San Juan River Basin Recovery Implementation Program Annual Habitat Monitoring Report: 2012

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INTRODUCTION

During the data integration process of 2004–2005, it became evident that backwater habitat types during base flow periods (800-1200 cfs) had reduced in number and surface area since September 1995. Backwater surface areas between RM 180 to 2 decreased from 140,000 m^2 in September 1995 to less than 20,000 m^2 by October 2003. Between 2005 ~~to~~ and 2007, backwater surface areas stabilized at approximately 40,000 m^2.

Several hypotheses have been proposed as possible causes; including channel simplification, secondary channel abandonment, or lack of high runoff flows. Additionally, the Channel Morphology Monitoring Program (specifically the across-stream transects) indicated a slightly narrower, deeper channel, which could have lead to channel simplification as a potential mechanism.

The data integration analysis in 2005 also indicated that complex channel reaches (those with high habitat diversity, islands, multi-threaded channels, and complex channel margins) correlated to native fish abundance. Furthermore, the captures of young-of-year (YOY) endangered fish also tended to be correlated with channel complexity. Finally, backwater and low-velocity habitats were more likely to occur in reaches with high complexity. As a result, two detailed reaches were identified for short-term monitoring in the San Juan River during the summer of 2006 through 2010. The goals of this study were to better understand the mechanism or process for creation and maintenance of these complex reaches, and to understand the processes resulting in the loss or creation of backwater habitat important for the rare and native fishes in the San Juan River.

To the greatest possible extent, habitat monitoring in these locations was closely coordinated and integrated with Fish Community Monitoring to allow assessment of changing habitat availability and fish use in response to management actions and population recovery.

The Habitat Monitoring Program for the San Juan River was revised for the 2011 Program Monitoring Plan. The Plan is designed to monitor and evaluate habitat changes through time. The data and information from the Habitat Monitoring Program is intended to be integrated with other monitoring activities (native fish population estimates and nonnative fish population abundances) to allow assessment of the efficacy of management actions, such as flow management. A focused habitat monitoring workshop was held in January 2012, the purpose of which was to evaluate, refine, and improve habitat monitoring and mapping work on the San Juan River. The workshop aimed to ensure that the program was implementing methodologies that were conducive to answering outstanding questions, and was providing the data necessary to evaluate and revise the SJRIP's flow recommendations. The data presented herein is a summary of the habitat data collected as part of the current long-term monitoring program.

PROJECT OBJECTIVES

The specific objectives of this project correspond to the overall objectives of the long-term monitoring protocols. Specifically the direct linkage of project objectives and protocol objectives include:

> **Objective 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.
>
> **Objective 2:** Develop relationships between habitat availability and antecedent flow conditions. Use key habitats for this analysis.
>
> **Objective 3:** Track long-term trends of habitat availability.

METHODS FOR ANNUAL HABITAT MAPPING

Utilizing Bureau of Reclamation staff, a helicopter using a high-resolution color digital video recorder acquired high-resolution images of the San Juan River from approximately the confluence of the Animas River (Rm 180) to the Clay Hills takeout area (Rm 2). The river was flown on September 21 and September 22, 2011 at flows of 1070 cfs and 840 cfs, respectively, as gaged at the Four Corners USGS Station (No. 09371010).

Using ESRI Arcmap 10.0, digital images were photo grabbed and subsequently overlaid on 2011 geo-referenced National Agriculture Imagery Program (NAIP) county mosaics for the full extent of the river floodplain boundaries. Each individual image was geo-referenced and rectified by first acquiring a minimum of 10 ground control points (GCP) (using the NAIP images as references), then transforming the video photo grabbed images using a 3rd order polynomial or spline raster transformation program. This transformation process optimized the GCP local control point accuracy. Each individual image was rectified with a minimum of 20% overlap with the previous up-river image. The end product was a collection of geo-referenced, high-resolution (0.1 meter) images of the San Juan River (Figure 1).

The initial total wetted area for the San Juan River was determined by using the editor program within Arcmap and the aforementioned rectified, high-resolution images. Using the polyline function, a vector image of the water's edge was created for each geomorphic reach in the San Juan (Figure 2). These vectors were then transformed into a large reach-specific polygon where a 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. Once delineated, these areas were subtracted from the total wetted area to find actual wetted area for each reach in the system. Island structures were delineated per mile and uniquely identified as part of the comprehensive data set.

Figure 1. An example of geo-referenced high-resolution images used in the analysis (River Mile River Mile 69.

Figure 2. An example of a habitat identification and delineation vector image used in the analysis (River Mile 69).

Backwater and embayment habitat types were also delineated using the same polygon-editing tool mentioned above, creating an individual vector image for each habitat (Figure 2). Habitats were first identified using the wetted edge vector image, then observed with the high-resolution image to ensure accurate habitat identification. All pertinent habitat and island structure locations, individual identifications, and areas were exported from Arcmap into Microsoft Excel for analysis.

RESULTS

The Bureau of Reclamation photographed the San Juan River between RM 180 and RM 2 on September 21 to 22, 2011. The flow hydrograph and the fight dates can be seen in Figure 3. The flows on the September flight dates were 840 – 1070 cfs as measured at the Four Corners USGS gage.

In addition, the characteristics of this hydrograph (Table 1) were determined. These antecedent conditions (prior to mapping) were used in the analysis to address Objective 2 of this project.

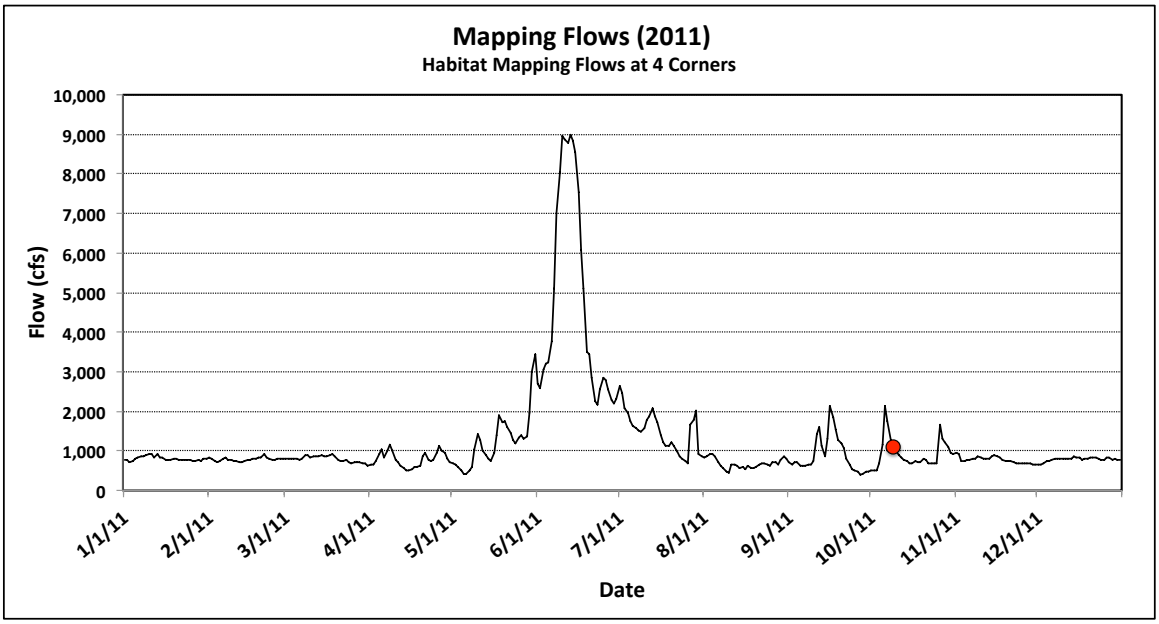


Figure 3. The hydrograph at the Four Corners USGS gaging Station (No. 09371010) in 2011. The red dot represents the flight dates/flows.

Table 1. The antecedent flow conditions for the 2011 hydrograph as measured at the Four Corners gaging station (No. 09371010).

Peak Runoff (cfs):	**8,980**
Runoff (March-July, acre-feet):	**545,803**
Total Runoff (Annual, acre-feet):	**871,147**
Peak Date:	**June 13**
Number of Days >10,000 cfs	**0**
Number of Days >8,000 cfs	**7**
Number of Days >5,000 cfs	**12**
Number of Days >2,500 cfs	**27**

TOTAL WETTED AREA

The total wetted area analysis is conducted as a check against photographic/mapping bias. A flow-total wetted area regression relationship had been developed based upon paired historical imagery and field mapping data sets for the same reaches of the San Juan River (Rm 2-180) as this study. Using a desktop interpretation without field verification could have resulted in an unexplained variation from this relationship. As a check against bias, the total wetted area as mapped in 2011 and the mapping flow was compared to the historical data. The results of this comparison can be seen in Figure 4. The 2011 data fall within the variation experienced by the field data mapped at flows less than 1000 cfs. This indicates that the rectification of the video imagery and the subsequent mapping methodology is as accurate as the historical field verification and post image processing.

