Long-term Effects of Humans on Beaches at Selected Colorado River Campsites in Grand Canyon National Park

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Abstract. Colorado River campsite beaches in Grand Canyon were monitored for human effects more than 10 years (1980–90). Observations included quantitative measurement of human litter, charcoal particles, and light reflectance from beach sands. Analysis of data from 21 selected campsite beaches and one noncamping beach used for control indicated the following:

1. heavily used beaches in Glen Canyon are and were significantly more degraded than those in Grand Canyon where camping is more carefully regulated;
2. litter and charcoal particles were essentially eliminated from all beaches by the high waterflows (spills) of 1983;
3. since 1983, a gradual increase in human contamination has occurred on most beaches monitored (90%);
4. contamination by charcoal is more significant than human litter on most beaches studied;
5. Grand Canyon beaches accessible only by river are generally less contaminated than those approachable by hikers, anglers, and river parties; and
6. the policies governing campsite procedures initiated by the National Park Service and followed by river recreationists seem to have substantially reduced human contamination of campsite beaches in Grand Canyon.

Key words: Beaches, campsites, Colorado River, human contamination, recreation.

Since the beginning of operation of Glen Canyon Dam in 1963, natural resource management problems have arisen along the Colorado River corridor through Grand Canyon National Park. These problems include extensive changes along the river shoreline as a result of changes in the hydrologic characteristics of the river and the dramatic increase in recreational use of the river corridor by river runners and hikers. By the mid-1970's, increased use of the beaches as campsites by approximately 20,000 recreationists annually had produced a marked increase in accumulation of camping-related human waste products within the beach sands. Because flow of the Colorado River through Grand Canyon is rarely allowed to rise above that necessary for maximum power generation at the dam (about 31,500 cfs), natural purging and replenishment of the beaches could no longer occur. The more popular campsite beaches were filling up with human waste, cat-box style.

In response to the urgent need for cleaning and preserving the fragile beaches in Grand Canyon—and as mandated by the National Park Service—a Colorado River Management Plan (Grand Canyon National Park 1981) was prepared to guide the management of the riverine and riparian areas within the national park. The plan requires that all wood and charcoal carried into the Grand Canyon by river recreationists be burned in fire pans and the ashes carried out. Gas stoves are now required for most cooking purposes. Additionally, all litter and solid human wastes are to be carried out.

In 1976, monitoring of 25 selected Grand Canyon beaches for human effect was begun. Additional beaches below the dam in Glen Canyon were added in 1980–81. More sites have been added, and some deleted, because of loss or disuse of campsites over the intervening years (Carothers and Johnson 1980; R. Matkin, D. Julander, L. Edwards, S. Martin, A. Stewart, and B. Bridenbecker, Northern Arizona University, Flagstaff, and Grand Canyon National Park, unpublished manuscript). This study presents the results of sampling for human effect on 21 selected campsite beaches and one noncamping beach as monitored during 1980–90. The sites selected for this report had the most complete data available or were among the most heavily used campsite beaches.

Our objectives were to monitor and analyze human influence on campsite beaches as measured by

1. the incidence of charcoal particles greater than 1-cm diameter on the beach sands,
2. the incidence of human litter on the beaches, and
3. the amount of beach sand discoloration from darker colored material, such as charcoal or other organic matter, as measured by light reflectance, compared to pure quartz sand.

Methods

At each campsite beach to be monitored, a 40-m transect was laid through the principal use area of the beach along an axis approximately parallel to the shoreline. Recorded compass bearings and black and white photographs—including a view of the transect and a chalkboard labeled with the river mile and side—permitted reoccupation of the same transect line in subsequent visits.

Ten 1-m^2 plots were established equidistant from each other and on alternating sides of the 40-m transect. Each 1-m^2 plot was inspected by hand

[1]Present location: Springfield Public School District, Springfield, Mo.

sifting through the top 1–2 cm of sand. All charcoal particles 1 cm in diameter or larger and all pieces of human litter within the plot were counted and recorded.

A sample of dry sand was collected from each plot. The sand samples were sifted through a 150-μ stainless steel mesh apparatus until the amount of sifted material covered the bottom of the container to a depth of 1 cm. A piece of number 7 coarse filter paper was placed in the lid of the apparatus with the hatched side up and the sifted sample was shaken against the filter paper 75 times. Discoloration of the filter paper by silt- or clay-sized dark material, chiefly charcoal or other organic matter as measured by light reflectance, was evaluated using a Colorgard II reflectometer. The reflectometer was calibrated against white and gray standards before each series of readings. Pure quartz sand, which is the typical beach deposit, reflects light almost the same as the gray standard.

