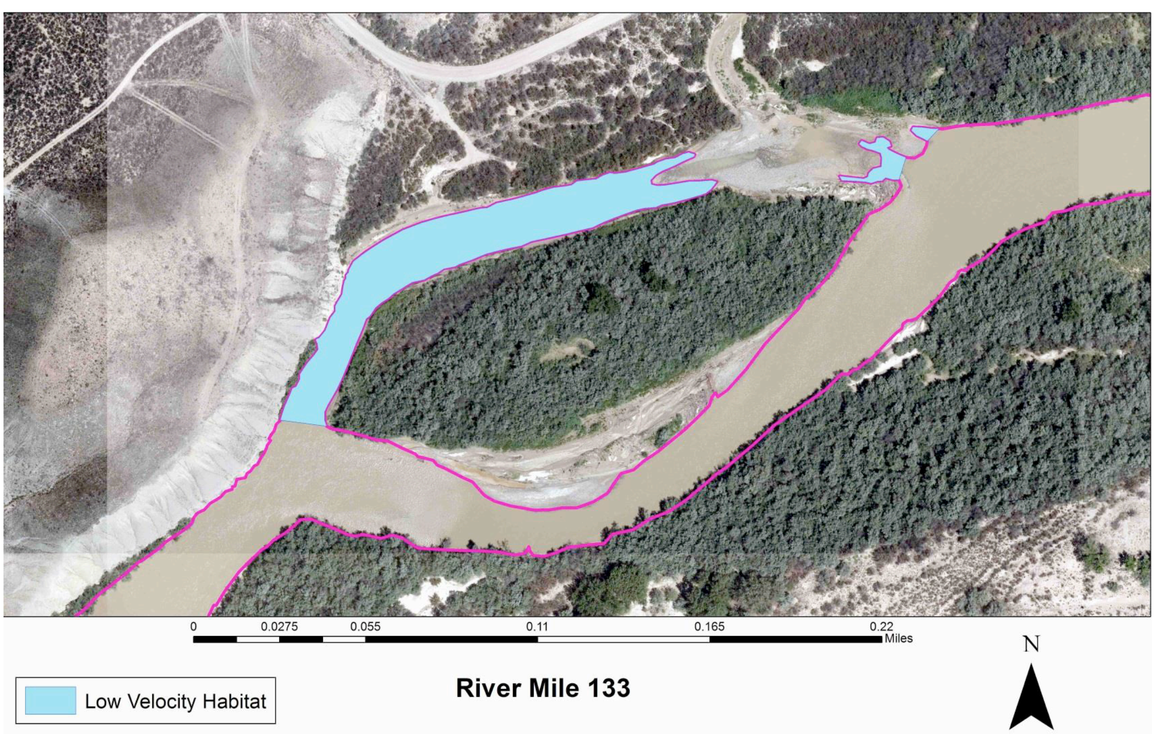


Figure 7: An example of a main channel split that was blocked by cobble and produced a large backwater at River Mile 133 in the San Juan River during baseflow conditions of 730 cfs.