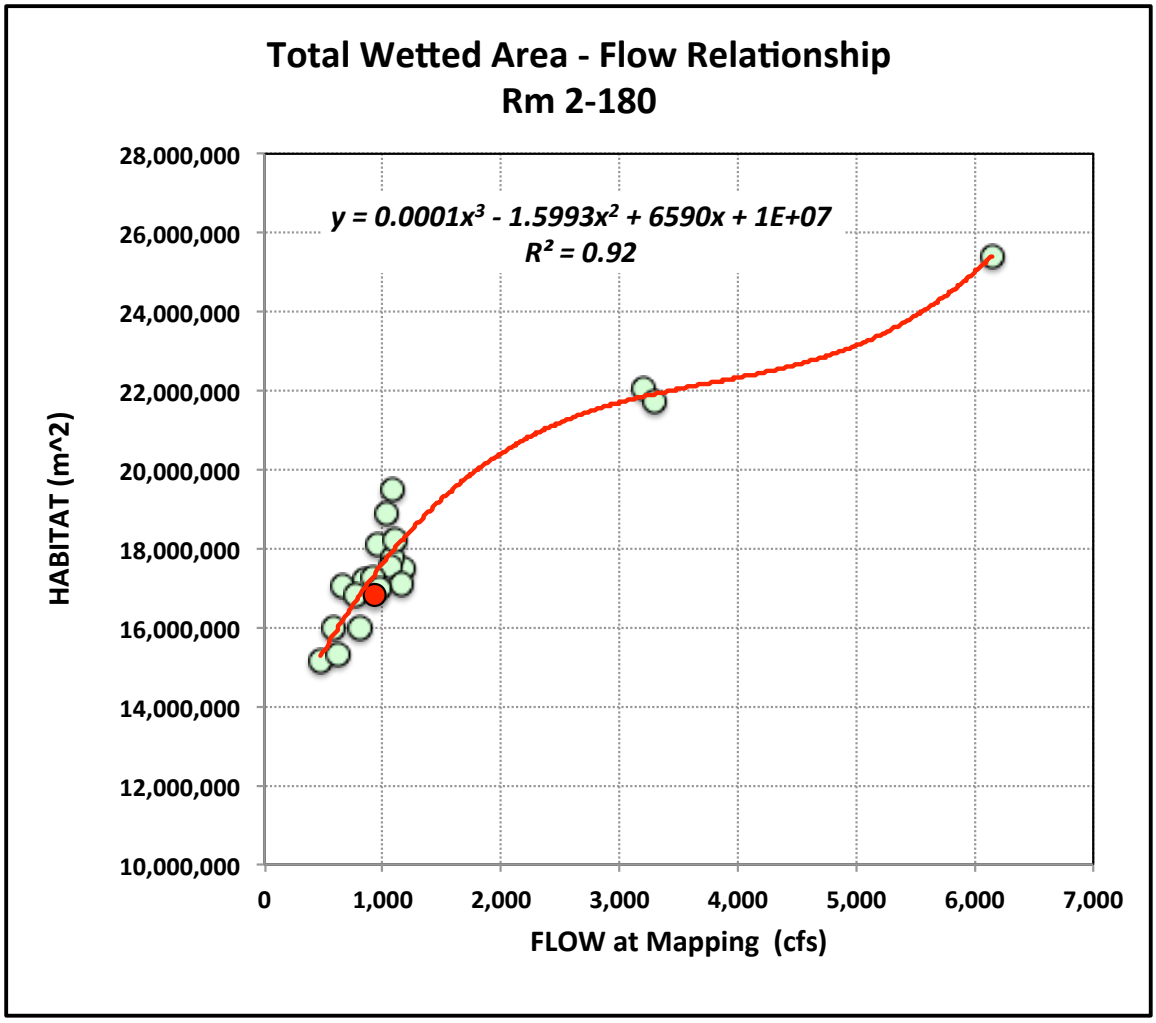


Figure 4. The total wetted mapped area (m^2) vs. flow at mapping (cfs) is compared to the 2011 data (red dot).

BACKWATERS AND EMBAYMENTS

The backwaters and embayments were mapped within the total wetted area perimeter. Data was summarized by river mile as well as by river reach. The spatial distribution of backwater surface area, count, and average size by river mile can be seen in Figure 5.

The data indicate that the highest surface area and densities (via counts) were found in the lower 16 miles of the San Juan River. Although the average surface area of each backwater in the lower 16 miles was only 50 m^2, in total it represented 16,700 m^2 of backwater surface area (29% of the river-wide total). In the non-canyon reaches of the San Juan River (3-6), large backwater complexes were found in eight separate river miles with total surface areas of over 1000 m^2/mile. The highest was found in Rm 134 (5,355 m^2). Fourteen individual river miles had no backwaters. In the 2011 mapping, the river-wide total surface area of backwaters was 57,991 m^2 summed over 1,034 individual locations.

Embayments are habitat features that represent the same low-velocity areas as backwaters, but their entrance into the main channel faces upstream rather than downstream, as do backwaters. Embayments represented only 14% of the surface areas of the total backwater type habitats (9,795 m^2). Highest densities were found between Rm 67 and 100 (Figure 6). This is in reach 3 of the river where the stream gradient is the lowest.

The counts of embayments averaged only 2 per mile (compared to 6 per mile for backwaters), however, ten individual river miles exceeded a total surface area of 200 m^2 per mile (Figure 6). The highest was found at Rm 79 with a surface area of 1040 m^2 per mile. Thirty-three individual river miles had no embayments. These river miles with no embayments were uniformly distributed throughout the river system.

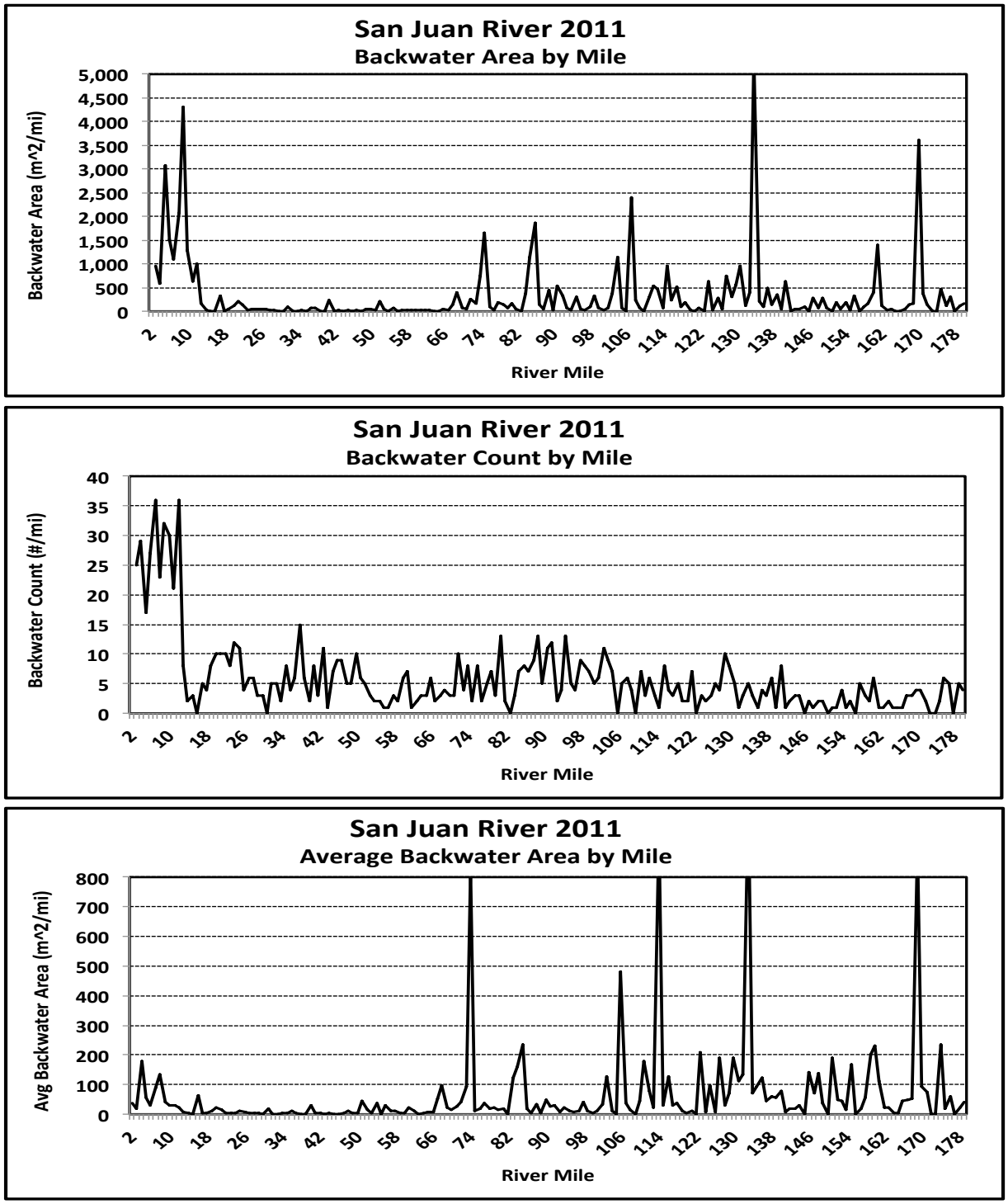


Figure 5. The spatial distribution of backwater area (above), count (middle), and average size (lower) in the San Juan River for the September 2011 video mapping.

