COLORADO RIVER INVESTIGATIONS # 10

July-August, 1991

By
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Northern Arizona University

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INTRODUCTION

This report presents the results of investigations conducted on the beaches in Grand Canyon as part of a graduate course-Geology 601, Biology 680--offered in July-August 1991, by Northern Arizona University. The course is designed as a workshop for science teachers from southwestern U.S. and is financially supported by grants the National Science Foundation (Grant # TPE-8954615) and Arizona Board of Regents with logistics and instructional support from the Grand Canyon National Park, Bureau of Reclamation, Union Pacific Resources Company and Museum of Northern Arizona.

The program included classroom, laboratory and short field trip instruction in geology and biology (2 weeks), an 11-day river trip through Grand Canyon, and preparation of research reports and teaching activities (10 days). On the river trip, each participated in at least one research investigation under the direction of Stanley S. Beus or Lawrence E. Stevens, the senior scientists, or Frank B. Lojko, research coordinator, in the course. Most of the 10 investigations reported here are parts of ongoing studies to address problems relative to resource management of the fragile sandy beaches used as campsites in the Grand Canyon.

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CHAPTER I

HUMAN IMPACT STUDY ON THE BEACHES OF THE COLORADO RIVER IN THE GRAND CANYON

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INTRODUCTION

Within the past twenty years two major and distinctly interrelated natural resource management problems have arisen along the river corridor of the Colorado River in Grand Canyon National Park. Specifically, the problems relate to: 1) the extensive environmental changes that have taken place in the hydrological characteristics of the river as a result of Glen Canyon Dam, and 2) the dramatic increase in recreational use of the systems by river runners and hikers.

Although located fifteen miles upstream of the national park boundary, Glen Canyon Dam changed the nature of the Colorado River flowing through the Grand Canyon. Post-dam changes in water flow, water temperature, and sediment discharge have combined, often synergistically, to alter the Grand Canyon river ecosystem. On one side of Glen Canyon Dam, the wildly variable and raging Colorado River has been buried beneath the deep waters of Lake Powell; on the other side, the river we still call the Colorado is now released through turbines and gates as a predictable, computer-regulated, icy cold, sediment-free, and partially tamed river. To further complicate the matter, the "new" dam-controlled Colorado River in the Grand Canyon has recently proven to be one of the most popular white-water recreation areas in the world, with a strict National Park Service permit system regulating and allocating both private and commercial use of the 225 miles of Colorado River from Lees Ferry to Diamond Creek (GCNP 1981). These stabilized patterns of water flow established during the past twenty years have been disrupted only once when unexpected high waters and the ensuing floods occurred in 1983.

Given the above considerations, the present challenges to developing an adequate system for resource management along the river corridor of Grand Canyon National Park include: a) determining the eventual ecological "steady state" of the dam-altered river in terms of sediment erosion and deposition, vegetation and animal community composition, and overall ecosystem stability; b) determining and evaluating the impacts of river recreationists on the changing aquatic and terrestrial systems; and c) mitigating such recreational impacts to the extent that natural park values are not compromised.

As mandated by "The Planning Process of the National Park Service in 1975," a Colorado River Management Plan (GCNP 1981) was drafted to guide short-and long-term management of the riverine and riparian areas of Grand Canyon National Park. Subsequently, a monitoring program was initiated to analyze and quantify human impacts and to determine how changes in management policies influence present resource trends. This monitoring program was designed to gather baseline data and show the impact (adverse and otherwise) of visitor numbers and use patterns on the riparian environment.

Heavy recreational use in other parks has caused changes in plant species composition and vegetation density and diversity (Johnson, et al. 1977). Preliminary data from Grand Canyon (Aitchison, et al. 1979) indicated that similar changes or impacts were taking place on the principal 100 plus campsites of the river corridor. All of these campsites are on alluvial terraces (sand and silt/sand compositon) that were deposited during pre- dam flood discharges. In the twenty years prior to 1983, vegetation previously scoured from the beaches on an annual basis proliferated, while human related debris incorporated into beach sands during normal camping activities accumulated. With no natural purging of recreation related debris there exists the potential for popular beaches to fill "cat box style" with various forms of human waste products. Additional problems of a similar vein have recently been observed in backcountry campsites where recreational use is clearly in excess of the natural purging capacity of the system.

In an effort to clean up the beaches, the Colorado River Management Plan requires that all wood and charcoal carried into the Grand Canyon by river recreationists be burned in fire pans and the ashes be carried out. Gas stoves are now required for most cooking purposes. Regulations also require all river users to haul out solid human wastes.

The 1983 floods cleaned the beaches, resorted the sand, and gave the system a fresh start. Along with this cleansing, new beaches formed and others disappeared. The 1983 study established important baseline data for future investigations. These data are the control for this study.

Early in 1976, 25 Colorado River campsites in Grand Canyon were selected for the purpose of monitoring levels of recreational impact. In 1980-81, nine additional beaches in the fifteen miles of Glen Canyon below Glen Canyon Dam were evaluated for levels of human impact. Other beaches have been added through time and have been monitored and evaluated for human impact as shown in Table 1-1.

OBJECTIVES

The objectives of the 1991 study were to:

1. Collect data on the degree of sand discoloration on 13 previous sampled beaches along the Colorado River corridor (1984-1991),

2. Collect data on the incidence of charcoal greater than or equal to 1 cm and human litter on 13 previously sampled beaches along the Colorado River corridor (1984-1991),

3. Compare data from objectives 1 & 2 with the findings from studies conducted in 1984-1990 to assess human impact on beaches after they were cleaned in the 1983 flood,

4. Collect data to investigate the potential influence of tamarisk organic matter on sand discoloration and the total amount of organic material in samples.

HYPOTHESIS

Human impact on selected beaches along the Colorado River corridor will result in significant increases in sand discoloration and increases in charcoal and human litter.

METHODS

1. A 40-meter transect line was run through the principal use area of the beach along the same upstream-downstream line established in previous years. If a 40-meter transect line could not be established, the longest possible line was run and the distance recorded. Compass readings, illustrations, and photographs of previous reports should be used in locating the transect lines.

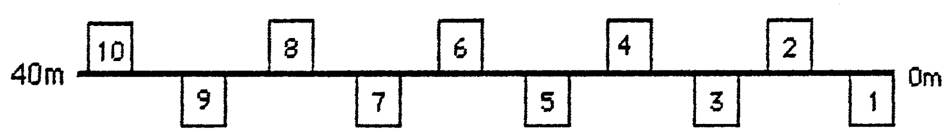
2. Black and white photographs of the transect, including the metric tape and river mile marker were taken from upstream and downstream directions. The campsite name, river mile number, the side of the river, date and compass reading were written on a chalkboard and included in the photograph.

Example:

BADGER
MILE 8 L
N 24 E
7-24-91

3. Ten 1-square-meter plots were laid out equidistant from each other in an alternating pattern along the transect line. When a forty meter transect line could not be established shorter intervals of equal distance were used. This year's study used the same intervals as the1990 study.

4. Each one square meter plot was inspected by hand sifting through the surface sand. All pieces of charcoal greater than or equal to 1 cm and all pieces of human litter found in the plot were counted, recorded, and removed. A dry sand sample from the surface of each plot was collected in a whirl pack. Any damp sand was collected and dried out before it was tested. All samples were labeled with the beach name, the river mile, and the plot number when they were collected. Plots were always numbered 1-10 beginning from the downstream end.



5. Sand samples were also collected at the sand/water interface and from the terrace above the beach at the old high water line. A limited number of samples were taken from under tamarisk trees that had well developed organic accumulation layers (duff) in order to test the alternative hypothesis that tamarisk duff discolors the sand.. Three samples were taken from under one tree at each of five sites. These samples were taken at the surface of the sand immediately below the duff layer, at 6 cm and at 12 cm. These samples were then subjected to the same reflectometer procedures described below.

6. Each sand sample was sifted through a 150 micron stainless steel mesh apparatus until the amount of sifted material completely covered the bottom of the container to a depth of 1 cm.

7. A piece of No. 7 coarse grade filter paper was placed in the lid of the apparatus with the hatched side up, and sifted material was shaken against the filter paper 75 times.

8. The filter paper was removed with tweezers, the discoloration on the filter paper was evaluated with a Colorgard II Reflectometer and recorded on the data sheets.

The Colorgard II Reflectometer is an instrument operating with an optical system, photocell amplifier, digital read-out and portable power system, and is used to make reflective measurements. The reflectometer was used to obtain reflective values from the filter paper discs which were discolored with filtrate from the sand samples. The reflectometer was calibrated prior to each series of readings against a white standard and a gray standard. The reflectivity of the filter paper was measured and recorded each time the reflectometer was calibrated

9. The shaking apparatus was then cleaned by swirling sand around the inside of the containers and discarding the sand. The wire mesh was cleaned with a toothbrush after each sample was shaken.

10. Means and standard deviations of the reflectometer readings from the ten transect samples were calculated for each beach that was sampled. These were then tabulated with the data from 1984-1991. T-score calculations at a 0.05 level of significance were used to compare the 1990 reflectometer readings with the 1991 reflectometer readings

11. The following procedure was used to determine the percent of organic matter present in twelve sand samples:

A.) Part of each sand sample was shaken and placed alongside the unshaken sand sample and placed in an oven at 80 F overnight to remove excess moisture.

B.) The shaken sand was divided into two samples of approximately one gram each and placed in a preweighed crucible. The weight of the sand was determined by subtracting the weight of the crucible from the total weight of the sand and crucible. The same procedure was followed for the unshaken part of the sand sample.

C.) The resulting four parts of each sample were heated until glowing and red hot over a bunsen burner for ten minutes.

D.) The sand was allowed to cool for 30 minutes before being reweighed The original weight of each sample was compared to the cooled weight of the sample and the percent of burned off organic material calculated.

$$\text{Percent of nonorganic matter} = \frac{\text{weight of heated sand}}{\text{weight of unheated sand}} \times 100$$

RESULTS

Thirteen beaches were sampled in 1991. Two new beach transects were established at South Canyon (Mile 31.6) and Nautiloid Beach (Mile 34.7). The levels of sand discoloration as measured by reflectometer readings are presented in Table I-1. For purposes of comparison, this data is presented with equivalent figures from 1984-1990. Due to lack of available time or erosion, four beaches were omitted from the previous year's study. No transect lines were changed.

In comparing the 1990 and 1991 sand analyses, three beaches showed an increase in sand discoloration, at a greater than 0.05 level of significance. The remaining ten beaches showed a decrease in sand discoloration. (See indivuidual data sheets for each beach.)

Results of the charcoal accumulation are summarized in Table 1-2 for the years 1984-1991. In comparing the 1990-1991 data, Pancho's Kitchen, Lower National and Granite Park beaches showed an increase in the incidence of charcoal greater than 1 cm. There was no change in charcoal accumulation at Lower Bass Camp. All other beaches showed a decrease in accumulation of charcoal.

In comparing the accumulation of human litter from 1990 to 1991 on Table 1-3, Badger, Grapevine, Granite Park, and Lower National beaches showed an increase in the amount of human litter. Eight beaches showed a decrease, while Pancho's Kitchen showed no change. These comparisons of human litter and charcoal debris were not analyzed using T-score calculations to determine the level of significance.

Preliminary studies were made to assess the role of tamarisk duff on beach discoloration, as per recommendations of the1990 research group. Not enough samples were taken to be statistically valid, but it appears that tamarisk does play some role in discoloring at least portions of some beaches where the tree forms dense stands (see Table 1-4). It is thought that the 1983 flood cleaned out the sand and that the duff is again working its way down through the sand, as is shown with the greater reflectivity with depth.

A related study was conducted to determine the percent of organic material present in beach sand. Twelve sand samples from Mile 208, previously tested for discoloration, were utilized to determine the percent of organic matter present. Each of the twelve samples produced four data entries. The shaken sand samples consistently yielded 4% organic material while the unshaken sand samples yielded a constant 2% organic matter. These percentages were compared with the sand samples' reflectometer readings. The unshaken sand readings were on the average higher than the shaken sand readings. The shaking procedure seems to concentrate the organic material present in the sand.

CONCLUSIONS

The Colorado River beaches in 1991 appear to have decreased in all measures of human impact from the previous year. This is a shift from previous findings in which human impact was generally increasing. It is unclear from the data whether this is a one year anomaly in human impact or the beginning of a future trend. Further research should shed light on this question. It should also be noted that some beaches appeared to be more contaminated with human litter and charcoal debris than the transect line samples indicated. This may be due to beach use patterns changing.

The initial hypothes suggests that human impact would lead to yearly increases in both sand discoloration and the incidence of charcoal and human litter since the 1983 flood scoured them clean. Previous studies have supported this hypothesis, while this year's study does not. The dynamics of human impact is obviously more involved and complex than previously thought.

RECOMMENDATIONS

Factors other than human use may be influencing the data obtained in the sand discoloration portion of the study. In order to better differentiate between human impact and other factors on the sand discoloration levels, we recommend: 1) more extensive samples be taken under established tamarisk trees or other vegetation, as well as nearby samples in bare areas, and 2) samples of sifted sand with low reflectometer readings be saved and brought back for laboratory analysis to differentiate between charcoal, tamarisk and other human organic materials. This needs to be done to test the assumption behind the reflectometer studies that it is human impact (and not other, natural organic materials) that is causing the discoloration. An alternative hypothesis may be that human impact <u>and</u> tamarisk/other plant duff are both influencing readings. Studies should be done to assign the relative value of each of these factors.

Because the present transect lines no longer consistently cross the most heavily impacted portions of the beaches, we recommend that future investigators consider relocating some transect lines to include the most used portions of the beaches. When done, these transects should be tied in to benchmarks of the beach profile studies, in order that the transects can be more easily and accurately located from year to year.

Equipment List

River Trip:

- Brunton compass (quadrant)
- Reflectometer II + battery; (extra battery)
- 500-1000 small whirl packs
- Transect line (40 meter tape)
- 2 magic markers (waterproof)
- 3-one square meter frames, collapsible
- 5 plastic sand sifters
- filter paper (#7 coarse grade) 12 per beach
- 2 tweezers (to pick up filter paper)
- 2 toothbrushes (to clean stainless steel mesh apparatus
- 12 large sample bags (to store and carry samples)
- 5-150 micron stainless steel mesh apparatus
- 1 table with legs
- calculator with statistical mode
- pad for writing, pencils, pencil sharpener
- blank data sheets
- 1 clip board
- chalkboard and chalk, to record location
- black and white film, camera
- umbrella
- previous year's beach sand report, including data sheets of each beach
- photos of previous year's transect lines
- epoxy glue to repair mesh screens

Laboratory equipment:

- computer diskettes
- table of T-scores
- blank data sheets
- computer program to calculate T-scores
- Cricket graphing program to display data
- previous year's report and tables on Macintosh diskettes
- crucibles
- tongs
- rings, ringstands
- ceramic triangles
- bunsen burners
- digital balance

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Table 1-1 Results of sand discoloration analysis of beach campsites in Grand Canyon 1984-1991 (means only).

Site No	Campsite Name	River mile	1984 (S.D.)	1985 (S.D)	1986 (S.D.)	1987 (S.D.)	1988 (S.D.)	1989 (S.D.)	1990 (S.D.)	1991 (S.D.)
1	Badger Rapid	8	69.69 (2.52)	70.55 (1.82)	59.65 (5.59)	69.03 (3.95)	68.76 (2.86)	73.42 (1.43)	69.70 (1.94)	62.42 (2.39)
2	20 Mile	20	68.78 (3.14)	64.29 (3.07)	67.47 (4.54)	69.20 (2.19)	deleted			
3	Shinumo Wash	29	69.10 (3.16)	68.62 (3.03)	68.24 (5.14)	72.57 (1.95)	67.42 (3.22)	64.64 (0.69)	69.5 (2.5)	
4	South Canyon	31.6								64.18 (3.17)
5	Nautiloid Beach	34.7								67.8 (3.65)
6	Anasazi Bridge	43.5	70.55 (1.83)	71.13 (1.80)	71.61 (1.79)	72.72 (2.24)	deleted			
7	Lower Nankoweap	53	64.91 (3.16)	69.33 (2.66)	66.67 (3.51)	71.36 (1.85)	65.67 (2.73)	62.28 (1.73)	70.06 (3.43)	68.42 (2.56)
8	Awatubi	58.1	64.48 (5.73)	66.97 (3.31)	64.96 (4.21)	70.90 (2.46)	69.61 (3.47)	73.21 (2.66)	73.8 (2.8)	
9	Lava Canyon (Chuar)	65.5	65.91 (4.05)	68.56 (3.81)	67.24 (2.87)	beach gone	beach gone			
10	Unkar	72.2	67.70 (2.28)							
11	Nevills Rapid	75.5	66.80 (4.87)	72.21 (1.35)	70.94 (2.98)	69.77 (3.12)	67.68 (3.20)	70.98 (2.28)	70.50 (4.03)	65.69 (6.18)
12	Hance Rapid	76.5	66.87 (5.14)	63.82 (2.92)	65.00 (4.12)	69.12 (3.56)		67.62 (1.96)		
13	Grapevine	81.1	67.62 (2.18)	67.39 (2.95)	69.38 (3.95)	71.25 (1.04)	67.98 (1.42)	67.15 (0.77)	68.65 (2.09)	68.76 (2.76)
14	Granite Rapid	93.2	68.48 (3.28)	62.35 (3.50)	68.55 (2.06)	67.52 (1.40)	58.66 (3.47)	54.38 (3.08)		61.46 (4.33)
15	Lower Bass Camp	108.5	63.38 (5.69)	64.46 (1.69)	68.87 (3.71)	70.31 (3.46)	63.00 (2.56)	61.56 (1.09)	68.71 (3.40)	65.92 (2.25)
16	114 Mile	114	69.22 (2.06)	63.77 (2.39)	71.44 (2.30)	deleted				
17	122 Mile	122	71.16 (2.15)	68.55 (2.65)	71.44 (2.30)	beach gone	69.47 (2.28)	69.87 (2.47)	68.3 (3.8)	
18	Forster	122.8	68.65 (5.16)	69.74 (0.74)	73.27 (1.93)	67.98 (1.43)	66.54 (4.04)	66.29 (1.38)	63.20 (2.03)	67.81 (3.03)
19	Bedrock	131	70.54 (3.40)	68.20 (2.02)	71.50 (1.64)	69.49 (1.68)	68.19 (2.55)			
20	Dubendorff	132	70.22 (2.51)	69.63 (2.35)	69.62 (1.76)	71.07 (2.51)	71.83 (1.50)	river protocol		
21	Deer Creek	136		65.46 (1.38)	66.68 (2.16)	65.43 (2.30)	68.43 (3.70)	63.96 (1.18)		
22	Pancho's Kitchen	137	65.90 (3.79)	67.20 (3.81)	69.43 (3.04)	69.32 (2.00)	66.35 (2.32)	62.19 (1.46)	68.77 (3.73)	69.58 (1.83)
23	Upper National	166.5	68.95 (3.00)	73.31 (0.98)	beach gone	beach gone				
24	Lower National Canyon	166.6	63.59 (3.00)	67.10 (2.42)	69.23 (1.66)	65.62 (2.17)	66.21 (2.09)	61.63 (0.99)	77.87 (1.43)	72.62 (1.82)
25	Upper Lava	179					71.73 (1.70)			
26	Lower Lava Falls	180		67.74 (1.65)	67.63 (2.92)	72.87 (3.16)	69.43 (1.56)	69.32 (1.45)		
27	186 Mile	186	72.06 (1.50)	70.95 (2.18)	69.54 (1.23)	67.43 (1.11)	64.65 (1.51)	70.87 (2.39)		
28	Helicopter Pad	187.2					63.53 (2.07)			
29	194 Mile	194					66.69 (1.56)	71.99 (1.45)	75.24 (1.01)	71.58 (3.45)
30	195 Mile	195				71.91 (1.71)				
31	Parashant	198.5	63.94 (4.77)	68.39 (2.68)	beach gone	beach gone				
32	Indian Canyon	207			71.09 (1.52)	72.8 (2.11)	69.17 (2.85)	70.06 (1.21)		
33	Granite Park	208.8	68.93 (2.17)	69.88 (2.13)	69.97 (2.48)	69.56 (4.52)	69.04 (2.54)	61.71 (2.27)	73.32 (2.55)	68.29 (3.59)
34	Pumpkin Bowl	213	70.83 (1.75)	68.63 (2.41)	69.54 (1.81)	69.17 (2.60)	66.52 (2.25)	72.32 (1.31)		
35	Trail Canyon	219	72.18 (1.45)	68.78 (3.38)	beach gone	beach gone				
36	220 Mile	220	67.71 ( )	66.93 (2.28)	68.67 (1.74)	69.18 (1.94)	64.97 (1.51)	70.30 (1.91)	65.1 (3.0)	

Table 1-2 Results of charcoal accumulations analysis of beach campsites in Grand Canyon 1984-1991 (means only).

Site No.	Campsite Name	River Mile	1984	1985	1986	1987	1988	1989	1990	1991
1	Badger Rapid	8	2.5	0.2	0.2	10.4	5.7	9.6	19	6.9
2	20 Mile	20	0	0.3	0	0.2				
3	Shinumo Wash	29	0	0	0	0.6	0.7	0.4	0.5	
4	South Canyon	31.6								13.4
5	Nautiloid Beach	34.7								0
6	Anasazi Bridge	43.5	0	0	0.2	0.2				
7	Lower Nankoweap	53	0.2	0.6	0.6	6.9	4.8	1.5	4.7	1.1
8	Awatubi	58.1	0	0	0	1.3	0.8	0.3	0.8	
9	Lava Canyon (Chuar)	65.5	1.6	1.3	4.5	beach gone	beach gone	0.3		
10	Unkar	72.2	0.2	beach gone	beach gone					
11	Nevills Rapid	75.5	0.3	0	0	0	0.8	0.6	1.1	0.1
12	Hance Rapid	76.5	0.2	0.9	1.5	3.6		3.1		
13	Grapevine	81.1	0	0	0	0.5	0.6	0.2	2	0.8
14	Granite Rapid	93.2	0	0	0	2.1	0.8	1.08		7.3
15	Lower Bass Camp	108.5	1.5	0.4	0.5	3.8	3.5	2.67	0.5	0.5
16	114 Mile	114	0.2	0	0.1	delete				
17	122 Mile	122	0	0	1		0	0	0.1	
18	Forster	122.8	0	0	0.6	0	0.2	0.8	0.7	0.2
19	Bedrock	131	0	0.3	0.5	0	0.9			
20	Dubendorff	132	0	0.5	0	0	0			
21	Deer Creek	136		2	1.8	1	1.1	1.7		
22	Pancho's Kitchen	137	0	0.1	1.3	0.8	0	0.8	0.1	0.7
23	Upper National	166.5	0	0	beach gone					
24	Lower National	166.6	0	0	0.2	0.3	0.1	0.5	1.1	0.2
25	Upper Lava	179						0		
26	Lower Lava	180		0.7	1.6	3.7	0.5	1.8		
27	186 Mile	186	0.2	0.6	0.8	0	0.1	0.1		
28	Helicopter Pad	187.2					0			
29	194 Mile	194					0.2	0.3	0.5	0.5
30	195 Mile	195								
31	Parashant	198.5	0	0	beach gone					
32	Indian Canyon	207				0	0	0.2		
33	Granite Park	208.8	0.1	0	1.2	1.9	0.8	2.2	1.1	2.7
34	Pumpkin Bowl	213	0	0.2	0.1	0	0.1	0.1		
35	Trail Canyon	219	0.1	0	beach gone					
36	220 Mile	220	0.4	0	0	1.4	2.1	1.1	0.7	

TABLE 1-3 Results of human litter accumulations analysis of beach campsites in Grand Canyon 1984-1991 (means only).

Site No	Campsite Name	River Mile	1984	1985	1986	1987	1988	1989	1990	1991
1	Badger	8	0.2	0	0.3	0.4	0.2	0.7	0.1	0.5
2	20 Mile	20	0.2	0.2	0	0				
3	Shinumo Wash	29	0.1	1	0.1	0.5	0.1	0.2	0.1	
4	South Canyon	31.6								0.4
5	Nautaloid Beach	34.7								1.1
6	Anasazi Bridge	43.5	0	0	0	0.1				
7	Lower Nankoweap	53	0.4	0	0	0.8	0.2	0.5	0.4	1.3
8	Awatubi	58.1	0	0.3	0.1	0.5	0.2	0.1	0.1	
9	Lava Canyon (Chuar)	65.5	0	0.2	beach gone					
10	Unkar	72.2	0.1	beach gone						
11	Nevills Rapid	75.5	0	0	0	0.1	0	0.1	0.2	0.1
12	Hance Rapid	76.5	0	0	0	0.2		0		
13	Grapevine	81.1	0	0	0	0	0.2	0.4	0.3	0.5
14	Granite Rapid	93.2	0	0	0.4	0.2	0.6	1.9		1.3
15	Lower Bass Camp	108.5	2.2	0	0.5	0.6	0.3	1.22	0.3	1
16	114 Mile	114	0	0.5	delete					
17	122 Mile	122	0.2	0.1			0	0.7	0.2	
18	Forster	122.8	0	0	0	0	0	0	0.2	0
19	Bedrock	131	0.1	0	0.1	0	0.1			
20	Dubendorff	132	0	0	0	0.3	0			
21	Deer Creek	136		0	0.6	0.4	0.4	0.4		
22	Pancho's Kitchen	137	0.4	0.1	0.8	0.4	0	0.7	0.4	0.4
23	Upper National	166.5	0.2	0.2	beach gone					
24	Lower National Canyon	166.6	0	0.2	0.7	0.5	0.1	0	0.3	0.6
25	Upper Lava	179					0.3			
26	Lower Lava Falls	180		0	0.9	0	0.1	0.3		
27	186 Mile	186	0	0	0	0	0.4	0.1		
28	Helicopter Pad	187.2					0			
29	194 Mile	194					0	0	0.1	0
30	195 Mile	195								
31	Parashant	198.5	0.2	0.3	beach gone					
32	Indian Canyon	207			0	0.1	0.1	0		
33	Granite Park	208.8	0.1	0	0.1	0.1	0.3	0.6	0.3	2.2
34	Pumpkin Bowl	213	0.1	0	0	0	0	0.4		
35	Trail Canyon	219	0	0	beach gone					
36	220 Mile	220	0.2	0	0	0.4	0	0.9	0.4	

Table 1-4 Reflectivity of sand under tamarisk

Site No	Campsite Name	Surface	6 cm	12 cm
11	Nevills Rapid	69.9	68.3	68.1
14	Granite Rapid	57.6	70.1	73.1
18	Forster	70	70	72.5
23	Upper National	65.2	70.3	67
29	194 Mile	62.7	72.3	77.3
	MEANS	65.1	70.2	71.6

Table 1-5

Beach name: Badger
River mile: 8.0

Sample #	Sand Discoloration (reflectometer reading)	
	1990	1991
1	70.9	64.9
2	71.4	59.9
3	71.9	63.3
4	69.2	65.5
5	67.6	58.6
6	70.4	60.3
7	71.7	61.4
8	65.9	65.0
9	69.4	62.4
10	68.6	62.6
Mean	69.7	62.42
Std. Deviation	2.1	2.39
T-value	-4.6	7.47
DF	9.0	18
Prob	0.001	0.715E-06

YEARLY SAND DISCOLORATION COMPARISONS

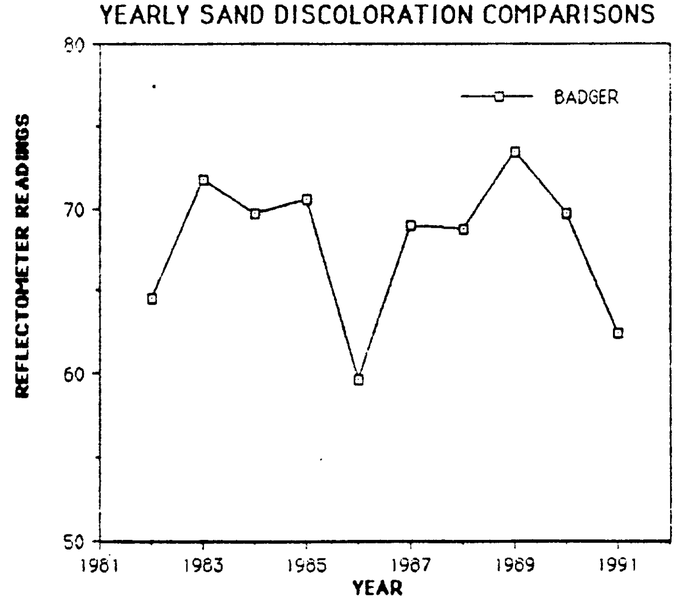


Table 1-6

Beach name: South Canyon
River mile: 31.6

Sample #	Sand Discoloration (reflectometer reading)	
	1990	1991
1		66.3
2		66.0
3		62.2
4		62.3
5		57.7
6		63.4
7		69.8
8		64.2
9		64.9
10		65.0
Mean		64.18
Std. Deviation		3.17
T-value		63.96
DF		18
Prob		0.596E-07

Table 1-7

Beach name: Nautiloid Beach
River mile: 34.7

Sample #	Sand Discoloration (reflectometer reading) 1990	1991
1		63.4
2		66.9
3		66.5
4		69.3
5		65.3
6		65.1
7		65.0
8		69.0
9		72.6
10		74.9
Mean		67.8
Std. Deviation		3.66
T-value		58.62
DF		18
Prob		0.119E-06

Table 1-8

Beach name: Lower Nankoweap
River mile: 53

Sample #	Sand Discoloration (reflectometer reading) 1990	1991
1	70.5	69.1
2	69.8	66.4
3	73.4	68.3
4	72.1	66.8
5	68.6	65.5
6	67.8	70.0
7	73.6	66.8
8	69.1	66.3
9	71.7	72.0
10	71.2	73.0
Mean	70.06	68.42
Std. Deviation	3.43	2.56
T-value	16.1	1.21
DF	9	18
Prob	.000	0.242

