Monitoring Campsite Area in the Colorado River Ecosystem Downstream from Glen Canyon Dam: 1998 to 2000

Final Report

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Abstract

This study describes changes in the area available for camping on sandbars along the Colorado River in Grand Canyon National Park downstream from Glen Canyon Dam. We used a total station survey-based methodology to monitor camping area at thirty-one sites in October 1998, 1999, and 2000. Our method represents a new methodology in campsite monitoring in that area measurement accuracy is improved compared to previously utilized inventory and aerial photographic techniques.

Survey results show that high elevation (above the 707 m^3/s [25,000 ft^3/s] stage elevation) camp area decreased between each survey. From October 1998 to October 2000 high-elevation camp area decreased by 25%. Two near powerplant capacity releases (877 m^3/s [31,000 ft^3/s]) in the spring and fall of 2000, respectively, deposited sediment that resulted in increased mid-level (556 m^3/s to 877 m^3/s [20,000 ft^3/s to 31,000 ft^3/s] camp area, particularly within critical reaches (Hazel et al., 2001). However, despite mid-level camp area increases, camp area above the 707 m^3/s (25,000 ft^3/s) stage elevation decreased by 10% between 1999 and 2000.

Introduction

River runners and hikers use sand bars deposited along the Colorado River below Glen Canyon Dam (hereafter referred to as the Colorado River ecosystem) as campsites (Figure 1). Since closure of Glen Canyon Dam (GCD) in 1963, sand bars used as campsites have noticeably decreased in number and size (Schmidt and Graf, 1990; Kearsley et al., 1994; Webb, 1996). However, a deliberately released flood in spring 1996, termed the 1996 controlled flood, demonstrated that deposition of sand at high elevation can temporarily increase campsite number and size (Kearsley and Quartaroli, 1997). High flows, greater than power plant capacity (~900 m^3/s) can also potentially scour vegetation that has encroached into camping areas and rinse campsites of elements that decrease campsite quality (e.g. human impacts, litter, and ant colonies). Larger and more numerous campsites are present when flow in the river is low. Low flows expose more sandbar area, and in some cases expose campsites that are not available during relatively higher discharges.

Because of their crucial role in the recreational experience, the relative size, distribution, and quality of campsites along the river are of concern to river managers (U.S. Dept. of Interior, 1995). We use a total station survey-based technique to measure campsite area at thirty-one long-term sediment-monitoring sites (Kaplinski et al., 1995; Hazel et al., 1999), (Figure 1). Our method for determining area is similar to the methods of Kearsley and Warren (1993), Kearsley et al. (1994), and Kearsley and Quartaroli (1997), but improves on measurement precision. We also incorporate empirically derived stage-discharge relationships for each site that allows an analysis of campsite area changes within specific ranges of discharge.

Background

Previous monitoring studies of campsite area were conducted by Weeden et al. (1975), Brian and Thomas (1984), Kearsley and Warren (1993), Kearsley et al. (1994), Kearsley (1995), and Kearsley and Quartoroli (1997). These studies evolved from qualitative estimates of campsite carrying capacity to quantitative aerial photographic measurements. Weeden et al. (1975) and Brian and Thomas (1984) focused on

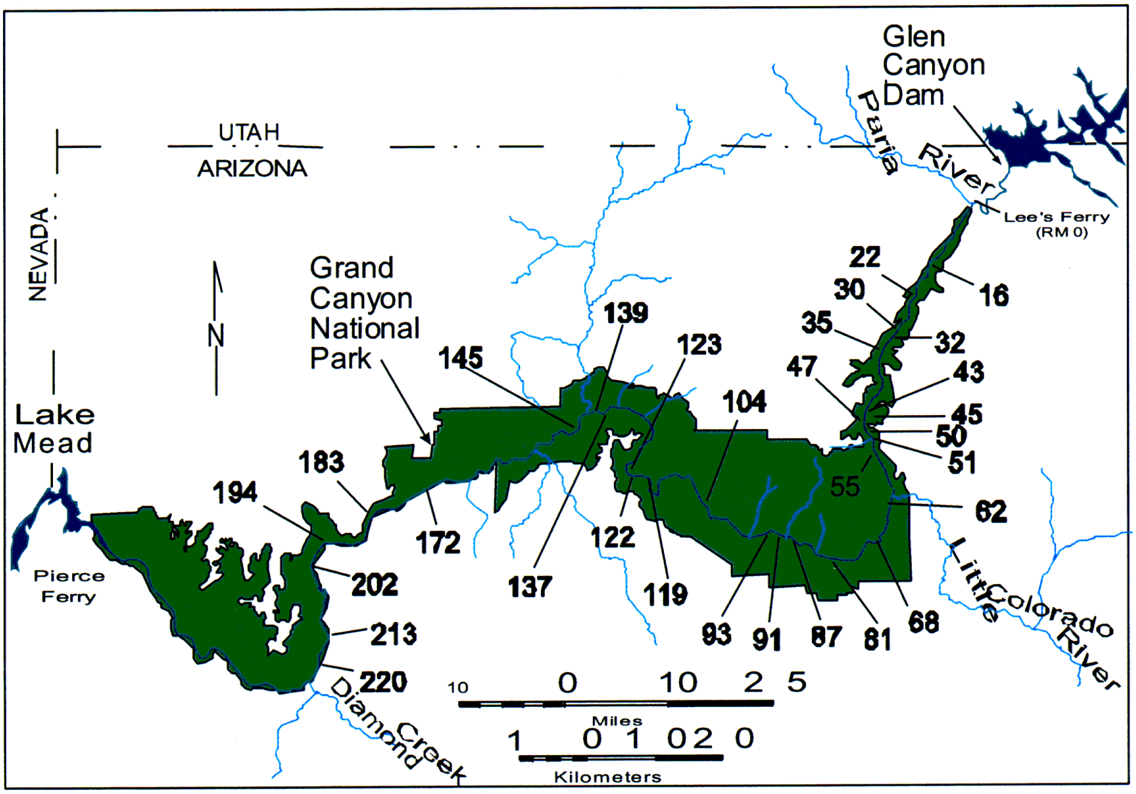

Figure 1. Map of study area showing the location of study sites. Shaded area is Grand Canyon National Park. Study site location is noted by river mileage (Stevens, 1983).

developing an inventory of the size and number of campsites throughout the river corridor. Both of these studies estimated the capacity of each site above the 679 to 792 m^3/s (24,000 to 28,000 ft^3/s) stage elevation, where capacity is defined as the number of campers that can occupy a campsite for an overnight stay. Kearsley and Warren (1993) repeated the inventory and improved the campsite area measurements by developing techniques to quantitatively measure camp area from aerial photography and videography. Kearsley and Warren (1993) also divided campsites between Lees Ferry and Diamond Creek into critical and non-critical reaches. A critical reach was defined as any contiguous stretch of the river in which the number of available campsites is limited due to geological characteristics, high demand due to attraction sites, or other logistical factors. Non-critical reaches were defined as any stretch of the river in which campsites are plentiful and little competition for the majority of sites occur. These reach definitions closely parallel the geomorphic reach definitions of Schmidt and Graf (1990).