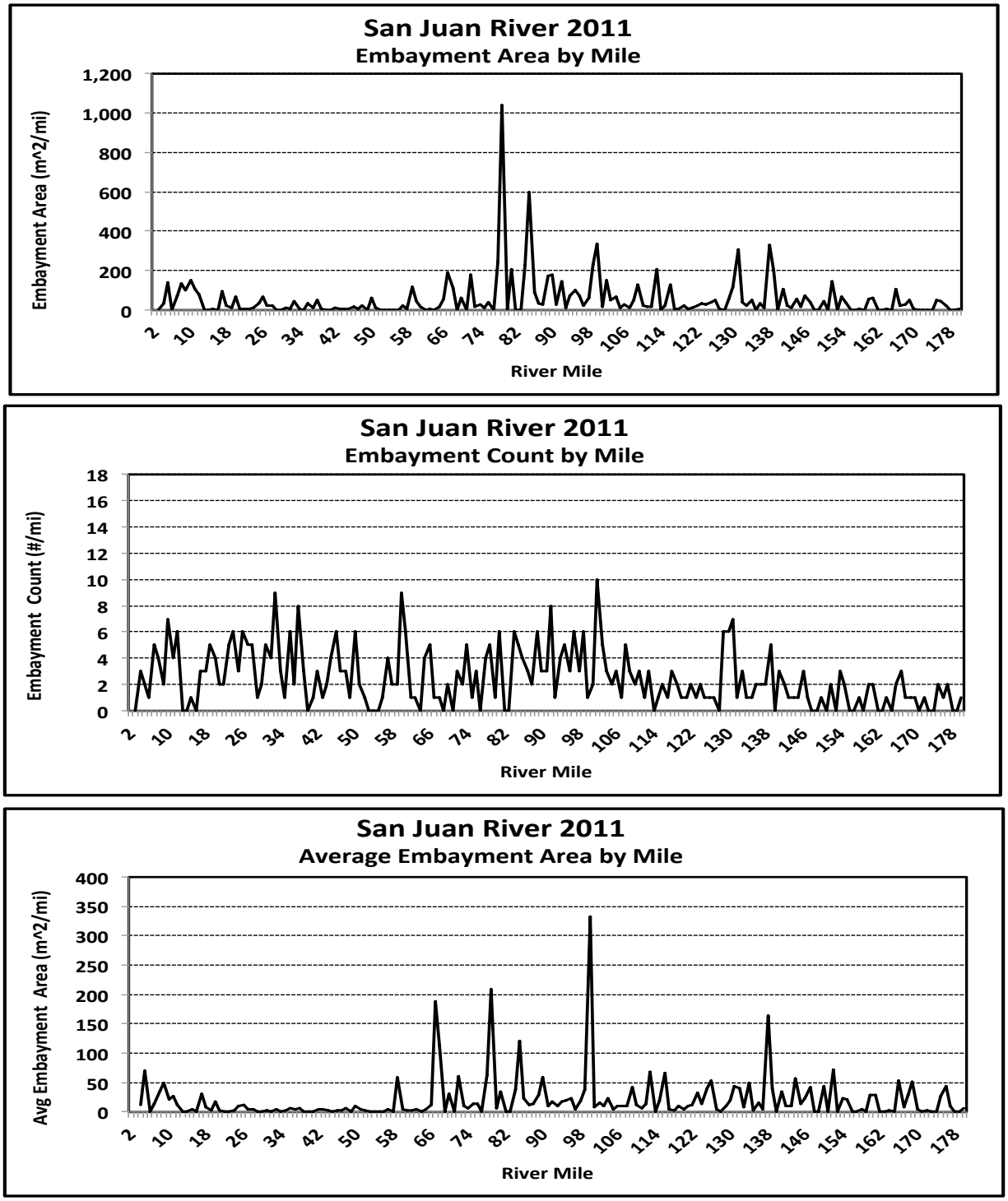


Figure 6. The spatial distribution of embayment area (above), counts (middle), and average size (lower) in the San Juan River for the September 2011 video mapping.

HISTORICAL COMPARISON OF TOTAL BACKWATER TYPE HABITATS

The last river-wide habitat mapping occurred in November 2007. As a comparison to this historical data, the sum of the embayments and backwaters per mile (defined as backwater type habitats) were compared to these same habitats from 2007. The resulting analysis can be seen in Figure 7. The lower graph of habitat counts clearly shows that the mapping in 2011 found a much higher number of backwater type habitats compared to 2007. The increase was found to be river-wide with an average increase of over 7 backwater types per mile.

The comparison of the surface area differences between the two years (Figure 7) showed major gains in 2011 for both the lower 16 miles of the river, and between Rm 67 and Rm 110. Losses were seen between Rm 113 to Rm 132, when compared to 2007. Overall, a river-wide gain in backwater type habitats occurred with an increase in 20,800 m^2 of habitat. This represents an increase of 44% over the 2007 densities.

A longer historical perspective can be obtained by comparing the annual baseflow Habitat Monitoring that occurred between 1995 and 2007 in the fall of each year, to the 2011 data. These data for the sum of embayments and backwaters by river reach are shown in Table 2, as well as Figure 8.

Historically, the largest amount of backwater type habitats measured during baseflow occurred in fall 1995 and winter 1996. From the fall of 1996 to the fall of 2003, backwater surface area substantially decreased from a river-wide high of 145,969 m^2 to a low of 20,294 m^2 in 2003 (86% decrease). Since 2003, backwater habitat area has been increasing annually, reaching a post 2003 high in 2011 of 67,786 m^2. This represents the largest backwater density since the winter of 1996.

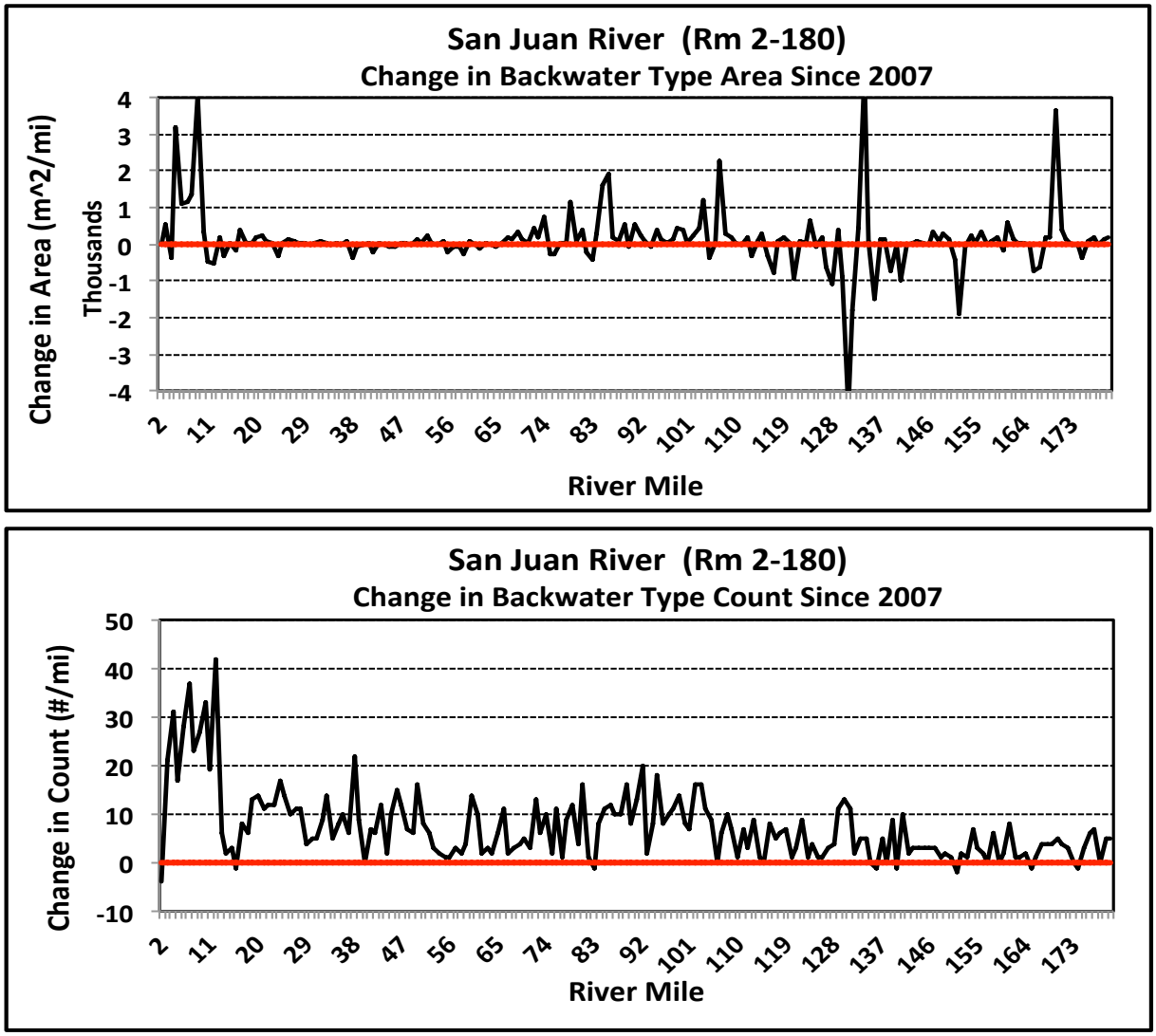


Figure 7. The comparison of the sum of embayments and backwater by river mile between 2007 and 2011. Positive values indicate gains since 2007, while negative values are losses since 2007. Both differences in area (above) and counts (below) are shown.