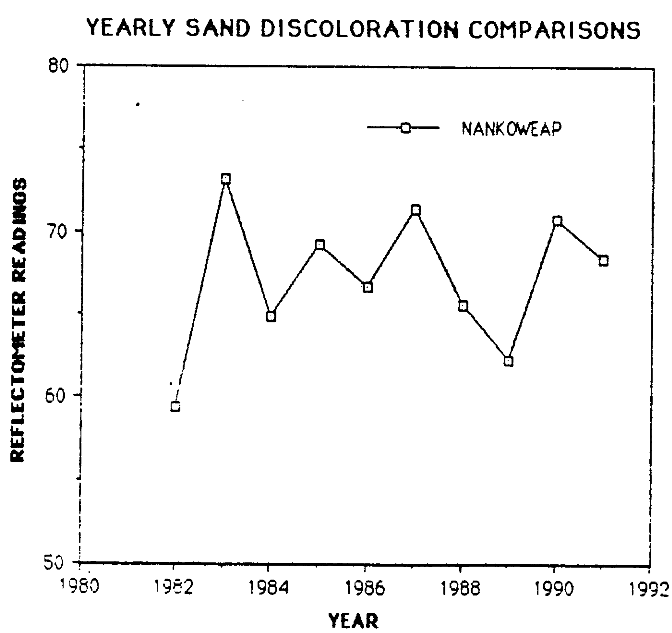


Table 1-9

Beach name: Nevills Rapid
River mile: 75.5

Sample *	Sand Discoloration (reflectometer reading)	
	1990	1991
1	75.0	68.1
2	73.3	54.9
3	74.2	67.1
4	72.3	70.3
5	63.3	65.0
6	68.8	60.1
7	73.9	64.1
8	69.9	64.8
9	64.6	64.5
10	70.0	78.0
Mean	70.5	65.79
Std. Deviation	2.9*	6.18
T-value	-0.341	2.116
DF	9	9
Prob	0.741	0.0635

*4.038 (recalculated 1991)

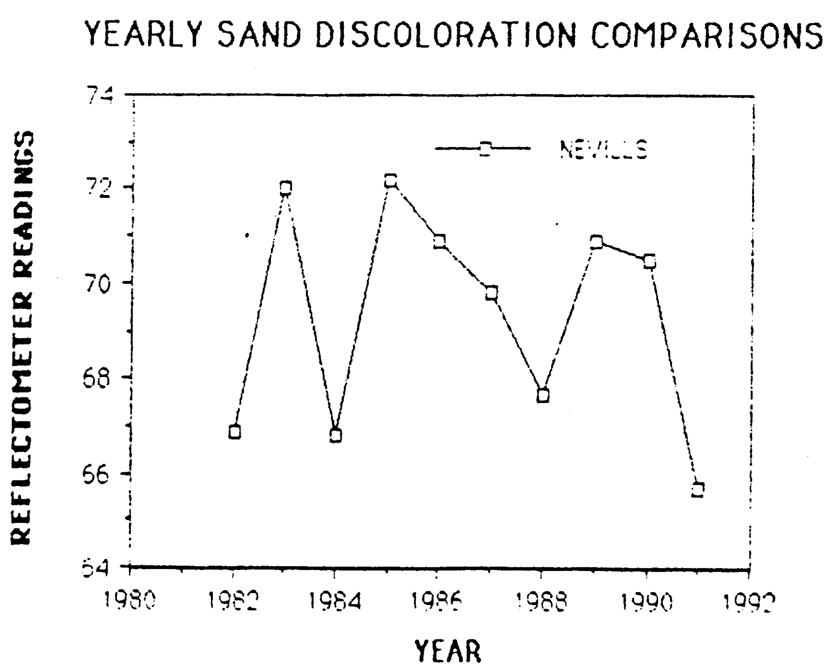


Table 1-10

Beach name: Grapevine
River mile: 81.1

Sample #	Sand Discoloration (reflectometer reading) 1990	1991
1	68.9	71.5
2	70.3	69.3
3	67.1	71.6
4	70.0	72.2
5	66.4	69.4
6	69.9	68.0
7	65.9	64.6
8	70.7	69.8
9	71.3	64.7
10	66.0	66.5
Mean	69.7*	68.76
Std. Deviation	2.9*	2.76
T-value	2.3	0.10
DF	9	18
Prob	0.043	0.921

*68.65 (recalculated 1991)
*2.09 (recalculated 1991)

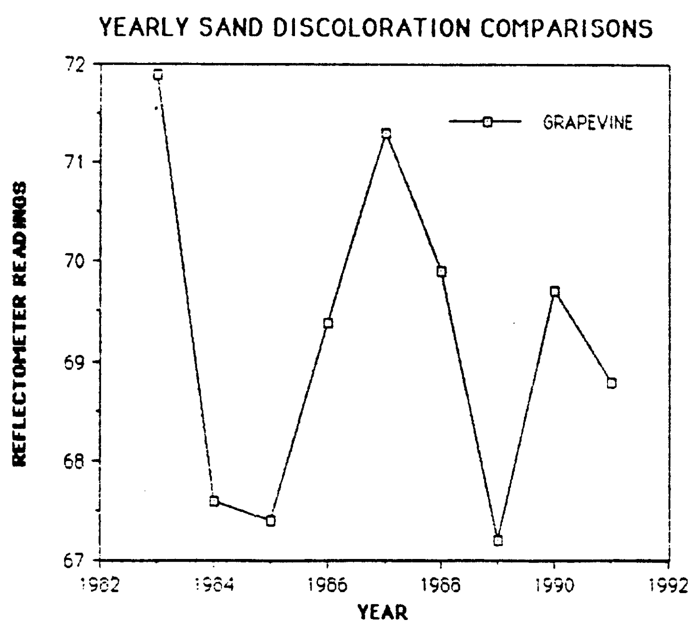


Table 1-11

Beach name: Granite Rapid
River mile: 92.3

Sample #	Sand Discoloration (reflectometer reading) 1990	1991
1		57.0
2		59.5
3		58.6
4		58.4
5		64.1
6		65.9
7		58.8
8		70.5
9		63.3
10		58.5
Mean		61.46
Std. Deviation		4.33
T-value		44.86
DF		18
Prob		0.000E-00

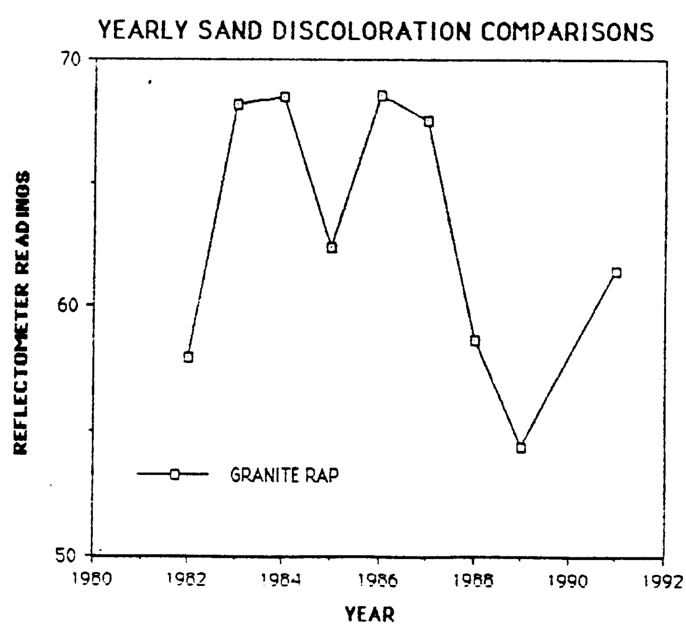


Table 1-12

Beach name: Lower Bass Camp
River mile: 106.5

Sample #	Sand Discoloration (reflectometer reading) 1990	1991
1	71.3	66.5
2	67.0	67.21
3	68.2	67.8
4	70.8	63.0
5	70.2	63.9
6	65.3	63.4
7	67.9	66.3
8	67.7	67.6
9	63.3	63.9
10	75.4	69.7
Mean	68.7	65.92
Std. Deviation	3.4	2.25
T-value	6.223	2.17
DF	8	18
Prob	0.000	0.044

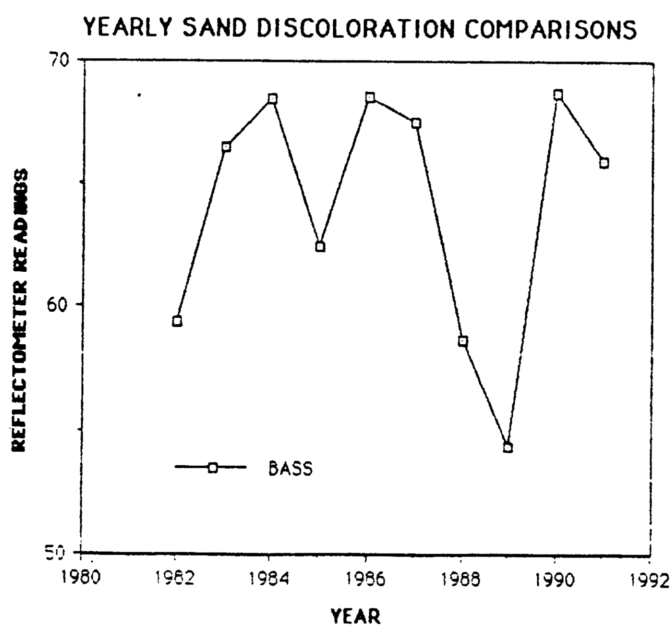


Table 1-13

Beach name: Forster
River mile: 122.8

Sample #	Sand Discoloration (reflectometer reading)	
	1990	1991
1	72.6	67.8
2	69.5	69.0
3	71.0	68.7
4	no sample	72.7
5	69.5	71.2
6	67.5	67.7
7	69.3	64.7
8	70.7	62.3
9	73.6	65.6
10	67.6	68.4
Mean	63.2	67.81
Std. Deviation	2.0*	3.034
T-value	7.086	1.96
DF	8	17
Prob	0.000	0.066

*2.03 (recalculated 1991)

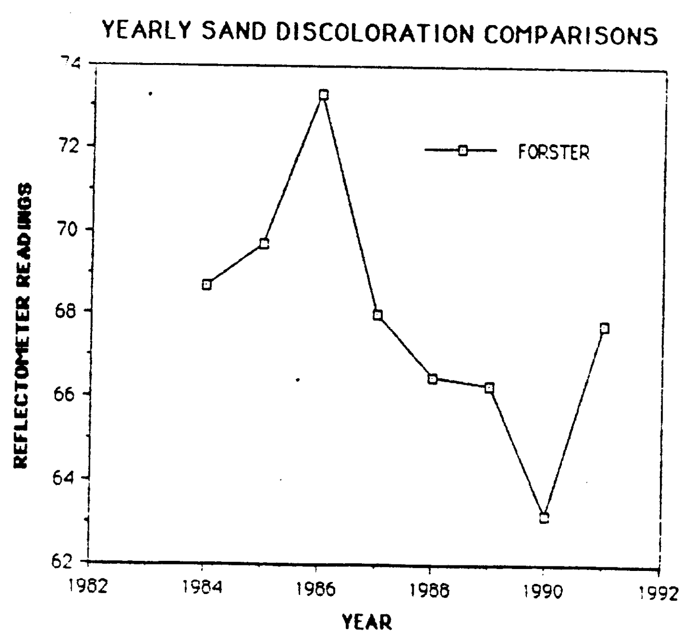


Table 1-14

Beach name: Panchos Kitchen
River mile: 137

Sample #	Sand Discoloration (reflectometer reading) 1990	1991
1	70.0	69.2
2	70.4	71.7
3	69.7	72.9
4	67.4	69.8
5	71.7	67.5
6	59.0	67.5
7	70.2	70.0
8	67.4	68.9
9	70.2	67.6
10	71.7	70.7
Mean	68.8	69.58
Std. Deviation	3.73	1.83
T-value	4.482	0.62
DF	9	18
Prob	0.002	0.546

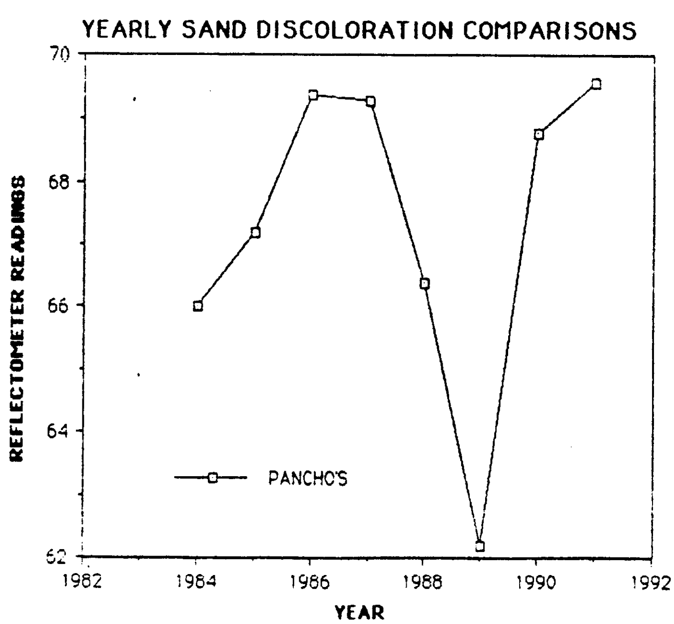


Table 1-15

Beach name: Lower National Canyon
River mile: 166.6

Sample #	Sand Discoloration (reflectometer reading) 1990	1991
1	78.4	72.2
2	78.8	74.2
3	77.1	73.2
4	80.6	72.7
5	78.2	70.8
6	78.6	72.4
7	77.9	74.4
8	75.3	72.9
9	77.2	68.7
10	76.6	74.8
Mean	77.9	72.62
Std. Deviation	1.43	1.82
T-value	41.83	7.17
DF	9	18
Prob	0.000	0.113E-05

YEARLY SAND DISCOLORATION COMPARISONS

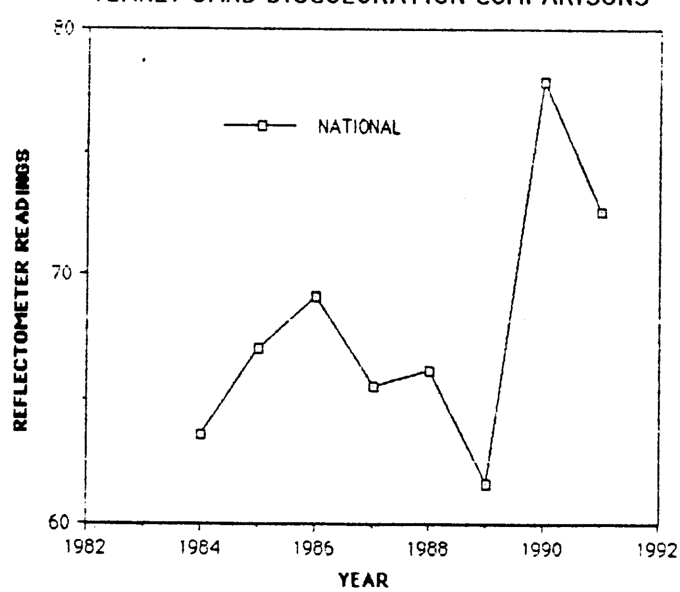


Table 1-16

Beacn name: 194 Mile
River mile: 194

Sample #	Sand Discoloration (reflectometer reading) 1990	1991
1	74.5	67.4
2	74.8	70.8
3	74.3	75.8
4	76.5	70.5
5	74.4	76.0
6	74.2	73.7
7	75.1	71.9
8	75.3	67.3
9	76.3	67.5
10	77.0	74.9
Mean	75.2	71.58
Std. Deviation	1.0	3.45
T-value	6.069	3.22
DF	9	18
Prob	0.000	0.005

YEARLY SAND DISCOLORATION COMPARISONS

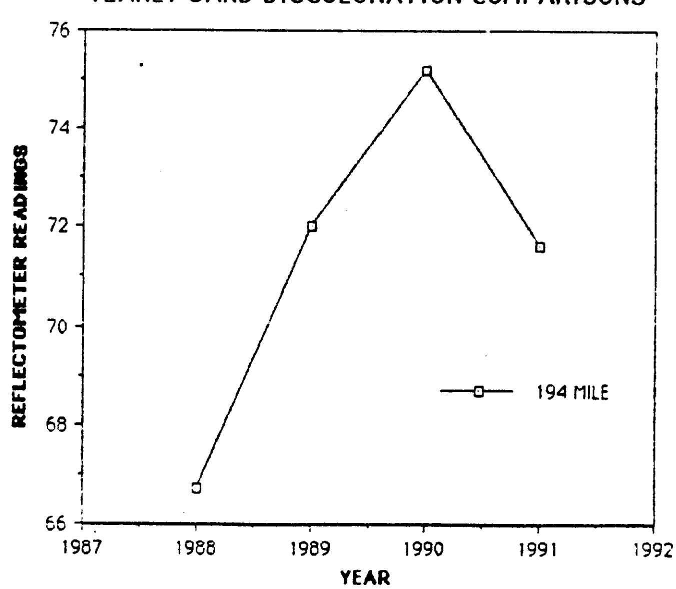
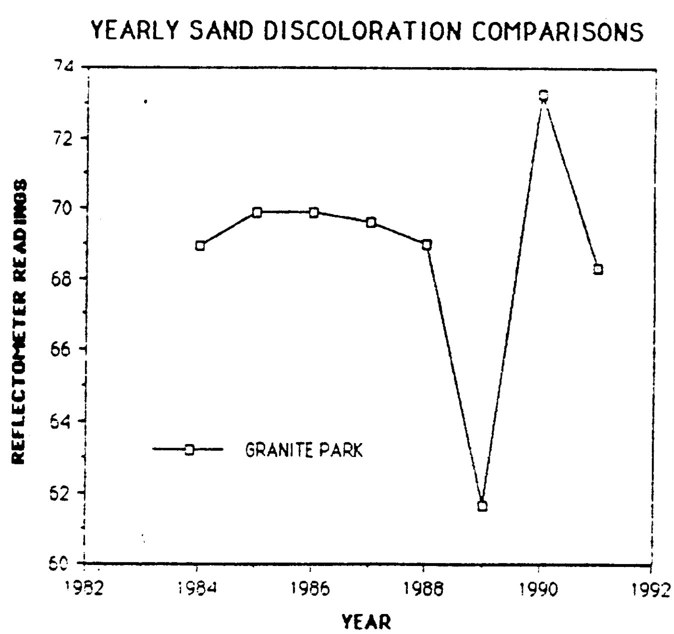


Table 1-17

Beach name: Granite Park
River mile: 208.8

Sample #	Sand Discoloration (reflectometer reading) 1990	1991
1	76.8	68.3
2	77.4	68.8
3	72.2	66.2
4	74.2	68.9
5	70.9	72.0
6	72.0	72.1
7	74.4	70.3
8	72.9	65.9
9	73.4	70.4
10	69.0	60.0
Mean	73.3	68.29
Std. Deviation	3.6*	3.59
T-value	9.0	3.61
DF	9	18
Prob	0.000	0.002

*2.55 (recalculated 1991)



CHAPTER 2

Topographic Changes On Selected Beaches In The Grand Canyon, 1990-1991

Stephen Ahmann, John Dassinger, David Duff, Julie Heal, Anthony Occhiuzzi, David Robertson

Introduction

The beaches along the Colorado River corridor are one of the most important resources found in Grand Canyon National Park. They provide an environment for a unique and varied riparian flora and fauna. In addition the beaches add to the recreational value of the park. Since the 1963 construction of the Glen Canyon Dam, these beaches have undergone considerable alteration. This alteration is of national concern prompting a five year environmental impact study as mandated by the National Environmental Policy Act of 1989.

A research team of science teachers conducted an eleven-day investigation of campsite beaches along the Colorado River in the Grand Canyon. This study, a continuation of research initiated in 1974 and conducted annually since 1982, was implemented to determine the direction, degree and speed of the alteration of selected beaches. Results of this investigation will assist management agencies of the Grand Canyon National Park to understand the positive and/or negative impact of the changes occurring as a result of the fluctuating river flows caused by the Glen Canyon Dam.

The investigation involved a transit survey along previously fixed profile lines from established benchmarks. The research team surveyed a total of 29 cross-sections on 15 beaches.

B. Procedures

Legend: BS (numbered) = Benchmarks or base stations
CS (numbered) = Cross section
Instrument station, once located, is referred to as CS
HI = Height of instrument (transit barrel)

1. Locate all BS's as noted in historical data records (refer to photo history as needed). Tie flag tape to point of BS nail to increase visibility.
2. Stretch measuring tape (foot or meter tape as per previous year's recordings) between BS's; mark instrument stations using red and white pins along this line (as per historical data). Tie flag tape to pins to increase visibility.
3. Set transit on first instrument station (hereafter referred to as CS).
4. Take and record rod reading from the CS onto (toward) whichever BS is to be used for elevation data.
5. Take and record HI.
6. Orient transit barrel along the designated profile direction (refer to historical data).
7. Take and record rod readings along this profile, from CS to water line or edge of beach. Readings are taken at arbitrarily selected positions based on topography (e.g. change in slope, or change in composition of beach).

Note: If horizontal sight readings cannot be taken due to extreme slope of beaches or excessive non-removeable vegetation, adjustments must be made in the angle of the transit barrel. If there is extreme downward slope of beach in relation to BS (resulting in insufficient height of rod), adjust the barrel downward. Record the change in barrel angle and take rod reading. If there is extreme upward slope of beach in relation to BS, adjust barrel upward so as to fix on 0.00 reading of rod height, and record change of barrel angle required to achieve this reading.

8. Take and record rod readings from the same CS onto (toward) any other available BS.
9. Return transit barrel to original BS to ensure vernier and elevation have not changed.
10. Repeat steps 1 thru 9 with the transit set on successive cross sections.
11. See addendum 2-1 for additional procedural recommendations.

(Photo note: Photograph each new benchmark from two angles, incorporating landmark features of the beach. Photograph each cross section if there is some obvious change from previous year's photos.

Methods

Previously established benchmarks were located (one to three per beach). Instrument stations were set (as per historical data) from which horizontal sight readings were taken, based on topography, following historical profiles. Recordings of this cross-sectional data were used to generate new beach profiles which were then compared and contrasted with past profiles.

A. Required Materials

1. 1 survey transit with box
2. 1 tripod
3. 1 100 ft. tape
4. 2 200 ft. tapes
5. 1 50 meter tape
6. 2 red and white steel pins (1 ft. in length)
7. 1 25 ft. retractable survey rod
8. 2 hand lens
9. 2 benchmark nails
10. 1 roll orange flag tape
11. graph paper
12. metal clipboard
13. machete
14. can of WD-40
15. shovel
16. chalkboard
17. chalk
18. pencil sharpener
19. pencils
20. eraser
21. umbrella
22. screwdriver
23. 3-hole paper punch
24. 4 permanent marking pens
25. file folders (one per beach)
26. calculator
27. beach profile location sheets
28. cross section data sheets
29. 3 binders (new data sheets and graph paper; historical record; photographic record)
30. camera and black and white film (1-20 exposures per beach)(optional if there is a camera crew)
31. brunton compass
32. bright cap for high visibility

RESULTS

Summary of Results

Comparison of inner beach profiles since last recorded survey:

41%	lost sediment
45%	remained the same
7%	gained sediment

Comparison of outer beach profiles since last recorded survey:

38%	lost sediment
35%	remained the same
27%	gained sediment

Comparison with original survey--inner beaches:

45%	lost sediment
21%	remained the same
34%	gained sediment

Comparison with original survey--outer beaches:

62%	lost sediment
14%	remained the same
24%	gained sediment

Conclusions and Recommendations

In comparing data from our 1991 survey to the last recorded surveys, we found that 12 of the inner beach sites experienced a loss of sediment, while 2 showed a gain in sediment. Outer beach comparison resulted in 11 of them showing a loss and 6 gaining material.

When correlating our 1991 data to the original survey dates, we derived that 13 of the inner beach profiles lost sediment and 10 gained. The outer beach statistics showed that 18 lost sediment and 7 gained.

In general, it appears that degradational processes have had the upper hand. Beach erosion is continuing. Any gains and some losses in inner beach sediments are probably due to shifting wind blown sand from other areas of the beach. Some gains along outer beaches may be due to the deposition of new sediment from flash flooding side canyons, but is more likely due to the redistribution of sediment from other areas of the beach. Natural mass wasting processes and human impact activity are both responsible for some of the beach slumping taking place.

A comparison of each beach with its original survey is sometimes difficult. Vegetative growth and gradational processes may obscure or eliminate reference points. This in turn complicates survey reading because the transit barrel needs to be tilted. Such changes must be mathematically corrected.

Profiles should be consistently extended to the water line and beyond in the case of high water levels. When known, the cfs discharge levels should be noted. It is recommended that future comparisons of all surveyed beaches be made to both the pre- and post- 1983 flood.

SOUTH CANYON BEACH
R 31.6
NEW 7/25/91

BEACH PROFILE LOCATION SHEET

Date established 7-25-91

Base station #1 TAN SANDSTONE BOULDER — Photo ✓ — Perm. mark ✓ X on ROCK

Base station #2 nearly flat, pale-orange sandstone vertical bedding — Photo ✓ — Perm. mark ✓

Base Station #3 PALE ORANGE SANDSTONE BOULDER — Photo ✓ — Perm. mark ✓

Elevation datum ______ Photo # ______

Length of base line #1 124.0ft from base line 2
Base line orientation N3°W from BS2-BS1

Length of base line # 2 40ft from CS 1 TO BS 1
Base line orientation N3° W from ~~BL 1~~

Length of base line #3 ______ from ______
Base line orientation ______ from ______

Cross section #~~1~~ 2: 90° from BS 2 TOWARD BS 1
at an angle of 90° (counter) clockwise from direction of BS2-BS1

Cross section #~~2~~ 1: 100° from CS 1 TO BS 1
at an angle of 100° (counter) clockwise from direction of CS 1 TO BS 1

Cross section #3: ______ from ______
at an angle of ______ (counter) clockwise from direction of ______

Comments
CS #2 AND BS #2 ARE THE SAME PLACE

Table 2-1. Beach Profiles Surveyed

River Mile	Beach Name	1974	75	80	82	83	84	85	86	87	88	89	90	91
L18.2	Upper 18 Mile Wash		2			2	2	2	2	2	1			
L19.3	19 Mile Wash (gone)		2	1		2		2	2					
L19.8	19.8 Mile											2	2	
R31.6	South Canyon													2
L34.7	Nautiloid Canyon	2	2			2	2	2	2	2	2	2	2	2
R53.0	Lower Nankoweap	3	3	1		1	3	2	1	2				1
R58.1	Awatubi						1		1	1	1	1	1	1
R61.8	Mouth of the Little Colorado	1		1		1	1	1	2	1			1	1
L65.5	Tanner Mine	2		2		2	2	2	2					
R72.2	Unkar Indian Village (gone)	1	1	3		2	1							
L75.5	Nevills Rapid (new 1984)						2	2	2	2	1	1	2	1
L81.1	Grapevine	2		2		2	1	2	2	2	2	2	2	2
L87.1	Lower Suspension Bridge		2	1				1						
L93.2	Upper Granite Rapid	2		1		2	2	2	2	2	2	2		2
R109.4	109 Mile (gone)	2				1	2							
R112.2	Waltenberg Canyon (gone)	1		1		1	1							
R120.1	Blacktail Canyon	2		2	1	2	2	2	2	2	2	2	2	2
R122.0	122 Mile Beach (new 1985)							2	2	2	2	2		
L122.8	Forster Canyon (new 1983)					3	3	3	3	2	3	1	2	2
L124.4	Upper 124 1/2 Canyon (gone)	2			1	1								
R131.0	Bedrock Rapid	2		2		2	2	2	2	2	2	2	2	2
L136.6	Poncho's Kitchen (new 1988)										2	2	2	2
L151.6	The Ledges (gone)	2	2			1	2	2		1				
L166.5	Upper National		2	1		1	2	2		2	2	1	2	
L166.6	Lower National (new 1985)							2	5	5	5	5	5	5
R180.9	Lower Lava Falls	2		2		2	2	2	2	2	2			
L190.2	190 Mile		1	1			1	1	1	1	1		1	
L193.9	194 Mile Beach (new 1987)									3	3	3		3
L208.8	Granite Park	2	2	2	1	2	2	2	2	2	2	2	2	1
R220.0	220 Mile Beach (new 1985)								2	2	2			

1974, 1975 data from Howard (1975)
1980 data from Dolan (1981)
1982 data from Beus and others (1982)
1984 data from Beus and others (1985)
1985 data from Beus and others (1986)
1986 data from Beus and others (1987)
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1988 data from Beus and others (1989
1989 data from Beus and others (1990)
1990 data from Beus and others (1991)
1991 data from this report