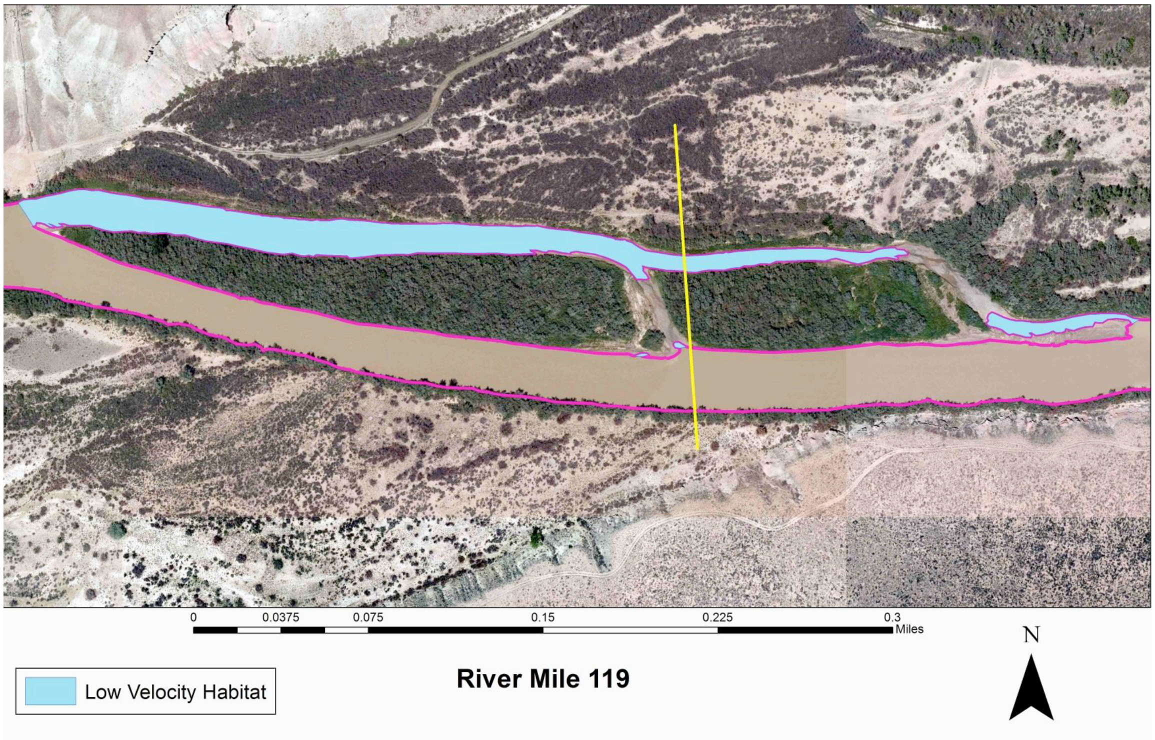
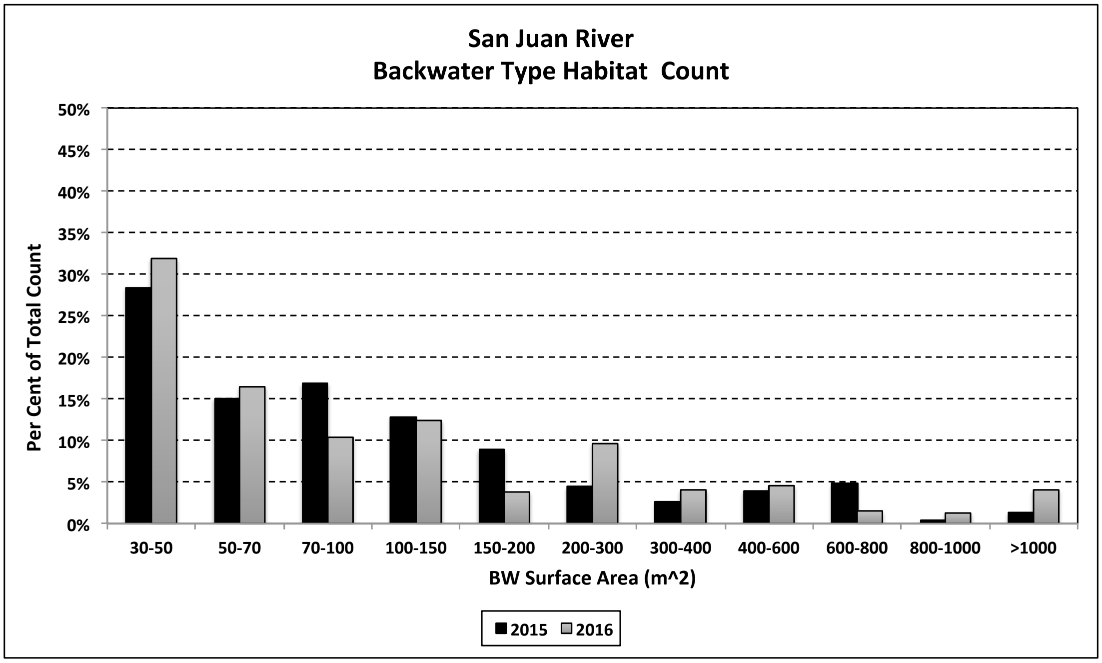


Figure 8: An example of a secondary channel split that was blocked by cobble and produced a large backwater at River Mile 119 in the San Juan River during baseflow conditions of 730 cfs.