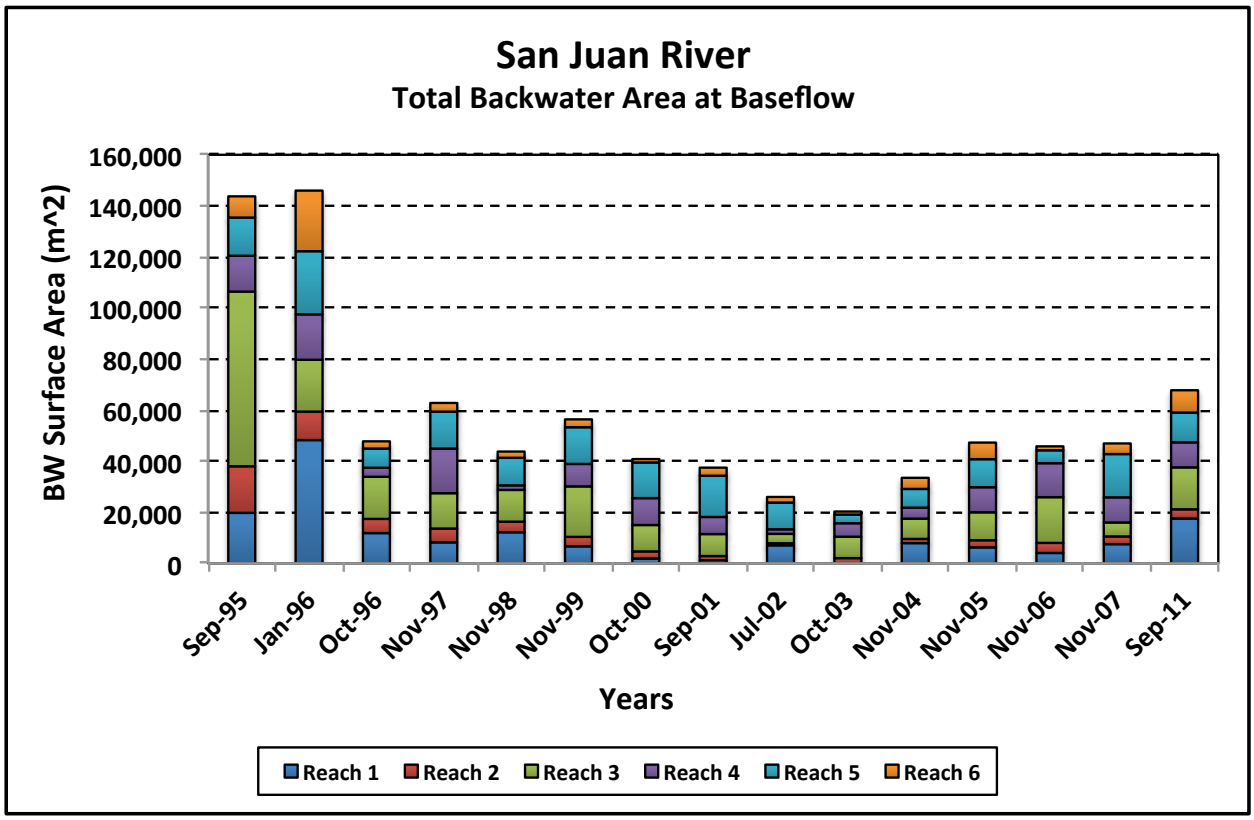


Figure 8. The densities of backwater type habitats by year and geomorphic reach for the San Juan River. Data were collected during fall baseflow.

Table 2. A summary of the surface areas of backwater type habitats found in the San Juan River annually from 1995 to 2007, compared to the recent data collected in 2011. Data are grouped by geomorphic reach or canyon/non canyon reaches. A river-wide summary is also included. Flows at mapping were less than 1400 cfs, and thus represent a baseflow habitat density.

REACH	RIVER MILES	Sep-95	Jan-96	Oct-96	Nov-97	Nov-98	Nov-99	Oct-00	Sep-01	Jul-02	Oct-03	Nov-04	Nov-05	Nov-06	Nov-07	Sep-11
1	2-16	19,769	48,269	11,862	8,224	12,173	6,670	1,886	1,235	7,057	0	7,926	6,261	4,063	7,521	17,549
2	17-67	18,249	11,152	5,547	5,399	4,151	3,703	2,784	1,631	815	2,060	1,631	2,791	3,948	3,025	3,617
3	68-105	68,406	20,300	16,473	13,860	12,433	19,761	10,339	8,608	3,667	8,359	7,952	10,937	17,913	5,453	16,415
4	106-130	14,029	17,797	3,540	17,452	1,784	8,797	10,543	6,694	1,809	5,296	4,293	9,822	13,306	9,847	9,805
5	131-154	14,971	24,723	7,519	14,473	10,796	14,375	13,951	16,152	10,453	3,378	7,336	10,990	5,047	16,958	11,662
6	155-180	8,299	23,727	2,838	3,400	2,439	3,075	1,333	3,153	2,191	1,201	4,362	6,494	1,540	4,148	8,738
Canyon	2-67	38,018	59,421	17,408	13,623	16,325	10,373	4,669	2,866	7,872	2,060	9,557	9,052	8,011	10,546	21,166
Non-Canyon	68-180	105,704	86,548	30,371	49,185	27,452	46,009	36,165	34,607	18,121	18,234	23,943	38,243	37,805	36,406	46,620
River Total	2-180	143,722	145,969	47,779	62,808	43,776	56,382	40,835	37,473	25,993	20,294	33,500	47,296	45,817	46,952	67,786

ISLANDS

The data integration analysis in 2005 indicated that complex channel reaches corresponded to those areas with islands or multi-threaded channels and complex channel margins.

This analysis used the habitat mapping data collected during the research and monitoring periods. The results are shown in Figure 9. They indicate that there is a significant relationship between the number of islands per mile and the habitat richness per mile (expressed as the total number of individual habitats per mile). Because of this relationship and the follow up work completed on several complex reaches between 2006 and 2010, it was decided that the Habitat Monitoring Program should track island count and area as part of the monitoring program as a surrogate for river complexity.

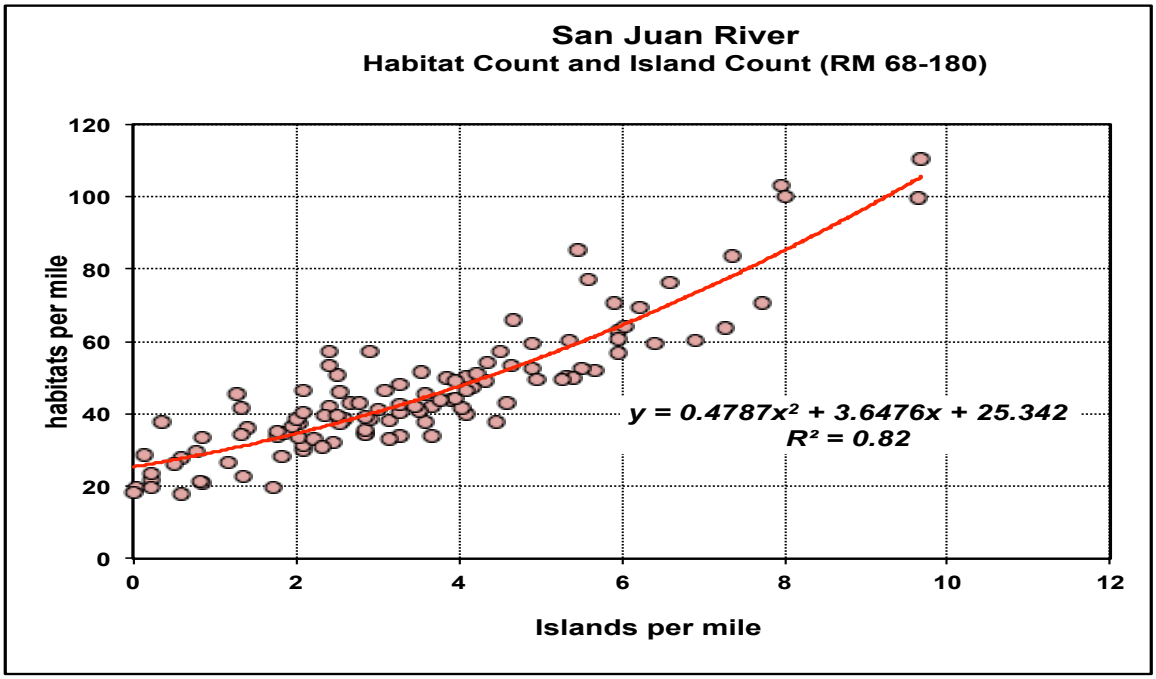


Figure 9. The relationship between the number of islands and the concurrent number of habitats in that same river mile in the non-canyon reaches of the San Juan River. Data are for a base flow time period.

ISLAND AREA, COUNT, AND AVERAGE SIZE

In 2011, islands were delineated as part of the Habitat Monitoring Program. The results of the spatial distribution of this river feature can be seen in Figure 10. Because there are no islands in the canyon reach of the San Juan River, the data start at Rm 68 and continue upstream to Rm 180. Nineteen individual river miles had island complexes greater than 100,000 m^2, with the largest surface area comprised of eight islands found in Rm 153 (1.221 million m^2). A second large complex of four islands

was found in Rm 140, having almost 1.0 million m^2 of surface area. Eighteen river miles had no islands (Figure 10). During the 2011 mapping, 300 islands were found with an average size of 21,400 m^2.