For convenience of reference to beach locations in this study, four subdivisions of the Colorado River corridor in the Grand Canyon area are recognized (Fig. 1):

1. Glen Canyon—Glen Canyon Dam to Lees Ferry (from river mile –15 to 0),
2. Marble Canyon—Lees Ferry to Nankoweap (from river mile 0 to 53)
3. Eastern Grand Canyon—Nankoweap to Bass Camp (from river mile 53 to 109), and
4. Central Grand Canyon—Bass Camp to 220-mile (from river mile 109 to 220).

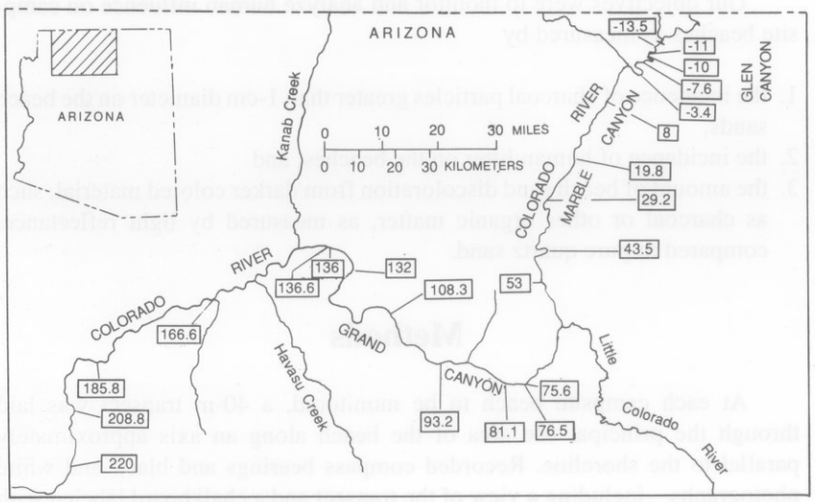

Fig. 1. Study area and location of beach sites identified by mile-post numbers. *Diagonal lines* mark area of report on state map.

Most of the sampling was done during summer river trips connected with an annual graduate course for science teachers conducted by the geology department at Northern Arizona University. Most of the data are from observations taken between 1981 and 1990, except for two of the Glen Canyon beaches sampled in 1991 because they were missed in several preceding years. Logistical and camping protocol constraints as well as National Park Service restrictions in Glen Canyon limited the sampling, and it was not possible to sample every beach every year.

Results

A summary of charcoal counts, litter counts, and reflectometer readings from 21 campsite beaches—4 in Glen Canyon, 5 in Marble Canyon, 5 in eastern Grand Canyon, and 7 in central Grand Canyon—is shown in Tables 1–3. An additional beach site—Faatz (–10 mile)—in Glen Canyon is used as a control since no camping is permitted there. The values listed for each beach represent a mean of the values from all (usually 10) of the 1-m^2 areas sampled.

Figures 2–9 illustrate the comparisons of selected beaches showing the most changes in charcoal and litter fragments. The most dramatic changes took place in 1983 when charcoal and litter counts on all beaches came to or near zero. An unexpected high water spill when discharges from Glen Canyon Dam reached 96,000 cfs during summer 1983 (Avery et al. 1987) produced a cleansing effect that re-sorted the beach sand, removed the human litter, and gave the system a fresh start. Along with the cleansing, new beaches formed and some old ones eroded away. Data from the 1983 event provide a useful reference for both previous and future beach observations.

The overall pattern for the beaches downstream from Lees Ferry and Glen Canyon is one of moderate to locally high incidences of charcoal and litter before the 1983 cleansing event and a gradual increase afterward to near-1982 levels by 1989 or 1990 (Figs. 10 and 11). Between 1989 and 1990, about half the beaches sampled both years showed a decrease, and half showed an increase in charcoal. Eight of 12 beaches showed a decrease in incidence of human litter. The incidence of charcoal and litter on some of the Glen Canyon beaches shows a similar pattern before and after the 1983 event, but the quantity of litter and charcoal is almost an order of magnitude higher than that of the beaches downstream in Grand Canyon (Figs. 2, 7, and 10).

Data from beach sand discoloration measurements are less diagnostic than expected. All the beach samples studied showed a marked increase in light reflectance between 1982 and 1983 when the cleansing spill occurred (Table 3). Post-1983 reflectance readings showed considerable variation in reflectance (Fig. 12 and 13). However, on 12 of 18 beaches sampled repeatedly, a higher reflectance reading (and presumably less contamination of beach sand) was reached 6 or 7 years after the cleansing event.

Table 1. Charcoal particles per square meter on Colorado River beaches.