Subsequent studies by Kearsley et al. (1994), Kearsley (1995), and Kearsley and Quartoroli (1997) improved upon the aerial photographic mapping by utilizing Geographic Information System (GIS) software. Their technique involved outlining camp area during on-site visits onto 400% Xerox copies of 1:4800 aerial photographs, then digitizing the polygons and calculating areas in a GIS environment. Ticks marks for registering the photographs were either taken from common points identified on orthophoto base maps (Werth et al., 1993), or using a conversion factor between digitizer units and actual ground distances. This conversion factor, derived by measuring the distance between recognizable features on the aerial photograph during the on-site visit and dividing the digitizer units between the same features, was used to convert digitizer units to square meters. This technique is subject to error from estimates of stage elevation, digitizing (registration, polygon digitizing, distortion of copies of aerial photography), and from using the conversion factor to derive square meters. Our approach, outlined below, eliminates these sources of error by measuring campsite area on-site with a greater accuracy and precision at locations with well-known stage-discharge relationships.

Objectives

The objectives of this study were directed at describing changes in the size of camping areas in the Colorado River ecosystem in Grand Canyon, specifically campsites downstream of Lees Ferry, AZ (Figure 1). The objectives of this study were:

1. Annually measure campsite area at thirty-one long-term monitoring sites during three consecutive years, 1998, 1999, and 2000.
2. Evaluate the measured change between each year and between different ranges of flow.
3. Develop recommendations for future long-term monitoring and management direction with regard to sustainability of campsites within the Colorado River ecosystem downstream from Glen Canyon Dam.

Methods

Surveys were conducted in October in 1998, 1999, and 2000 to quantify campsite change. Surveys at the selected study sites were conducted using standard total station survey techniques (USACOE, 1994). Survey crews consisted of an instrument operator, one to two rodmen and a crew chief. At each site, the crew chief would direct the rodman to points that outline the perimeter of camping areas, as well as points that outline the perimeter of exclusions to the camp, such as trees and rocks (Figure 2A). We adopted the criteria of Kearsley (1995) and Kearsley and Quartoroli (1997) to identify campable area. Campable area is defined as a smooth substrate (preferably sand) with no more than eight degrees of slope with little or no vegetation. Slope angle was determined visually by the crew chief. The crew chief also mapped the areas onto 400% enlargements of the most recently acquired aerial photographs, following the methods used by Kearsley and Quartoroli (1997). These sketch maps were used on return visits to enable duplication of the camp area on subsequent surveys by different personnel and to assist in the interpretation of variables causing campsite area change (i.e vegetation encroachment, runoff, bank erosion, etc.). These maps will also be utilized to assess the relative accuracy of the Kearsley approach to other methods in a future report. Not all