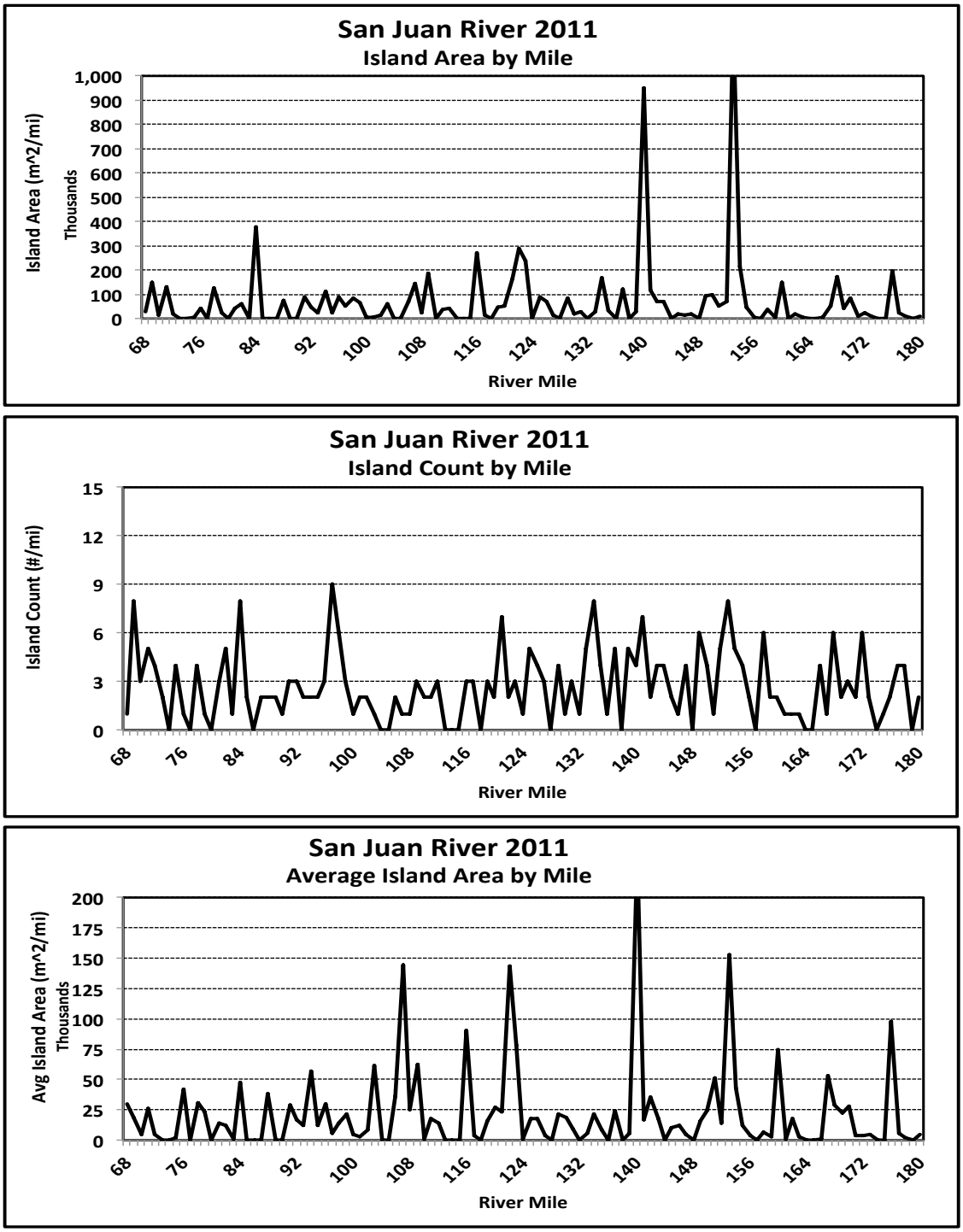


Figure 10. The spatial distribution of island area (above), island count (middle), and average island size (lower) per river mile in the San Juan River. Data were collected in September 2011 during fall baseflow.

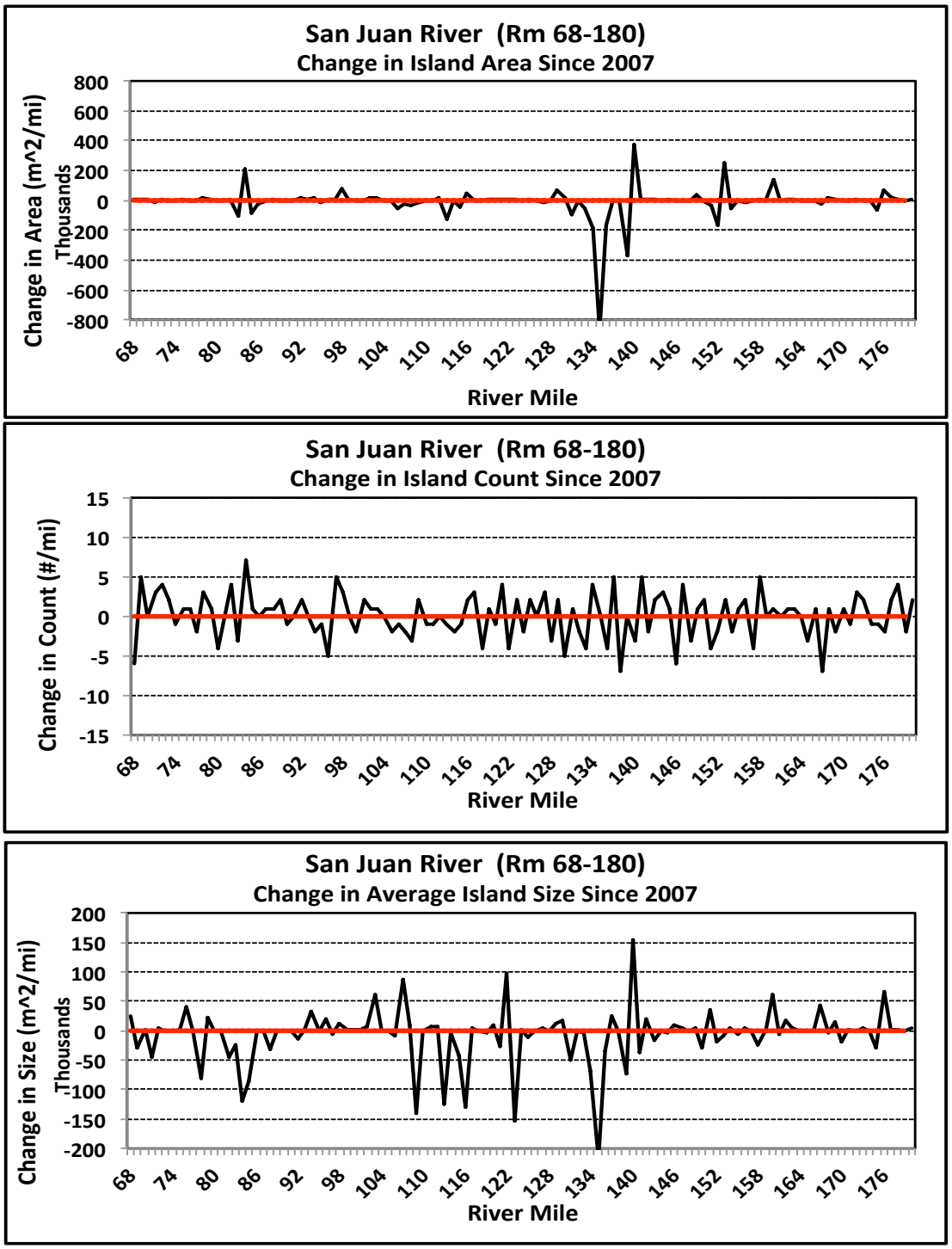


Figure 11. A comparison between 2007 and 2011 data for islands in the San Juan River in the non-canyon area. Data are for area (above), count (middle), and average island size (below) by river mile. Data are for November 2007 and September 2011. Positive values indicate a gain in 2011, while negative values represent a loss in 2007.

Using the most recent river wide mapping data (2007), the 2011 data was compared by river mile for total area, total count, and average island size. In Figure 11, a positive response indicates that that the island parameters were greater in 2011 when compared to 2007 for that river mile. What is immediately evident is that in 2011, almost 1.3 million m^2 of islands were lost between Rm 133 and 136. The reason for this loss is unclear, however, throughout the remainder of the river the additional loss of islands was offset with island gains in 2011. The net result between 2007 and 2011~~,~~ was a loss of 1.13 million m^2. The island counts compared to 2007 reflect this gain and loss of islands throughout the river course (Rm 68-180). The change in island density from 2007 to 2011 ranged from plus or minus five islands per mile (Figure 11 middle).

The long-term trend in total annual island area, count, and average island size between 1995 and 2011 can be seen in Figure 12. The total island area in the San Juan River has ranged between 6.9 million m^2 (January 1996) and 11 million m^2 in November 2005. The total island area has shown a decreasing trend since the high in 2005.

The historical trend in total river-wide island counts has been a steady, annual decline from a high of 339 islands in November 2007 to a low in October 2003 (182). From October 2003, the island counts have uniformly increased with time. The 2011 island counts have continued this trend, increasing the number of islands from 295 in 2007, to 300 in 2011.

The average island size over time has shown three distinct patterns. Initially, average island size was approximately 48,000 m^2 in 1995 and 1996. In 1997, the average size dropped to about 30,000 m^2 and remained at that level until 2004. In 2005, the average size again increased to 48,000 m^2, but has steadily declined since that high. The 2011 data has continued that trend with the average size now at its lowest level (25,000 m^2) since 1995.