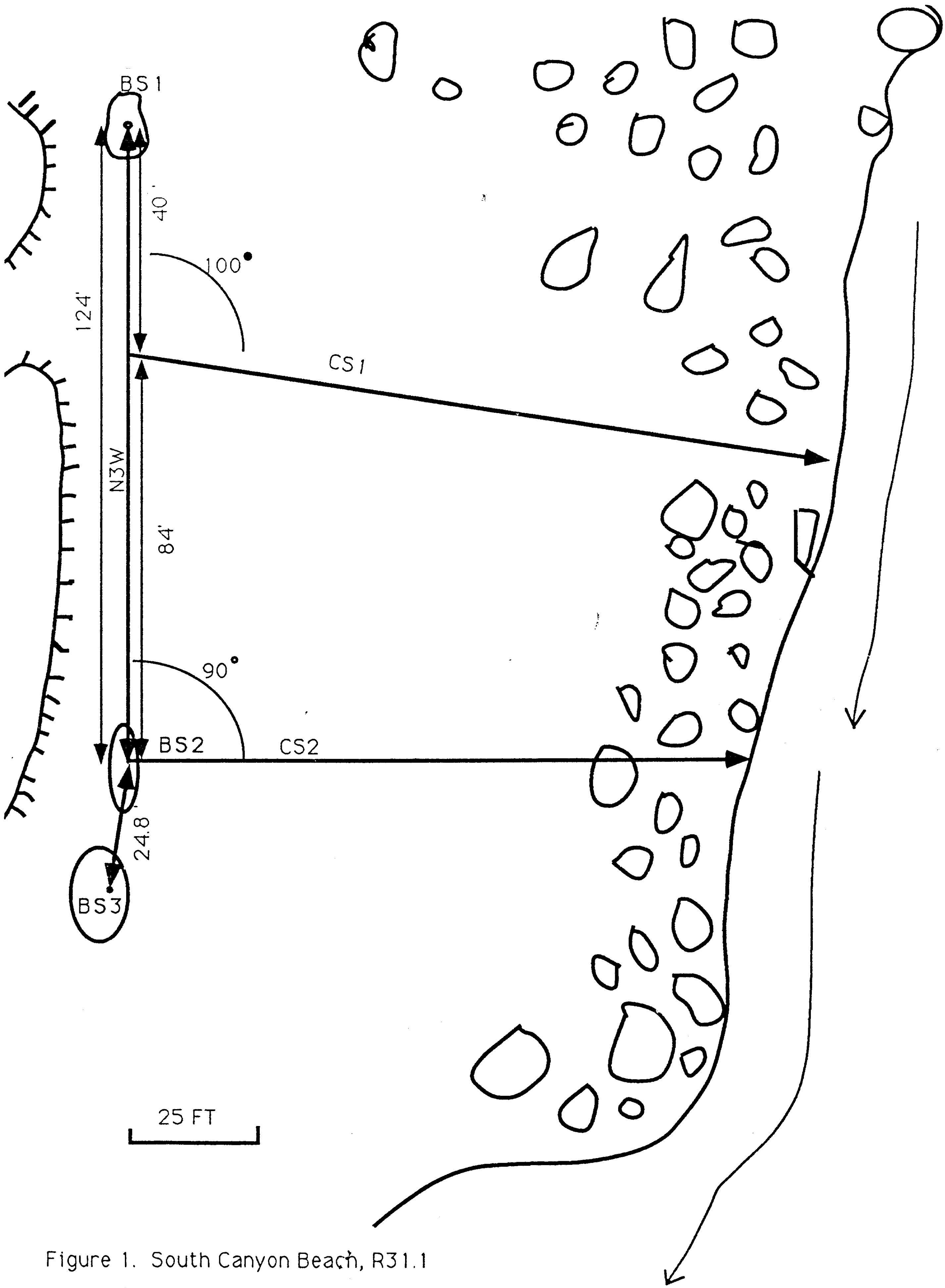

Figure 1. South Canyon Beach, R31.1

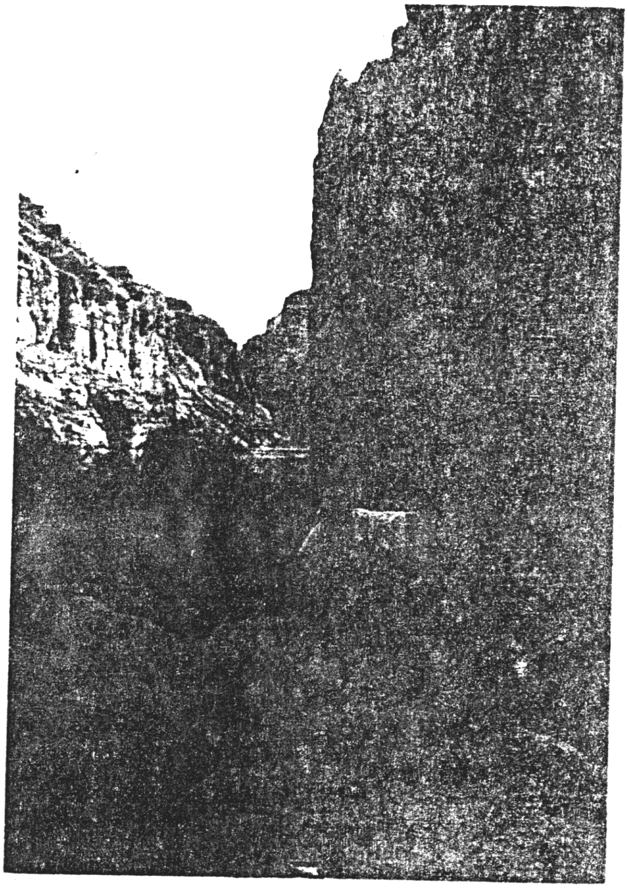

FIGURE 2. BS1 SOUTH CANYON BEACH R31.6

FIGURE 3. BS2 SOUTH CANYON BEACH R31.6

FIGURE 4. BS3 SOUTH CANYON BEACH R31.6

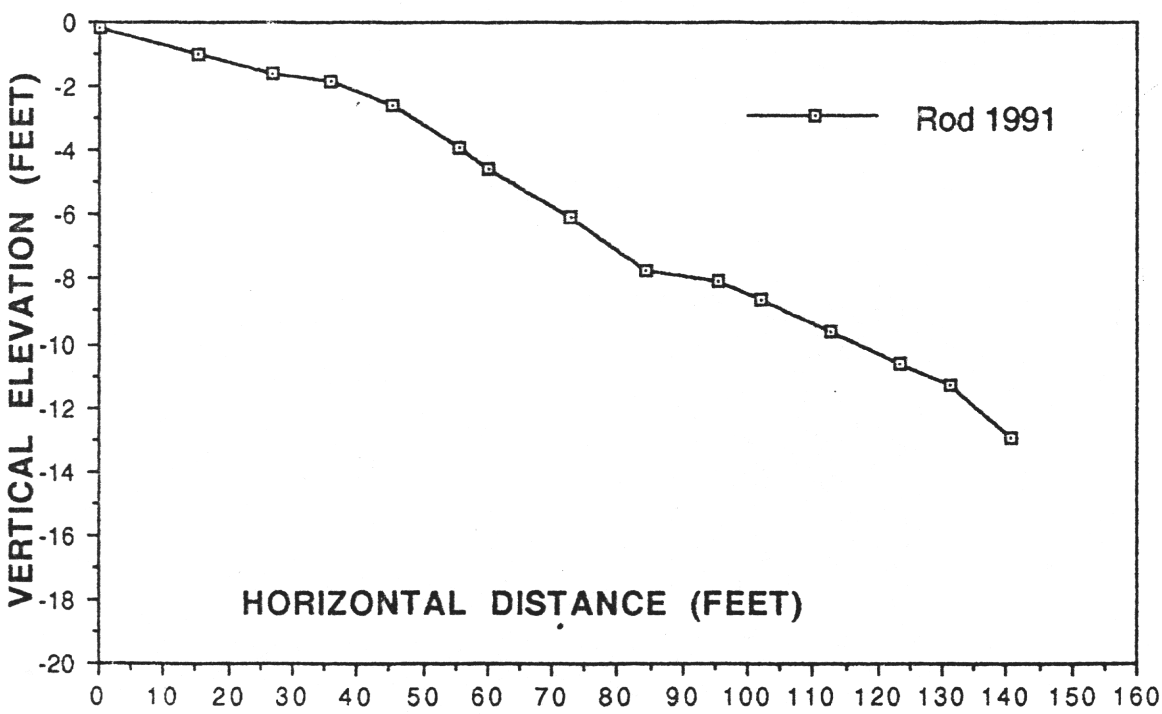

FIGURE 5. CS1 SOUTH CANYON BEACH R31.6

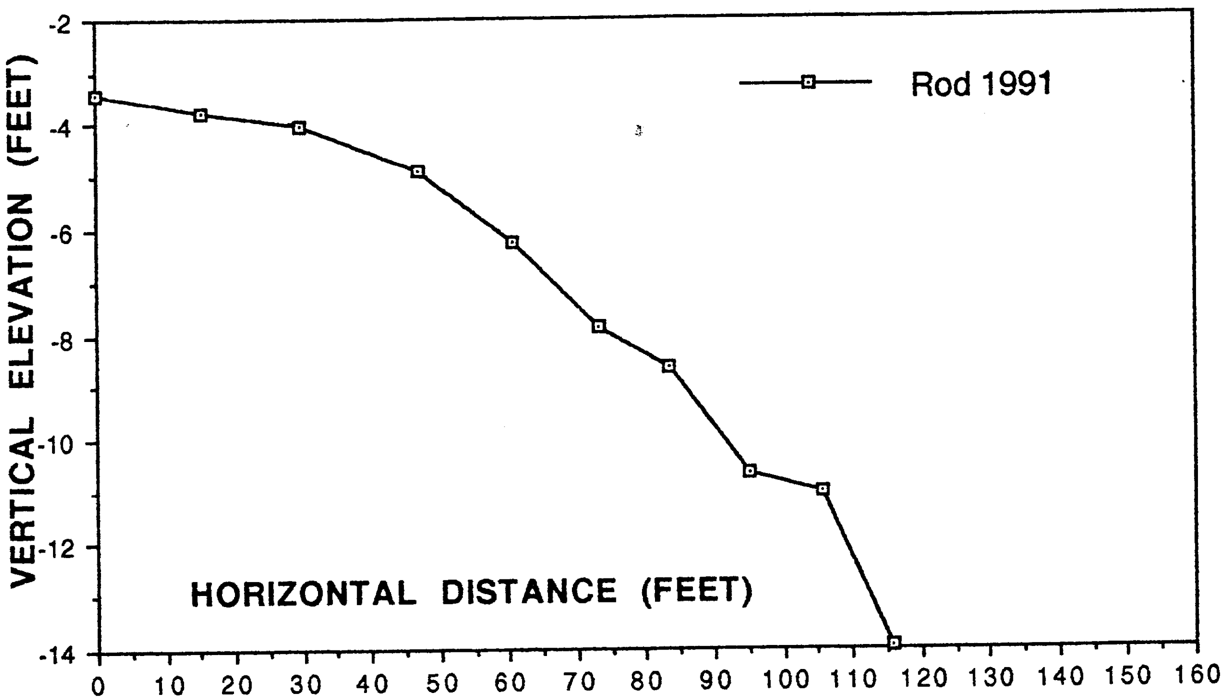

FIGURE 6. CS2 SOUTH CANYON BEACH R31.6

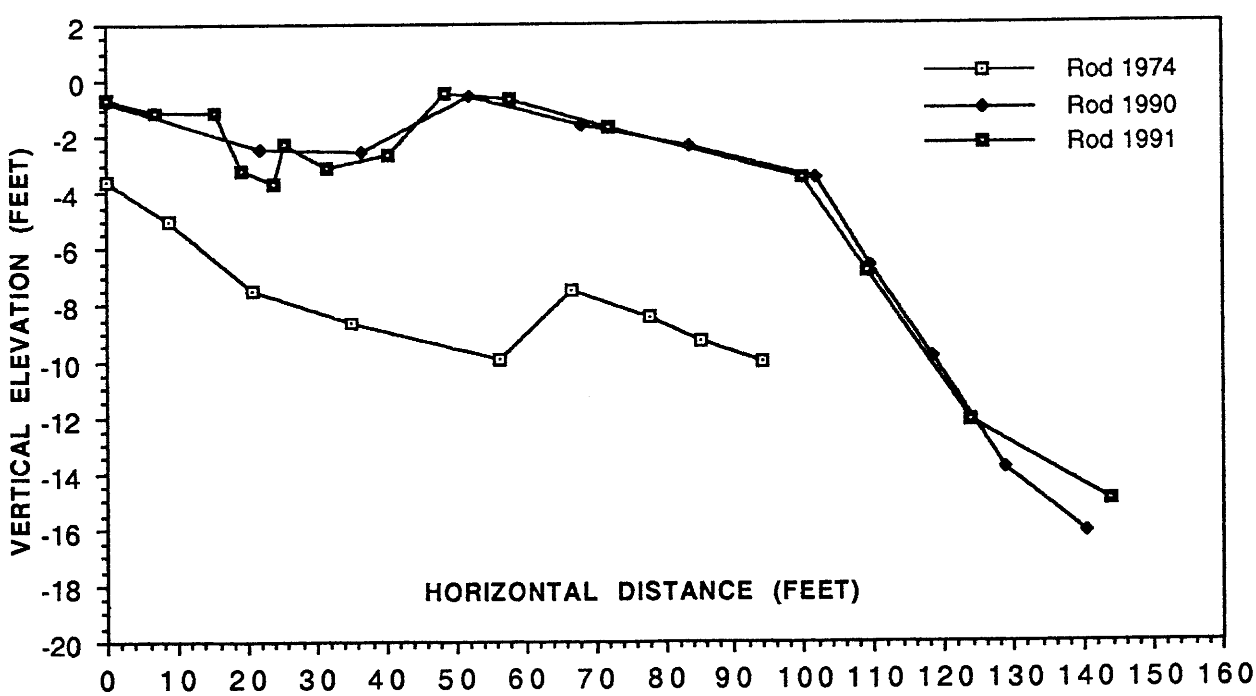

FIGURE 7. CS1 NAUTILOID BEACH L34.7

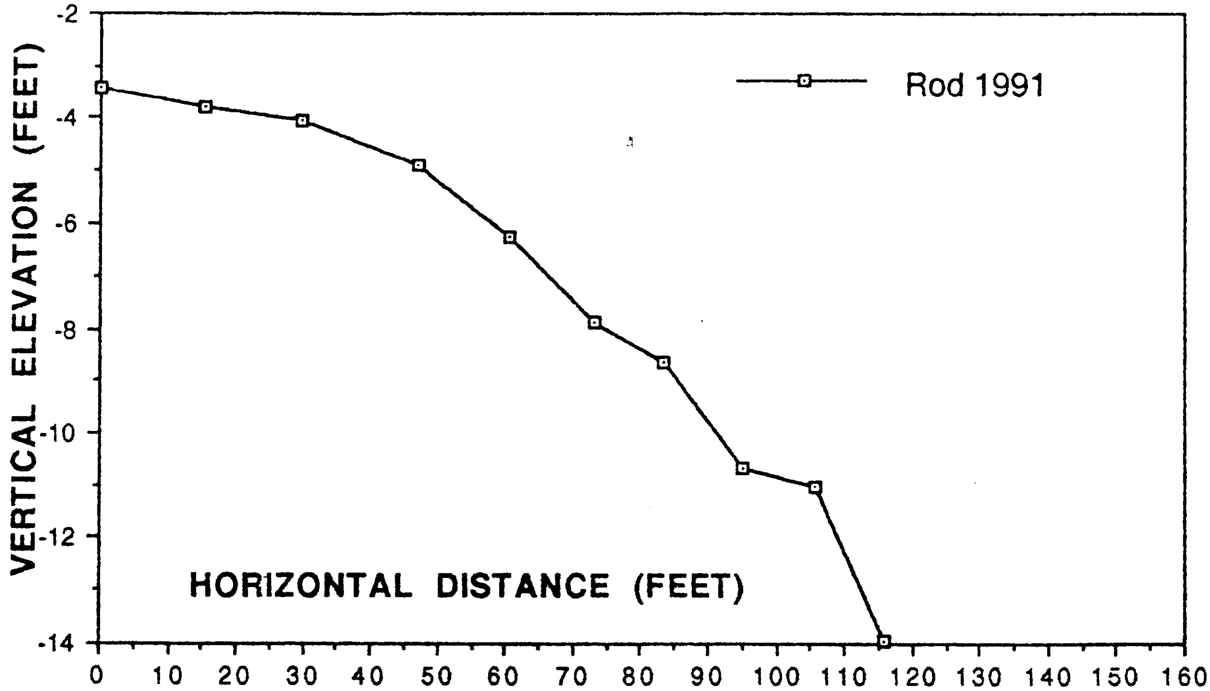

FIGURE 6. CS2 SOUTH CANYON BEACH R31.6

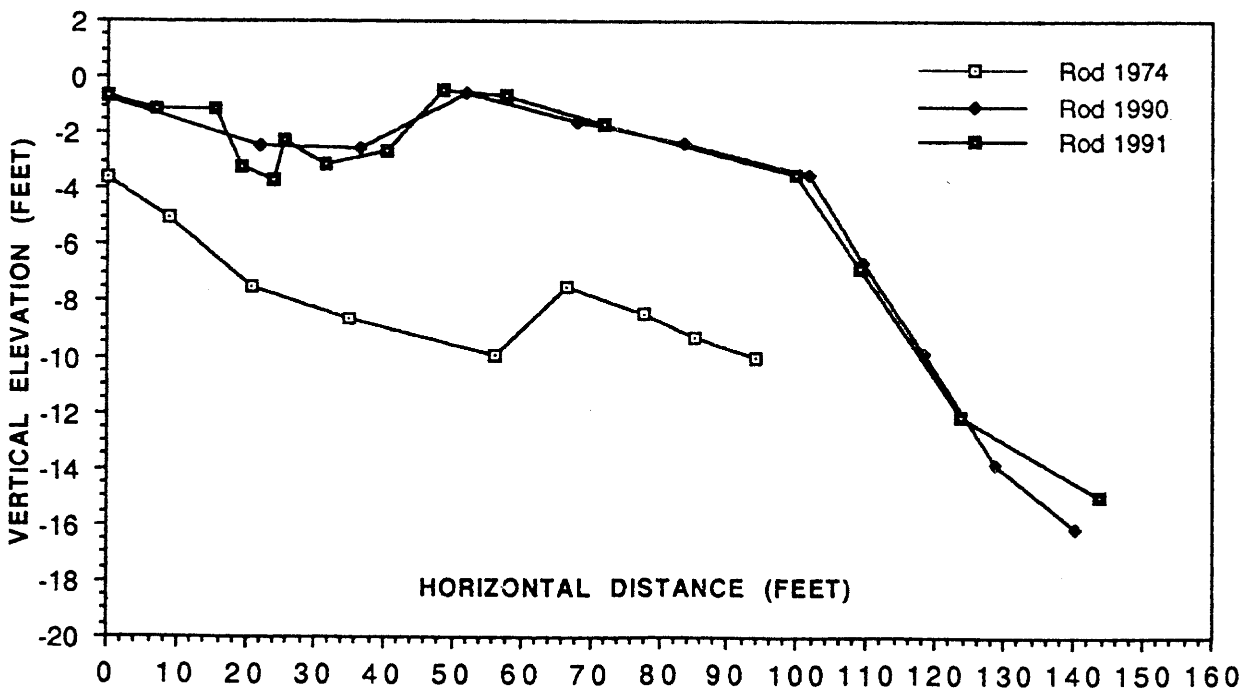

FIGURE 7. CS1 NAUTILOID BEACH L34.7

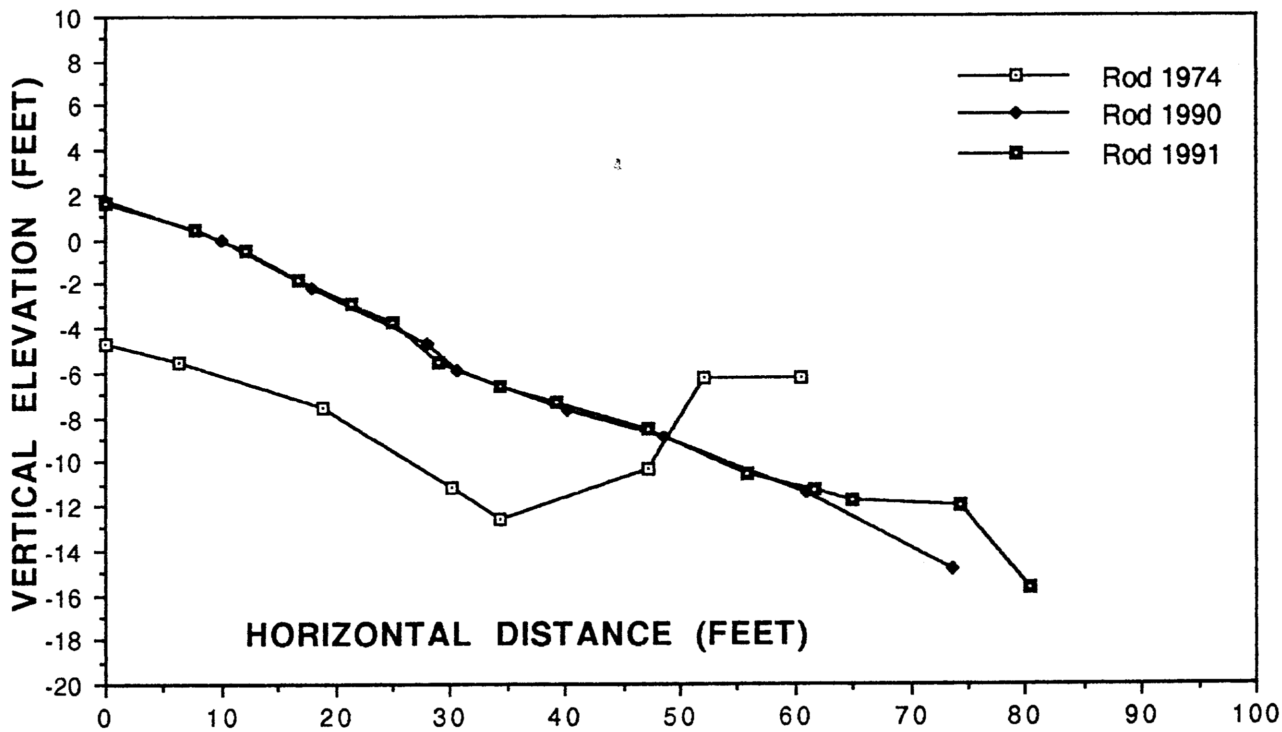

FIGURE 8. CS2 NAUTILOID BEACH L34.7

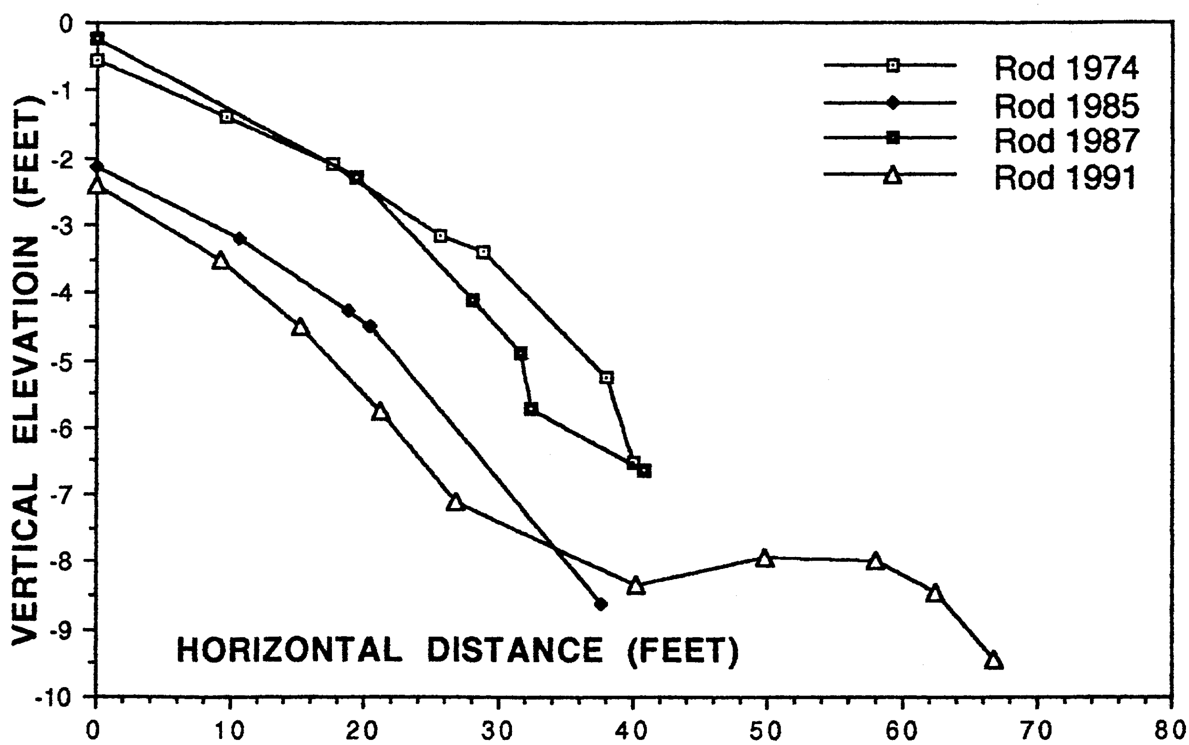

FIGURE 9. CS3 LOWER NANKOWEAP BEACH R53.0

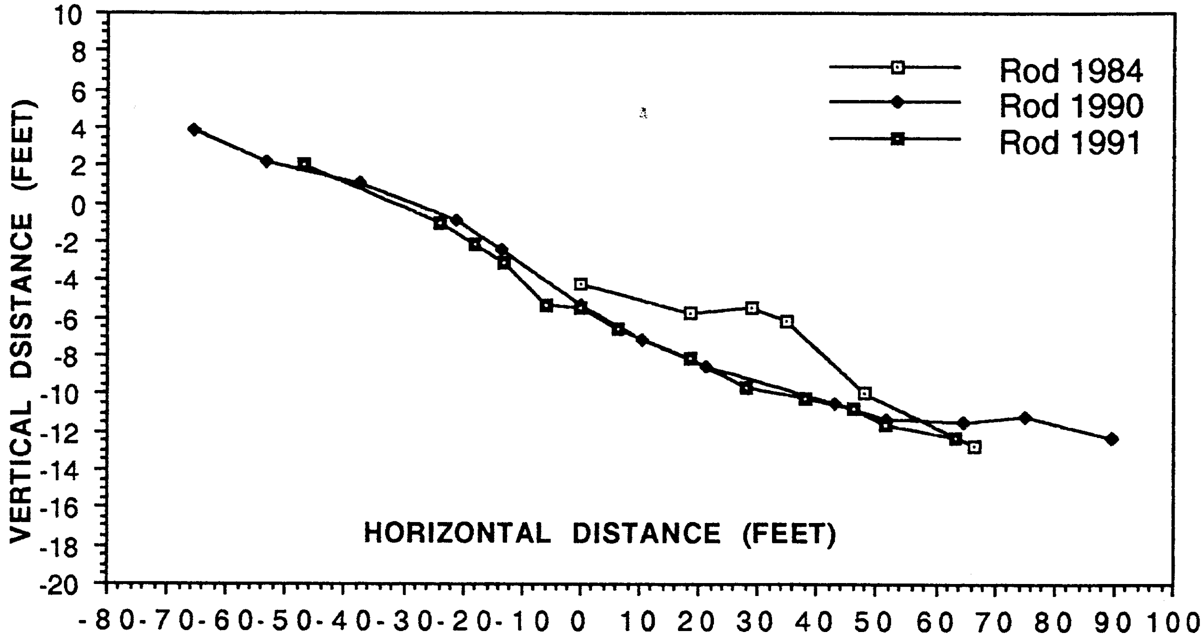

FIGURE 10. CS1 AWATUBI BEACH R58.1

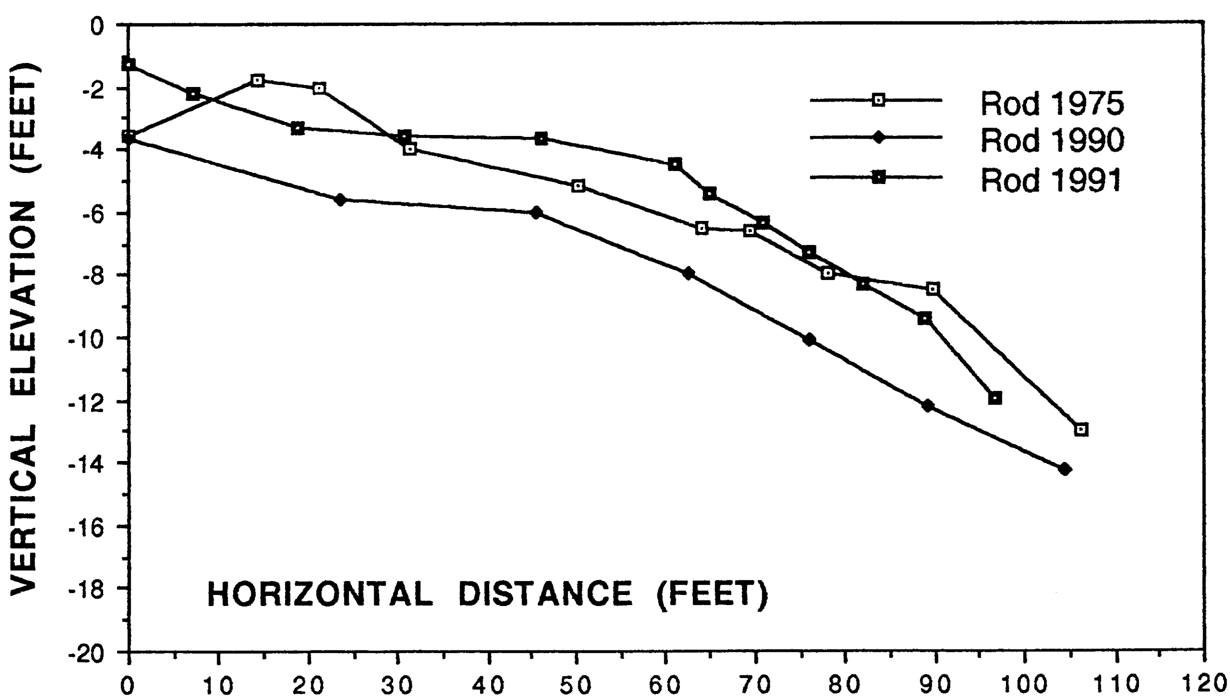

FIGURE 11. CS1 61.8 MILE BEACH R61.8

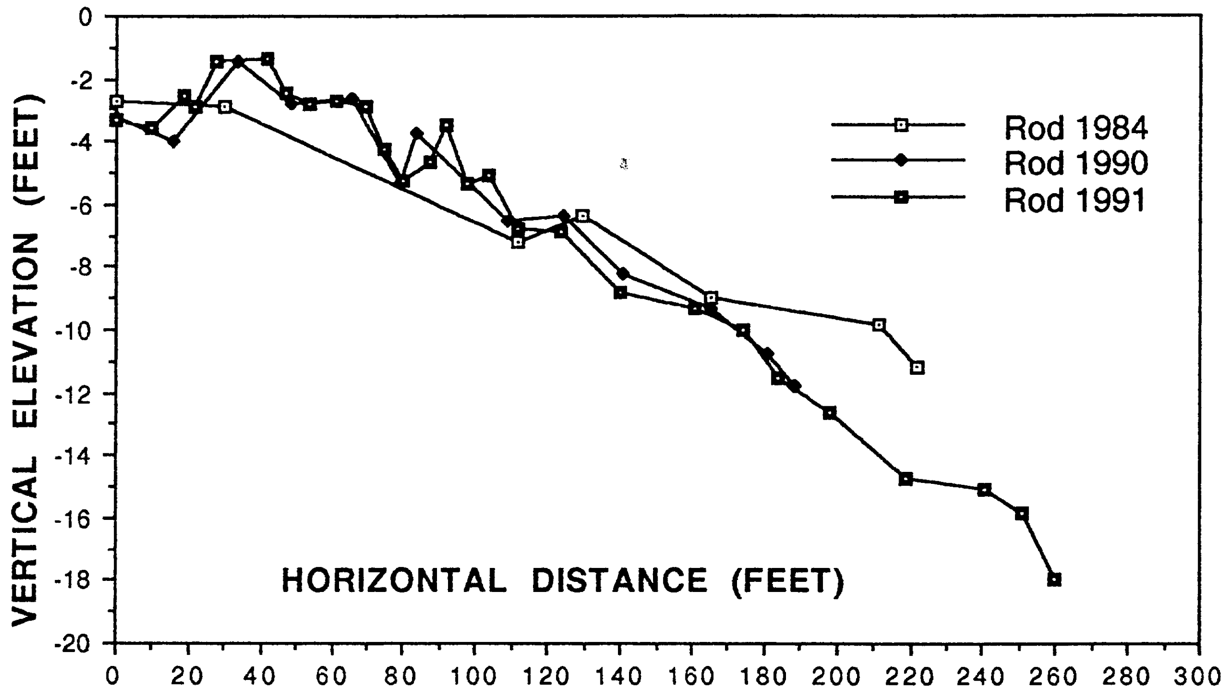

FIGURE 12. CS1 NEVILL'S BEACH L75.5

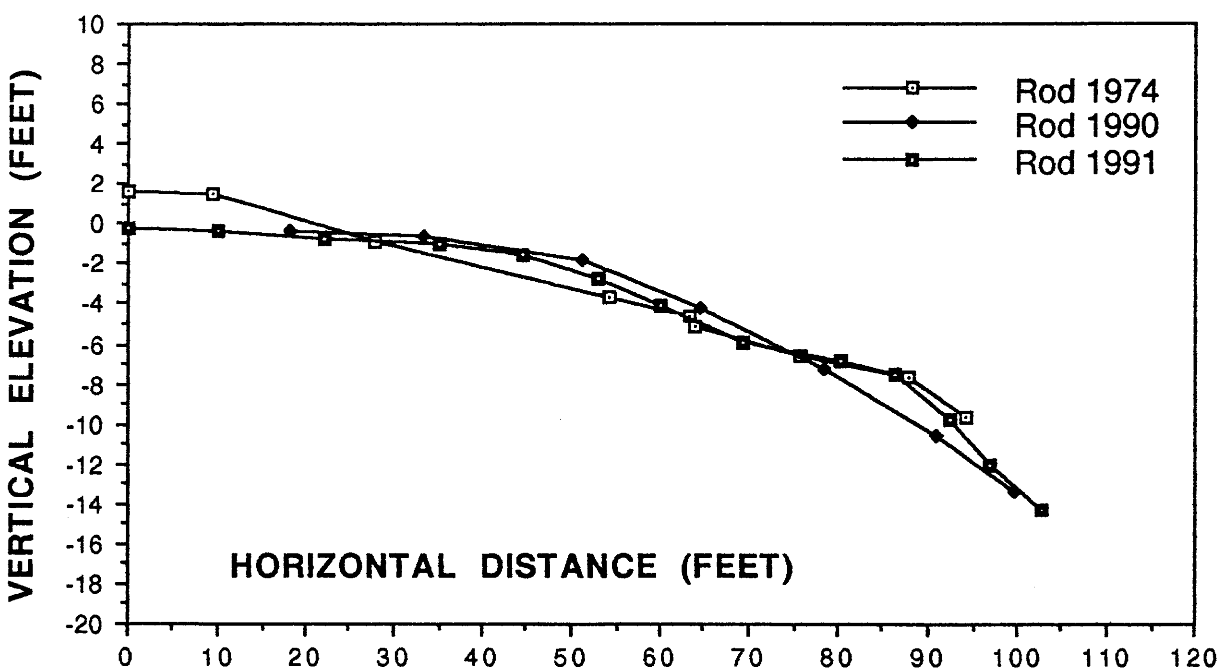

FIGURE 13. CS1 GRAPEVINE BEACH L81.1

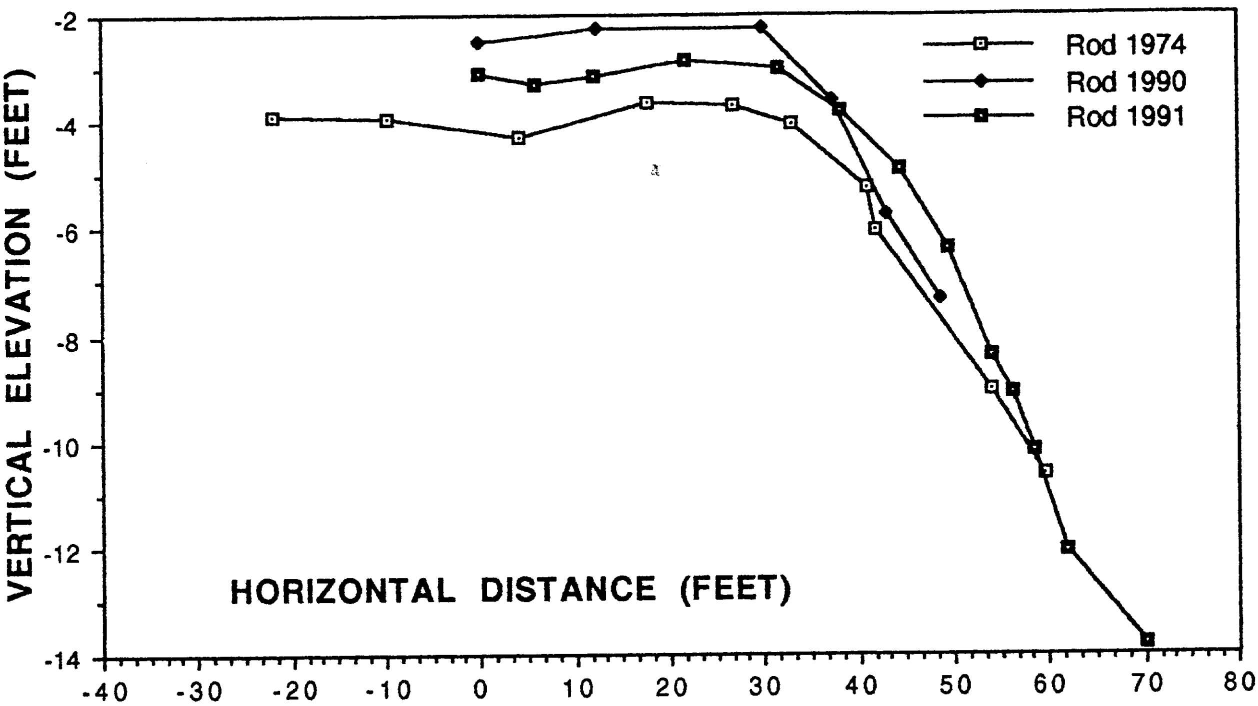

FIGURE 14. CS2 GRAPEVINE BEACH L81.1

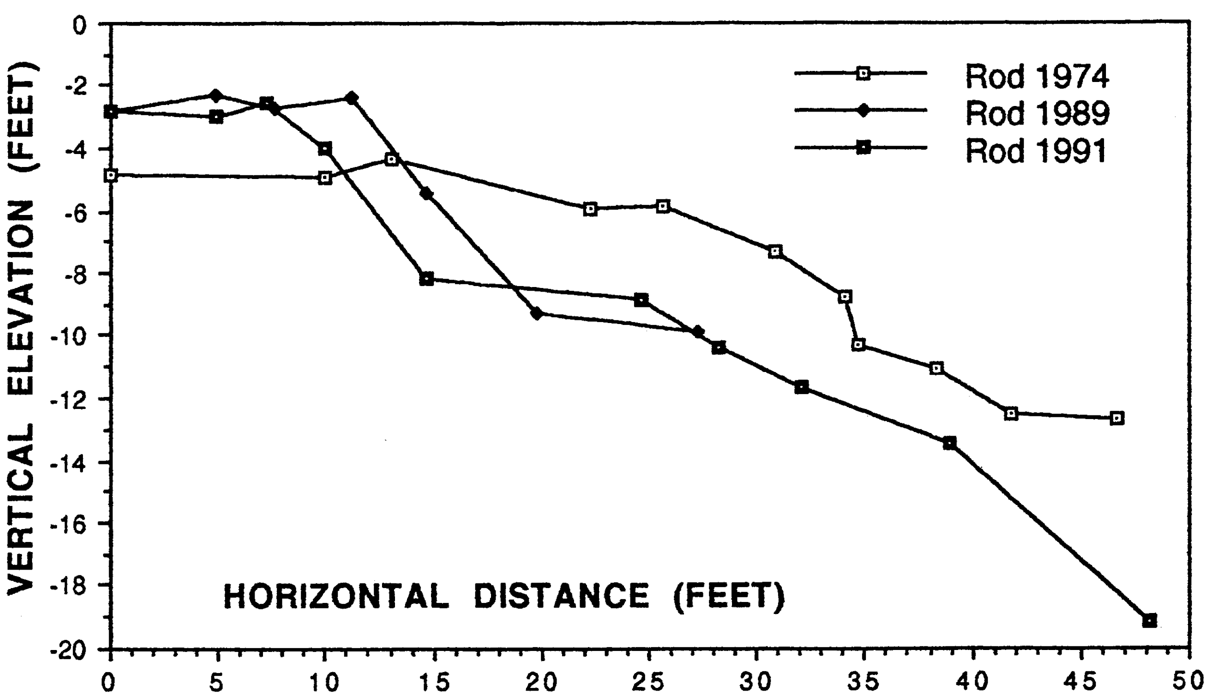

FIGURE 15. CS1 UPPER GRANITE RAPIDS L93.2

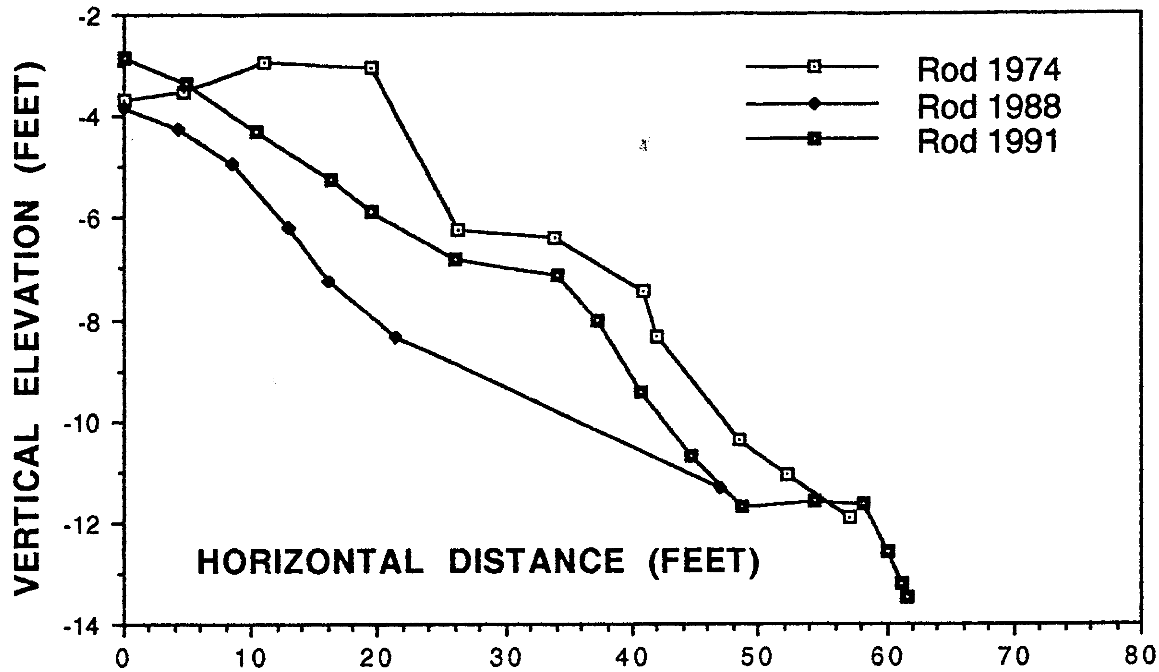

FIGURE 16. CS2 UPPER GRANITE RAPIDS L93.2

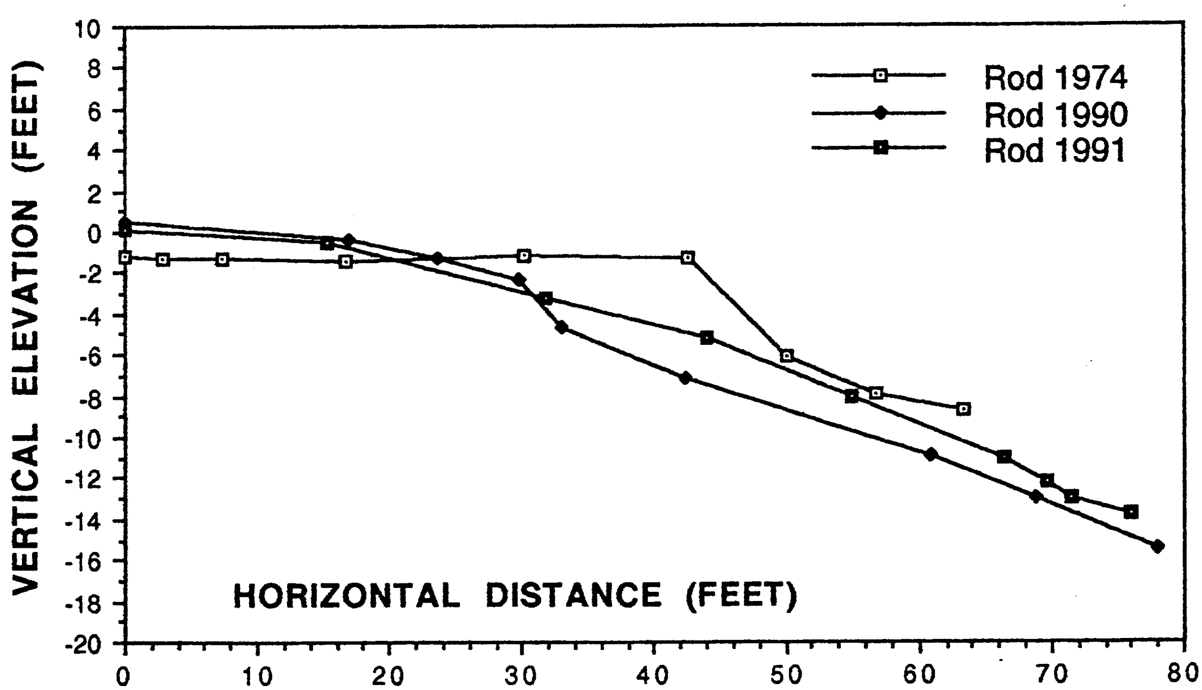

FIGURE 17. CS1 BLACKTAIL BEACH R120.1

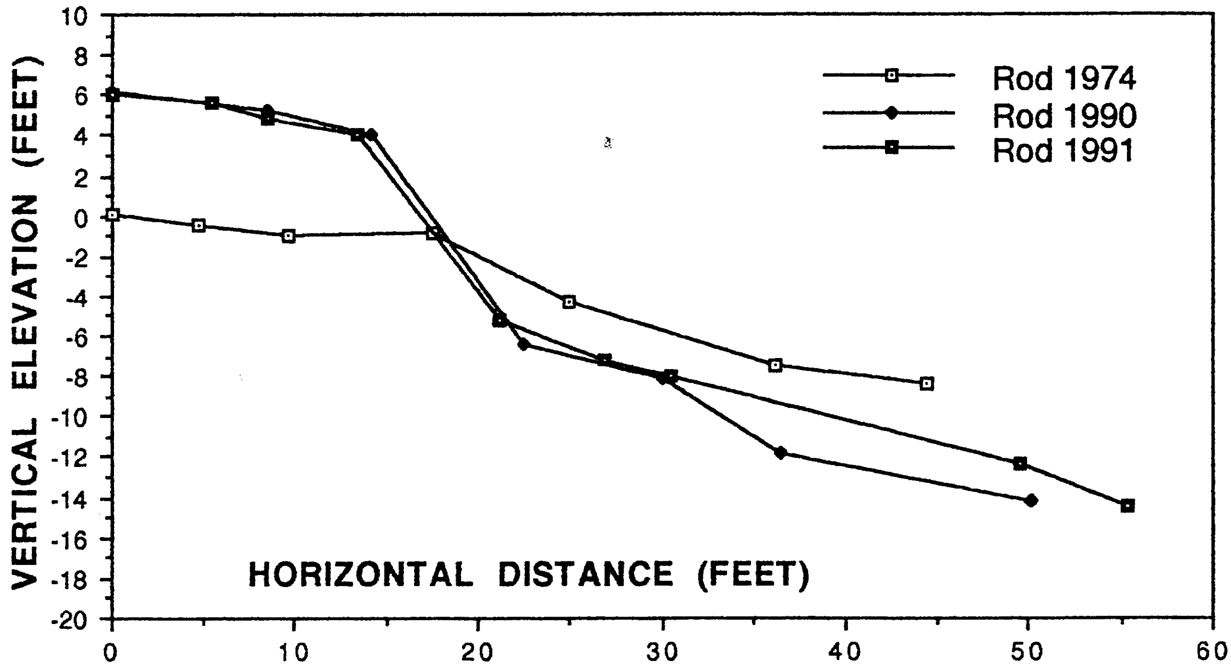

FIGURE 18. CS2 BLACKTAIL BEACH R120.1