River mile	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
–13.5	23.5		0								181.0
–11.0	26.0	32.1	0				50.6				18.0
–1.0	0.1	0	0				0				
–7.6	121.8	32.0	0				0.8				
–3.4	69.0	35.7	0				0.2				
8	4.0	10.7	0.8	2.5	0.2	0.2	10.4	5.7	9.6	19.0	
19.8		1.0	0.1	0	0.3	0	0.2				
29.2	1.1	0.5	0	0	0	0	0.6	0.7	0.4	0.5	
43.5	0.1	0.1	0	0	0	0.2	0.2				
53	12.4	0.2	0	0.2	0.6	0.6	6.9	4.8	1.5	4.7	
75.6	2.8	0.7	0	0.3	0	0	0	0.8	0.6	1.1	
76.5	23.5	8.1		0.2	1.9	1.5	3.6		3.1		
81.1			0	0	0	0	0.5	0.6	0.2	2.0	
93.2	4.8	3.0	0	0	0	0	0	2.1	0.8	1.1	
108.3	2.5	3.6	0	1.5	0.4	0.5	3.8	3.5	2.7	0.5	
132	1.0	1.2	0	0	0.5	0	0	0			
136	1.0	4.7	0.2		2.0	1.8	1.0	1.1	1.7		
136.6	0.3	1.6	0	0	0.1	1.3	0.8	0	0.8	0.1	
166.6	1.5	9.0	0	0	0	0.2	1.3	0.1	0.5	1.1	
185.8	0	0		0.2	0.6	0.8	0	0.1	0.1		
208.8	5.3	7.7	0	0.1	0	1.2	1.9	0.8	2.2	1.1	
220	2.2	13.8	0	0.4	0	0	1.4	2.1	1.1	0.7	

Discussion and Conclusions

We confirmed that human activity on selected campsite beaches contributes to the contamination of beach sands by charcoal and human litter. A moderate increase in human-produced debris occurred on nearly all campsite beaches sampled (90%) following the 1983 cleansing event. The beaches accessible by hikers, such as Badger (mile 8) at the mouth of Jackass Canyon, generally have a higher incidence of litter and charcoal than beaches approachable mainly by river travel. Even so, the beaches downstream of Glen Canyon within the Grand Canyon show a modest occurrence of human contamination when compared with those in Glen Canyon, where the litter and charcoal counts are about 10 times as high! The beaches in Glen Canyon are under less stringent regulations than those in Grand Canyon. The two most affected, Ropes Trail (–13.5) and Ferry Swale (–11), are heavily used by anglers on a day basis.

The variation in reflectometer readings as a measure of sand discoloration provides a less distinctive pattern. Although all beaches sampled showed lighter (and presumably less contaminated) sand in 1983 compared with

Table 2. Human litter pieces per square meter on Colorado River beaches.

River mile	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
–13.5	7.8		0								9
–11.0	1.5	6.2	0				3.4				8
–1.0	0.1	0.1	0				0				
–7.6	18.9	1.3	0				0				
–3.4	5.3	3.9	0				0.2				
8		0.4	0.1	0.2	0	0.3	0.4	0.2	0.7	0.1	
19.8		0.5	0	0.2	0.2	0	0				
29.2	1.1	0.5	0		0.1	1.0	0.5	0.1	0.2	0.1	
43.5	0.1	0.1	0	0	0	0.2	0.2				
53	0.4	0	0	0.4	0	0	0.8	0.2	0.5	0.4	
75.6	0.6	0.2	0	0	0	0	0.1	0	0.1	2.0	
76.5	1.2	0.3		0	0	0	0.2		0		
81.1			0	0	0	0	0	0.2	0.4	0.3	
93.2	0.7	0.2	0	0	0	0.4	0.2	6.0	1.9		
108.3	0.9	1.2	0	2.2	0	0.5	0.6	0.3	1.2	0.3	
132	0.2	0.3	0	0	0	0	0.3	0			
136	0.1	2.5	0.1		0	0.6	0.4	0.4	0.4		
136.6	0.3	1.3	0	0.4	0.1	0.8	0.4	0	0.7	0.4	
166.6	0.3	0.4	0	0	0	0.2	1.3	0.1	0.5	1.1	
185.8	0	0		0	0	0	0	0.4	0.1		
208.8	0.4	0.3	0	0.1	0	0.1	0.1	0.3	0.6	0.3	
220	0.2	0.4	0	0.2	0	0	0.4	0	0.9	0.4	

1982, 66% showed an even higher (and presumably even cleaner) reading several years after the 1983 cleansing. The beach sands sampled are consistently 98–99% clear quartz grains, which should provide a consistent high light reflectance unless contaminated by charcoal or other darker material. On some beaches, it seems that duff from nearby tamarisk (*Tamarix* spp.) trees or other naturally occurring organic matter is working its way into the beach sands and may locally influence and lower the reflectometer readings. We need to refine the sampling and other techniques if sand discoloration is to be useful as a measure of human influence on campsite beaches.