ISLAND PERIMETER

In addition to island area, count, and average size, the spatial trend in island perimeters per mile and historical trends were determined. An investigation of the summed total of island perimeters can be considered as a surrogate for additional wetted edge provided by the presence of the islands. This data can be seen in Figure 13. In 2011, there were 172,380 linear meters of additional river's edge because of islands in the San Juan River. This represented an average of 1,540 meters per mile from Rm 68 to 180. The historical trend in this parameter can be seen in Figure 14. A high of 200,000 linear meters was measured from the mapping data for 1998. Since that time, the linear edge attributed to the presence of islands in the San Juan River has remained somewhat stable, ranging from 124,000 to 185,000 linear meters. Compared to 2007, the river lost 1,582 linear meters in 2011.

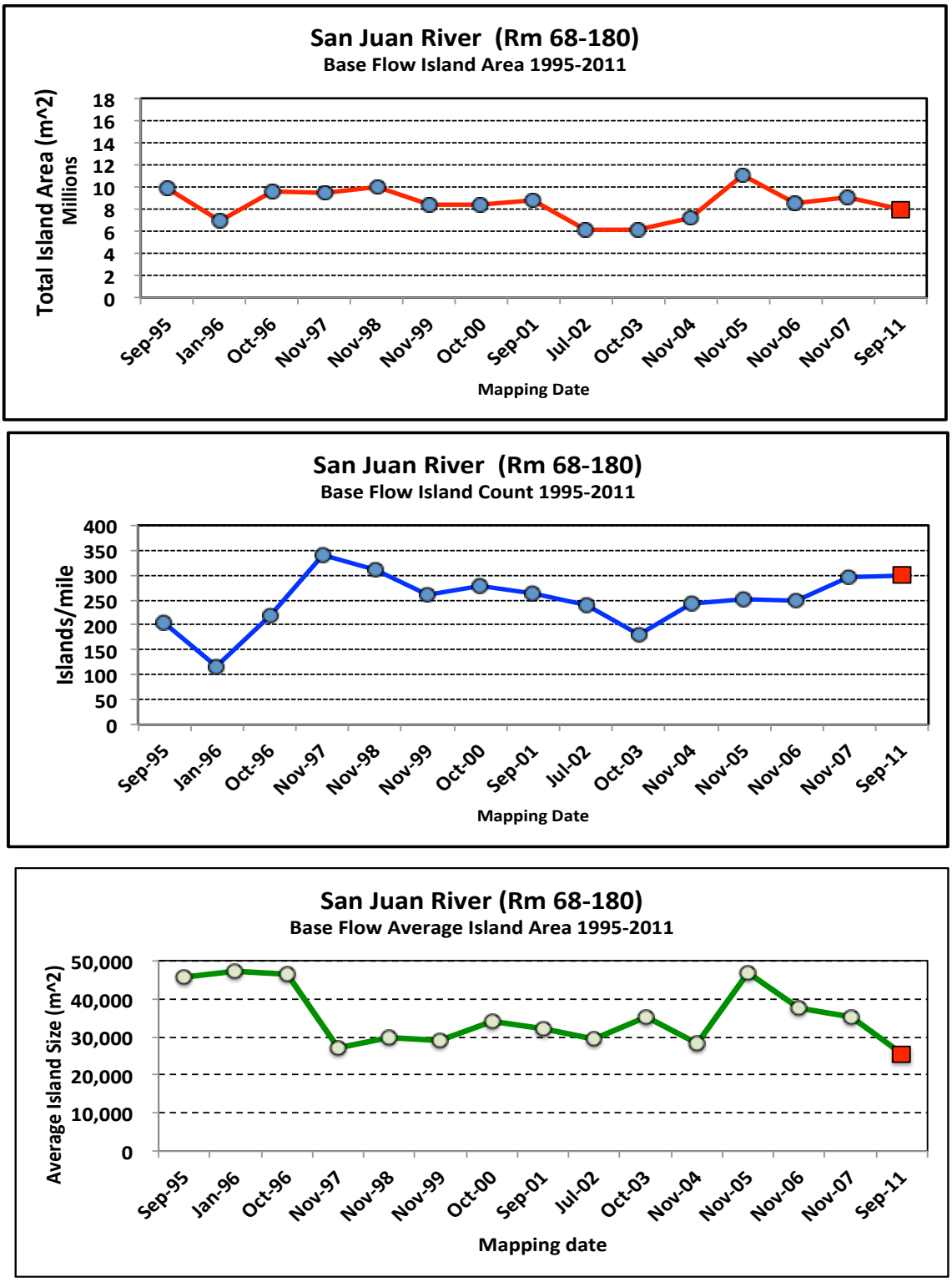


Figure 12. The long-term trend in island area (above), island count (middle), and average island size (lower) for the San Juan River between 1995 and 2011 for Rm 68 to 180.

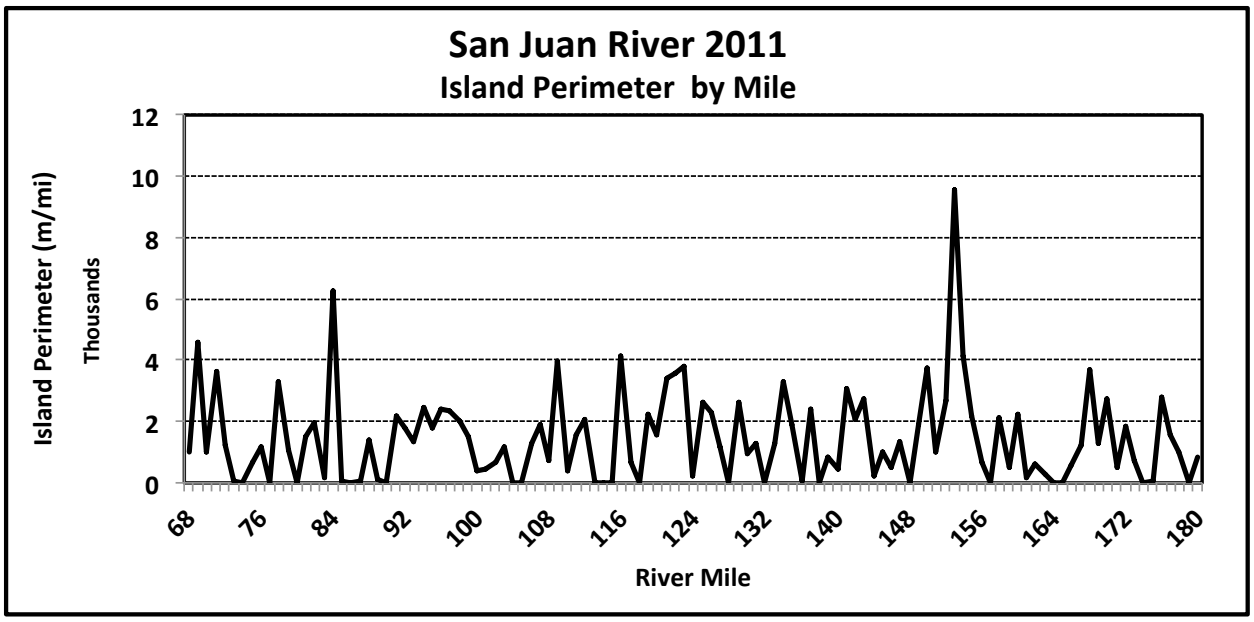


Figure 13. The spatial distribution of the total perimeters of all islands within a river mile in the San Juan River in 2011. The data are for Rm 68 to 180.