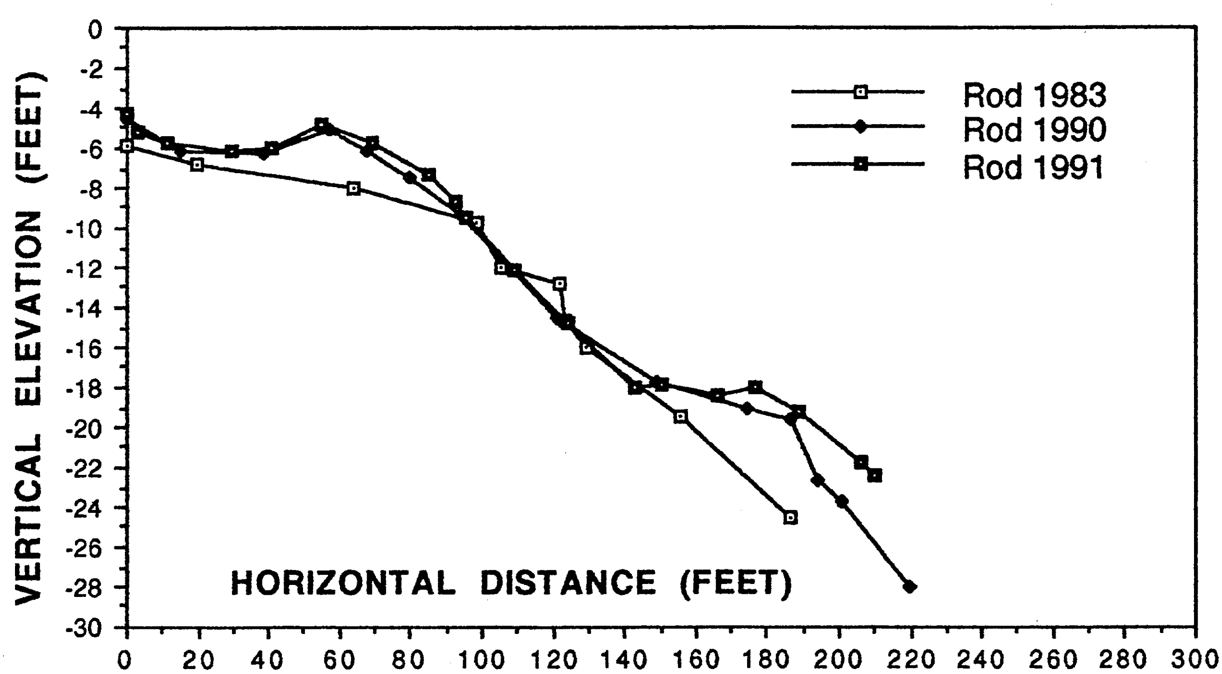

FIGURE 19. CS1 FORSTER BEACH L122.8

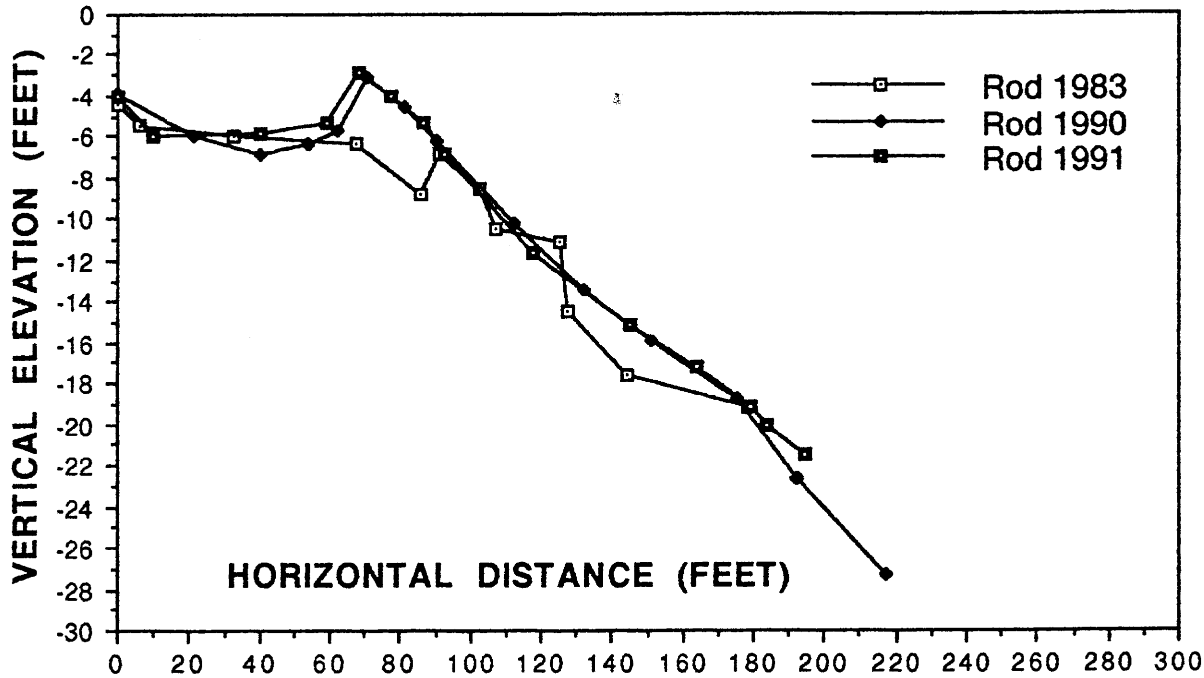

FIGURE 20. CS2 FORSTER BEACH L122.8

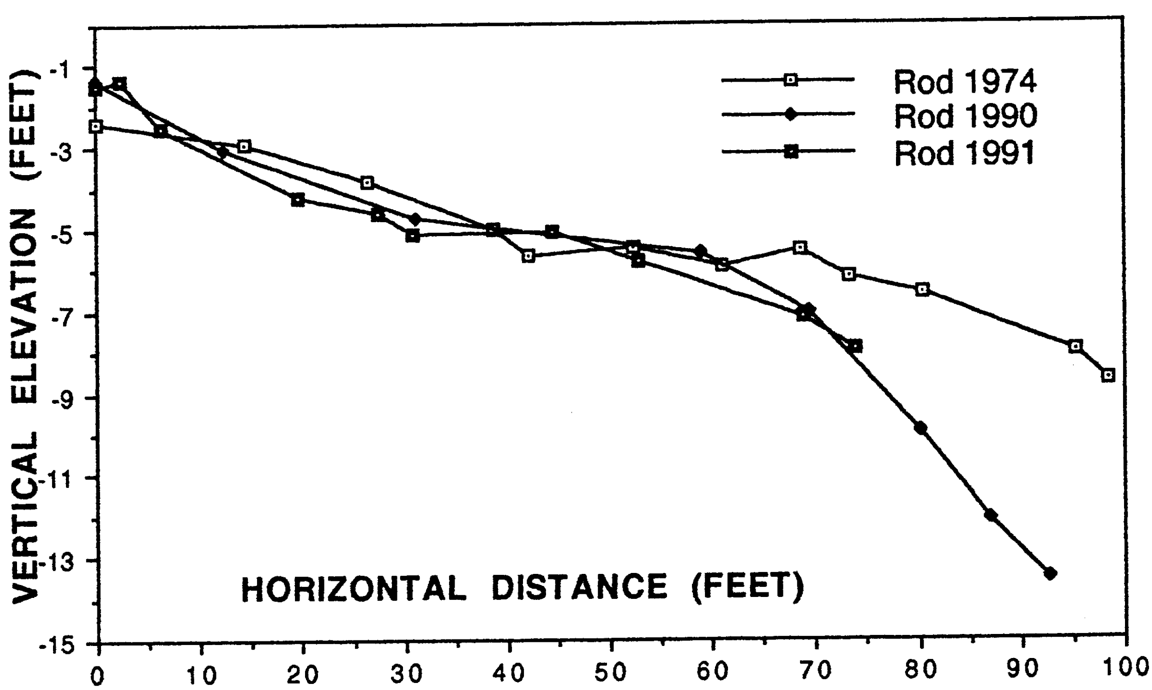

FIGURE 21. CS1 BEDROCK RAPIDS BEACH R131.0

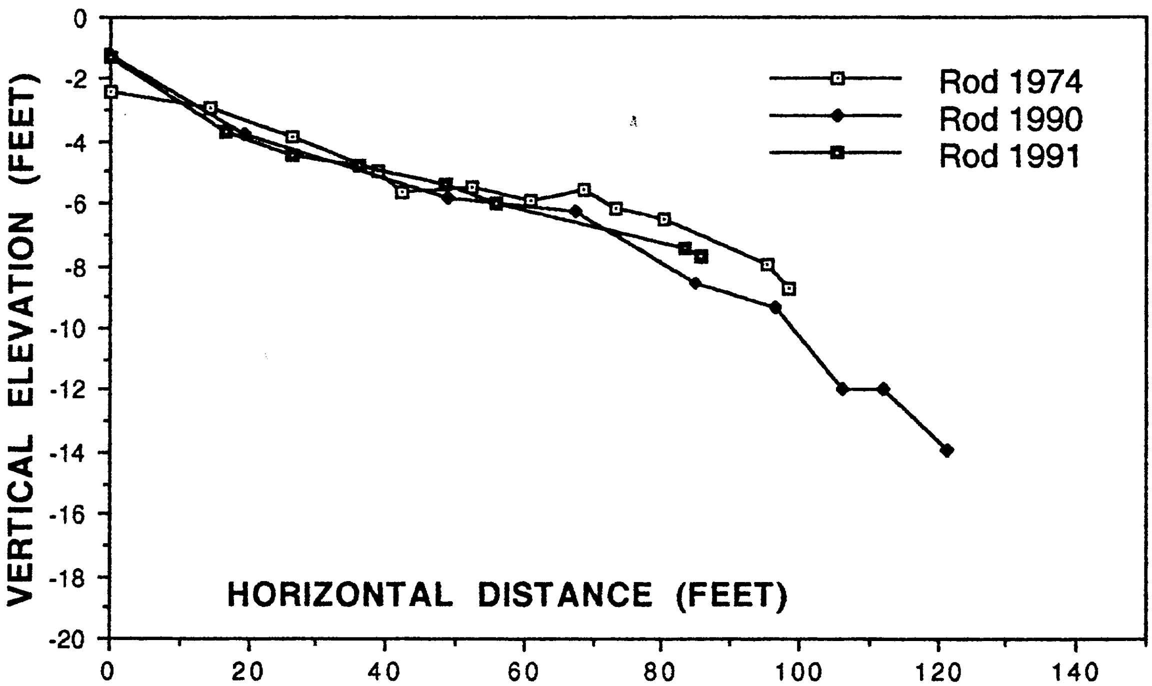

FIGURE 22. CS2 BEDROCK BEACH R131.0

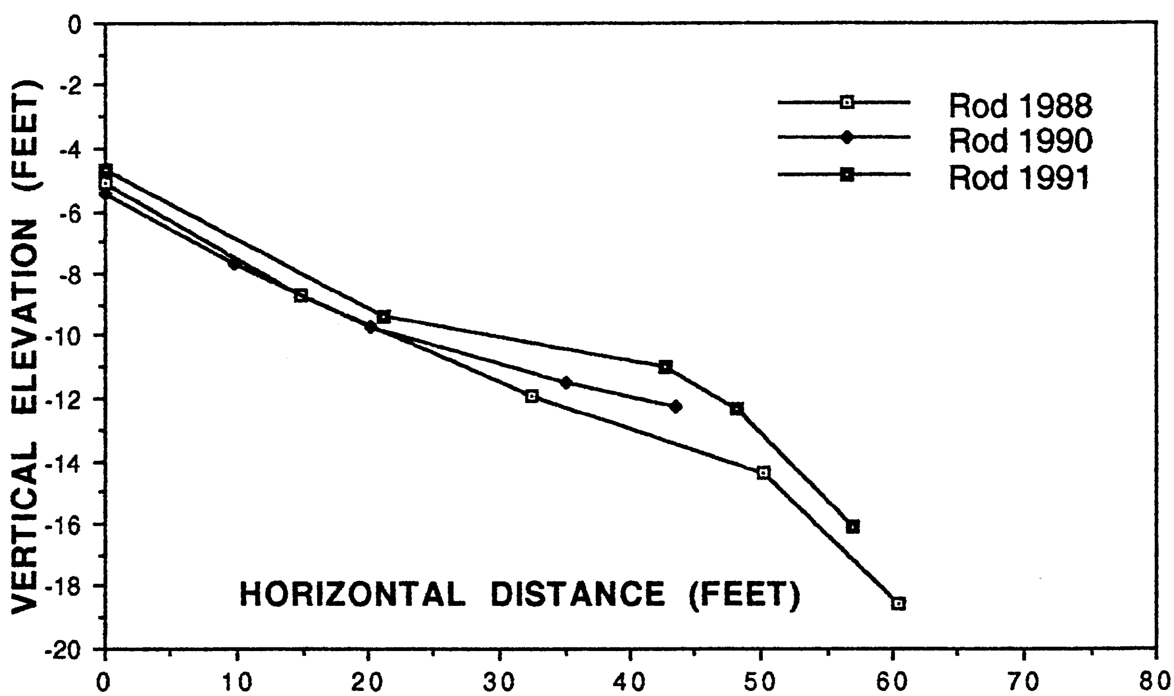

FIGURE 23. CS1 PONCHO'S KITCHEN R136.6

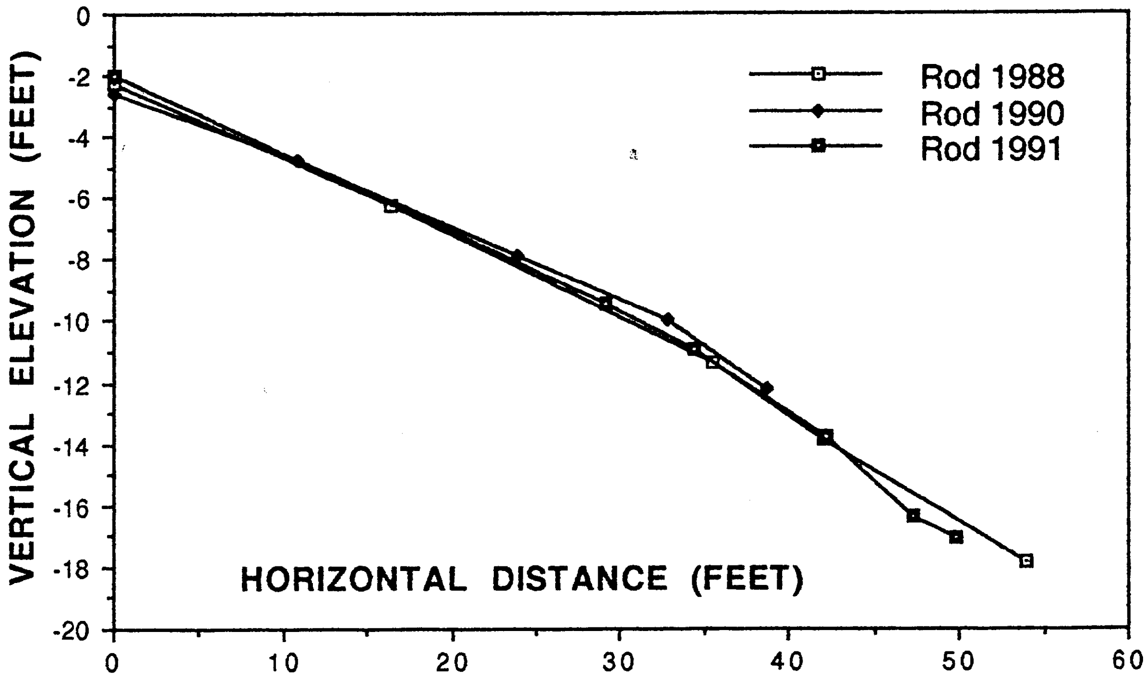

FIGURE 24. CS2 PONCHO'S KITCHEN L136.6

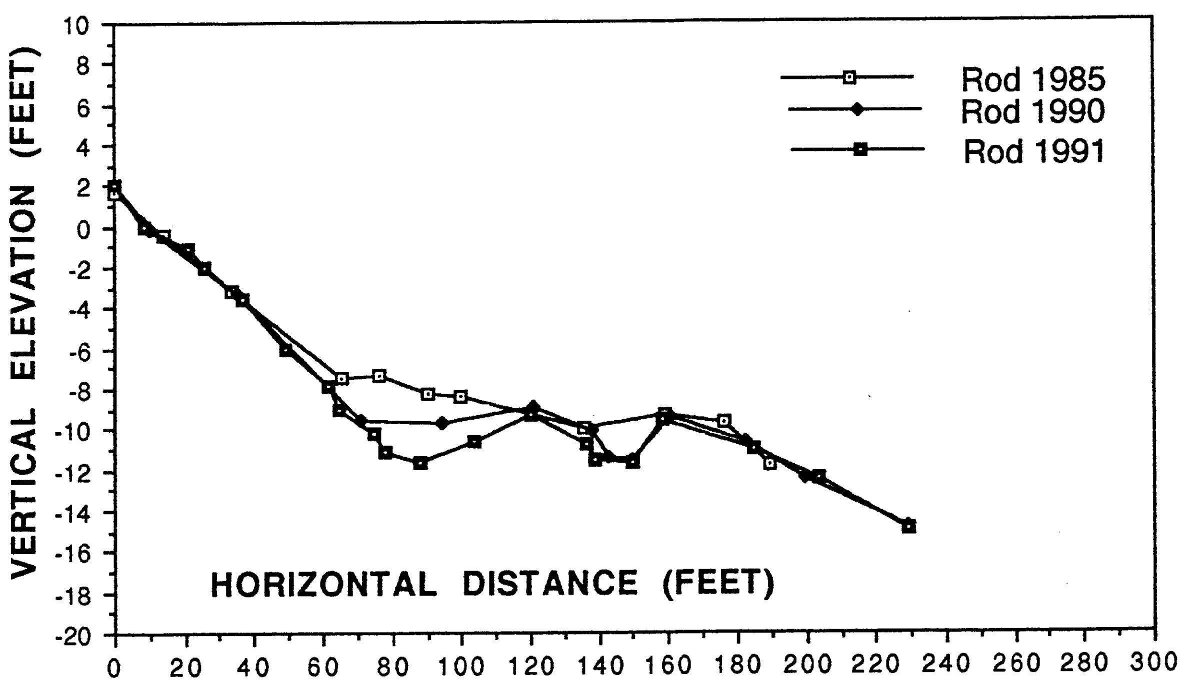

FIGURE 25. CS1 LOWER NATIONAL BEACH L166.6

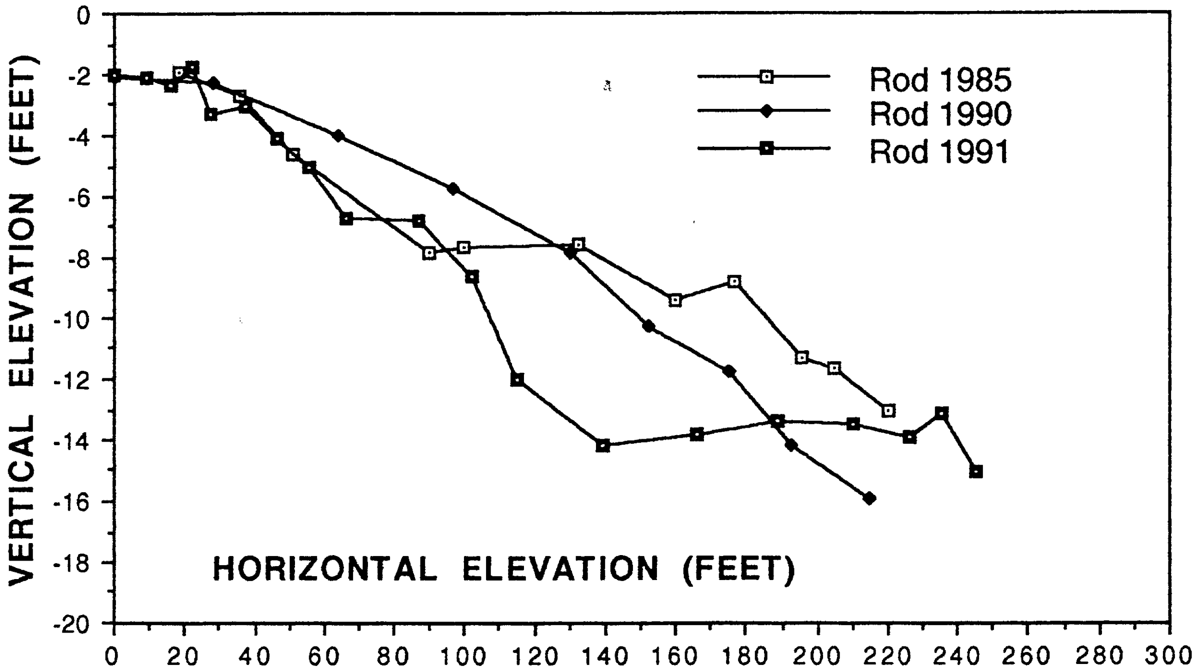

FIGURE 26. CS2 LOWER NATIONAL BEACH L166.6

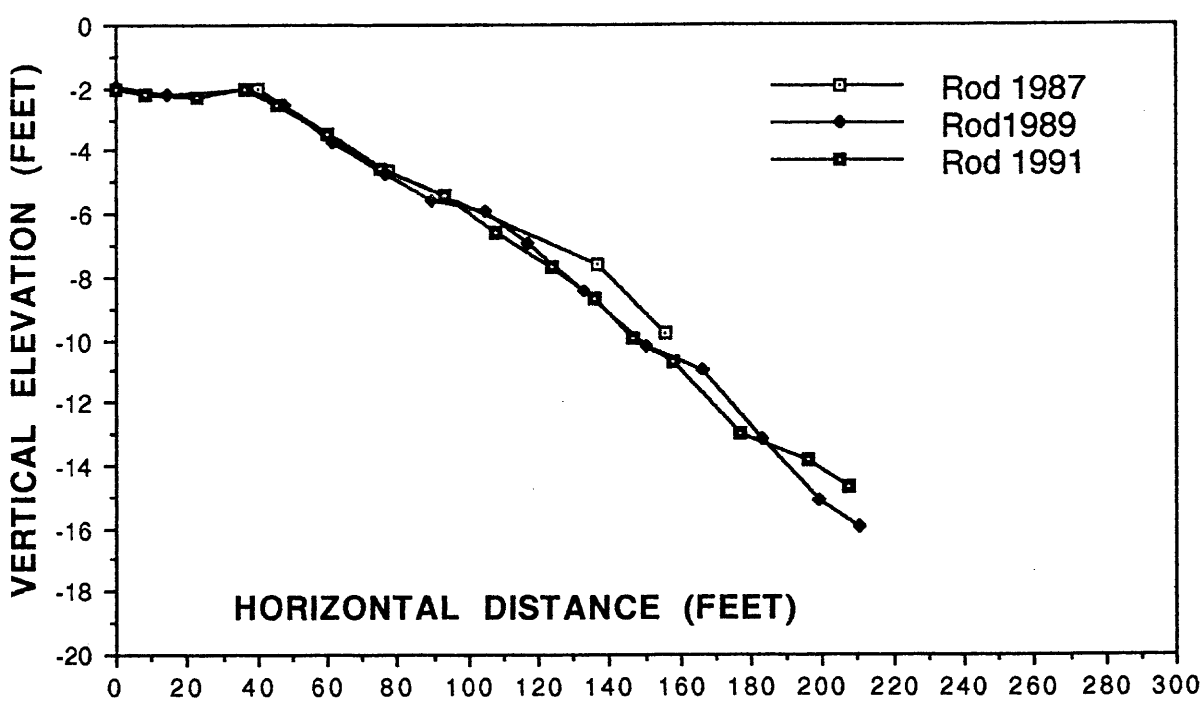

FIGURE 27. CS3 LOWER NATIONAL BEACH L166.6

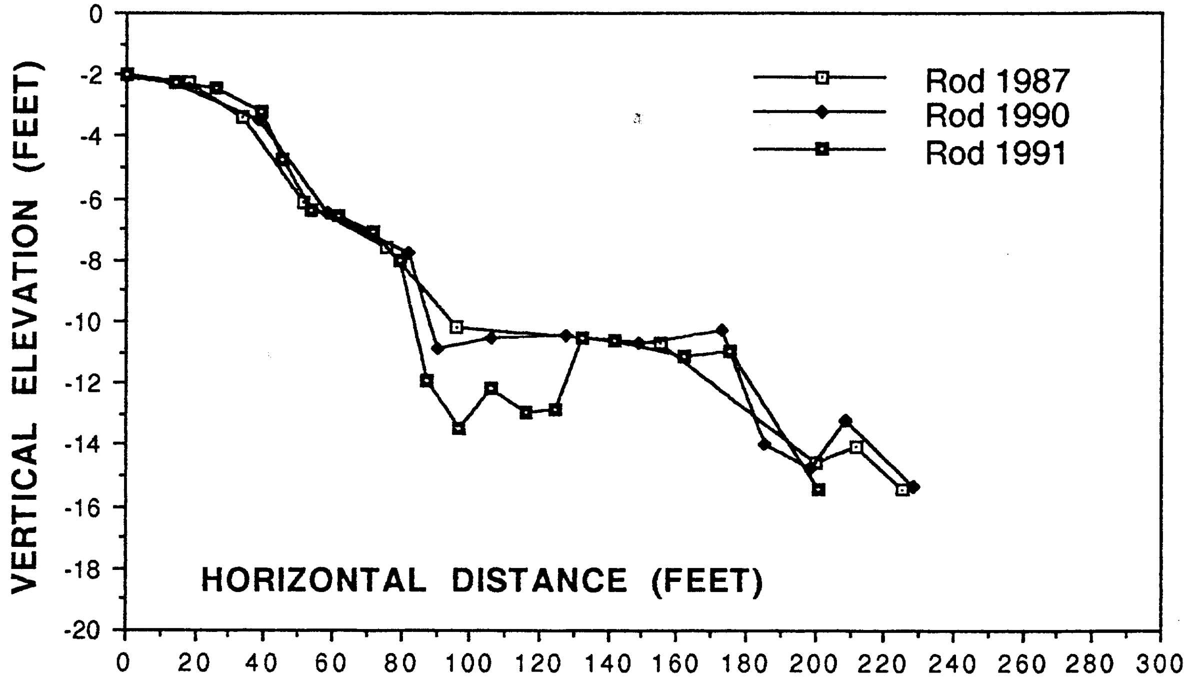

FIGURE 28. CS4 LOWER NATIONAL BEACH L166.6

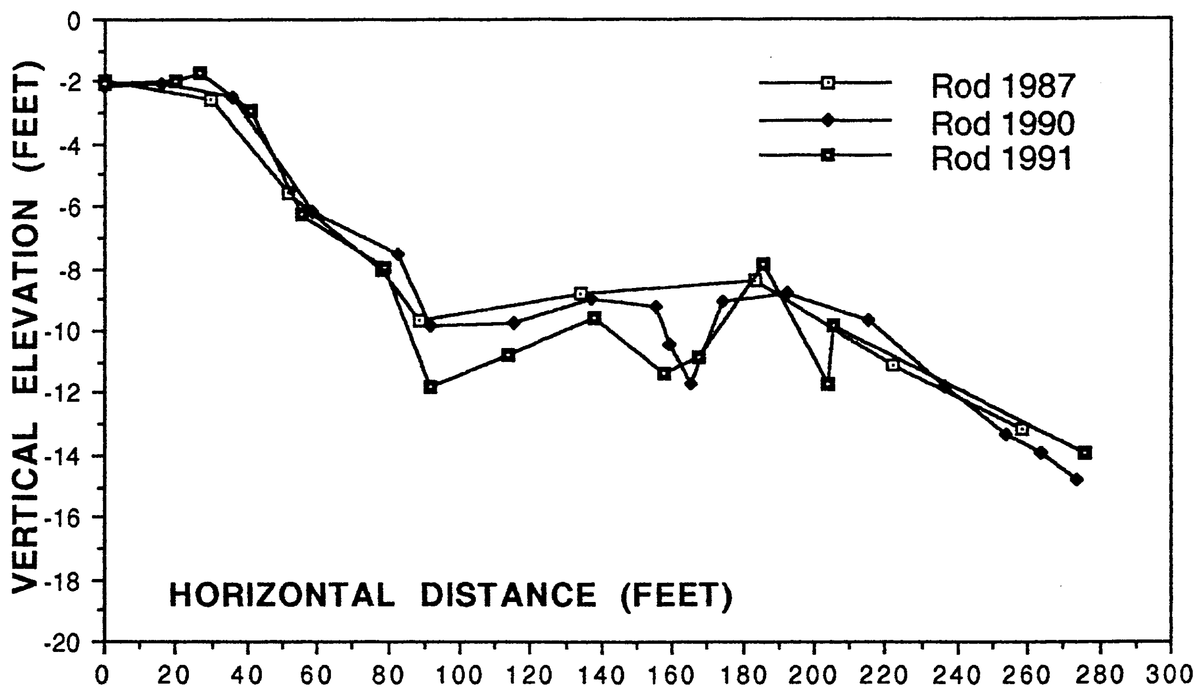

FIGURE 29. CS5 LOWER NATIONAL BEACH L166.6

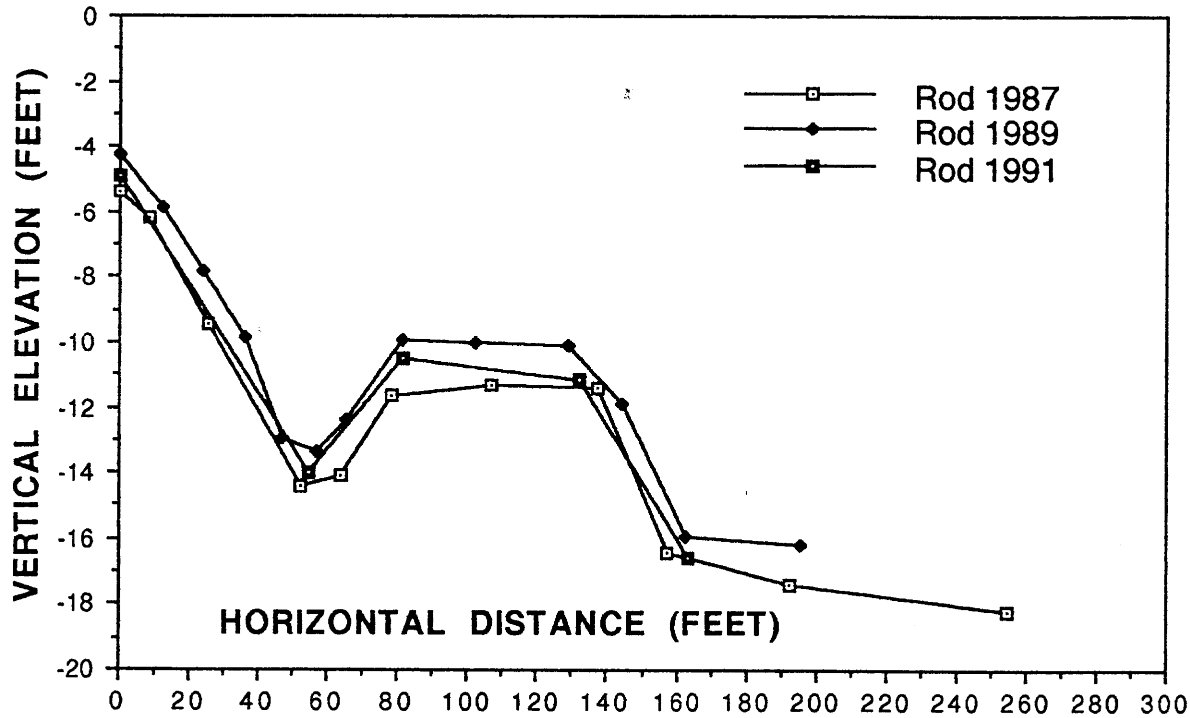

FIGURE 30. CS1 194 MILE BEACH L193.9

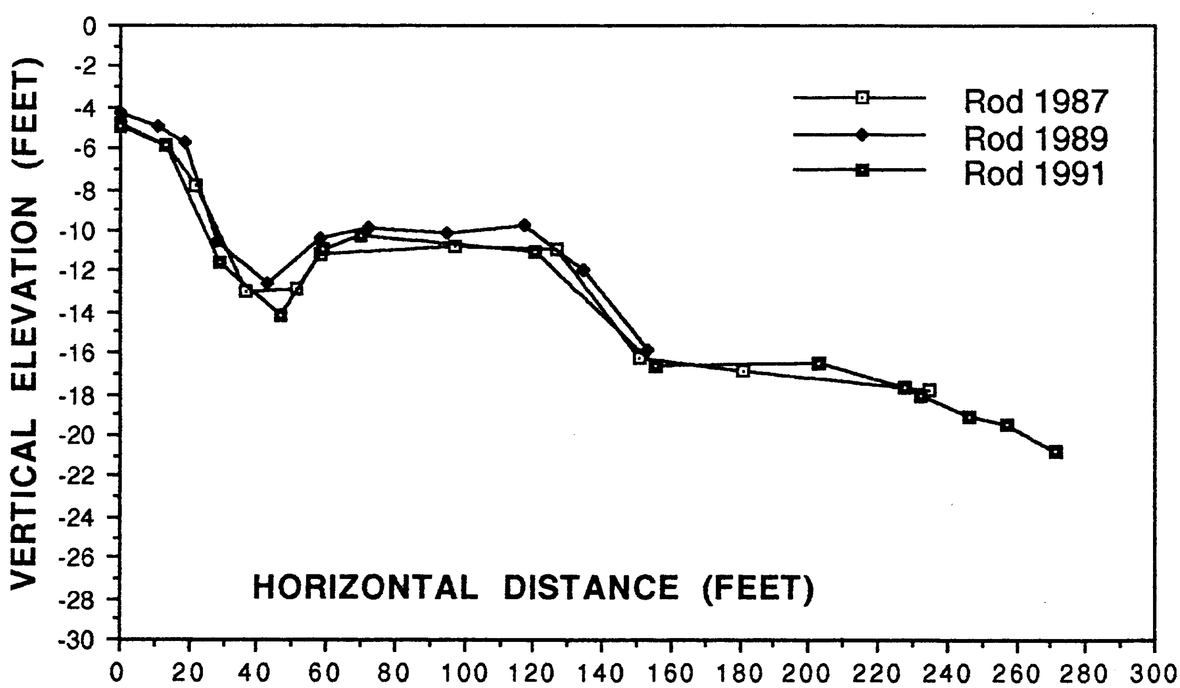

FIGURE 31. CS2 194 MILE BEACH L193.9

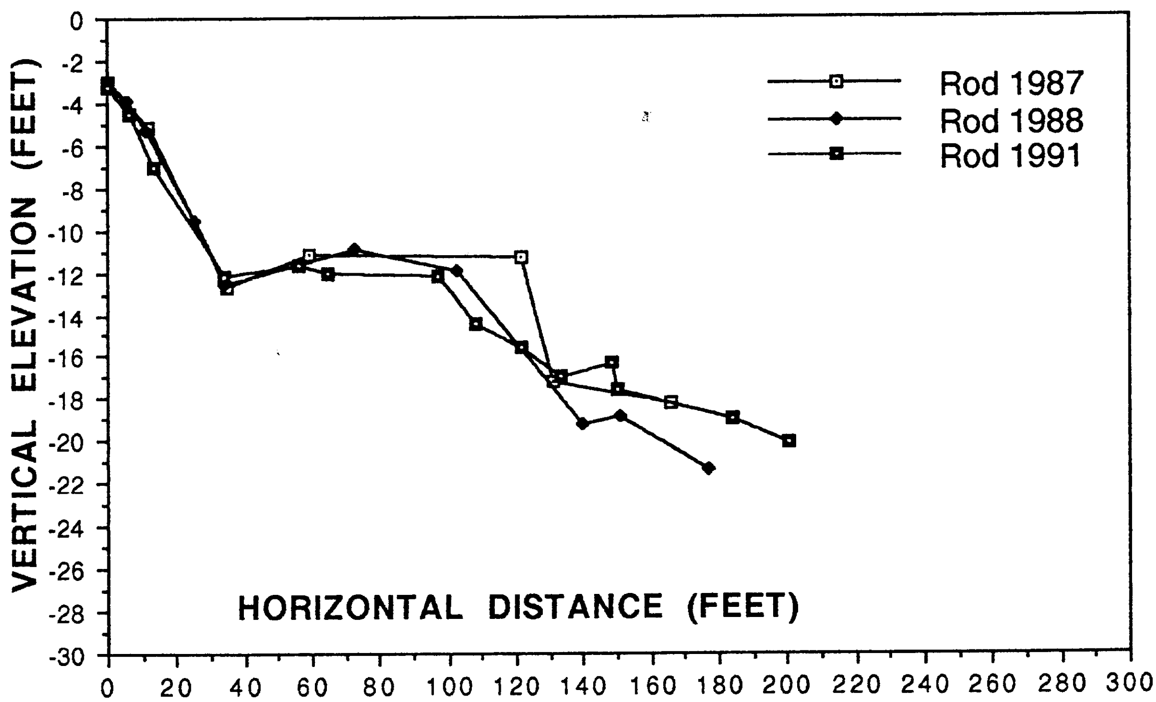

FIGURE 32. CS3 194 MILE BEACH L193.9

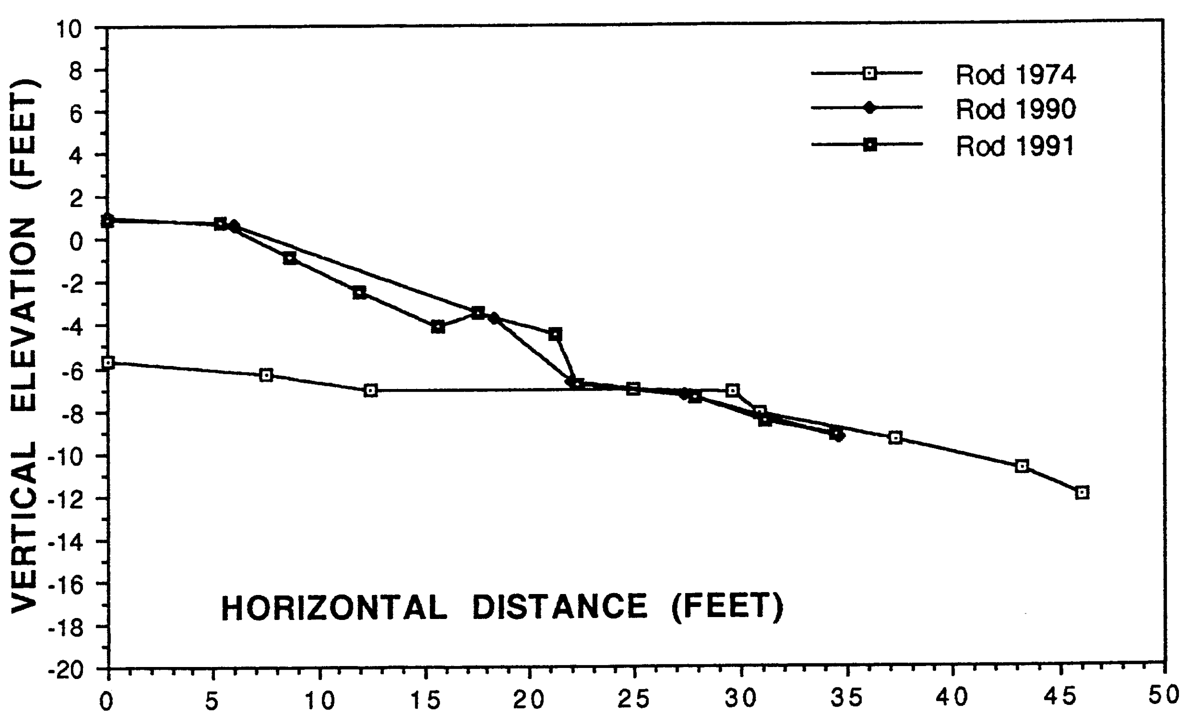

FIGURE 33. CS2 GRANITE PARK L208.8

Table 2-2 Summary of Loss or Gain of Beach Sand

		Comparison of 1990 and 91 beaches		Comparison of Original Survey to 1991		
Beach	Profile	Inner	Outer	Inner	Outer	Year of Original Study
L34.7	CS1	-0.50	0.00	5.75	6.50	1974
L34.7	CS2	0.00	0.00	4.00	-4.00	1974