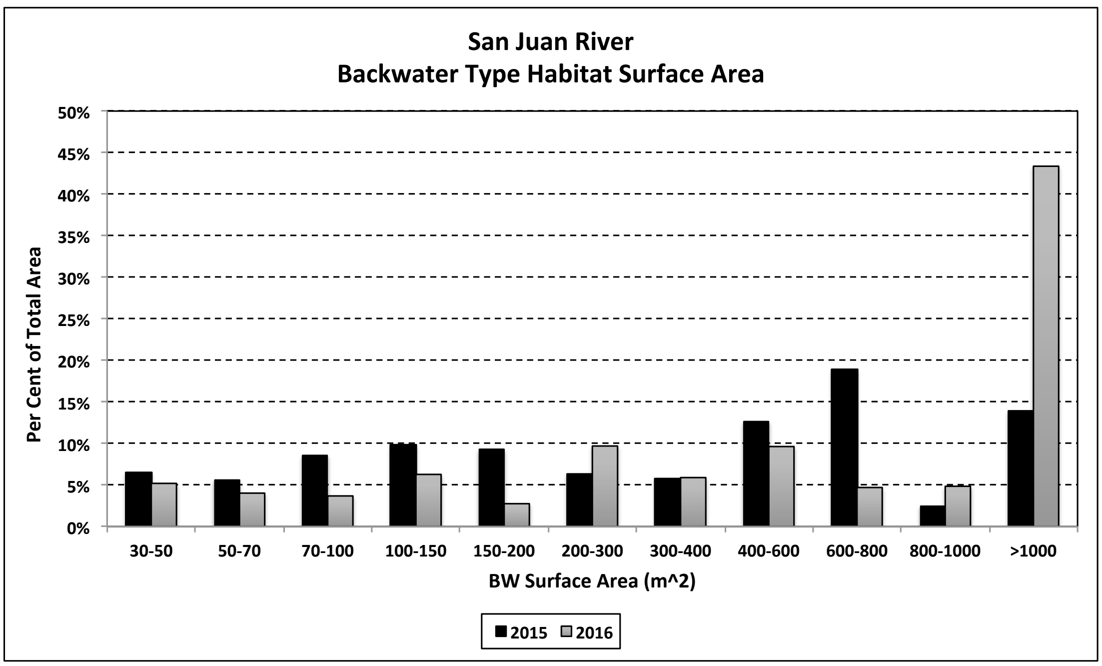


Figure 9: The distributions backwater sizes based up total counts (above) and total area (below) in the San Juan River at a baseflow of 730 cfs in 2016.

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Appendix A: Response to comments

Tom Wesche:

How about the large pulse (25,000 cfs) that occurred right before sampling?
The large storm event that pulsed in the watershed right before the river was flow was theorized to have deposit large amounts of silt and sand into the river from tributaries mainly around Shiprock.

Relating results for 2016 to years other than 2015?
An extensive historical review and analysis was conducted through the 2015 mapping and it is believed that the current data may not add new insights. Also, a new approach is currently underway with the help of the PO. That analysis does use the data through 2016 including the historical mapping. The results of this analysis will be reported in 2017.

Importance of these results for habitat comparing rearing and recruitment?
While we do think that the presence of high numbers of large backwater and embayment areas is important to the recruitment and rearing of the endangered fishes, the integration of the various fisheries projects data currently underway will require more time. That effort was beyond the scope of this monitoring report. It is our opinion that the program should accept proposals from the P.I's for in-depth integration of habitat and fisheries data.

Relate findings to other hydraulic and geomorphic variables?
Our approach was to look at the two years (2015 and 2016) and evaluate the hydrologic differences given their similarities. The 2016 hydrology produced major habitat differences compared to 2015 hydrology.

Relate to other studies form the literature?
Moving forward we will make a greater effort to integrate with other literature and ongoing upper basin projects.

Are there other recommendations you could make about other studies the program could conduct to quantify the benefits of what you observed in 2016?
We feel that the most important process moving forward is the observance of the effects of the 2017 hydrograph given that 2017 will be the first back to back high flow events since the early 1990s.