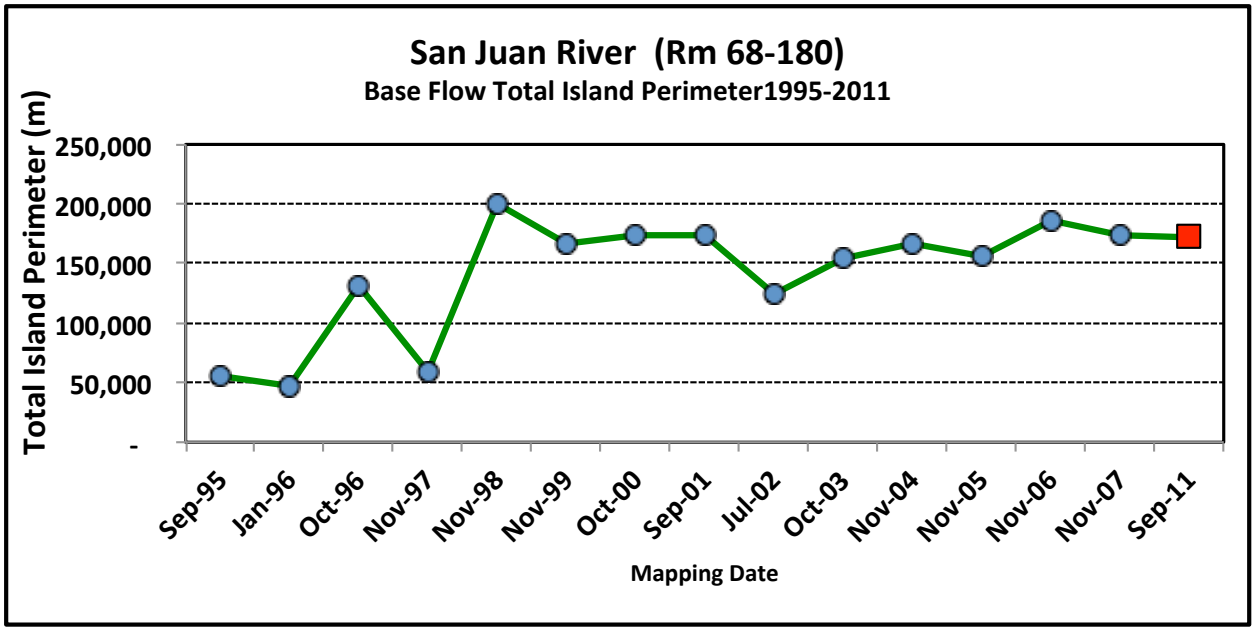


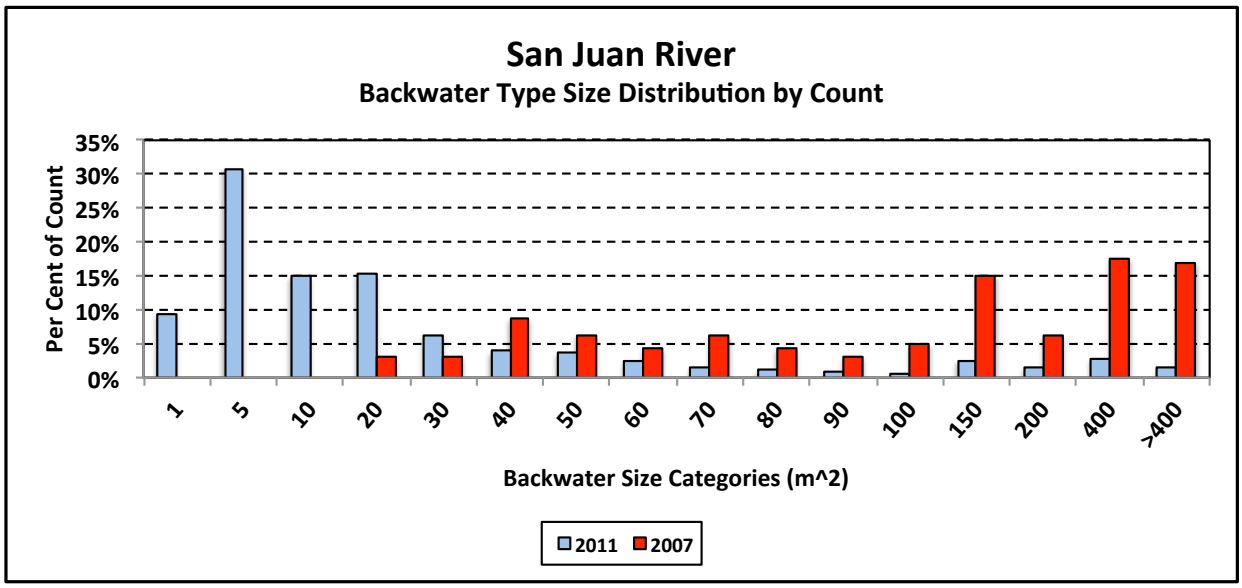
Figure 14. The temporal changes in total linear edge of all islands in the San Juan River from 1995 to 2011. Data were collected at base flow.

DISCUSSION

In 2011, a new methodology for habitat mapping was employed relative to the field mapping undertaken in previous years. This new approach has allowed the Habitat Monitoring Program to map at a resolution of approximately 10 centimeters (compared to over 1 meter in past efforts). This has led to the mapping of smaller backwater type habitats and smaller islands than in previous years, and the effects can be clearly seen in Figure 15.

Using 2007 as an example, the smallest surface area of a backwater mapped was 20 m^2, but in 2011, almost 50% of the mapped backwaters were smaller than 20 m^2. Because 1,472 backwater type habitats were mapped in 2011 compared to 160 in 2007, this skewed the frequency distribution to smaller sizes (Figure 15, upper). Care should be taken when comparing the counts between the two years. A more accurate comparison would be to compare the number of backwater types greater than 30 m^2 between the two years. In that case, 433 backwater types were mapped in 2011, compared to 160 in 2007. Looking at the frequency distribution of the various sizes of backwaters (expressed in m^2) as they relate to the total summed area in each size category and expressed as a percent of total river-wide backwater area~~,~~ demonstrates that although the smaller backwaters were 55% of the total count, they were less than 5% of the total area. In terms of surface area, in both years backwater types greater than 400 m^2 represented 60-80% of the total surface area. Because of the similarities of the frequency distributions, using surface area in the comparison between years may be more realistic in terms of looking at temporal trends.

Islands were also investigated using a frequency distribution analysis. Island area, count, and perimeter were binned into size classes based upon surface area. In each case, the total area, count or perimeter was summed for all islands falling within each bin, and a frequency was calculated based upon the river wide total area, count, or linear perimeter. The results can be seen in Figure 16. The comparison between 2007 and 2011 data sets are very similar except for island counts in the smaller size categories. Most of the islands in this smallest size category were small islands located in secondary channels. These small islands did not register on the earlier videography. The frequency distributions of the island surface area and linear island edge were in agreement with the historical data collected in 2007 when compared to the 2011 data. This indicates that island area and island edge may be good parameters to track over time.



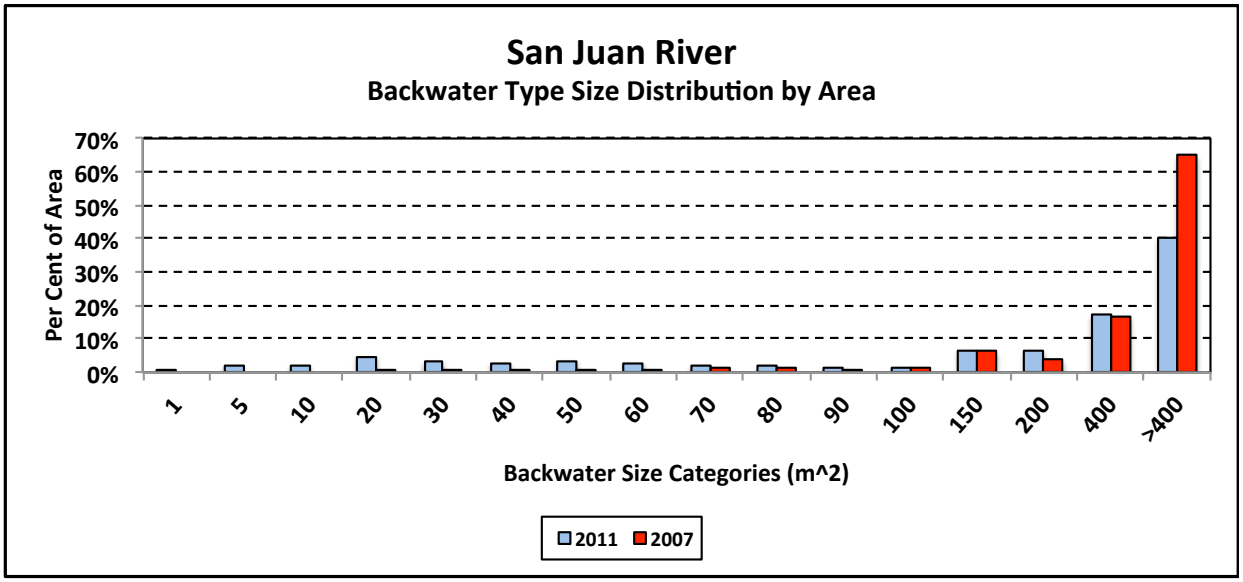
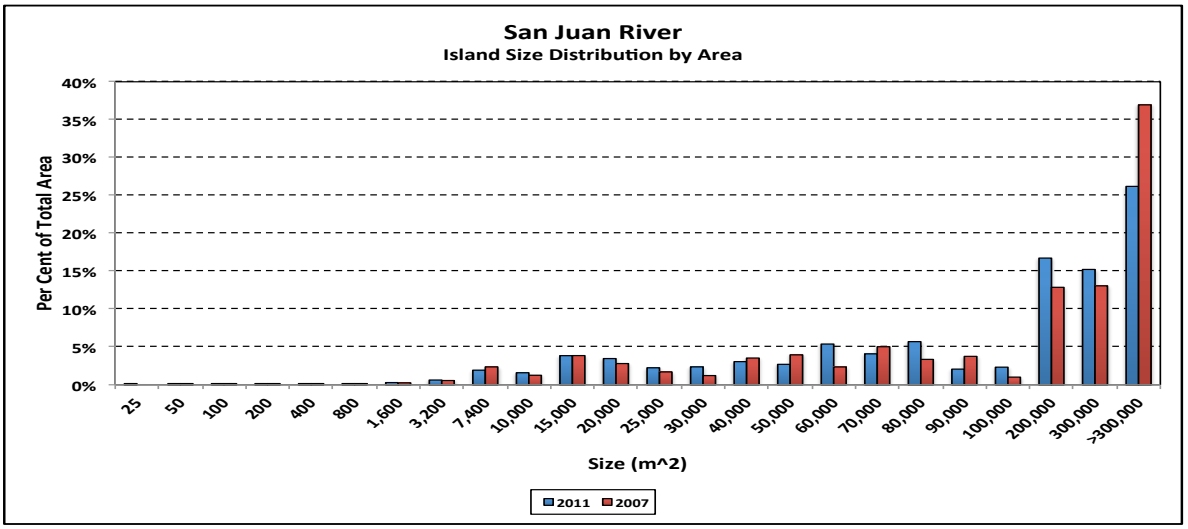
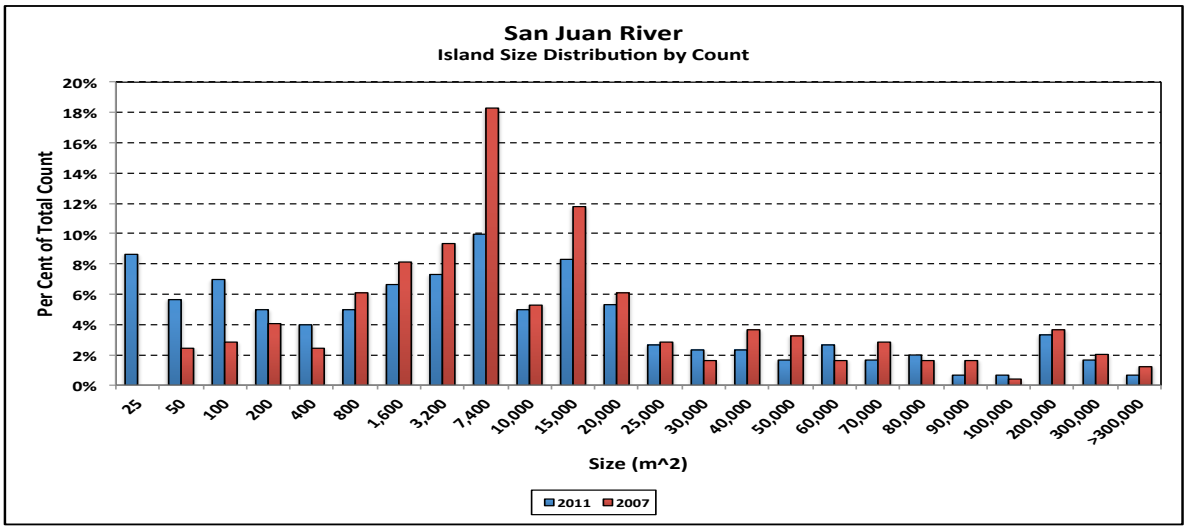