* R53	CS3	-2.00	-1.50	-2.00	-2.00	1974
R58.1	CS1	0.00	-2.50	-2.00	-2.00	1984
R61.8	CS1	0.00	0.00	2.50	0.00	1975
L75.5	CS1	0.00	0.00	1.00	-1.50	1984
L81.1	CS1	-0.75	1.50	-1.75	0.25	1974
L81.1	CS2	-0.75	0.75	-1.00	1.00	1974
* L93.2	CS1	-1.50	0.00	-2.75	-3.00	1974
* L93.2	CS2	1.25	1.00	-2.00	-1.00	1974
R120.1	CS1	0.00	1.00	-1.50	-2.00	1974
R120.1	CS2	0.00	-0.25	4.00	-2.00	1974
L122.8	CS1	0.00	0.50	1.50	1.75	1983
L122.9	CS2	0.00	0.00	1.00	1.00	1983
R131.0	CS1	-0.25	0.00	-0.25	-1.00	1974
R131.0	CS2	0.00	0.00	0.00	-0.75	1974
R136.6	CS1	0.75	0.75	0.75	1.75	1988
R136.6	CS2	0.00	-0.25	0.00	-0.25	1988
L166.6	CS1	-1.00	-1.00	-1.00	-1.00	1985
L166.6	CS2	-1.50	-1.50	-2.50	-3.00	1985
* L166.6	CS3	0.00	0.00	0.00	-0.50	1987
L166.6	CS4	-0.50	-0.50	-0.75	-0.25	1987
L166.6	CS5	-0.50	-0.50	-1.00	-1.00	1987
* L193.9	CS1	-0.50	-0.50	0.50	0.00	1987
* L193.9	CS2	-0.50	-0.25	0.00	0.00	1987
* L193.9	CS3	0.00	-0.50	-0.75	-1.00	1987
L208	CS2	0.00	0.00	5.00	-2.00	1974

*R53.0-CS3: comparsion of 1987 to 1991 beach surveys
*L93.2-CS1, CS2: comparsion of 1989 to 1991 beach surveys
*L166.6-CS3: comparsion of 1989 to 1991 beach surveys
*L193.9-CS1, CS2: comparsion of 1989 to 1991 beach surveys
*L193.9-CS3: comparsion of 1989 to 1991 beach surveys

Note: The designation of inner and outer beach is made by dividing the graph subjectively in half, the inner beach half being away from the waters edge and the outer beach being near the waters edge.

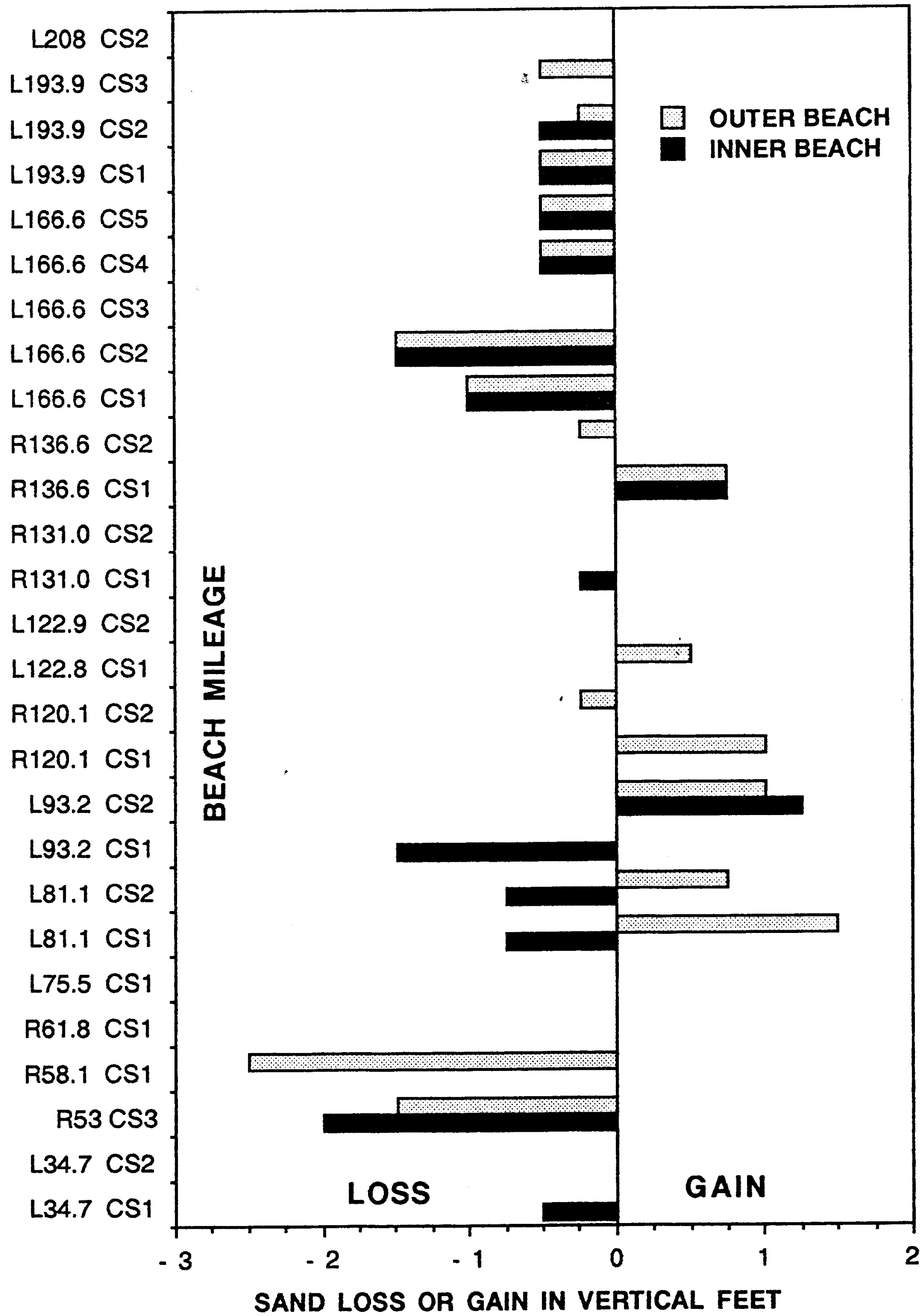

Figure 34. Gain or loss of sand from selected beaches, 1990-1991.