Additional investigation of human influence on beaches might compare plant communities at heavily and lightly used campsites. Preliminary study in 1982 provided baseline data for investigations (Phillips et al. 1986) subsequent to the 1983 high water. Also, distribution and density of harvester ant (*Pogonomyrmex* spp.) colonies seem to be positively correlated with heavy campsite use and accompanying food spills that provide a food resource for ants (S. L. Ward and R. LaChat, Northern Arizona University, Flagstaff, and Grand Canyon National Park, unpublished manuscript). Additional monitoring for changes in both plant communities and ant colony distribution seems

Table 3. Light reflectance, Colorado River beach sands.[a]

River mile	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
–13.5		72.4								41.4
–11.0										54.5
–1.0										
–7.6										
–3.4										
8	64.6	71.7	69.7	70.6	59.7	69.0	68.8	73.4	69.7	
19.8	58.8	70.0	69.1	68.6	68.2	72.6	67.4	64.6	69.5	
29.2	62.9	70.0	69.1	68.6	68.2	72.6	67.4	64.6		
43.5	67.3	73.3	70.6	71.1	71.6	72.7				
53	59.5	73.2	64.9	69.3	66.7	71.4	65.7	62.3	70.8	
75.6	66.9	72.9	66.8	72.2	70.9	69.8	67.7	71.0		
76.5	64.1		66.9	63.8	65.0	69.1		67.6	70.5	
81.1		71.9	67.6	67.4	69.4	71.2	68.0	67.2		
93.2	58.0	68.2	68.5	62.3	68.6	67.5	58.7	54.4	69.7	
108.3	59.4	66.5	63.4	64.4	67.9	70.3	63.0	61.6	68.7	
132	64.4	69.1	70.2	69.6	69.6	71.1	71.8			
136	62.0	67.8		65.5	66.7	65.4	68.4	64.0		
136.6	62.3	65.9	67.2	69.4	69.3	66.3	62.2	68.8		
166.6	66.7	69.4	63.6	67.1	69.2	65.6	66.2	61.6	77.9	
186	60.9		72.1	70.9	69.5	71.4	64.7	70.9		
209	60.4	69.7	68.9	69.9	70.0	69.6	69.0	61.7	73.3	
220	62.3	67.5	67.7	66.9	68.8	69.2	64.9	70.3	65.1	

[a] No data for 1981.

warranted and could be conveniently done in connection with other beach studies.

Acknowledgments

S. Carothers provided some of the initial data in 1982 on the beaches and the sampling design. Financial support for river trips in 1989–90 was provided by grant TPE 8954618 from the National Science Foundation. Grand Canyon National Park afforded some of the river-user days from their research allotment and granted permits for sampling the beaches. We thank the science teachers (more than 50) from around the nation who helped gather data over the preceding decade.

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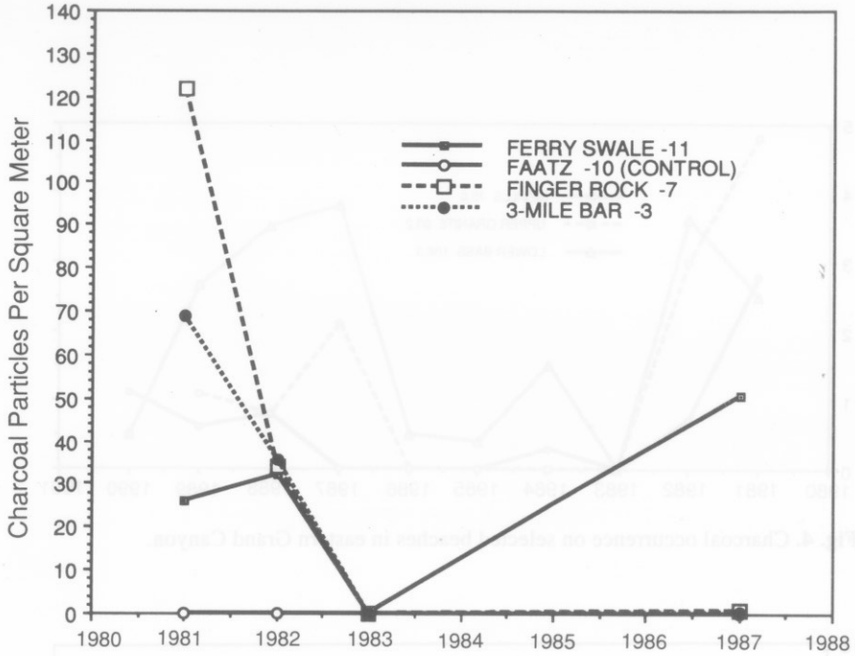

Fig. 2. Charcoal occurrence on Glen Canyon beaches.