Figure 15. The frequency distributions of backwater types based upon count (above) and surface area (below). The bins are based on the sizes of backwaters expressed in m^2. Data are for Rm 2-180 in the San Juan River.





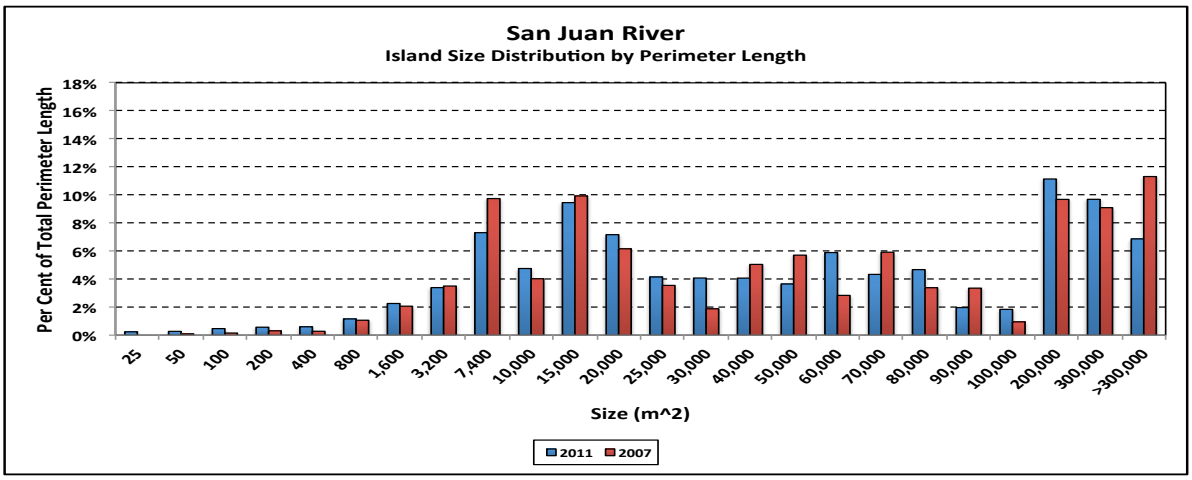


Figure 16. The frequency distributions of Island area (above), count (middle), and linear perimeter (below) based upon island size bins. Data are for Rm 68-180, in the San Juan River.

HABITAT AND ANTECEDENT FLOW CONDITIONS

One of the objectives of the Habitat Monitoring Program is to investigate the potential role of the antecedent flow conditions as they relate to the density of the habitats monitored. The datasets collected since 1991 relative to the habitats in the San Juan River can be used to retroactively look at characteristics of the San Juan River hydrograph, and compare these characteristics to fall, base flow habitat densities. An example of the hydrograph characteristics (antecedent flow conditions) was provided for 2011 in Table 1. Using the paired data from the backwater mapping and the previous hydrologic conditions since 1995, regression analysis was undertaken to look for potential relationships between antecedent flow conditions and backwater surface areas (Figure 17). Using a third degree polynomial fit, five of the six hydrologic parameters had r^2 values in excess of 0.93 with backwater surface area. Understanding the cause and effect in the relationships may prove problematic in that there are significant cross-correlations between the hydrologic parameters.

CONCLUSIONS

1) The methods employed in the 2011 habitat mapping proved to be effective in delineating backwaters, embayments, and islands.
2) The data was found to be comparable with past year efforts.
3) In the case of backwater and island counts, the new technology allows more resolution, and therefore the mapping of smaller sized habitats.
4) Island linear edge may prove to be a valuable parameter in the integration of biological data.
5) Five antecedent flow conditions produced strong polynomial relationships when compared to backwater surface areas.

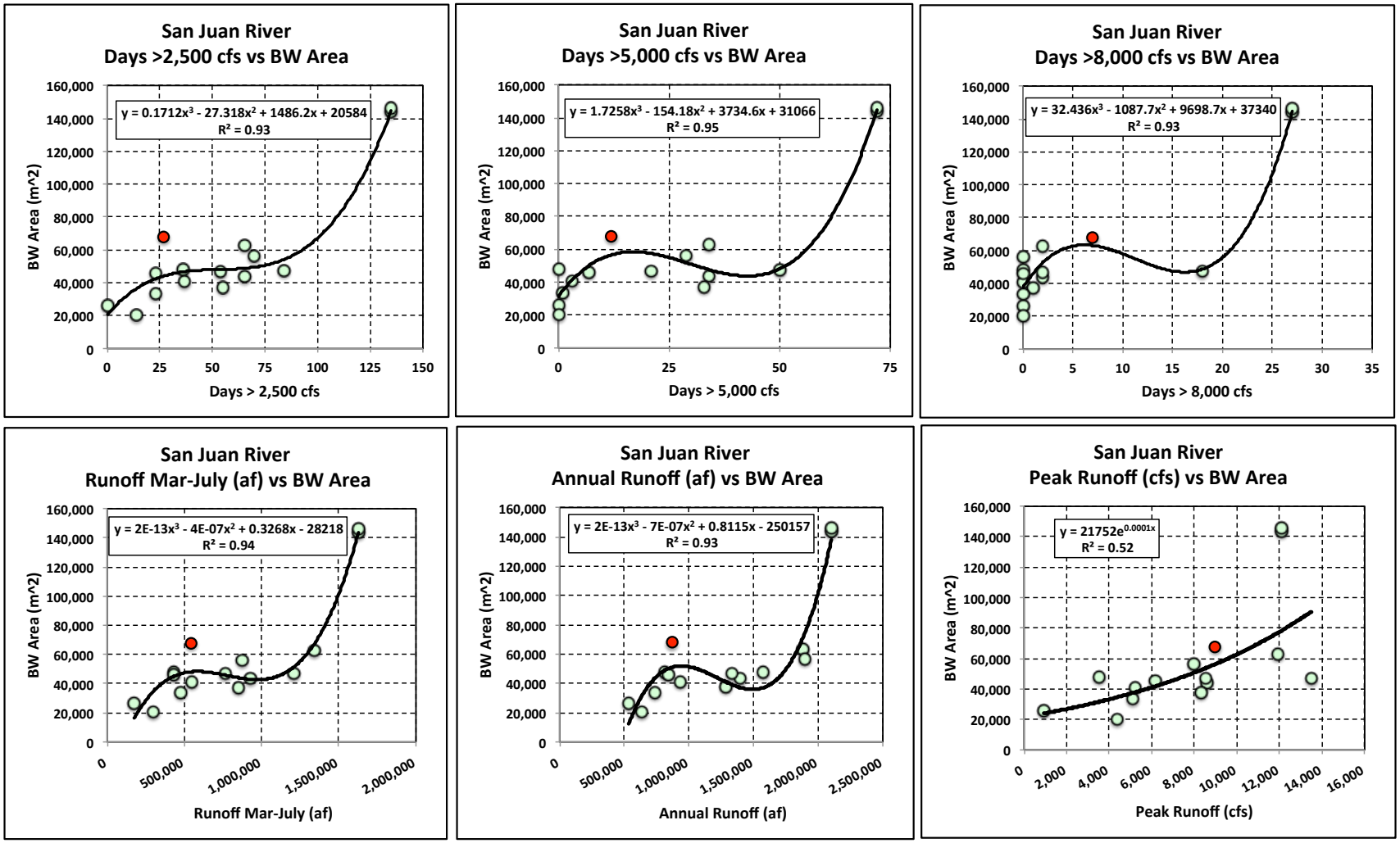


Figure 17. A series of non-linear regressions between antecedent flow condition parameters and backwater surface area. Data are from 1995 to 2011 in the San Juan River. Red sample points are the current data collected in 2011.