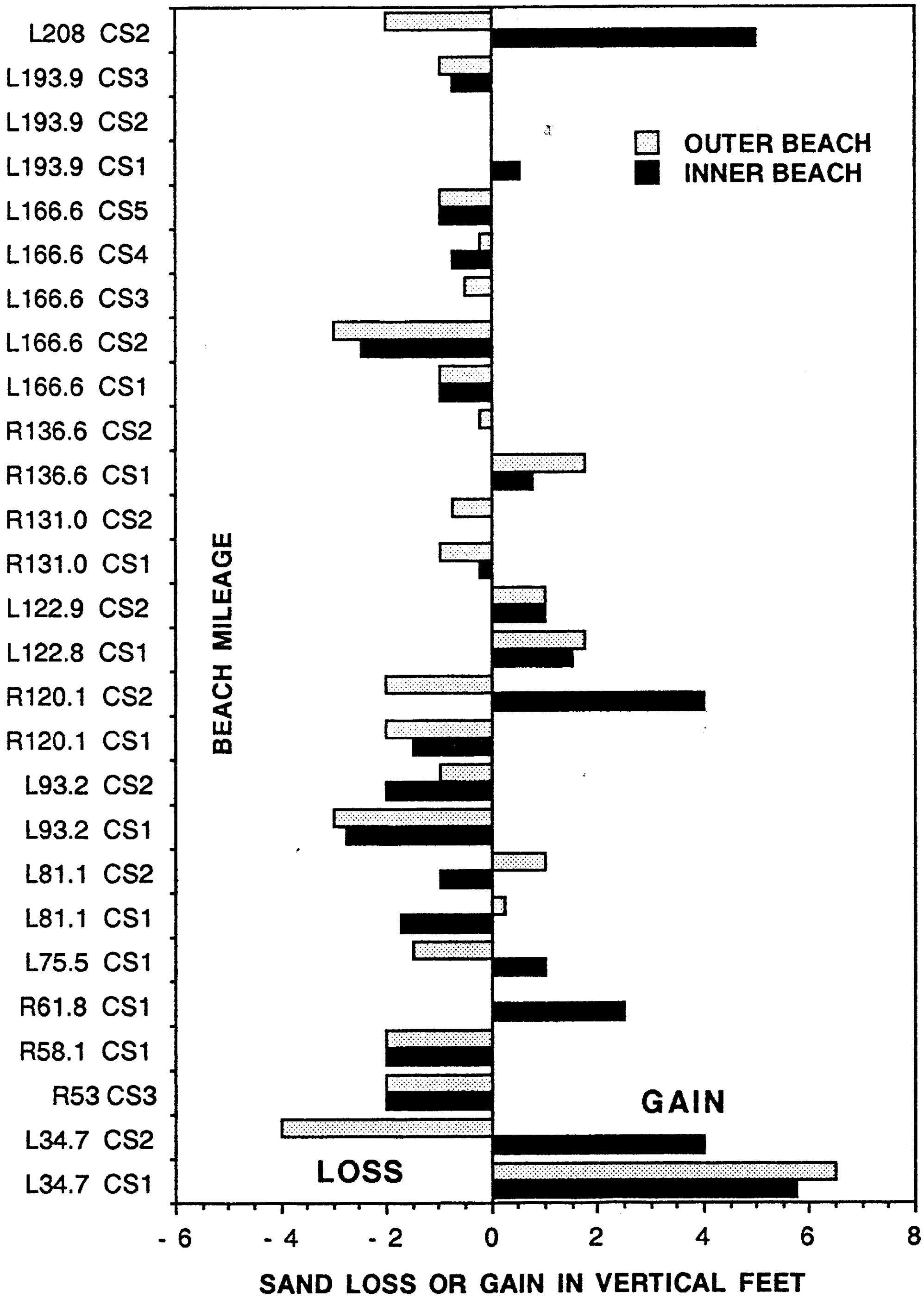

Figure 35. Gain or loss of sand from original survey to 1991

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ADDENDUM 2-1
To Beach Profile Survey Team:

1. *To increase speed and accuracy of data collection, we recommend training and sticking to specific job assignments while in the field. Rotating tasks in order to learn various roles, and discover the most efficient and functional assignments for each team member can be accomplished during instructional field trips prior to the river trip.*
2. *To simplify your data summary and final report, we suggest the following be done as you collect your data or on layover days during the raft trip:*
   a. identify which BS is to be used for zero point on graphs and record it as ED (elevation data) on the bottom of each data sheet.
   b. correct for barrel tilt. Accuracy of the tilt angle is most important, especially over long distances when the length of line may not be quite true (due to interference of rocks and trees, extreme sloping of beaches, sagging of the measuring tape).
3. *Rod Person:*
   a. watch transit person for directions at all times during readings
   b. pick or plant two points (a stick, someone's shoes) to help you keep in line with the transit as you back up holding the rod
   c. keep your hands alongside the rod so as not to block the numbers.
4. *Line People:*
   a. try for a true horizontal between you to eliminate slope effect on measurement.
   b. do not exceed limit of line strength as lines do break.
5. *Transit Person:*
   a. shoot both base stations on each cross-secton
   b. if barrel is tilted for BS, try for 0.00 reading
   c. if barrel is tilted otherwise, try for whole degree reading.
6. *Recorder:*
   a. prepare data sheets in advance by entering "mile-date-cross-section number-campground name" at top
   b. have old report and old data sheet for each beach
   c. have maps at hand; get BS to CS distances from the map while in the field
   d. under "Comments", give reasons for tilting the transit barrel, reasons for skipping a cross section, and locations for each rod reading.
7. *General:*
   a. practice setting up and calibrating transit before leaving for the river. This is the most time consuming aspect of the beach profile.
   b. keep hand lenses on hand as readings are hard to make off transit without them.
   c. make every attempt to recover buried benchmarks as they will increase the accuracy of results.
   d. upon return from the river assign one member of the team to become familiar with the graph generating software to be used (Cricket graph on a Macintosh computer). This will make producing research reports much easier.
   e. wear bright hats in field to aid in visibility of each other. Neon orange is most easily seen.

CHAPTER 3

BEACH GRAIN SIZE ON TWO SELECTED BEACHES IN THE GRAND CANYON

SCOTT MCKAY

INTRODUCTION

There are many forces rearranging sand grains on the beaches of the Grand Canyon. Some of these forces are: wind, humans, flash floods, rain and fluctuating river levels. In this study sand samples were collected from two beaches to see if there is a relationship between these forces and the distribution of different grain particles.

METHODS

On Anasazi beach, Mile 43, four transect lines were randomly set up, three of them perpendicular to the river about 24 m apart, and one parallel to the river crossing the other three, about 30 m from the water (table 1). About every 8 m on each transect two sand samples were collected: one at the surface and one at a depth of 10 cm. At mile 172 four transect lines were set up perpendicular to the river about 10 m apart (table 2). A surface sample and a subsurface (10 cm) sample were collected from points about 8 m apart on each transect. About half of the samples were sifted in the field through a set of standard three inch diameter U.S. sieves with a device that clamped two sieves together. The device was shaken by hand to sift the sand. The remaining samples were sifted mechanically back at the lab for the same length of time and through the same set of sieves. The sieves consist of nine graduated screens and a pan at the bottom. The graduations range from U.S. Standard Sieve Sieve mesh #18 (phi 0.0) to mesh # 230 (phi 4.0) (table 3). The pan at the bottom collects any particles finer than phi 4.0.

After sifting the samples for 10-15 minutes each fraction was weighed and the total sample weight was figured. By dividing the total weight into the fraction weight the percent of each fraction was calculated. At this point the figures could be used several ways. One way was to make a histogram comparing the percent sizes of each fraction (figure 1). Another way to use the percents was to graph them on semilog paper and use the Folk's formula to calculate the average phi for each sample (tables 1 and 2).

RESULTS

Three observations resulted from the data analysis. Each is listed below and will be discussed in the conclusion.

1. Surface samples were not significantly different from the subsurface samples.

Mile 43 average surface size....................3.1
Mile 43 average subsurface size.............3.0

Mile 172 average surface size..................1.9
Mile 172 average subsurface size...........1.9

2. The samples close to the water were much finer than the samples higher up on the beach.

Mile 43 lower beach average......................2.6
Mile 43 upper beach average......................1.7

Mile 172 lower beach average....................3.9
Mile 172 upper beach average....................2.8

3. The average grain sizes on Mile 172 were much finer than those on Mile 43.

Mile 43 average..1.9
Mile 172 average..3.0

For a comparison of Mile 43 grain size with past studies, see Lojko 1983 (numbers indicate phi sizes).

CONCLUSION

1. Since the surface and subsurface samples were not significantly different, the forces that sort grain size on the beaches must work the same to a depth of at lease 10 cm. Taking the subsurface samples from a depth greater than 10 cm may have led to more significant difference.

2. The sand on the lower beach is exposed to the fluctuating river flows, and the sand on the upper beach is affected more by the wind. Wind and water erode sand in different ways (Tarbuck and Lutgens 1988). Water picks up and moves coarser grains more easily because the finer grains are more compacted when moist. Studies have been made on the velocity of the current necessary to move certain sized sand particles (Lojko 1984). Wind, on the other hand, picks up finer grains more easily because they are lighter. Thus the dry upper beach sand loses fine grains to wind erosion while the lower beach loses coarse grains to water erosion.

3. The grains at beach 172 were much finer than those at Mile 43. There is not enough data to make a generalization about finer grain sands being found farther from the dam but this may be a possibility for further studies. If this is so, one explanation may be the high water flows of the mid 80's. These floods may have picked up all sizes of sediments and the heavier grains were deposited farther upstream while the lighter particles stayed in suspension longer and were deposited farther from the dam (Lojko 1984).

Another explanation for the finer grains at Mile 172 may be the topography or vegetation of the beach. Mile 42 is quite a steep beach (figure 2) with little vegetation. Mile 172 is a low, flat beach with thick stands of arrowweed and tamarisk. The finer particles hold more water and create a better habitat for vegetation, which in turn may reduce wind erosion.

TABLE 1: MILE 43 SAMPLE SITES

UPPER BEACH

*D-6 s: 1.3 * ss: 1.5						
*D-5 s: 1.4 ss: 1.6			*B-6 s: 1.7 ss: 2.0			
*D-4 s: 1.6 ss: 1.9			*B-5 s: 1.7 ss: 1.6			*A-5 s: 2.2 ss: 1.8
*C-5 s: 1.9 ss: 1.6	*C-4 s: 1.8 ss: 1.6	*C-3 s: 1.3 ss: 1.6	*B-4 s: 1.6 ss: 1.1	*C-2 s: 1.2 ss: 1.2	*C-1 s: 2.0 ss: 1.9	*A-4 s: 1.5 ss: 1.7
*D-3 s: 1.1 ss: 2.0			*B-3 s: 1.8 ss: 2.1			*A-3 s: 1.8 ss: 2.2
*D-2 s: 2.6			*B-2 s: 2.9 ss: 1.5			*A-2 s: 2.2 ss: 2.6
*D-1 s: 2.7 ss: 2.6			*B-1 s: 2.9 ss: 2.9			*A-1 s: 2.5 ss: 3.2

WATER'S EDGE CURRENT ----->

* Numbers indicate phi size

s = surface sample

ss = subsurface sample

0-1.....coarse sand
1-2.....medium sand
2-3......fine sand
3-4......very fine sand
4+.......silt to clay

TABLE 2: MILE 172 SAMPLE SITES

		UPPER BEACH	
	Ledge Sample s: 2.9		
	*C-5 s: 2.8 ss: 2.6	*B-5 s: 2.2 ss: 2.6	
*D-4 s: 2.6 ss: 2.3	*C-4 s: 2.7 ss: 2.5	*B-4 s: 2.4 ss: 2.6	*A-4 ss: 2.3
*D-3 s: 3.6 ss: 3.3	*C-3 s: 3.5 ss: 3.8	*B-3 s: 2.7 ss: 2.6	*A-3 s: 2.2 ss: 2.3
*D-2 s: 3.7 ss: 3.5	*C-2 s: 4.0 ss: 3.5	*B-2 s: 3.5 ss: 4.0	*A-2 s: 2.3 ss: 2.0
*D-1 s: 3.5 ss: 3.3	*C-1 s: 3.4 ss: 3.3	*B-1 s: 3.3 ss: 3.3	*A-1 s: 3.6 ss: 3.4
	WATER'S EDGE	CURRENT----->	

* Numbers indicate phi sizes

s = surface sample

ss = subsurface sample

0-1........coarse sand
1-2........medium sand
2-3........fine sand
3-4........very fine sand
4+ ....silt to clay

TABLE 3: GRAIN SIZE COMPARISONS

US STANDARD SIEVE SIZES	MILLIMETERS	PHI	DESCRIPTION
18	1.00	0.0	very coarse sand
25	0.71	0.5	coarse sand
35	0.50	1.0	coarse sand
45	0.35	1.5	medium sand
60	0.25	2.0	medium sand
80	0.177	2.5	fine sand
120	0.125	3.0	fine sand
170	0.088	3.5	very fine sand
230	0.0625	4.0	very fine sand
325	0.044	4.5	coarse silt

Figure 1

HISTOGRAMS FROM REPRESENTATIVE SAMPLES

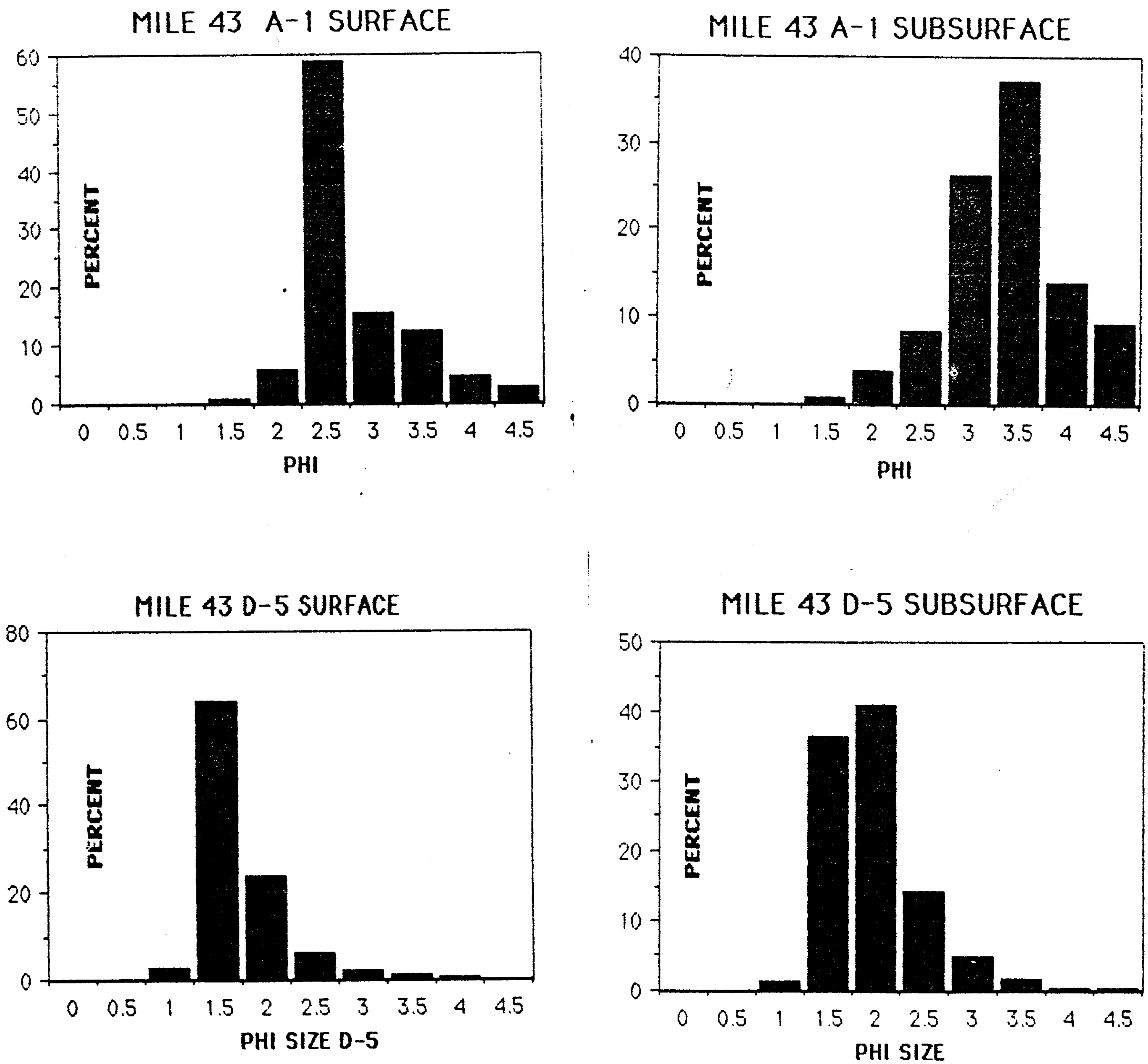
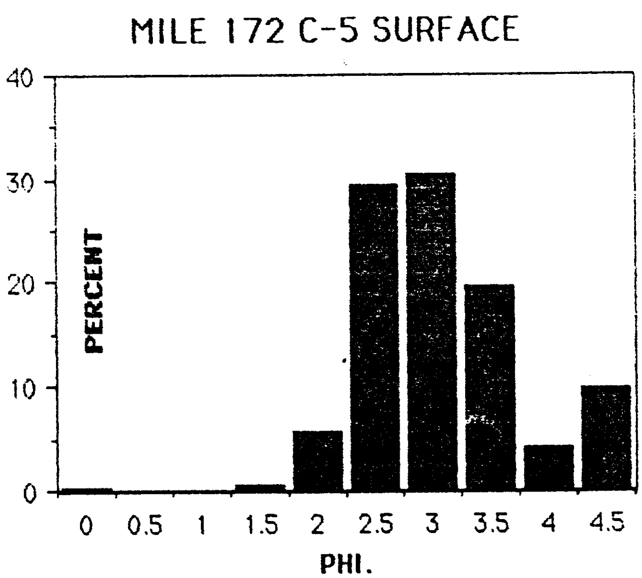
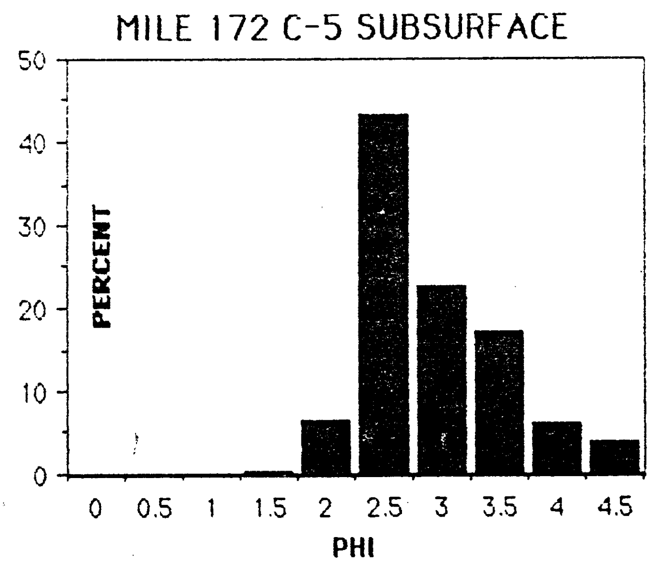
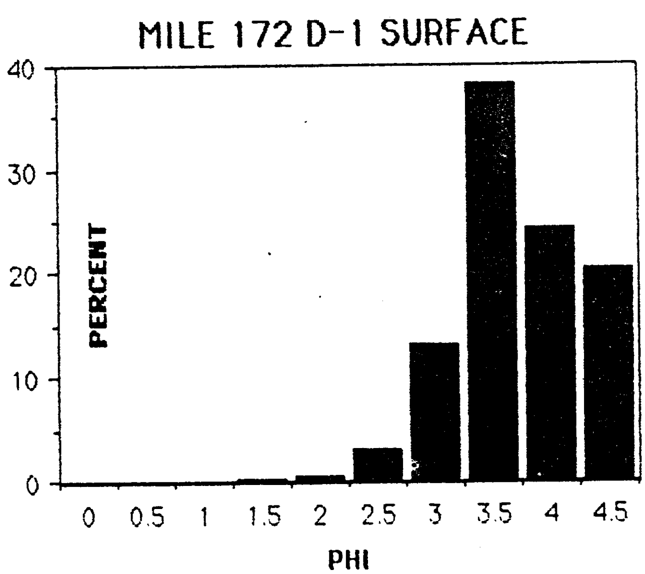


Figure I (CONTINUED)

HISTOGRAMS FROM REPRESENTATIVE SAMPLES







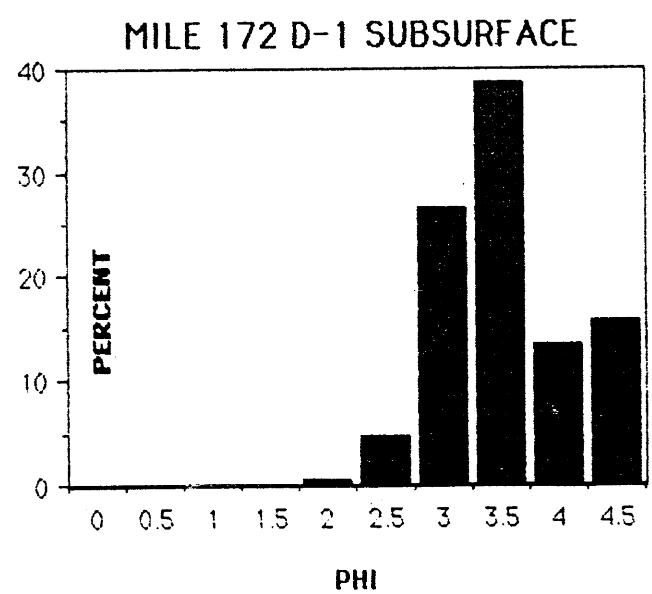
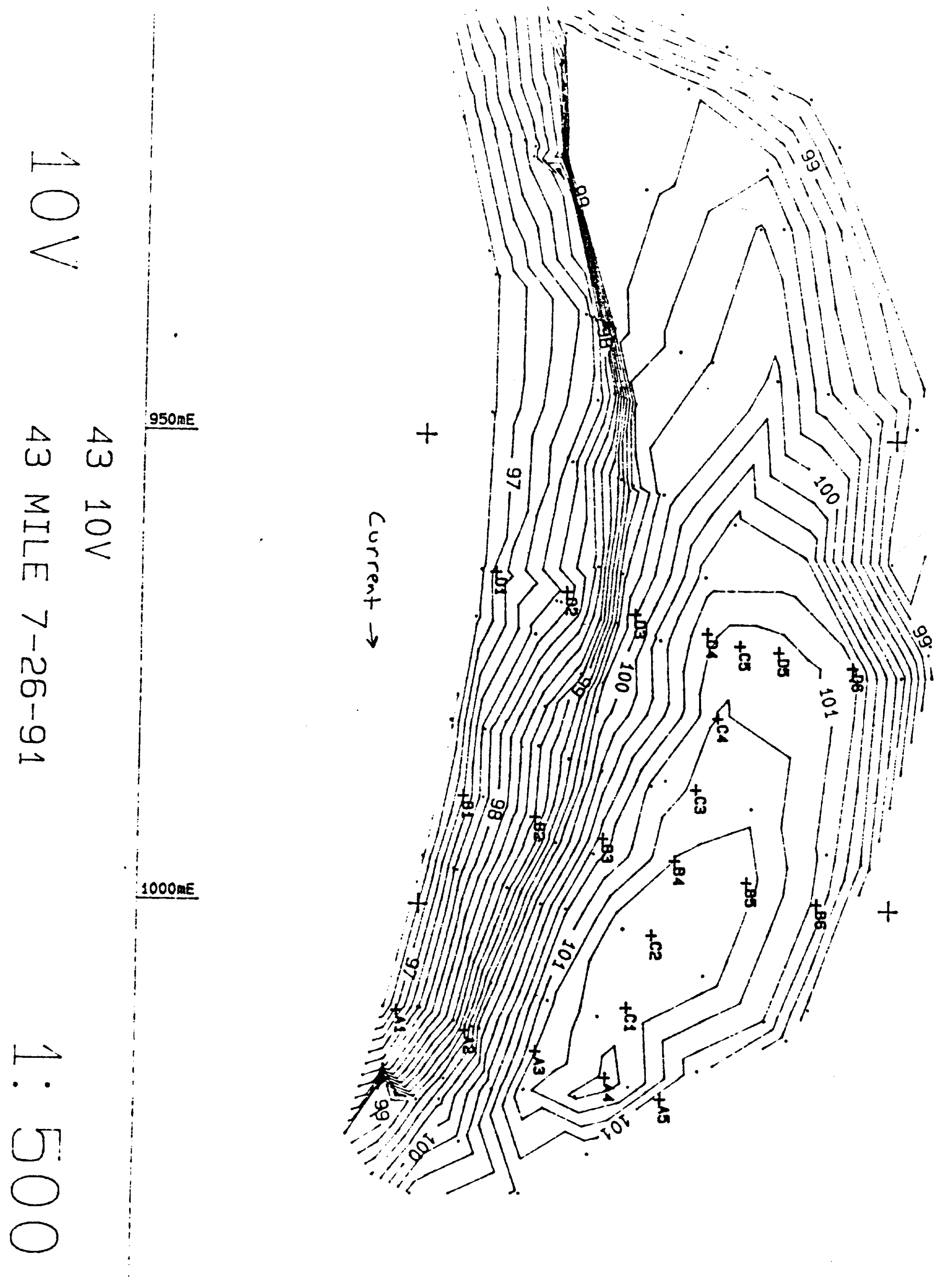


Figure 2: Topographic Map and Sample Sites of Mile 43



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I am indebted to the following people for their assistance in the completion of this project: Nancy Garavito for sharing her computer expertise, Nancy, Garry Mowry, and Roy Narvaez for their help in laying transect lines and collecting samples, and Bob Mier and Ron Edwards for their photographic assistance. And finally, Frank Lojko for overseeing and mentoring the project.

CHAPTER 4

1991 GRAND CANYON MARSH SURVEY

Neil K. Westover, Scott McKay, Nancy Brookes, Lawrence E. Stevens

INTRODUCTION

Relatively little research has been conducted on marshes that develop along regulated rivers like the lower Colorado. Although marshes and wetlands such as these have quite limited distribution in the southwestern United States, they still are among the most productive of terrestrial habitats and play extremely important roles within North American ecosystems. Prior to construction of the Glen Canyon Dam, these riverside marshes did not even exist. But, by 1973 Phillips et al. (1977) had identified 37 marshes. Studies since then have described a variety of animal species that prefer or may even depend on these marshes for breeding or rearing areas (Maddux et al. 1987; Stevens 1983; Warren and Schwalbe 1986; Brown and Johnson 1987). It is also believed that these highly productive wetlands contribute a vital source of nutrients for this fluvial ecosystem (Stevens 1983).

Increased understanding of the structure and successional development of riverine marshes as they respond to varied flow regimes below Glen Canyon Dam is essential to protecting these extremely valuable and threatened habitats. A recent example of the potential for heavy losses of this habitat involved the extensive river flooding during the years 1983 to 1986, which resulted in almost complete elimination of marshes which had developed within the Grand Canyon since completion of the dam. Since 1987, flow regimes have returned to more stable fluctuations and marshes have again begun to establish themselves along the Grand Canyon corridor (Schmidt et al., in prep.).

The goals of this study were to collect data from six of these marshes which had developed after the 1983-1986 flooding, in order to develop baseline data regarding their (1) soil profiles, (2) standing crops, and (3) species richness. Information collected in this study has been added to research data already being gathered by one of us (Stevens) and will provide additional baseline data for future comparative or developmental studies.

METHODS

The study sites for this project included six marshes located downstream from Lee's Ferry at river miles 43L, 55R, 71L, 123L, and 194L. These marshes are located in wider reaches of the Grand Canyon and are all positioned on the left side of the river except for the marsh at mile 55.5R. Each marsh varies as to its overall size, shape, successional age, and geomorphology, but shares the characteristics requisite to marsh formation; i.e. moist, fine-grained substrate where river flow regimes provide varying degrees of inundation without severe or prolonged water current disturbances (Stevens 1989).

Data collection at each site began by locating transect lines marked in an earlier study or by creating a new single transect line (as in the case of the marsh at mile 71L which was not previously marked). Transect lines ran perpendicular to the river and across the marshes and were located parallel to each other at 10 meter intervals. Once these transect lines had been situated, small soil profile trenches were excavated at 2 meter intervals, parallel to and one meter upriver from the transect line. Trenches were dug beginning at 0 meters and continued across the marsh toward the riverward stake marking the distal end of the transect line. Descriptions of soil horizons at each trench were recorded and soil samples were taken at various depths to help analyze unique strata or grain size features; as well to test for soil nutrients.