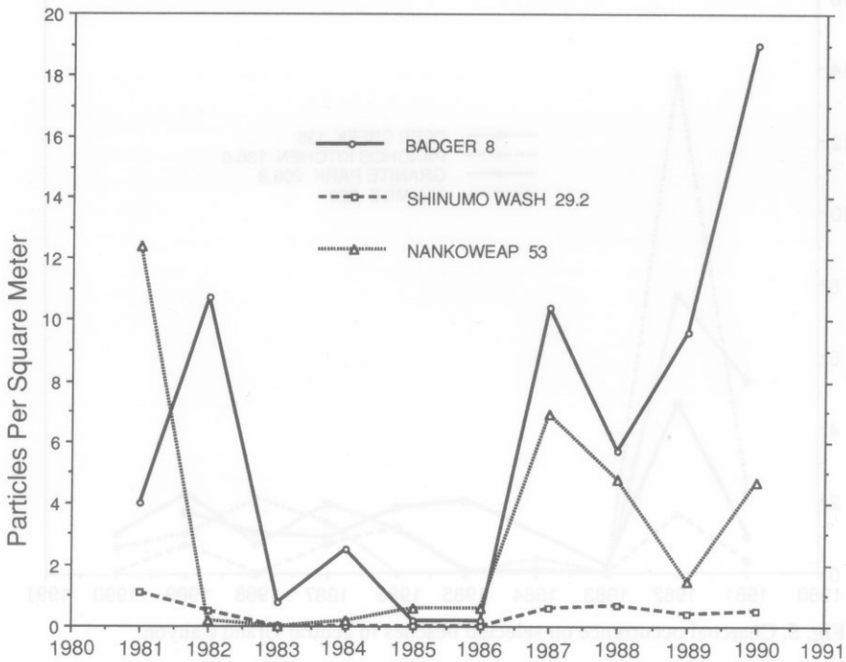

Fig. 3. Charcoal occurrence on selected Marble Canyon beaches.

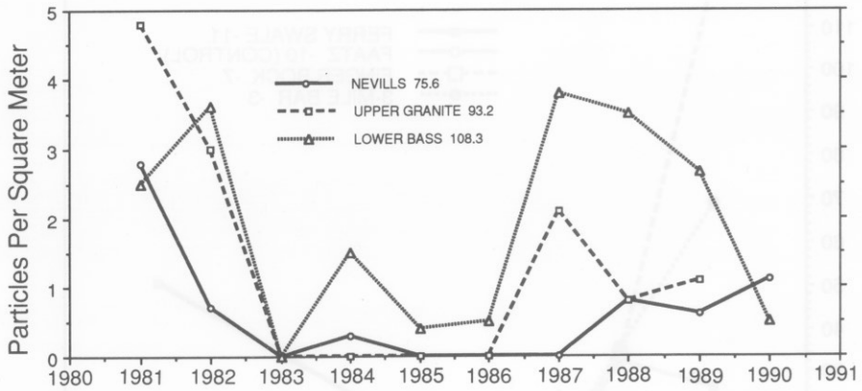

Fig. 4. Charcoal occurrence on selected beaches in eastern Grand Canyon.

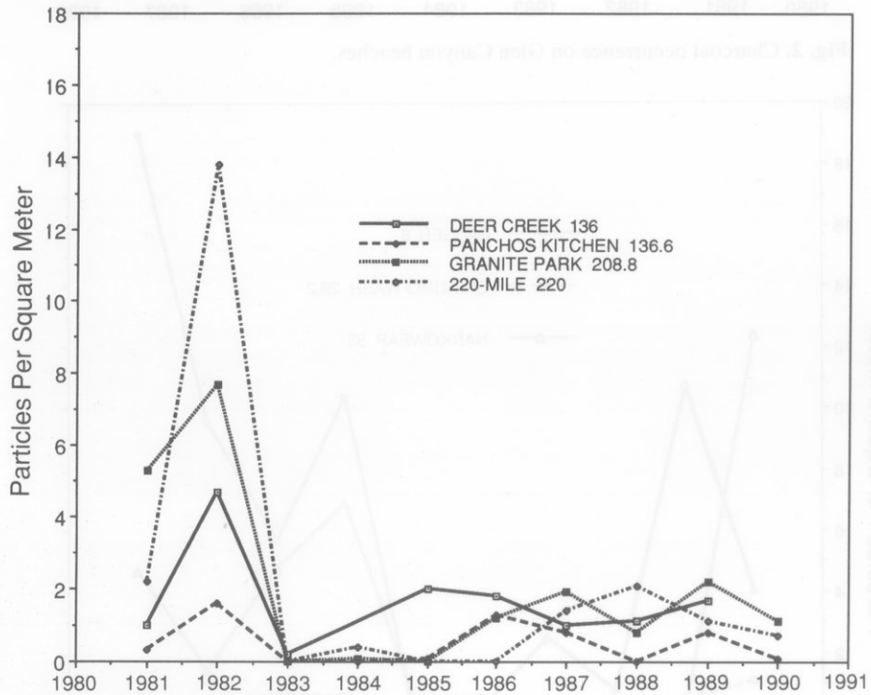

Fig. 5. Charcoal occurrence on selected beaches in central Grand Canyon.