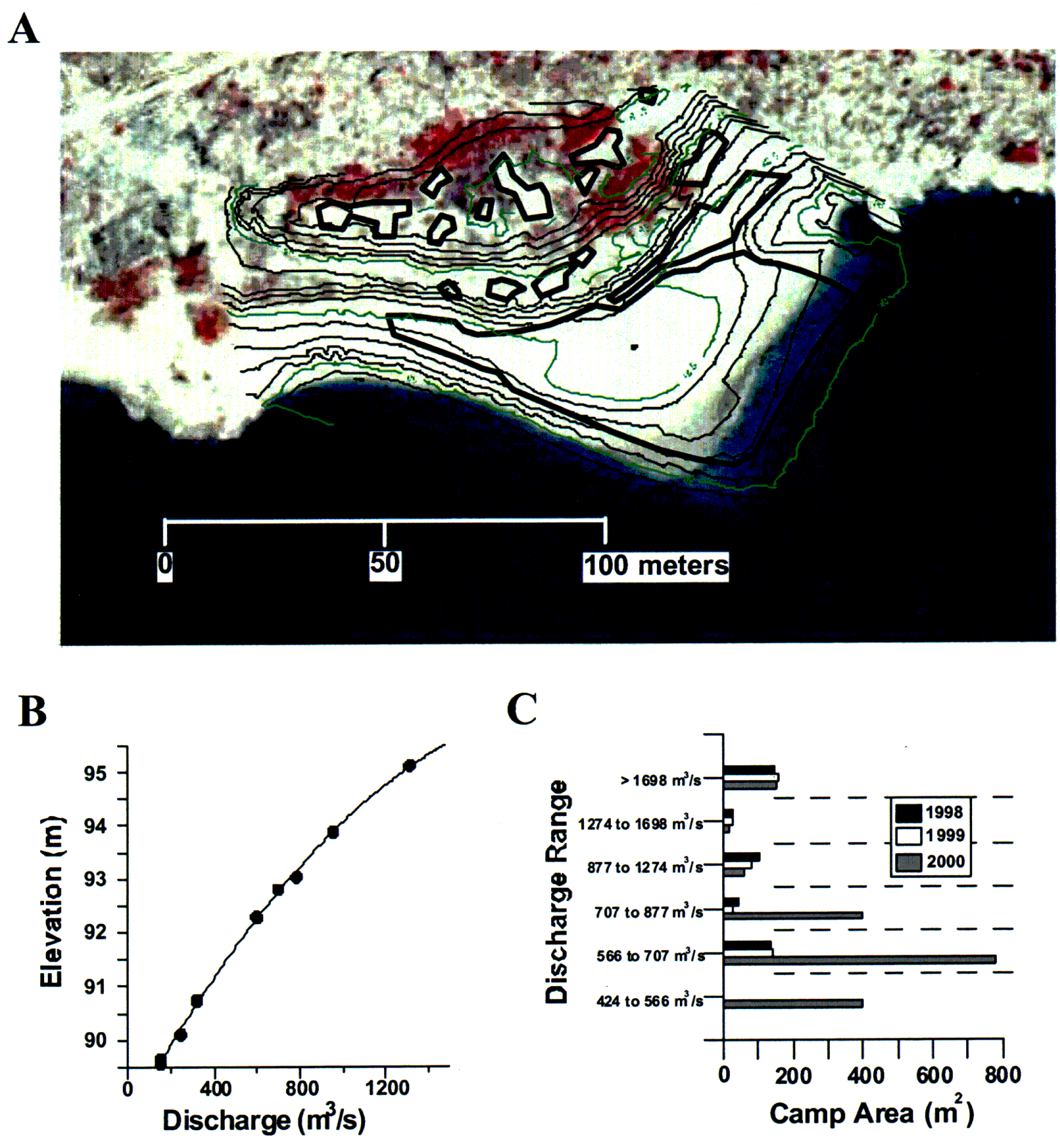

Figure 2. Examples of data from the 119R study site. A) March 2000 Orthophoto base overlain with 0.5 contours derived from topographic survey conducted on June 14, 2000 and campsite area polygons collected on October 12, 2000. B) Stage discharge relationship. C) Campsite area divided into specific stage ranges. Note the large increase in camp area within the 566 m^3/s to 877 m^3/s stage ranges from 1999 to 2000. Two high flow events (877 m^3/s) in the spring and fall of 2000 aggraded the lower portion of the reattachment bar, thus increasing the area available for camping. Note also that the orthophoto was collected prior to the high flow events and does not reflect the configuration of the lower elevations of the sand bar at the time of the camp area mapping.

camp areas were mapped at every site. Instead, representative camp spots were selected across a range of stage elevations. Camping areas not represented in the mapping were typically far (>100 m) from the main mooring/cooking areas.

Survey points for each site were downloaded from field data collectors and checked for proper control coordinates and elevation. Digital elevation models (DEMs) were formed within the area boundaries. The elevations of the various stage elevations were derived from an empirically derived stage discharge relationship at each site (Figure 2B). We measured camp area above the 566 m^3/s (20,000 ft^3/s) stage elevation on all trips. To examine camp area changes within different flow ranges, we divided camp area into six categories: 424 m^3/s to 566 m^3/s (15,000 ft^3/s to 20,000 ft^3/s), 566 m^3/s to 708 m^3/s (20,000 ft^3/s to 25,000 ft^3/s), 708 m^3/s to 877 m^3/s (25,000 ft^3/s to 31,000 ft^3/s), 877 m^3/s to 1274 m^3/s (31,000 ft^3/s to 45,000 ft^3/s), 1274 m^3/s to 1698 m^3/s (45,000 ft^3/s to 60,000 ft^3/s), and above 1698 m^3/s (60,000 ft^3/s). These categories reflect different stage elevation reached by previous and proposed GCD operations (Figure 2C). The plan area within different ranges of stage elevation was calculated from the DEMs and tabulated in a spreadsheet.

This method greatly improves on the accuracy and precision of camp area measurements. We investigated the repeatability of the method at one site (351 or Nautaloid) by mapping camp area with two separate crews on the same day. The difference in area between these two surveys was less than 3%. However, a certain level of subjectivity is inherent in choosing where to outline the areas to be mapped – even while following the criteria outlined above. Subjective decisions are made at each site before accurately mapping the areas chosen. Therefore, we use a more conservative estimate of change detection and consider changes of 10% or greater to be significant.

Dam releases during the study period

Dam releases during the study period included normal operations guided by the 1996 Record of Decision (ROD, U.S. Department of Interior, 1996) during 1998 and 1999, and a Low Steady Summer Flow (LSSF) experiment during 2000 (Figure 3). Normal dam releases fluctuate diurnally and seasonally, based on power demand and

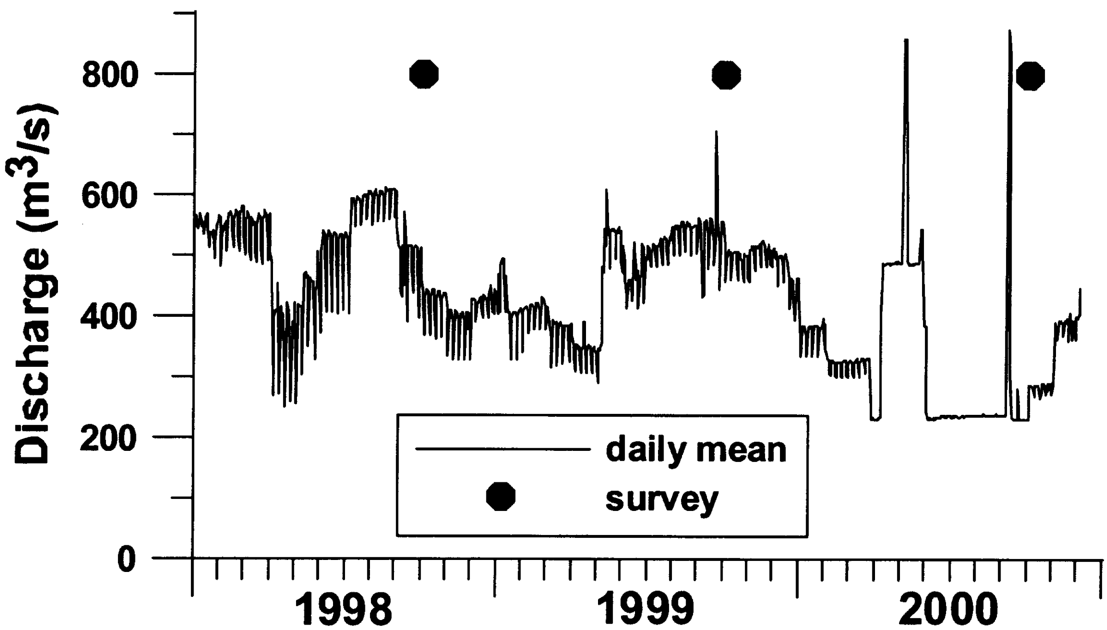

Figure 3. Daily mean discharge hydrograph from USGS gaging station Colorado River near Lees Ferry (09380000) during period of study. Note the daily and seasonal fluctuations in flow volume during 1998 and 1999, and the Low Steady Summer Flow (LSSF) experiment in 2000 that included two high flow events.

water delivery schedules. Typically, flow releases are higher in the winter and summer months, and lower during the spring and fall months. In 1998 and 1999, flows generally followed this pattern. Daily mean flow releases ranged from an average of approximately 550 m^3/s (19,400 ft $^3/s$) in high-volume months to approximately 350 m^3/s (12,400 ft $^3/s$) in low-volume months. The Low Steady Summer Flow (LSSF) experiment in 2000 consisted of two high flow releases in the spring and fall, and a period of low steady (no diurnal fluctuation) flow during the summer. The high flows were short-duration (4 days) releases of 877 m^3/s (31,000 ft $^3/s$). The low steady flow during the summer was lowered to a constant 226 m^3/s (8,000 ft $^3/s$).