Species diversity and standing crop data were collected from areas measuring 0.5 m^2 and located within the marsh thalweg 2 m upriver from the established transect line. A species list was created for each sample site and then all living plant matter plus associated duff (organic surface debris) were removed to ground level and stored for later analysis. Depending on marsh size, 4 to 6 samples were collected at each marsh (one at each transect line in small marshes or one at every other line for larger marshes). Some washing, drying, and sorting of samples was then performed at river camps as time and weather conditions permitted.

Upon return to the lab, biomass samples were dried and weighed to provide standing crop data for the 1987-1991 time period. Soils were also sieved using standard procedures to provide grain size data and were then saved for soil nutrient testing.

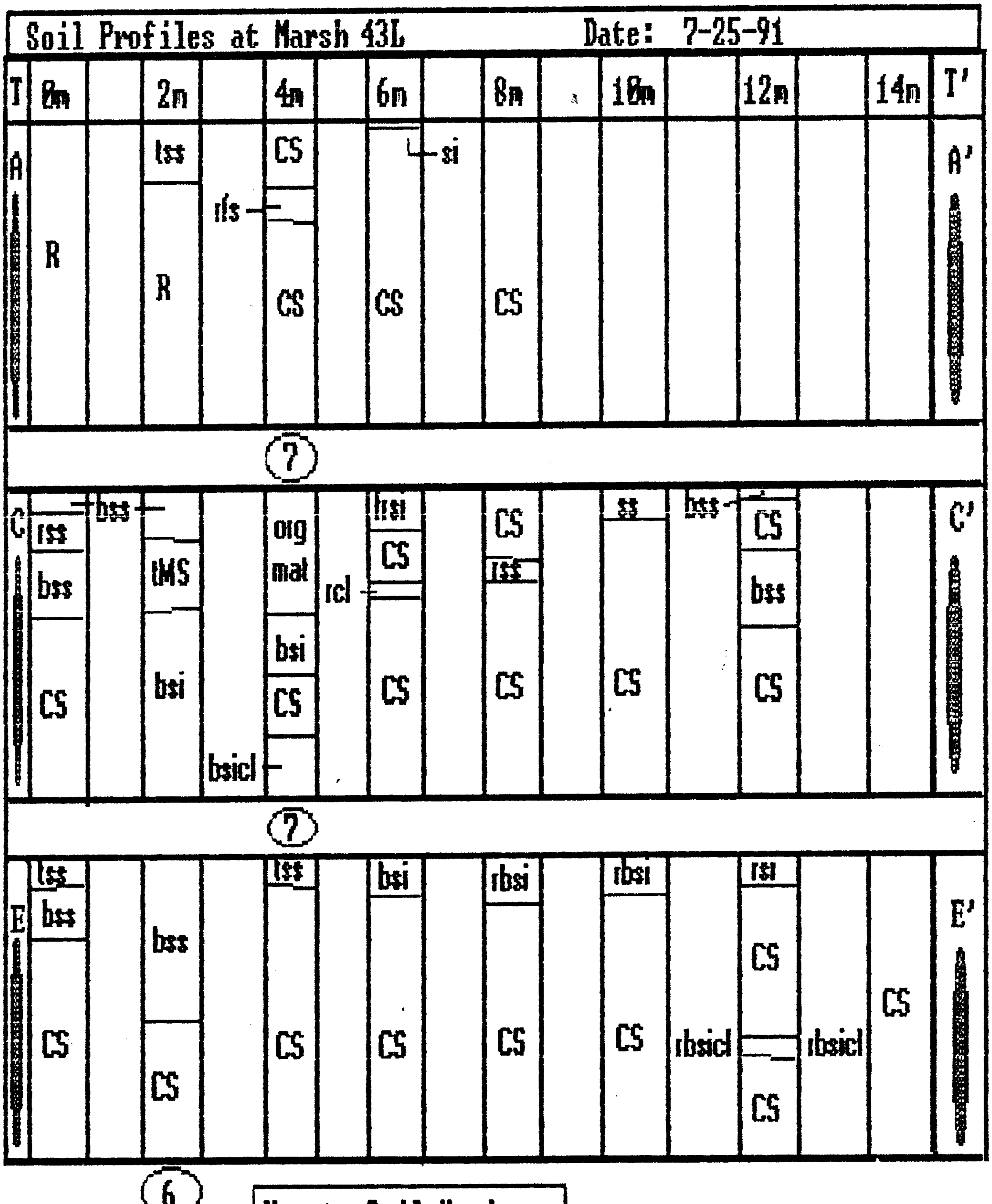
Several problems of collecting, storing, drying, and transporting biomass and soil samples within limitations of time and boat space became apparent early in the study. Several collection sites were submerged making sampling difficult. Future studies of this type would benefit from the use of soil augers instead of trenches to both speed up the process and decrease human impact on the marshes. A photographic record might also prove to be a valuable aid to provide consistency to written descriptions of soil horizons. Specific soil samples might also be taken of surface substrate in an area adjoining the 0.5 m^2 sample site to provide more accurate information concerning the possible relationship between grain size and species diversity or standing crop.

Drying of plants is difficult and time-consuming at best, but might be accelerated in the field by the use of fine mesh bags which could be hung out during the day or night as travel schedules and weather permit. Lab drying time of plant materials might also be accelerated by building special drying ovens using heat lamps and circulating fans. The size of these ovens could vary from $1m^2$ to room size for larger collection efforts. Metric scales with potential to weigh large, bulky samples ranging in mass from a few grams to 3,000 g are also highly desired for checking for sample dryness as well as for final biomass determination.

RESULTS

In general, soil surface units tended to coarsen upslope through the marshes and most sites exhibited a superficial, fine layer of sediments, a prerequisite to colonization by marsh plant species. Soil profiles at a characteristic marsh (43L) are shown in Figure 1. In most marshes, the mouths of current return-channels had deep (>50cm) deposits of fine silt, with increasing depth downslope and towards the river.

Marsh development, measured as productivity and species richness, on most sites examined was extensive (Table 1). We observed or collected 45 species of plants within marshes studied, with dominance by clonal monocots, especially Typha domingensis, Carex, and various rushes and grasses. Productivity ranged from a low of 0.066 kg/m2/yr to 0.213 kg/m2/yr, based upon total standing crop accumulation since August of 1986. A negative correlation was observed between productivity and species richness (Figure 2). The 123L site had more stratigraphic development than other marshes we investigated. No correlation was observed between stratigraphic complexity and species richness. We did however, observe a trend towards a negative correlation between stratigraphic complexity and productivity.



Key to Soil Horizons

R = rock
CS = coarse sand
MS = medium sand
FS = fine sand
si = silt
ss = silty sand
sc = silty clay
cl = clay
b = brown
r = red
bu = buff
rb = reddish brown
t = tan
(n) = Species # at thalweg

Figure 1. Marsh soil profiles at Colorado River Mile 43L.

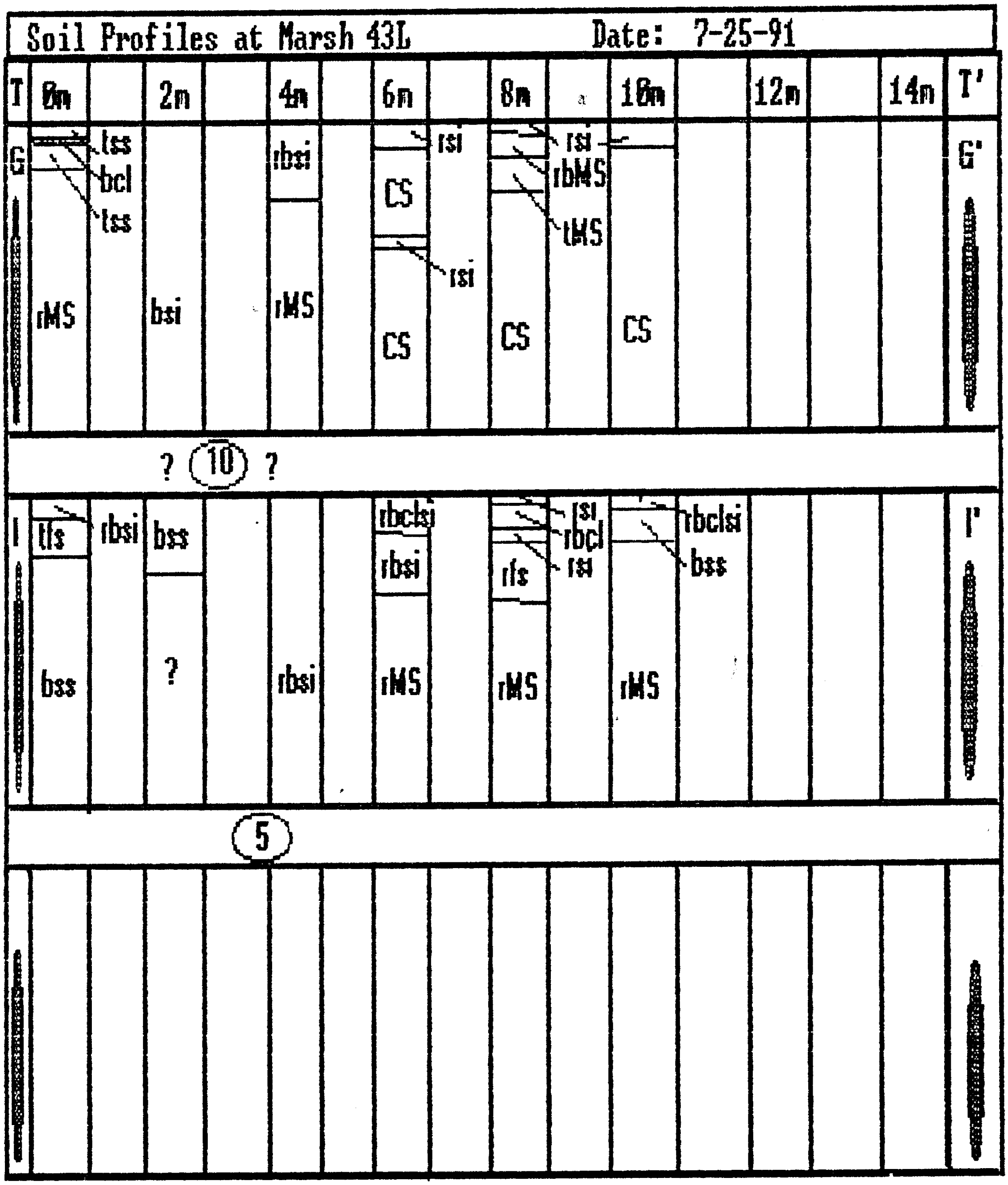


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Figure 1 (continued).

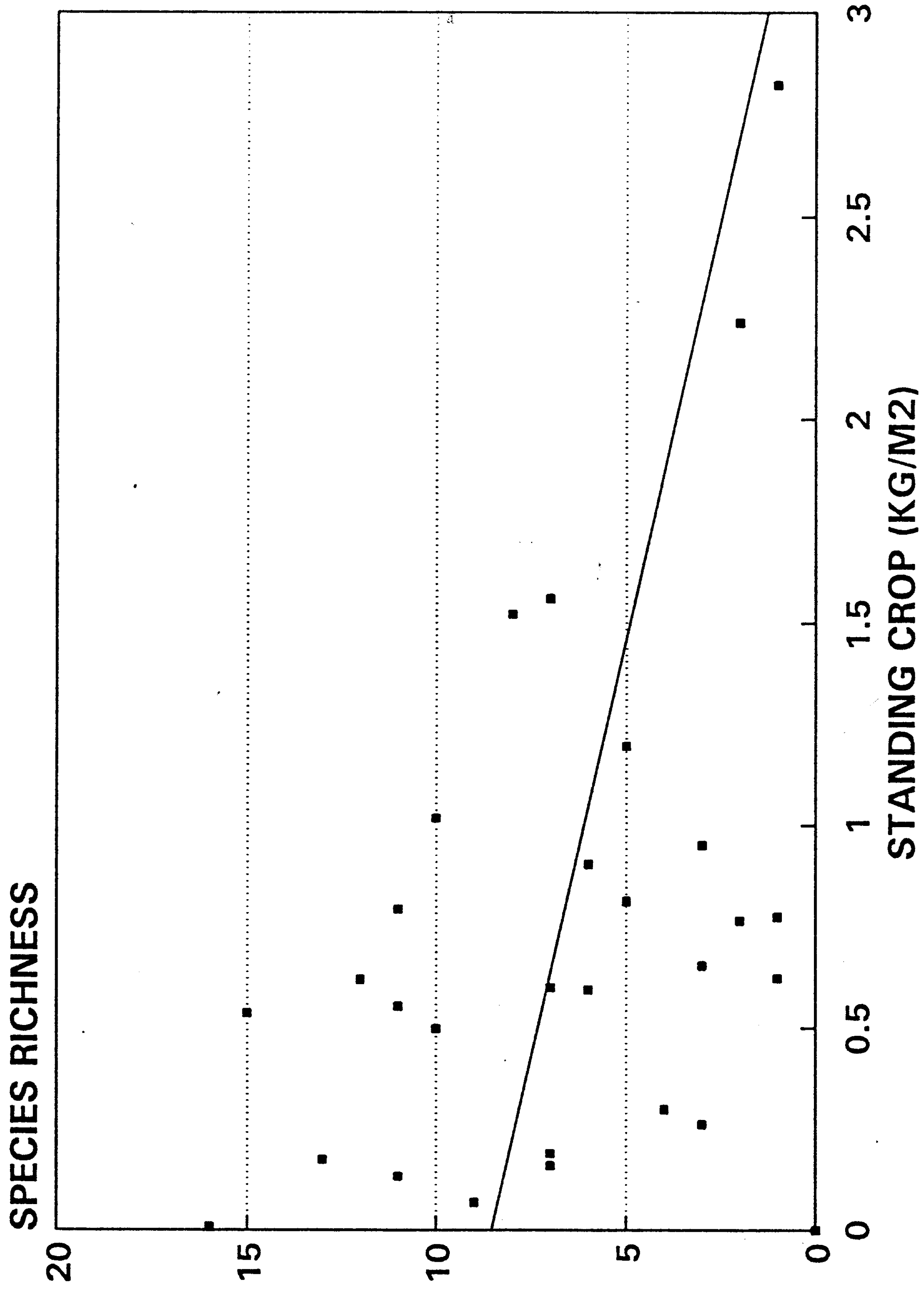

Figure 2. Standing Crop vs. Species Richness

Table 1. Marsh Productivity and Species Richness

SITE (MILE)	N	$P (KG/M^2/YR)$	SPECIES RICHNESS/$0.5M^2$	SPECIES RICHNESS/ $0.5M^2$/MARSH
43L	5	0.183	7.00	18
55R	5	0.075	11.00	27
71L	6	0.122	8.00	25
123L	4	0.066	9.75	22
172L	4	0.213	2.75	8
194L	6	0.211	2.33	11
	TOTAL=31	MEAN=0.145	MEAN=6.80	TOTAL=45

DISCUSSION

The goals of this study were the collection of data on soil profiles, standing crops and plant species richness of six marshes in the Colorado River corridor in Grand Canyon National Park. Soil data collected in this effort revealed variability in stratigraphic complexity between marshes, with Marsh 123L exhibiting the greatest degree of complexity and Marsh 43L revealing the least complexity. Stratigraphic complexity was somewhat predictable based on geomorphologic conditions that created fluvial marshes in this system, particularly elevation of marsh surfaces in relationship to discharge regimes and marsh location with respect to sediment sources. Large fluctuations in flow regimes have played a significant role in soil development in marsh habitats.

The observed variation in stratigraphic complexity, especially at Marsh 123L, further suggested a relationship between geomorphology, stratigraphic complexity and successional status. Productivity was negatively correlated with stratigraphic complexity. Stratigraphic complexity may relate to increased energy in the depositional environment. Increased turbulence probably removed standing crop and kept more highly disturbed marshes in an earlier state of successional development.

We interpret overall trends observed within these marshes to mean that dominant marsh species quickly begin to out-compete earlier successional species, thus reducing species richness. The high productivity of marsh dominants (e.g. *Typha domingensis*) relative to early-successional species should lead to accumulation of large quantities of associated litter and thick beds of decomposing matter. However, we found only thin beds, if any, of decaying organic matter, suggesting that erratic discharges may prevent accumulation of organic matter in these fluvial marshes. The relatively young age of these marshes is important; however, several growing seasons of litter have been produced in marshes such as 194L, yet litter load was nominal. The loss rate of organic matter produced in the marshes may affect long-term soil nutrient cycles and the overall rate of successional process, both of which ultimately affect marsh productivity and stability.

Additional study of these unique natural resources is recommended to more accurately determine the complex interactions and processes affecting abiotic and biotic marsh components. Continued efforts to improve methodologies and training of research assistants will enhance the productivity of future research efforts and will provide much-needed knowledge about these small but biologically important American wetlands.

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Chapter 5

MACROINVERTEBRATE STUDIES IN SIDE CANYON TRIBUTARIES OF THE GRAND CANYON

G. W. "Pat" Lauman, James G. Schulz, James A. Thomas, Daryl H. Willis

Introduction

Side canyon tributaries are unique riparian corridors accessing the Colorado River. These streams provide for abundant aquatic vegetation and invertebrate growth that generates necessary nutrients for the micro as well as macro-fauna within the Grand Canyon. The current investigation focuses on the abundance, standing crop, habitat and species diversity of aquatic macroinvertebrates (which include but are not limited to Simulidae and Chironimidae) in eight Colorado River tributaries. From this baseline data on macroinverbrates, their ecological postion and importance in intertributary, intratributary and the main river system may be compared.

Few studies on aquatic benthic macroinvertebrates in the tributaries of the Grand Canyon have been done. This is due in part to the inaccessability of many of these tributaries. It has been established that biodiversity in the side canyon streams is significantly higher than in the Colorado River (Polhemus and Polhemus 1976, Stevens 1976, Hofknecht 1981, Blinn 1990). Hofknecht (1981) reported fifty-four families of aquatic invertebrates from 30 tributaries. This study included comparisons between the creeks of species diversity, density, biomass, water quality, and seasonal variability. Other baseline data has been accumulated in conjunction with studies conducted by Carothers (1981,1991) and Stevens (1976,1988).

In 1990 Dr. Dean Blinn of Northern Arizona University initiated a project through the U.S. Department of the Interior to study the ecology of aquatic Diptera in the Colorado River System below Glen Canyon Dam (Blinn 1990). A parallel study of the tributaries to the river, using similiar methodology and providing comparable data is underway to increase the understanding of how the two aquatic ecosystems interact.

METHODS

Ten side streams were selected for study. These represent most of the major tributaries to the Colorado River in the Grand Canyon, with an equal number located on wide reaches and narrow reaches of the river. Due to weather conditions, two creeks were eliminated from the study (Table 1).

At each tributary, three pre-designated transects 30 meters apart were located and the distance of the actual sample sight from each transect was randomly determined. The normal sampling procedure yielded six samples per tributary, consisting of invertebrate/vegetation biomass as well as invertebrate/vegetation taxonomy samples from each of the three transects.

Collecting was done using a Hess substrate sampler which covers .092 sq. meters of the stream substrate. The Hess sampler has an overall height of 40 cm, so care must be taken to insure that water does not flow over the sampler's top and that it is placed as securely as possible against the stream bottom. In the event that the randomization placed the sample area in a stream depth in excess of 39 cm, lateral movement to a similiar but shallower area was undertaken. The substrate within the Hess was agitated for 30 seconds, with the researcher attempting to dislodge as much of the substrate contained within the Hess as possible. Special attention was given to the process in order to avoid contamination of the sample in the collection jar. It is imperative that all detritis, algae and invertebrates are emptied into the sample container.

Error analyses were implemented to determine the accuracy of the Hess substrate sampler. The Hess was left in place and four additional samples were taken. The results of those samples indicate how thoroughly the area within the Hess is being sampled (Fig. 3: A,B,C). Repeated sampling was also conducted within a tributary to determine the utility of the n = 3 samples/tributary for each of the standing crop categories and taxonomy approaches. Hess samples were taken from a fourth, fifth, and sixth transect. These were treated as taxonomy samples, and the results compared with data obtained in the first 3 transects (Fig. 4: A,B,C).

A pygmy sphygnomanometer is used in determining velocity at each sampling site. Revolutions for thirty seconds were counted and multiplied by 2 to yeild the number of revolutions per minute. This value was multiplied by .005 to convert to meters per second.

Invertebrates in each biomass sample were sorted into eight pre-established categories and placed in pre-weighed, numbered vials. The vial number is recorded on data sheets for future reference. Primary producers and detritis were placed in whirlpacks and labeled for site, date, and contents.

Invertebrates in taxonomy samples are separated from other organic matter and placed in a labeled whirlpack with 70% ethyl alcohol. Primary producers and detritus were also placed in whirlpacks and labeled for site, date, and contents.

All primary producers, detrital, invertebrate biomass, and taxonomy samples were air dried in the field to prevent decomposition.

In the lab all invertebrate taxonomy samples were sorted for abundance of each category and the results recorded (Fig. 1). Biomass specimens were placed in a lab oven where they were dessicated at 50 C for 48 hours and weighed (Fig. 2).

All data sheets and samples are on file in the NAU Biology Department.

The following equipment was used to collect data:

Glass vials with cork stoppers
70% ethyl alcohol
10 plastic petri dishes
100 whirl bags
6 volt flashlights
Portable table
Vial storage racks
50-1 gal. plastic storage bags
Thermometer (Celsius)
Hess Sampler with trowel
Pygmy sphygnomanometer
Data Sheets
Stop watch
50 meter tape
15 1 pt. plastic collection containers with lids
Probes
Forceps
Wire screens

DISCUSSION

The purpose of this study was to obtain baseline data on macroinvertebrate ecology in the Colorado River tributaries for comparison with the main system macroinvertebrate ecology. Seven significant relationships revealed by analysis of the data are discussed below.

a. Dissolved oxygen and temperature are negatively correlated. This relationship has long been established (reference #5 in Table 3).

b. Biomass of Simulidae and Chironomidae are positively correlated. Possible explanations include that they have similiar habitat requirements (1).

c. Both Simulidae and Chironomidae are positively correlated with standing crop(sc) of Oscillataria spp. Little is documented on the niche requirements of blue-green algae in the Colorado River System. Further study is recommended. Particular areas of interest are relationships aquatic Diptera have with blue-green algae forms, including similiar water quality needs, the role of refugia and possible mutualistic relationships (2).

d. Primary producers and macroinvertebrate sc are positively correlated (3).

e. Some Diptera, lumbricids and oligochaetes are detrital feeders (4).

f. Relationships between trophic levels (2,3,6,9,11) are generally positively correlated, indicating food resource dependance of macroinvertebrate populations. These biotic environments appear to have a normal Eltonian trophic pyramid structure.

g. Chironomidae, Simulidae, Plecoptera, Ephemeroptera and Trichoptera comprised the majority of macroinvertebrates collected during the study (1,7,8,11-14).

CONCLUSION

This study of macroinvertebrates in the side canyon tributaries of the Grand Canyon revealed several interesting relationships between components of the stream ecosystems. Examination of these relationships provided some insights, but the greatest value to this study lies in the potential to use our data in future investigations, especially in comparing our findings to similiar studies of the Colorado River itself.

RESULTS

Raw data collected from this tributary survey are presented in Table 2, and dry biomass of current data are presented in Figure 2. The eight streams studied revealed significantly different patterns of primary producers, detritus, and macroinvertebrates (Figs. 1,2). Vasey's Paradise showed elevated primary and detrital standing crops when compared to the other tributaries. In analyzing the data, it was found that a highly significant positive relationship existed between invertebrate standing crop (sc) and the standing crop values of primary producers and detritus ($Y = .131X + .116Z + 0.430$ where Y = invert. sc, X = primary producers sc, Z = detrital sc; $F = 39.611$, $p = 0.000$, df = 2,21, $R = .771$).

Biomass samples showed that the standing crop of detritus varied significantly between the tributaries ($F = 3.159$, $p = 0.027$, df = 7,16). The standing crop of macroinvertebrates varied marginally significantly different between the tributaries suggesting that more sampling may be needed for statistical analyses such as this effort ($F = 2.574$, $p = .056$, df = 7, 16; Fig. 1). A Pearson Correlation Matrix was developed and significant relationships are listed in Table 3. We found no statistically significant relationships between water quality variables and standing crop values (Table 3).

Taxonomic samples showed different patterns. Here the density of the standing crop of primary producers showed no significant difference ($F = 1.154$, $p = 0.378$, df = 7,17) between tributaries. The standing crop of detritus showed only marginal significant differences ($F = 2.469$, $p = 0.061$, df = 7,17), and the density of invertebrates showed no significant difference between sites ($F = 1.460$, $p = 0.246$, df = 7,17, Fig. 2).

Hess error analyses results of multiple sampling at a single site (Bright Angel Creek) are shown in graph form (Fig. 3: A,B,C). The purpose of the analyses was to determine if our method of sampling for 30 seconds/transect site was effective in collecting a viable sample or if a longer sampling time was needed. The error variance data exhibited a collection value of 90% for the first time. Error samples 2-5 demonstrated a significant drop in material acquired. A minimal amount of new material may have been collected by removing the Hess from the spot between samples. Improved error sampling techniques would include leaving the Hess substrate sampler in place while continuing to remove and empty the collection jar. The data indicated that a sampling time of 30 seconds was appropriate for collecting reasonable estimate or density of the standing crop.

Results from repeated sampling within a tributary (Havasu Creek) are displayed in a multiple transect graph (Fig. 4: A, B, C). The purpose of this investigation was to determine if 3 taxonomy samples per tributary were adequate. Analysis of the data demonstated that the average of the first three samples was not significantly different from the average of the six error samples. However a few error samples differed sufficiently from the mean to render our results inconclusive. It is possible that incorporating a reliable log transformation of the error values would moderate "noise in variance" and yield a more reliable result.

RECOMMENDATIONS

1. Researchers need to be oriented in collection and laboratory procedures by qualified lab personnel (specifically the lab supervisor).

2. Researchers should be familiar with the operation of the Hess substrate sampler and pygmy sphygnomanometer prior to departure on the river trip.

3. Each tributary sampled should have its own separate, labeled wooden vial rack. This would alleviate confusion and mixing of biomass samples from different sites.

4. Use of 6 volt flashlights should be mandatory when sorting samples.

5. Field equipment should include a 100 quart cooler to store specimens and prevent decomposition.

6. Researchers should practice specfic sampling procedures prior to river trip. Field duties should be assigned among group members with each researcher preforming the same task throughout the trip in order to standardize field methods.

7. Researchers should have a set of preserved specimens of all pertinent invertebrates for reference. Vials containing varieties of each specimen would be benificial in field identification.

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Table 1. Tributaries surveyed

Tributary	Mile #	Date surveyed	Reference # in data
Vasey's Paradise	31.5	7-25-91	2.0000
Nankoweap	53.0	7-26-91	3.0000
Little Colorado River	61.5	7-26-91	4.0000
Bright Angel Creek	88.7	7-28-91	5.0000
Tapeats Creek	133.5	7-30-91	6.0000
Kanab Creek	144.0	7-31-91	7.0000
Havasu Creek	157.0	7-31-91	8.0000
Spring Creek	204.0	8-02-91	9.0000

Table 2. Field Data : biomass(g/m²) and taxonomy of side canyon tribs.

Tributary	Mile	Date	Transect	Taxonomy=1 Biomass=2	Lumbricid	Gammarus	Oligochetae	Simuliidae	Chironomidae
2.00000	31.50000	725.00000	2.00000	1.00000	9.00000	0.00000	0.00000	19.00000	[illegible]
2.00000	31.50000	725.00000	4.00000	1.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
2.00000	31.50000	725.00000	6.00000	1.00000	0.00000	0.00000	0.00000	2.00000	21.0000
2.00000	31.50000	725.00000	1.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.0000
2.00000	31.50000	725.00000	2.00000	2.00000	0.05120	0.00000	0.14331	0.00117	[illegible]
2.00000	31.50000	725.00000	4.00000	2.00000	0.05690	0.00000	0.00272	0.00286	[illegible]
2.00000	31.50000	725.00000	6.00000	2.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
3.00000	53.00000	726.00000	2.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.0000
3.00000	53.00000	726.00000	4.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.0000
3.00000	53.00000	726.00000	6.00000	1.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
3.00000	53.00000	726.00000	2.00000	2.00000	0.00000	0.00000	0.00000	0.00008	[illegible]
3.00000	53.00000	726.00000	4.00000	2.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
3.00000	53.00000	726.00000	6.00000	2.00000	0.00000	0.00000	0.00000	0.00000	0.0102
4.00000	61.50000	726.00000	2.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.0000
4.00000	61.50000	726.00000	4.00000	1.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
4.00000	61.50000	726.00000	6.00000	1.00000	0.00000	0.00000	0.00000	1.00000	[illegible]
4.00000	61.50000	726.00000	2.00000	2.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
4.00000	61.50000	726.00000	4.00000	2.00000	0.00000	0.00000	0.00000	0.00000	0.0000
4.00000	61.50000	726.00000	6.00000	2.00000	0.00000	0.00000	0.00000	0.00000	0.0000
5.00000	88.70000	728.00000	2.00000	1.00000	5.00000	0.00000	0.00000	1.00000	[illegible]
5.00000	88.70000	728.00000	4.00000	1.00000	4.00000	0.00000	0.00000	0.00000	[illegible]
5.00000	88.70000	728.00000	6.00000	1.00000	1.00000	0.00000	0.00000	0.00000	[illegible]
5.00000	88.70000	728.00000	2.00000	2.00000	0.00420	0.00000	0.00085	0.00000	0.0000
5.00000	88.70000	728.00000	4.00000	2.00000	0.00000	0.00000	0.00000	0.00000	0.0000
5.00000	88.70000	728.00000	6.00000	2.00000	0.00000	0.00000	0.00115	0.00000	[illegible]
6.00000	133.50000	730.00000	2.00000	1.00000	0.00000	0.00000	0.00000	7.00000	[illegible]
6.00000	133.50000	730.00000	4.00000	1.00000	0.00000	2.00000	0.00000	0.00000	[illegible]
6.00000	133.50000	730.00000	6.00000	1.00000	0.00000	0.00000	0.00000	0.00000	189.0000
6.00000	133.50000	730.00000	2.00000	2.00000	0.00000	0.00000	0.00000	0.00000	0.0000
6.00000	133.50000	730.00000	4.00000	2.00000	0.00000	0.00000	0.00000	0.00918	[illegible]
6.00000	133.50000	730.00000	6.00000	2.00000	0.00227	0.00000	0.00000	0.00000	[illegible]
7.00000	144.00000	730.00000	2.00000	1.00000	0.00000	0.00000	0.00000	2.00000	[illegible]
7.00000	144.00000	730.00000	4.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.0000
7.00000	144.00000	730.00000	6.00000	1.00000	0.00000	0.00000	1.00000	4.00000	10.0000
7.00000	144.00000	730.00000	2.00000	2.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
7.00000	144.00000	730.00000	4.00000	2.00000	0.00000	0.00000	0.00017	0.00001	[illegible]
7.00000	144.00000	730.00000	6.00000	2.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
8.00000	157.00000	731.00000	2.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.0000
8.00000	157.00000	731.00000	4.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.0000
8.00000	157.00000	731.00000	6.00000	1.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
8.00000	157.00000	731.00000	2.00000	2.00000	0.00000	0.00000	0.00000	0.00029	[illegible]
8.00000	157.00000	731.00000	4.00000	2.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
8.00000	157.00000	731.00000	6.00000	2.00000	0.00000	0.00000	0.00000	0.00000	0.0066
9.00000	204.00000	802.00000	2.00000	1.00000	0.00000	0.00000	0.00000	0.00000	2.0000
9.00000	204.00000	802.00000	4.00000	1.00000	0.00000	0.00000	0.00000	6.00000	[illegible]
9.00000	204.00000	802.00000	6.00000	1.00000	2.00000	0.00000	0.00000	12.00000	[illegible]
9.00000	204.00000	802.00000	2.00000	2.00000	0.01263	0.00000	0.00000	0.00000	[illegible]
9.00000	204.00000	802.00000	4.00000	2.00000	0.00000	0.00000	0.00000	0.00000	0.0005
9.00000	204.00000	802.00000	6.00000	2.00000	0.00000	0.00000	0.00000	0.00019	0.0039
5.50000	88.70000	728.00000	2.10000	1.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
5.50000	88.70000	728.00000	2.20000	1.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
5.50000	88.70000	728.00000	2.30000	1.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
5.50000	88.70000	728.00000	2.40000	1.00000	0.00000	0.00000	0.00000	0.00000	1.0000
8.50000	157.00000	731.00000	1.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.0000
8.50000	157.00000	731.00000	1.50000	1.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
8.50000	157.00000	731.00000	2.00000	1.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
8.50000	157.00000	731.00000	2.50000	1.00000	0.00000	0.00000	0.00000	0.00000	[illegible]
8.50000	157.00000	731.00000	3.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.0000
8.50000	157.00000	731.00000	3.50000	1.00000	0.00000	0.00000	0.00000	0.00000	0.0000

Table 2. Field Data (cont.)