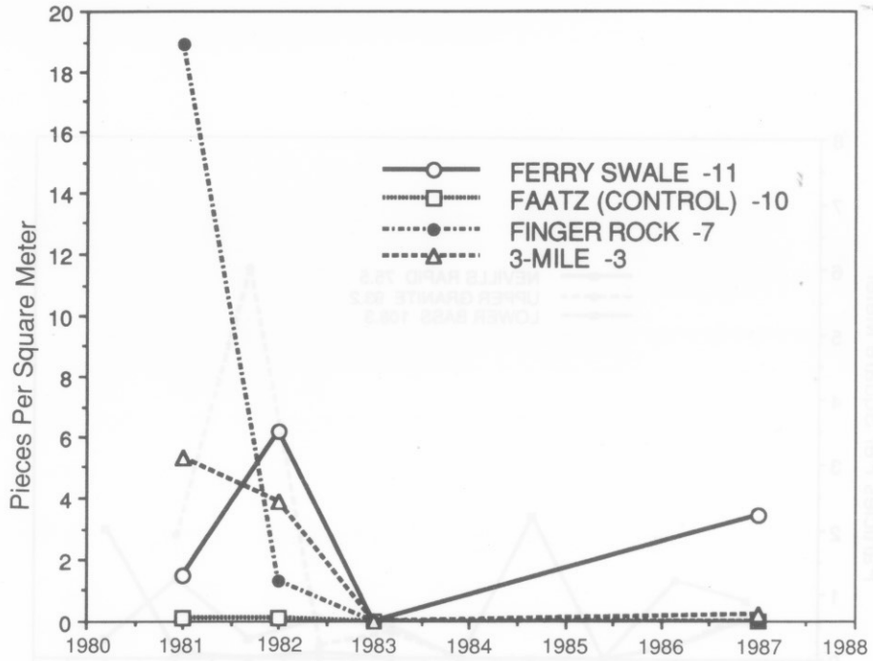

Fig. 6. Human litter occurrence on Glen Canyon beaches.

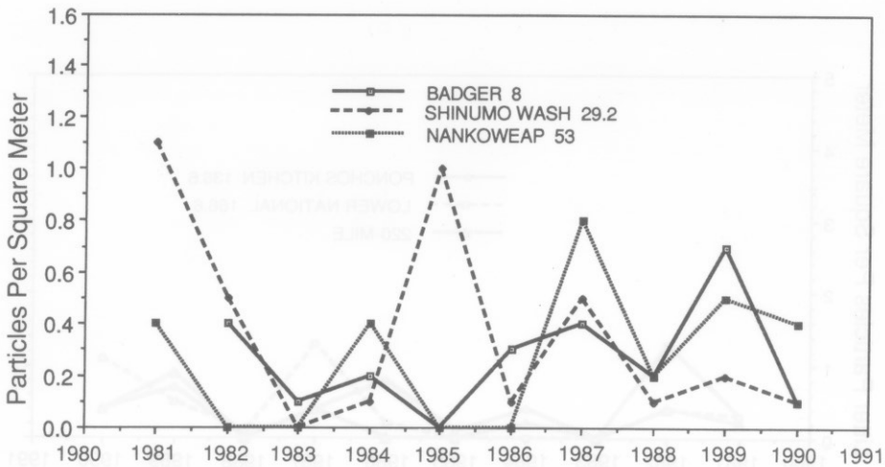

Fig. 7. Human litter occurrence on Marble Canyon beaches.