Flow levels during the 1998 and 1999 survey trips were medium volume. Therefore, we were only able to measure camp areas above the 556 m^3/s (20,000 ft $^3/s$) stage elevation. During the 2000 survey, low volume releases allowed measurement of camp area above the 283 m^3/s (10,000 ft $^3/s$) stage elevations at some sites and above 425 m^3/s (15,000 ft $^3/s$) at all sites. Comparison of camp area change between surveys was conducted using area measured above the 708 m^3/s (25,000 ft $^3/s$) stage elevation, the maximum stage of fluctuating flows under ROD operating criteria.

Study Sites

The study sites are located throughout the Colorado River ecosystem between Lees Ferry and Diamond Creek (Figure 1). Distances along the Colorado River in Grand Canyon are traditionally measured in river miles, with river mile 0 beginning at Lees Ferry, Arizona. Accordingly, study site reference numbers use river mile location (Figure 1). Table 1 lists which side of the river (left or right as viewed downstream) the camp is located, informal camp names used by the river running community, and whether the site is located within a critical or non-critical reach. This study did not evaluate any campsites above Lees Ferry in the Glen Canyon reach, nor below Diamond Creek. These are the same long-term study sites used by Kaplinski et al. (1995, 1998) and Hazel et al. (1999) to monitor changes in sand bar area and volume. Camp area changes can be integrated with a long-term record of morphological change at the same sites.

Results

Camping area above the 708 m^3/s (25,000 ft $^3/s$) stage elevation is specifically identified in the Glen Canyon Dam Adaptive Management Program (GCDAMP) management objectives as the focus of monitoring activities concerned with recreational carrying capacity of the river (GCDAMP, 2001). Our results show that the total camp area above 708 m^3/s (25,000 ft $^3/s$) has significantly decreased during the 2-yr study period (Figure 4; Table 1). This decrease was detected between each survey and the magnitude of change was greatest from 1998 to 1999. Overall, camp area decreased by 25% above this critical stage elevation between 1998 and 2000.

While the management objectives specifically identify camp area above the 708 m^3/s (25,000 ft $^3/s$) stage elevation as being the most important, camping area exists within a range of stage elevations and the amount of camp area available at any site is greatly dependent on river stage. For example, during the study period the high elevation camping area (above 708 m^3/s [25,000 ft^3/s]) decreased but deposition below this stage elevation during the 2000 LSSF combined with low flows resulted in more camp area being available (Figure 5). The mode of the distribution of camp area with elevation shows that the greatest amount of camp area exists below 708 m^3/s following the 2000 LSSF. During the study period the mode of the camp area distribution has shifted from high to low elevation bar areas. However, because this area lies within the zone of flow fluctuation, these increases may not persist for more than a few months because lower elevations of sand bars are more susceptible to bank erosion than sand at higher elevations (Hazel et al., 1999). The camp area that is most likely to persist for longer periods is located within the 877 m^3/s to 1274 m^3/s (31,000 ft $^3/s$ to 45,000 ft $^3/s$) stage range. Nonetheless, the greatest concentration of camp area now lies within the 424 m^3/s to 566 m^3/s (20,000 ft $^3/s$ to 25,000 ft $^3/s$) stage range. Unfortunately for campers, the lower elevations are inundated during mid to high volume dam operations (283 m^3/s to 707 m^3/s [10,000 ft $^3/s$ to 25,000 ft $^3/s$]) and are not available for camping.

There was little spatial difference in site response between 1998 and 1999. Although the monitoring sites are not evenly distributed throughout the Colorado River

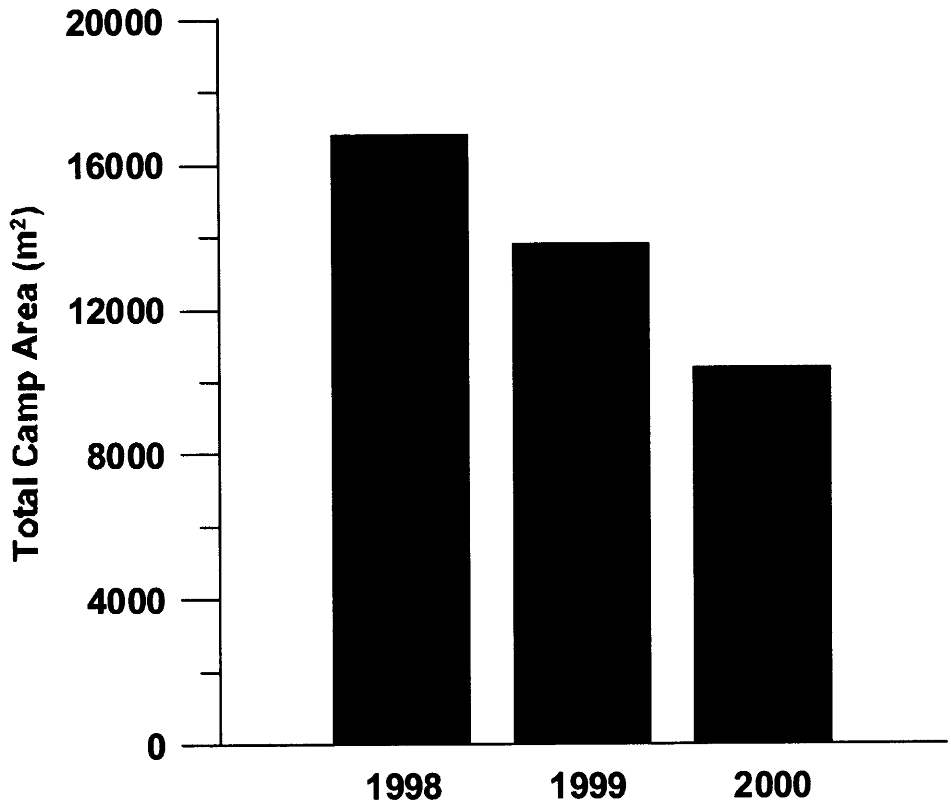

Figure 4. Cumulative camp area above the 707 m^3/s (25,000 ft^3/s) stage elevation for the 1998, 1999, and 2000 surveys.

Table 1. Campsite area data

mile	side	name	reach	1998 area	1999 area	2000 area	1998 - 1999 area change	1998 - 1999 % change	1998 - 1999 change*	1999 - 2000 area change	1999-2000 % change	1999 - 2000 change*	1998 - 2000 area change	1998 - 2000 % change	1998 - 2000 change*
16	l	Hot Na Na	C	514	494	534	-20	-4	s	40	8	s	20	4	s
21.8	r	22 mile	C	66	42	152	-24	-36	d	110	262	i	86	130	i
30	r	fence fault springs	C	297	353	99	56	19	i	-254	-72	d	-198	-67	d
31.6	r	south canyon	C	642	675	618	33	5	s	-57	-8	s	-24	-4	s
35	l	nautoloid	C	602	556	502	-46	-8	s	-54	-10	s	-100	-17	d
43	l	anasazi bridge	NC	1124	1019	520	-105	-9	s	-499	-49	d	-604	-54	d
45	l	eminence	NC	1135	1143	933	8	1	s	-210	-18	d	-202	-18	d
47	r	lower saddle	NC	765	757	282	-8	-1	s	-475	-63	d	-483	-63	d
50	r	dino	NC	703	784	677	81	12	i	-107	-14	d	-26	-4	s
51	l	51 mile	NC	1257	646	550	-611	-49	d	-96	-15	d	-707	-56	d
55	r	kwagunt marsh	NC	536	420	267	-116	-22	d	-153	-36	d	-269	-50	d
62	r	Crash	NC	220	60	141	-160	-73	d	81	135	i	-79	-36	d
68	r	tanner	NC	856	764	750	-92	-11	d	-14	-2	s	-106	-12	d
81	l	grapevine	C	1157	1119	1135	-38	-3	s	16	1	s	-22	-2	s
87	l	cremation	C	529	369	421	-160	-30	d	52	14	i	-108	-20	d
91	r	91 mile - above trinity	C	286	286	300	0	0	s	14	5	s	14	5	s
93	l	granite	C	204	162	352	-42	-21	d	190	117	i	148	73	i
104	r	104 mile	C	193	99	117	-94	-49	d	18	18	i	-76	-39	d
119	r	119 mile	NC	317	300	631	-17	-5	s	331	110	i	314	99	i
122	r	122 mile	NC	472	456	289	-16	-3	s	-167	-37	d	-183	-39	d
123	l	forster	NC	753	707	415	-46	-6	s	-292	-41	d	-338	-45	d
137	l	football field - middle poncho's	C	827	699	873	-128	-15	d	174	25	i	46	6	s
139	r	fishtail	C	293	232	163	-61	-21	d	-69	-30	d	-130	-44	d
145	l	145 mile - above Olo	C	145	140	295	-5	-3	s	155	111	i	150	103	i
172	l	172 mile - below mohawk	NC	119	21	2	-98	-82	d	-19	-90	d	-117	-98	d
183	r	183 right - old river channel	NC	146	136	179	-10	-7	s	43	32	i	33	23	i
183	l	183 left	NC	391	115	199	-276	-71	d	84	73	i	-192	-49	d
194	l	194 mile - Hualapai Acres	NC	1123	815	800	-308	-27	d	-15	-2	s	-323	-29	d
202	r	202 mile	NC	740	714	525	-26	-4	s	-189	-26	d	-215	-29	d
213	l	Pumkin Springs	NC	411	216	128	-195	-47	d	-88	-41	d	-283	-69	d
220	r	220 mile - middle gorilla	NC	1600	1108	1009	-492	-31	d	-99	-9	s	-591	-37	d
			Avg	594	497	447	-97	-19		-50	11		-147	-14	
			Total	18423	15407	13858	-3016			-1549			-4565		

* s- same, change less than 10%. d - decrease greater than 10%. i - increase greater than 10%