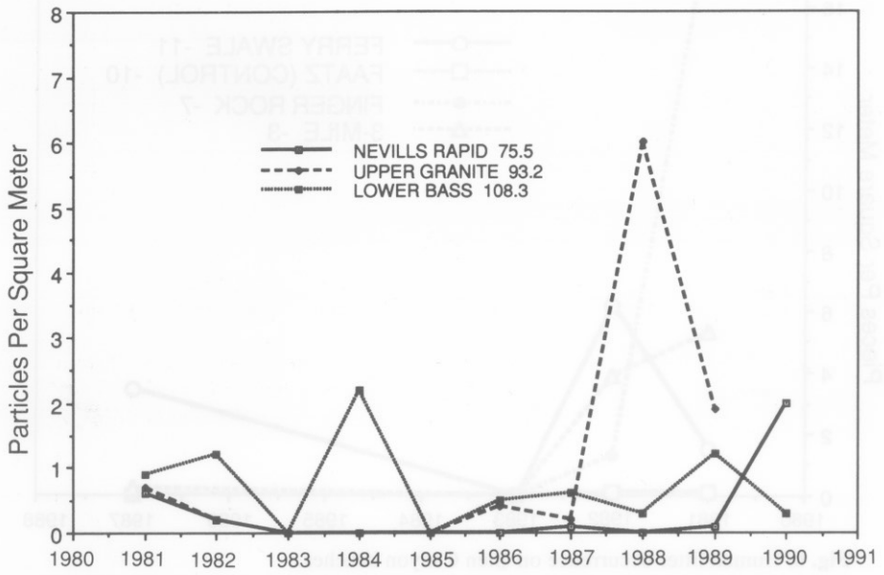

Fig. 8. Human litter occurrence on selected beaches in eastern Grand Canyon.

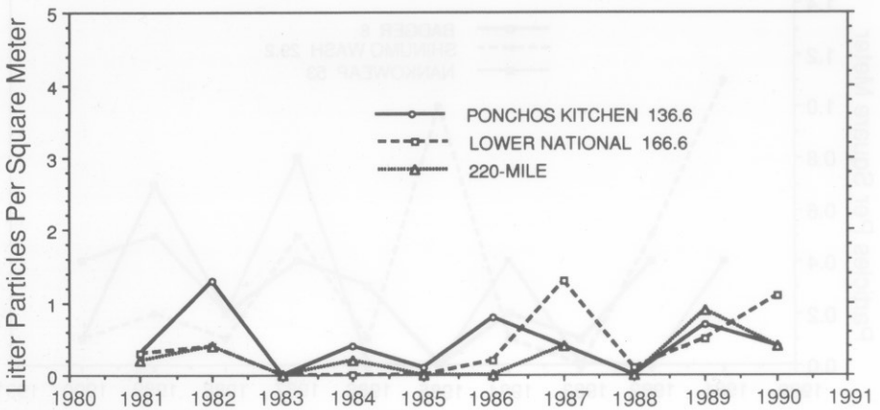

Fig. 9. Human litter occurrence on selected beaches in central Grand Canyon.

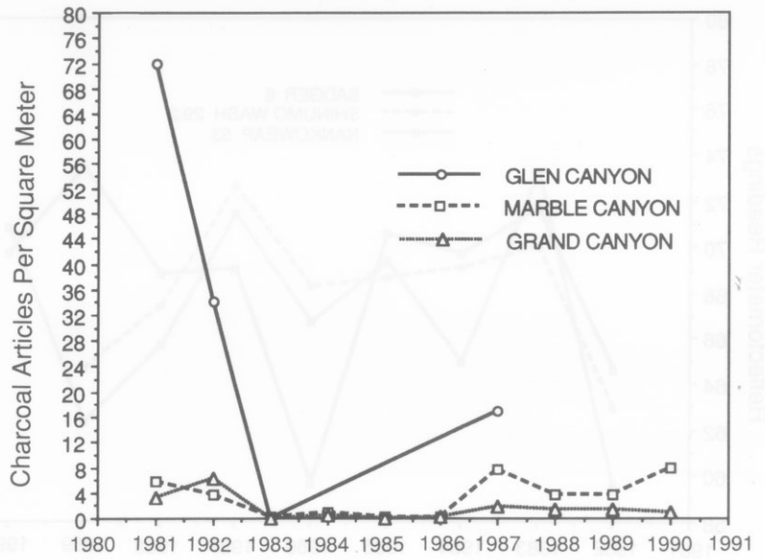

Fig. 10. Summary of charcoal occurrence (mean of means of selected beaches) in Glen Canyon—miles –13.5, –11, –7.6, –3.4; Marble Canyon—miles 8, 29.2, 53; and Grand Canyon—miles 75.6, 93.2, 108.3, 136, 137.6, 166.6, 208.8, and 220.