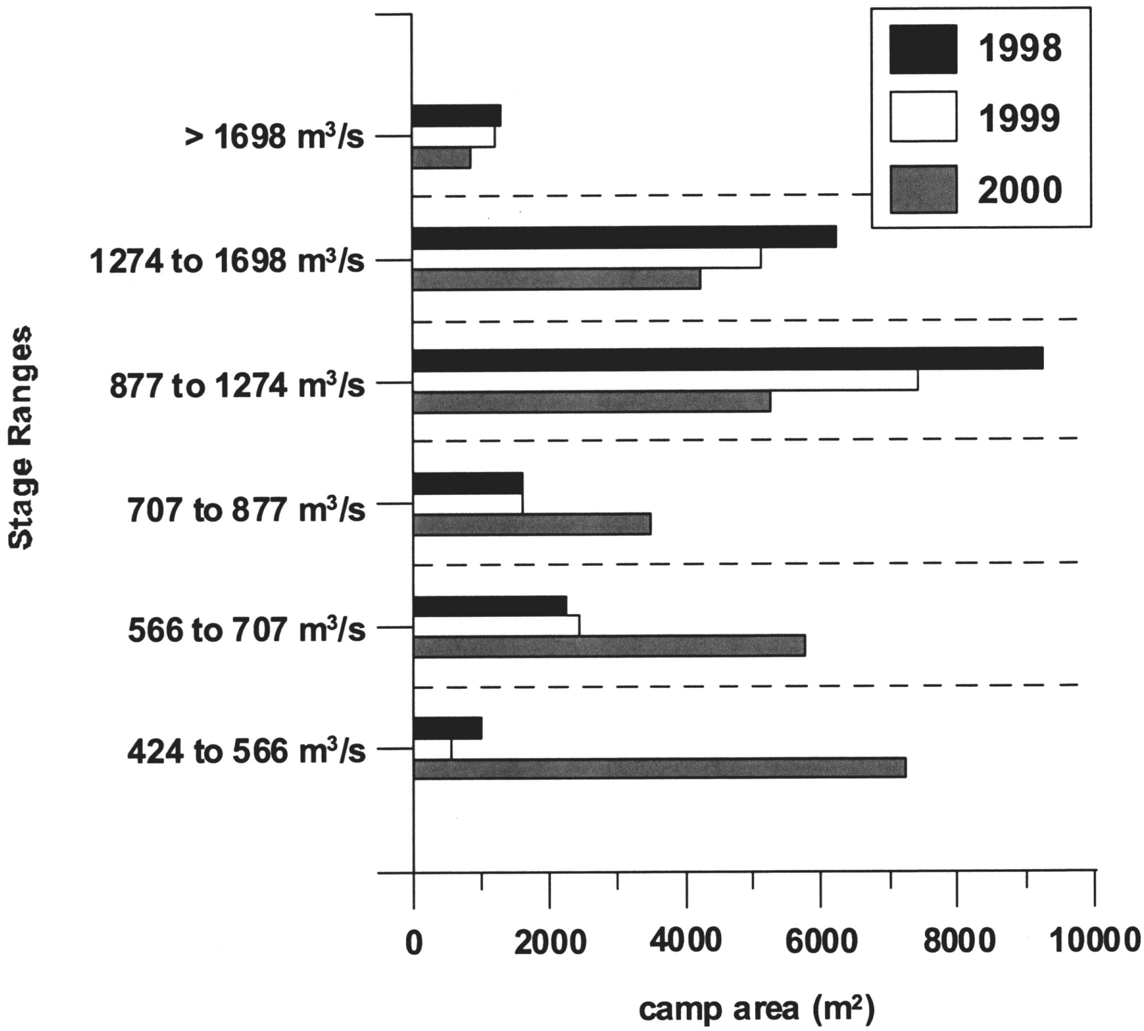

Figure 5. Total camp area measured within the six stage range categories from the 1998, 1999, and 2000 surveys. Note the shift in the greatest amount of camp area from high to low elevation through time.

ecosystem, they do provide a general indication of system-wide response as well as response within critical and non-critical reaches (Table 1). Thirteen sites are located within critical reaches, while eighteen sites are located within non-critical reaches. The percent area change above the 707 m^3/s (25,000 ft^3/s) stage elevation was uniformly negative between 1998 and 1999 and sites in both critical and non-critical reaches lost area (Figure 6a). Overall, camp area decreased by an average of 19% (Figure 7a). Critical reaches lost an average of 12% and non-critical reaches lost an average of 24%.

Between 1999 and 2000 several sites gained camp area and there was a difference in response between critical and non-critical reaches (Figure 6b). The mean percent change in campsite area above the 707 m^3/s (25,000 ft^3/s) stage elevation was 11% during this period (Figure 7b). Critical reaches increased by an average of 34%, while non-critical reaches decreased by an average of 5%. However, percent change must be analyzed carefully. Sites within critical reaches are typically smaller sites and a small change in camp area can equate to a large percent change. For example, the largest percent change from 1999 to 2000 was measured at the 22L site. The actual area change was caused by deposition along the lower reattachment bar platform. As a result, camp area increased from 42 m^2 to 152 m^2, a 262% gain in area (Table 1). In contrast, the largest area change during this period was measured at 43L, or Anasazi Bridge site, where the decrease in camp area (499 m^2) equated to a 49% loss. While several small camps within critical reaches showed large increases in percentage of change, the overall median value of change for this period was –8.4% and indicates that the majority of sites lost camp area (Figure 7b).

Sand bar surveys indicate that only a minor amount (i.e. volume) of sediment was deposited during the two 877 m^3/s (31,000 ft^3/s), high-flow events in 2000 (Hazel et al., 2001; Parnell et al., 2001). However, bar surfaces were reworked and more bar area suitable for camping was created at lower elevations. Unfortunately, this increase was at the expense of high elevation campsite area, which decreased because of bank retreat located at the elevation reached by the 877 m^3/s flows. Camp area above the 877 m^3/s (31,000 ft^3/s) stage elevation has decreased at a greater rate than erosion of sand bar volume detected from topographic surveys (Figure 8). This indicates that other factors,