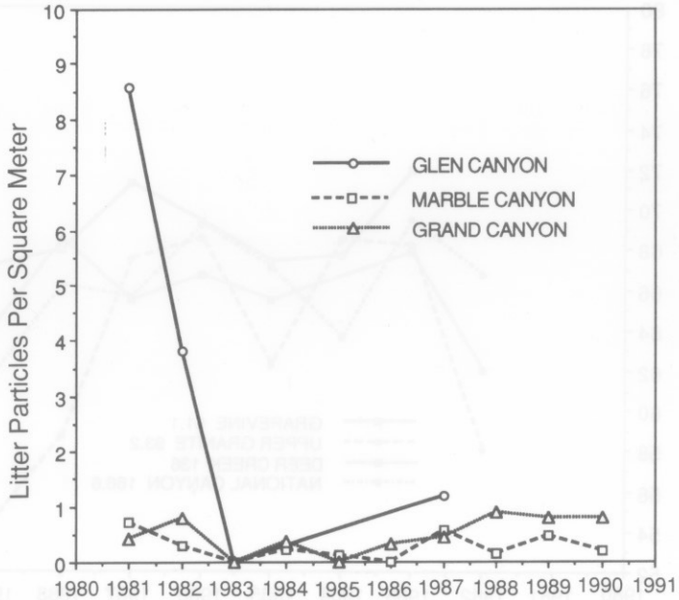

Fig. 11. Summary of human litter occurrence (mean of means of selected beaches) in Glen Canyon—miles –13.5, –11, –7.6, –3.4; Marble Canyon—miles 8, 29.2, 53; and Grand Canyon—miles 75.6, 93.2, 108.3, 136, 136.6, 166.6, 208.8, and 220.

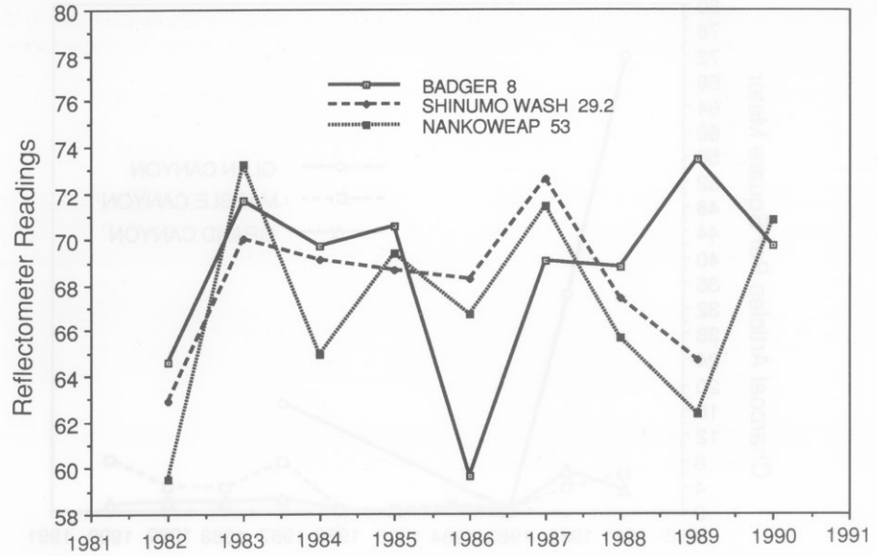

Fig. 12. Light reflectance of selected beaches, Marble Canyon.

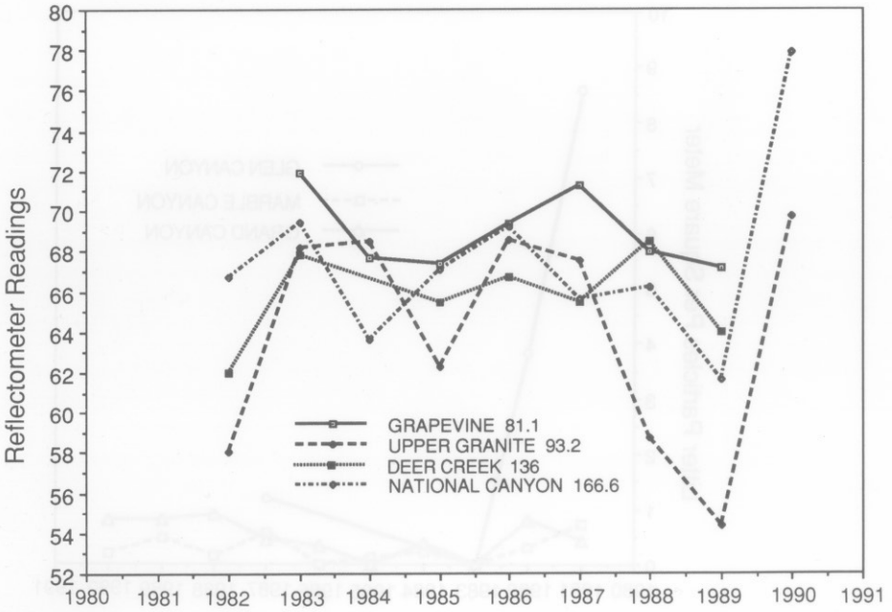

Fig. 13. Light reflectance of selected beaches, Grand Canyon.

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