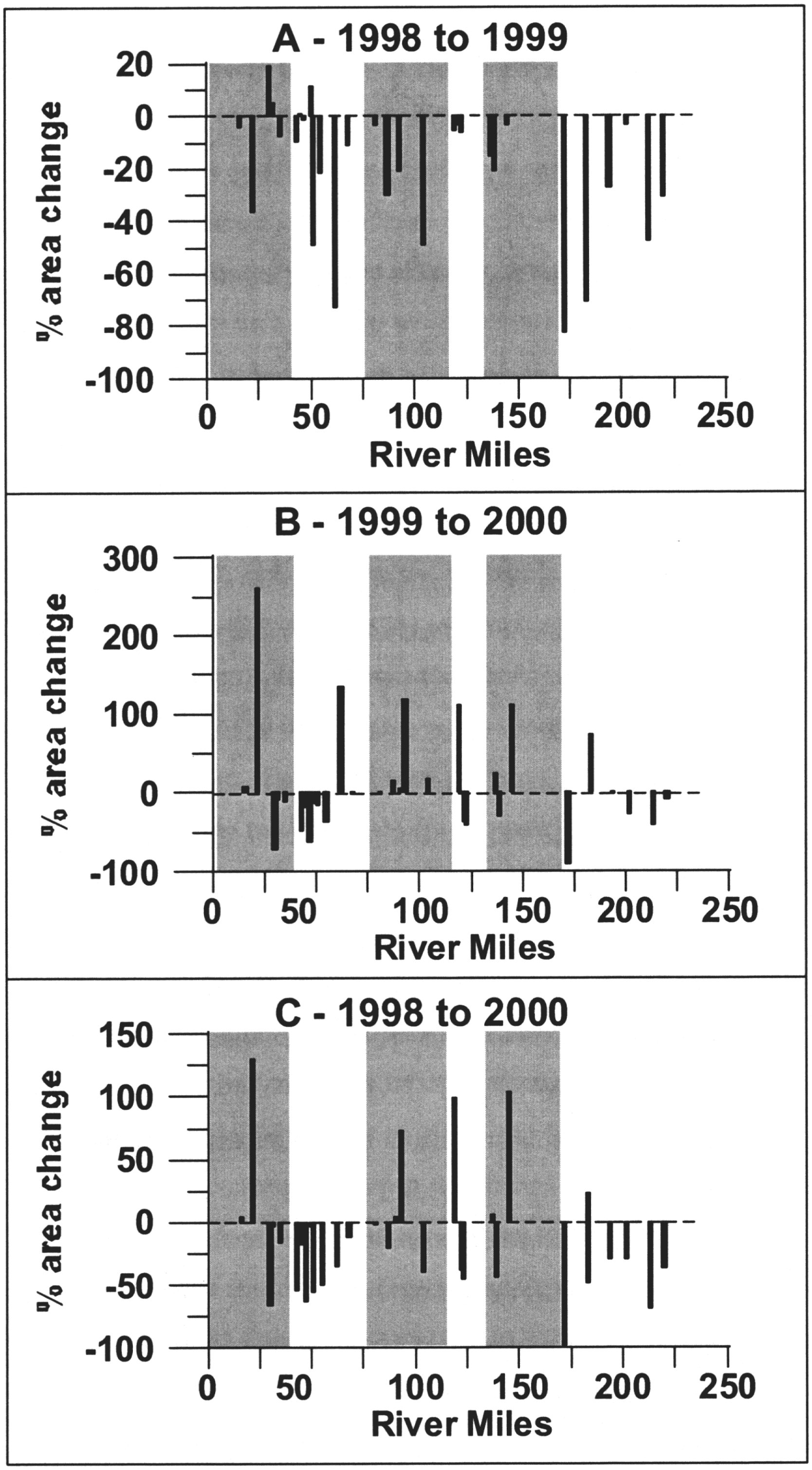

Figure 6. Bar charts showing the percent area change above the 707 m^3/s (25,000 ft^3/s) stage elevation with distance downstream. Shaded areas indicate critical reaches. A) 1998 to 1999, B) 1999 to 2000, C) 1998 to 2000.

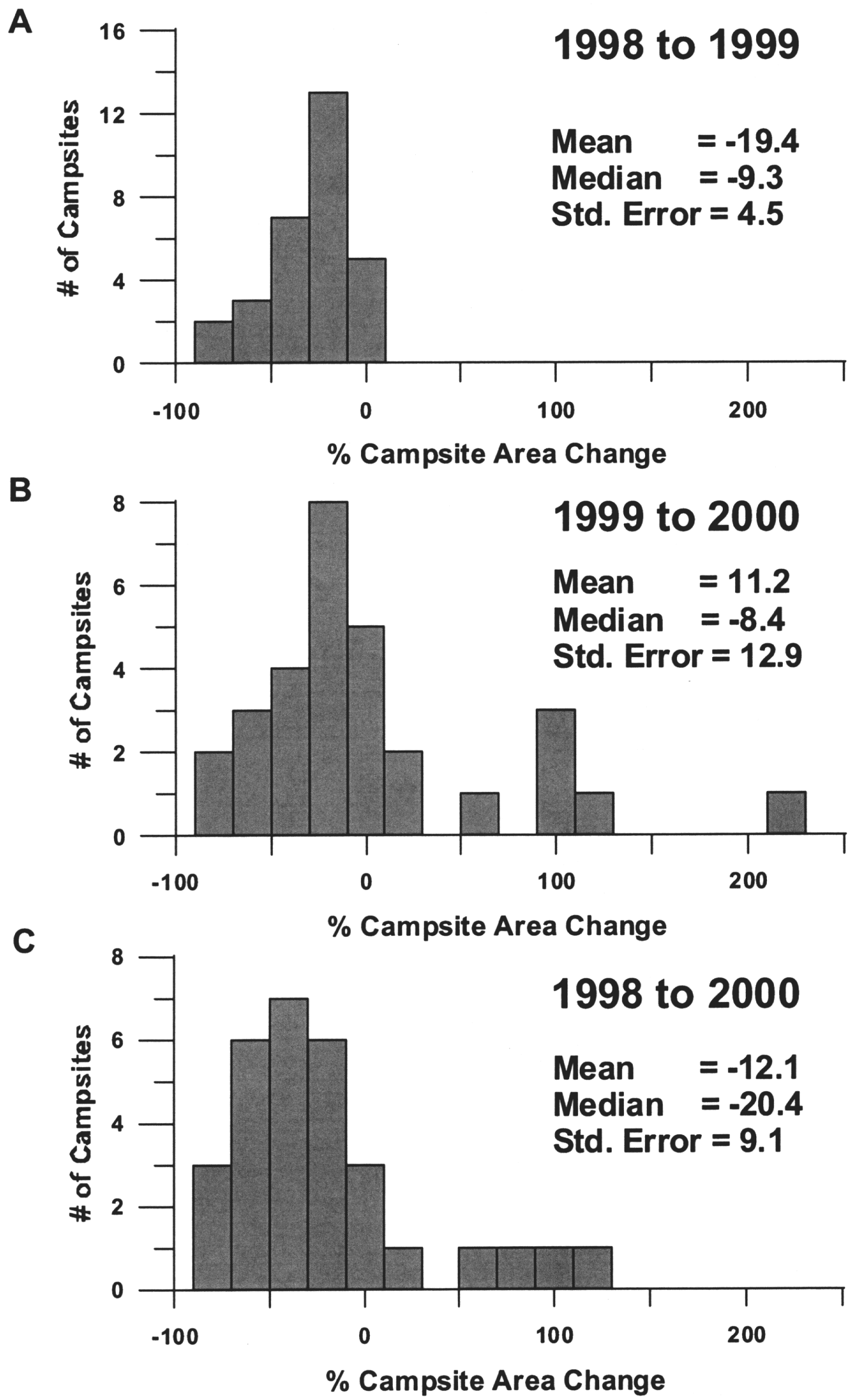

Figure 7. Histograms showing the distribution of percent area change above the 707 m^3/s (25,000 ft^3/s) stage elevation between surveys. A) 1998 to 1999, B) 1999 to 2000, C) 1998 to 2000.

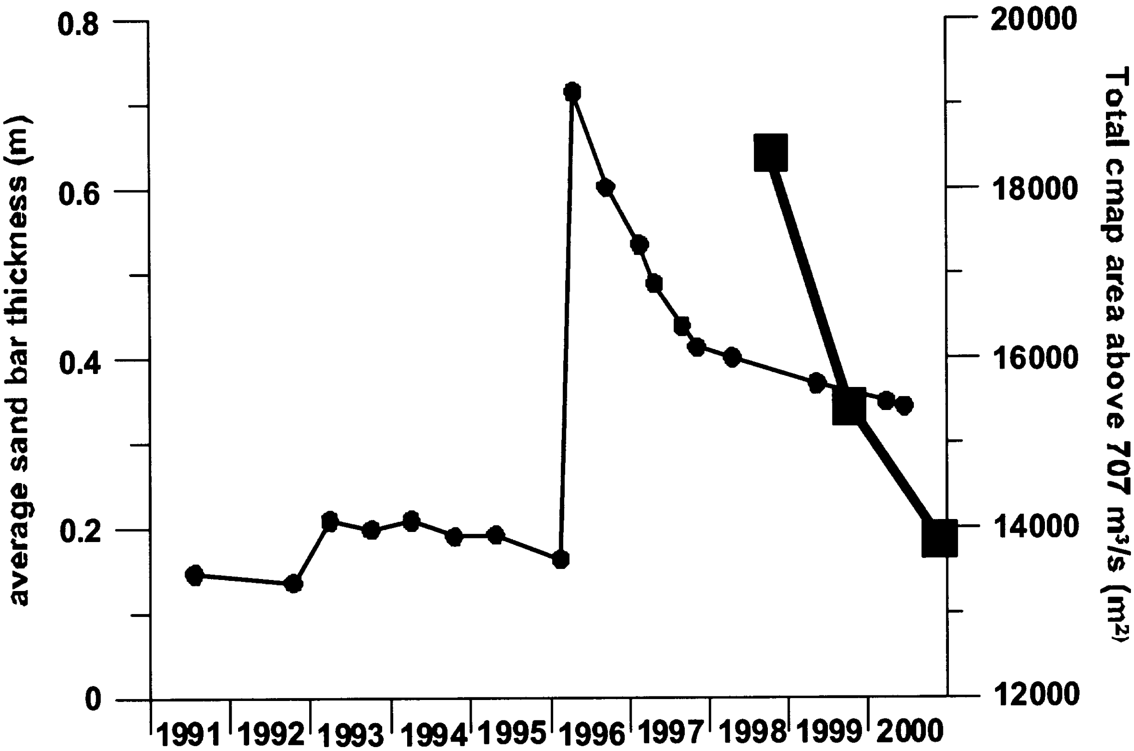

Figure 8. Time series of average sand bar thickness and camp area. Sand bar thickness was calculated as the bar volume divided by bar area.

such as vegetation encroachment, wind deflation, erosion from precipitation runoff, and human traffic have contributed to the loss of high elevation camping area.

Discussion

Campsites within the Colorado River ecosystem exist primarily on sand bars and the size and capacity of camping area is directly related to the areal extent of sand bars and the amount of vegetation colonizing the sand bars (Kearsley et al., 1994). The continued existence of sand bars suitable for camping in this system is dependent on high flows to redeposit sediment lost through the natural processes of erosion and to scour or remove vegetation. Therefore, the availability of campable area is closely linked with the frequency of flood events from GCD. Unless vegetation is physically removed, high flow events are the only mechanism by which sand bars used as campsites can be built and maintained. In fact, the only increases in campsite area measured in previous studies were after high flow events (Brian and Thomas, 1984; Kearsley et al., 1994; Kearsley and Quartoroli, 1997). During this study, high flow events in the spring and fall of 2000 contributed to camp area increases at several of the study sites (Table 1).

Our results show that campsite area has decreased each year since the 1996 controlled flood. Because our approach is different from previous techniques we were not able to directly compare our results to previously reported campsite area values for years prior to 1998. However, both of these techniques measured campsites areas at specific study sites and the trends resulting from each technique are comparable. Kearsley and Quartaroli (1997) reported a 37% decrease in the mean percent area change at 53 monitoring sites in the six months following the 1996 controlled flood. Although their measurements were of campsite area above the 566 m^3/s (20,000 ft^3/s) stage elevation, rather than the 707 m^3/s (25,000 ft^3/s) stage elevation used in this study, their results are comparable to ours and indicate that rate of high-elevation campsite area loss has declined since 1996. This is consistent with sand bar monitoring results that show decreasing high-elevation sand bar erosion rates since the 1996 controlled flood (Parnell et al., 2001). Sand bar surveys also show that while the rates of erosion have decreased, sand bar volume and area continues to decline. The changes detected in our 2-yr study period suggest that camp area will continue to decline in the near term. While the number of people visiting and camping in the ecosystem has been regulated and held at a specific number by the National Park Service, campsite area and carrying capacity continues to decline.

Future campsite monitoring may benefit from recently tested remote sensing technologies. However, the accuracy and precision of these technologies are still under review. The strengths of the methods used in this study are that: 1) the accuracy and precision of the measurement technique is the best available; 2) camp area can be assessed at different stage levels; and 3) results of camp area monitoring are directly related to morphological changes. The drawback of the method is that it is requires on-site visitation for at least 30 minutes to 2 hours and it is only feasible to measure approximately thirty sites on one river trip. Digital orthophotos or locally rectified aerial photography would allow at least twice as many sites to be assessed. However, additional sites would not have the benefit of supporting information such as stage discharge relationships or morphological change history.

Regardless of the number of sites, campsite area monitoring is necessary to document the continuing changes in the capacity of the river corridor to accommodate visitor use levels. Future monitoring should also include inventories of the total number of campsites available. This would compliment the detailed area measurements and provide dam managers a more complete assessment of the effects of dam operations on the environmental and social values for which Grand Canyon National Park was formed.

Conclusions

We developed a new method for mapping campsite area. This method involves using total station survey techniques to accurately delineate campsite area polygons. We investigated the repeatability of the mapping by conducting surveys of the same site on the same day by two separate crews. The difference between area measurements was less than 3%. However, due to the subjective nature of choosing campsite areas, we consider changes of 10% or greater to be significant.

Survey results show that high elevation (above the 707 m^3/s [25,000 ft^3/s] stage elevation) camp area decreased between each survey. From October 1998 to October 2000 high-elevation camp area decreased by 25%. Two near-powerplant capacity releases (877 m^3/s [31,000 ft^3/s]) in the spring and fall of 2000, respectively, deposited sediment that resulted in increased mid-level (556 m^3/s to 877 m^3/s [20,000 ft^3/s to 31,000 ft^3/s] camp area, particularly within critical reaches (Hazel et al., 2001). However, despite mid-level camp area increases, camp area above the 707 m^3/s (25,000 ft^3/s) stage elevation decreased by 10% between 1999 and 2000.

Campsite area above the 707 m^3/s (25,000 ft^3/s) stage elevation has decreased at a greater rate than sand bar volume above this level. This indicates that other factors, such as vegetation encroachment, wind deflation, erosion from precipitation runoff, and human traffic have contributed to the loss of high elevation camping area.

In addition, high-elevation camp area has continued to decline despite the release of two near-powerplant capacity floods in 2000, which suggests that near-powerplant capacity floods are not of sufficient magnitude to replenish high-elevation campsite area.

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