Trichoptera	Plecoptera	Ephemeroptera	Megaloptera	Odonata	Coleoptera	Other/unidentified	Primary producers	Detritus	Gastropoda
0.00000	0.00000	0.00000	0.00000	0.00000	5.00000	9.00000	0.01766	0.26921	69.0
3.00000	20.00000	2.00000	0.00000	1.00000	0.00000	7.00000	0.00000	0.01213	49.00
3.00000	0.00000	5.00000	0.00000	0.00000	0.00000	6.00000	0.00000	0.06199	13.000
1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	5.00000	0.00000	0.00000	0.000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.03074	0.61463	8.33724	0.749
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.18472	4.07985	4.95158	1.09
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01833	0.60881	0.01835	0.0
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00229	0.00000	0.00
0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	2.00000	0.00028	0.01534	0.00
0.00000	0.00000	1.00000	0.00000	0.00000	1.00000	0.00000	0.00918	0.00000	0.00
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01247	0.00663	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00819	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00299	0.01645	0.000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00099	0.04114	0.000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00239	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00358	0.000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.64
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00225	0.00116	0.000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.01408	0.0000
4.00000	0.00000	0.00000	0.00000	0.00000	1.00000	4.00000	0.09578	0.19648	42.0000
10.00000	0.00000	12.00000	0.00000	0.00000	4.00000	4.00000	0.01700	0.00302	0.0000
0.00000	0.00000	7.00000	0.00000	0.00000	0.00000	0.00000	0.01555	0.05097	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.09589	0.16425	0.02595	0.0012
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.02630	0.46727	0.06739	0.0000
0.00000	2.00000	0.00000	0.00000	0.00000	4.00000	0.00000	0.12363	0.22381	0.0000
16.00000	5.00000	15.00000	0.00000	1.00000	0.00000	1.00000	0.24840	0.00000	0.0000
108.00000	79.00000	27.00000	1.00000	0.00000	0.00000	60.00000	11.25417	0.00000	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00072	0.00000	0.00762	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.07704	0.10112	0.09018	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.03656	0.03127	0.05437	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	6.00000	0.58304	0.15530	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	5.00000	0.12059	0.00761	1.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	7.00000	0.03274	0.04137	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00020	0.34249	0.02351	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00018	0.06160	0.09004	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.07488	0.13876	0.02489	0.0000
2.00000	0.00000	4.00000	0.00000	0.00000	0.00000	1.00000	0.06149	0.00392	0.0000
6.00000	0.00000	2.00000	0.00000	0.00000	0.00000	3.00000	0.00000	0.00295	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	3.00000	0.00846	0.00109	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.08776	0.00681	0.25543	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00213	0.00999	0.01128	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.07167	2.11115	0.46602	0.0000
24.00000	2.00000	9.00000	1.00000	3.00000	0.00000	8.00000	0.01299	0.20128	0.0000
0.00000	0.00000	2.00000	13.00000	6.00000	1.00000	16.00000	0.00116	0.37758	0.0000
27.00000	0.00000	0.00000	5.00000	2.00000	1.00000	2.00000	0.00000	0.18570	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.20120	0.00000	1.12746	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.14864	0.00000	0.14630	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.04370	0.00000	0.21927	0.0000
1.00000	0.00000	5.00000	0.00000	0.00000	0.00000	0.00000	0.01668	0.04087	0.0000
0.00000	0.00000	2.00000	0.00000	0.00000	0.00000	0.00000	0.00420	0.00819	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.04075	0.0000
0.00000	0.00000	2.00000	0.00000	0.00000	0.00000	0.00000	0.00423	0.00371	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	111.00000	0.00000	0.01215	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	27.00000	0.00325	0.00602	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.02158	0.00610	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	27.00000	0.00000	0.19139	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	20.00000	0.04782	0.00157	0.0000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	3.00000	0.01944	0.00101	0.0000

Table 2. Field Data (cont.)

Oscillatoria	Density	Invertebrate weight	pH	Conductivity	Dissolved Oxygen	Velocity	Temperature	Depth
0.02801	1.00000	114.00000	8.16000	0.33000	9.80000	0.45000	15.22000	25.00000
0.00000	1.00000	100.00000	8.16000	0.33000	9.80000	0.22000	15.22000	10.00000
0.00000	1.00000	50.00000	8.16000	0.33000	9.80000	0.35000	15.22000	16.00000
0.06481	1.00000	6.00000	8.16000	0.33000	9.80000	1.09000	15.22000	5.00000
0.00000	.	0.97640	8.16000	0.33000	9.80000	0.07000	15.22000	30.00000
0.00000	.	1.34129	8.16000	0.33000	9.80000	0.13000	15.22000	22.00000
0.00000	.	0.01906	8.16000	0.33000	9.80000	0.79000	15.22000	5.00000
0.00000	0.00000	0.00000	8.40000	0.05500	7.65000	0.42000	28.35000	12.00000
0.00000	1.00000	3.00000	8.40000	0.05500	7.65000	0.23000	28.35000	5.00000
0.00000	1.00000	2.00000	8.40000	0.05500	7.65000	0.60000	28.35000	10.00000
0.00000	.	0.00008	8.40000	0.05500	7.65000	0.15000	28.35000	35.00000
0.00000	.	0.00000	8.40000	0.05500	7.65000	0.43000	28.35000	18.00000
0.00000	.	0.01028	8.40000	0.05500	7.65000	0.40000	28.35000	10.00000
0.00000	0.00000	0.00000	7.46000	4.49000	8.36000	0.15000	24.33000	25.00000
0.00000	0.00000	0.00000	7.46000	4.48000	8.36000	0.10000	24.33000	27.00000
0.00000	1.00000	1.00000	7.46000	4.49000	8.36000	0.19000	24.33000	15.00000
0.00000	.	0.64271	7.46000	4.49000	8.36000	0.24000	24.33000	20.00000
0.00000	.	0.00000	7.46000	4.49000	8.36000	0.13000	24.33000	10.00000
0.00000	.	0.00000	7.46000	4.49000	8.36000	0.13500	24.33000	10.00000
0.00000	1.00000	58.00000	8.38000	0.32200	8.17000	0.23500	25.43000	19.00000
0.00000	1.00000	37.00000	8.38000	0.32200	8.17000	0.29000	25.43000	18.00000
0.00000	1.00000	11.00000	8.38000	0.32200	8.17000	0.48000	25.43000	27.00000
0.00000	.	0.10216	8.38000	0.32200	8.17000	0.31000	25.43000	30.00000
0.00000	.	0.00000	8.38000	0.32200	8.17000	0.64500	25.43000	15.00000
0.00000	.	0.02745	8.38000	0.32200	8.17000	0.45500	25.43000	20.00000
0.00000	1.00000	19.00000	8.24000	0.23000	10.72000	0.63000	14.60000	28.00000
0.00000	1.00000	62.00000	8.24000	0.23000	10.72000	0.26000	14.60000	22.00000
0.00000	1.00000	464.00000	8.24000	0.23000	10.72000	0.93000	14.60000	20.00000
0.00000	.	0.00072	8.24000	0.23000	10.72000	0.29000	14.60000	30.00000
0.85212	.	0.10209	8.24000	0.23000	10.72000	0.35000	14.60000	15.00000
0.00000	.	0.04046	8.24000	0.23000	10.72000	0.27500	14.60000	30.00000
0.00000	1.00000	8.00000	7.69000	0.01800	10.23000	0.18000	22.79000	26.00000
0.00000	1.00000	6.00000	7.69000	0.01800	10.23000	0.07000	22.79000	20.00000
0.00000	1.00000	22.00000	7.69000	0.01800	10.23000	0.01500	22.79000	35.00000
0.00000	.	0.00031	7.69000	0.01800	10.23000	0.27000	22.79000	15.00000
0.00000	.	0.00260	7.69000	0.01800	10.23000	0.66000	22.79000	5.00000
0.00000	.	0.07488	7.69000	0.01800	10.23000	0.13000	22.79000	18.00000
0.00000	1.00000	7.00000	8.02000	0.69500	9.21000	0.22000	21.48000	39.00000
0.00000	.	11.00000	8.02000	0.69500	9.21000	1.20000	21.48000	25.00000
0.00000	1.00000	3.00000	8.02000	0.69500	9.21000	0.22000	21.48000	36.00000
0.00000	.	0.08805	8.02000	0.69500	9.21000	0.34000	21.48000	28.00000
0.00000	.	0.00213	8.02000	0.69500	9.21000	0.90000	21.48000	27.00000
0.00808	.	0.07835	8.02000	0.69500	9.21000	0.03000	21.48000	38.00000
0.00000	1.00000	49.00000	7.49000	0.65300	7.25000	0.14000	28.00000	6.00000
0.00000	1.00000	48.00000	7.49000	0.65300	7.25000	0.36000	28.00000	8.00000
0.00000	1.00000	51.00000	7.49000	0.65300	7.25000	0.12000	28.00000	11.00000
0.00000	.	0.21483	7.49000	0.65300	7.25000	0.14000	28.00000	5.00000
0.00000	.	0.14916	7.49000	0.65300	7.25000	0.36000	28.00000	9.00000
0.00000	.	0.04786	7.49000	0.65300	7.25000	0.18000	28.00000	9.00000
0.00000	.	6.00000	8.38000	0.32200	8.17000	0.23500	25.43000	19.00000
0.00000	.	2.00000	8.38000	0.32200	8.17000	0.23500	25.43000	19.00000
0.00000	.	0.00000	8.38000	0.32200	8.17000	0.23500	25.43000	19.00000
0.00000	.	3.00000	8.38000	0.32200	8.17000	0.23500	25.43000	19.00000
0.00000	.	111.00000	8.02000	0.69500	9.21000	1.30000	21.48000	25.00000
0.00000	.	27.00000	8.02000	0.69500	9.21000	1.02000	21.48000	27.00000
0.00000	.	0.00000	8.02000	0.69500	9.21000	0.36000	21.48000	38.00000
0.00000	.	27.00000	8.02000	0.69500	9.21000	0.03000	21.48000	33.00000
0.00000	.	20.00000	8.02000	0.69500	9.21000	0.42000	21.48000	24.00000
0.00000	.	3.00000	8.02000	0.69500	9.21000	0.67000	21.48000	38.00000

Table 3. Significant relationships between variables relating to tributary macroinvertebrate standing crop per sq. meter and density per sq. meter.

A. Standing crop/sq. meter analyses variables	Bonferroni significance	Pearson correlation coefficient	Reference in text
Oligocheta X detritus biomass	0.000	.859	
Simulidae X Chironomidae	0.008	.748	1
Simulidae X crust	0.000	.948	2
Chironomidae X crust	0.004	.765	
Cladophera X invert biomass	0.068	.687	3
Detritus X Gastropoda	0.002	.785	
Detritus X invert biomass	0.000	.836	4
Gastropoda X invert biomass	0.000	.982	
Gastropoda X detritus biomass	0.002	.785	
Dissolved oxygen X temperature	0.000	-.873	5

B. Density/ sq. meter analyses varibles	Bonferroni significance	Pearson correlation coefficient	Reference in text
Lumbricid X Coleoptera	0.010	.731	
Lumbricid X Gastropoda	0.008	.737	
Simulidae X Coleoptera	0.074	.670	
Simulidae X detritus	0.056	.679	
Chironomidae X other/unidentified	0.000	.943	
Chironomidae X primary producers	0.000	.983	6
Chironomidae X density	0.000	.958	14
Trichoptera X Plecoptera	0.000	.918	7
Trichoptera X Ephemeroptera	0.000	.832	8
Trichoptera X other/unidentified	0.000	.895	
Trichoptera X primary producers	0.000	.939	
Trichoptera X density	0.000	.925	13
Plecoptera X Ephemeroptera	0.002	.766	
Ephemeroptera X other/unidentified	0.000	.928	
Plecoptera X primary producers	0.000	.966	
Plecoptera X density	0.000	.955	12
Ephemeroptera X other/unidentified	0.012	.726	
Ephemeroptera X primary producers	0.002	.769	9
Ephemeroptera X density	0.001	.778	11
Megaloptera X Odonata	0.000	.903	
Other/unidentified X primary producers	0.000	.946	
Other/unidentified X density	0.000	.949	
Primary producers X density	0.000	.938	

TRIBUTARY STANDING CROP
GRAND CANYON NATIONAL PARK

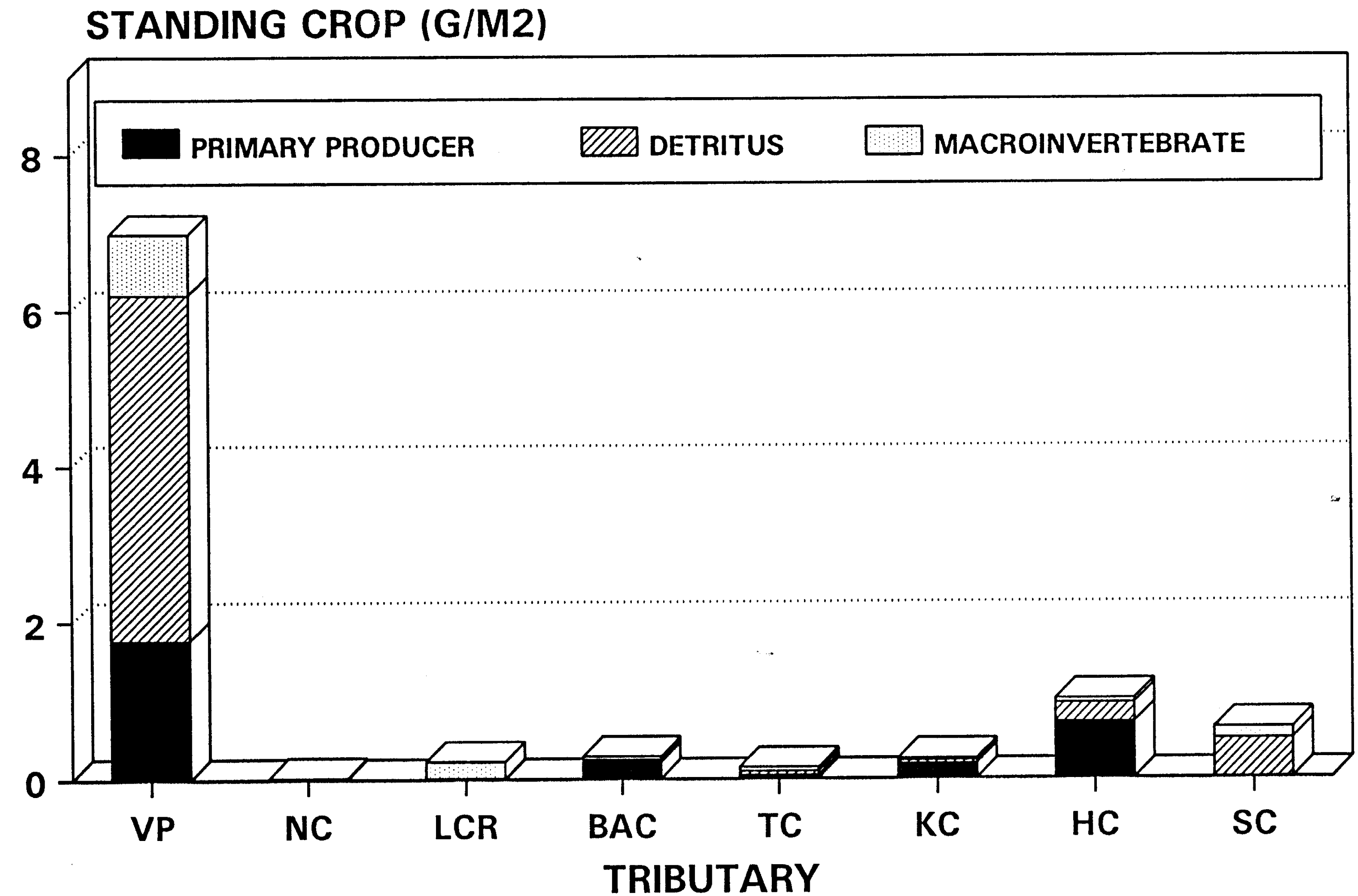

FIGURE 1: STANDING CROP (G/M^2) OF PRIMARY PRODUCERS, DETRITUS AND MACROINVERTEBRATES IN EIGHT COLORADO RIVER TRIBUTARIES IN THE GRAND CANYON.

VP = VASEYS PARADISE, NC = NANKOWEAP CREEK, BAC = BRIGHT ANGEL CREEK, TC = TAPEATS CREEK, KC = KANAB [redacted] HC [redacted] AV[redacted]U C[redacted]EK,[redacted] = [redacted]RIN[redacted]CRE[redacted]

TRIBUTARY MACROINVERTEBRATE DENSITY
GRAND CANYON NATIONAL PARK

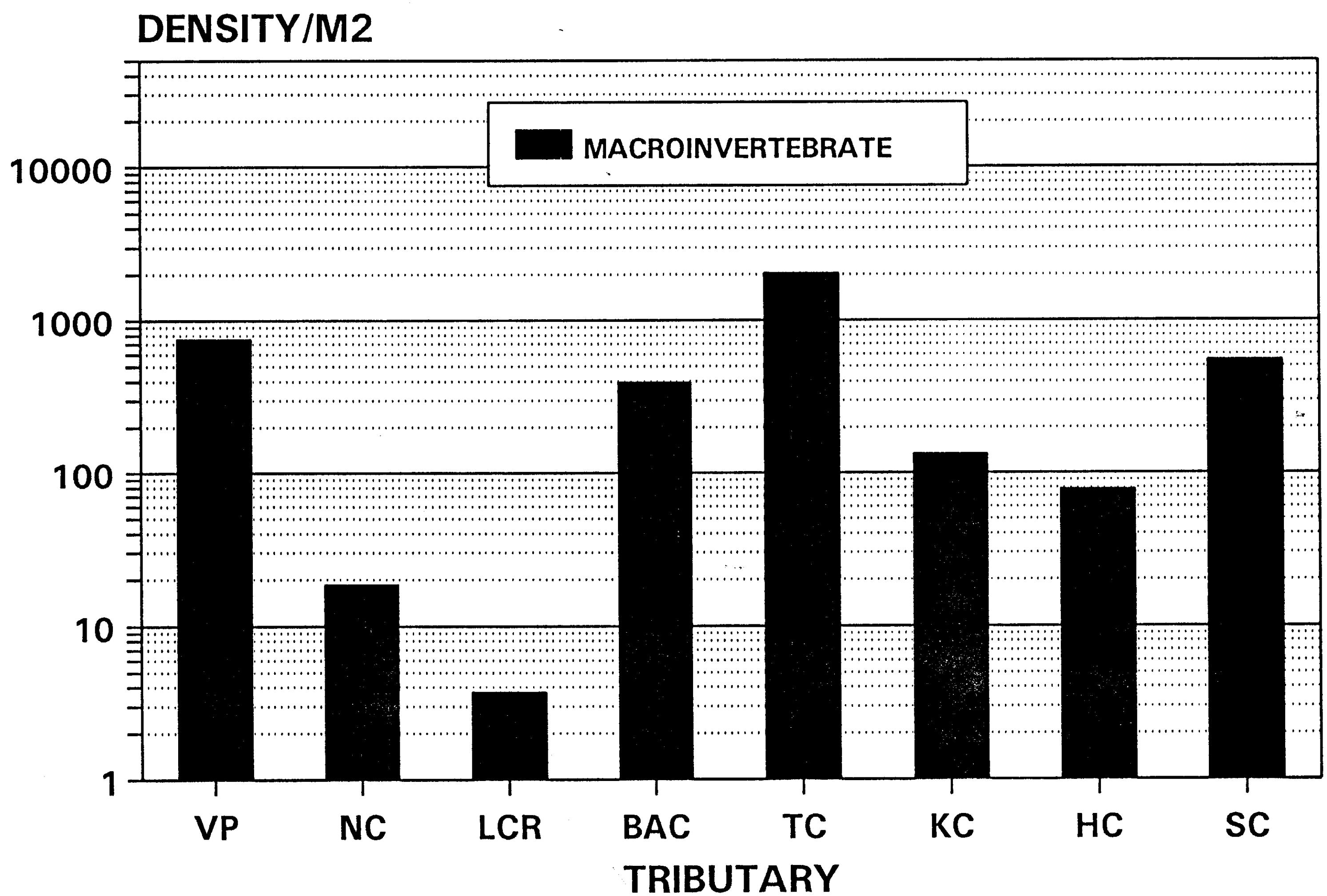

FIGURE 2: DENSITY/M^2 OF MACROINVERTEBRATES IN EIGHT TRIBUTARIES IN GRAND CANYON. (NOTE CATEGORIES ARE THE SAME AS IN FIGURE 1)

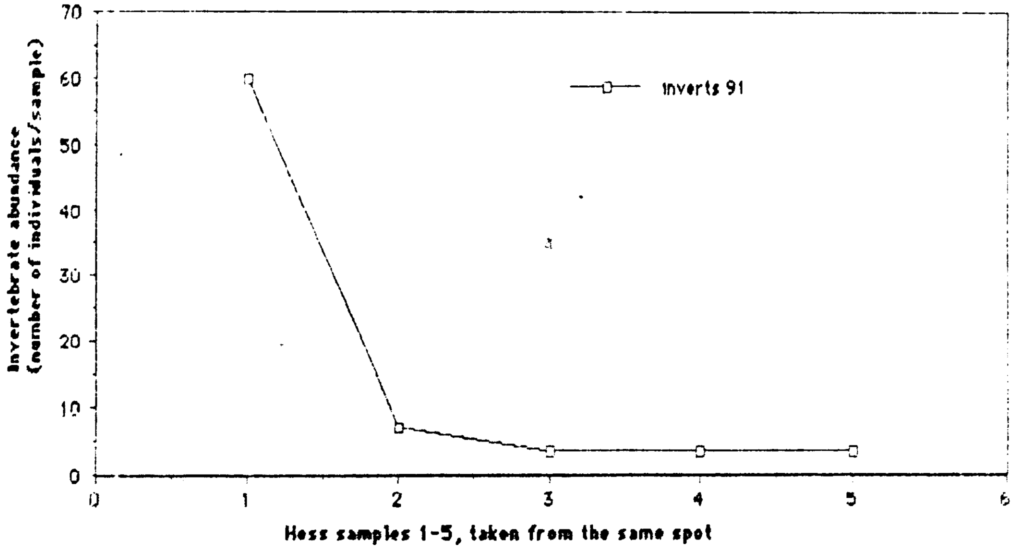

FIGURE 3A- HESS ERROR VARIANCE SAMPLES FOR INVERTEBRATES-BRIGHT ANGEL CREEK- 1991

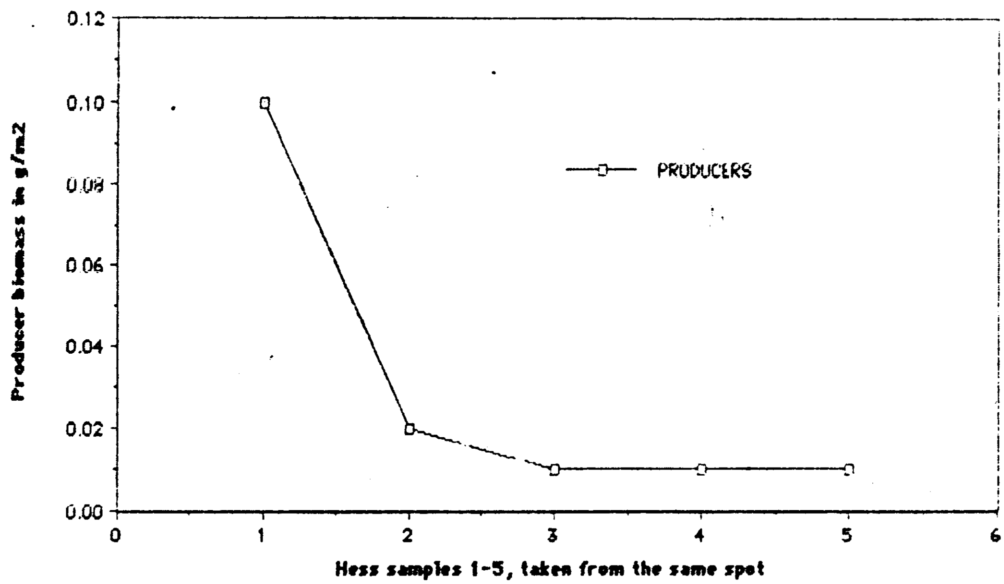

FIGURE 3B- HESS VARIANCE ERROR SAMPLES FOR PRODUCERS-BRIGHT ANGEL CREEK-1991

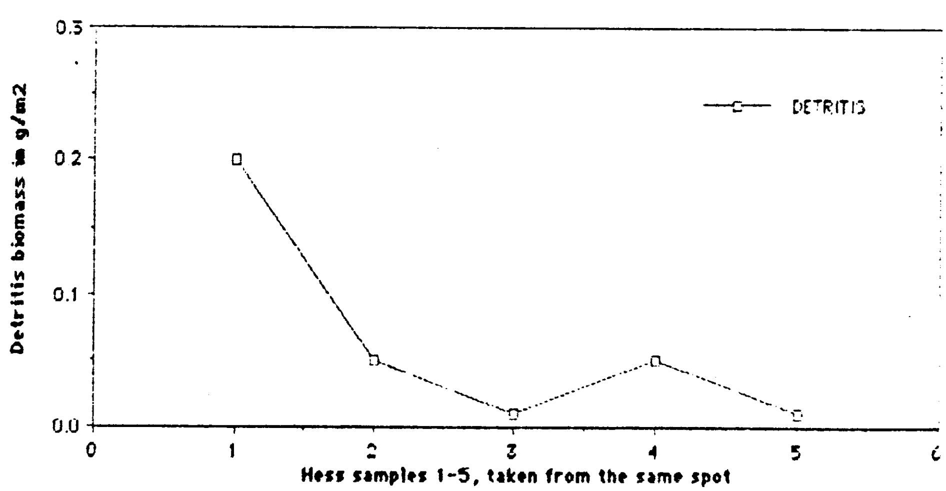

FIGURE 3C- HESS ERROR VARIANCE SAMPLES FOR DETRITIS-BRIGHT ANGEL CREEK-1991

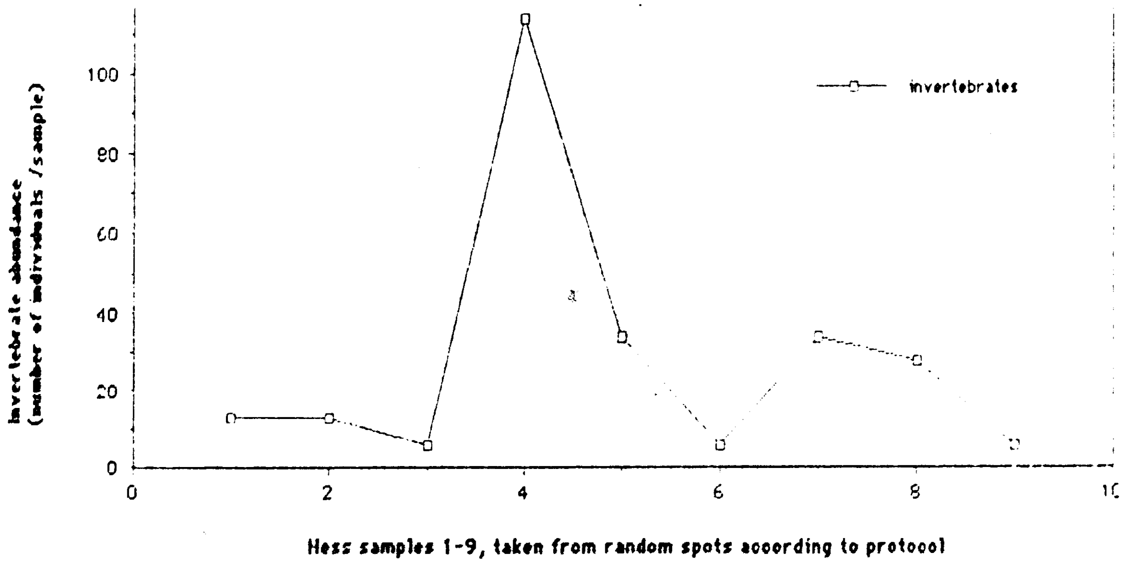

FIGURE 4A-TRANSECT MULTIPLE ERROR SAMPLES FOR INVERTEBRATES- HAVASU CREEK-1991

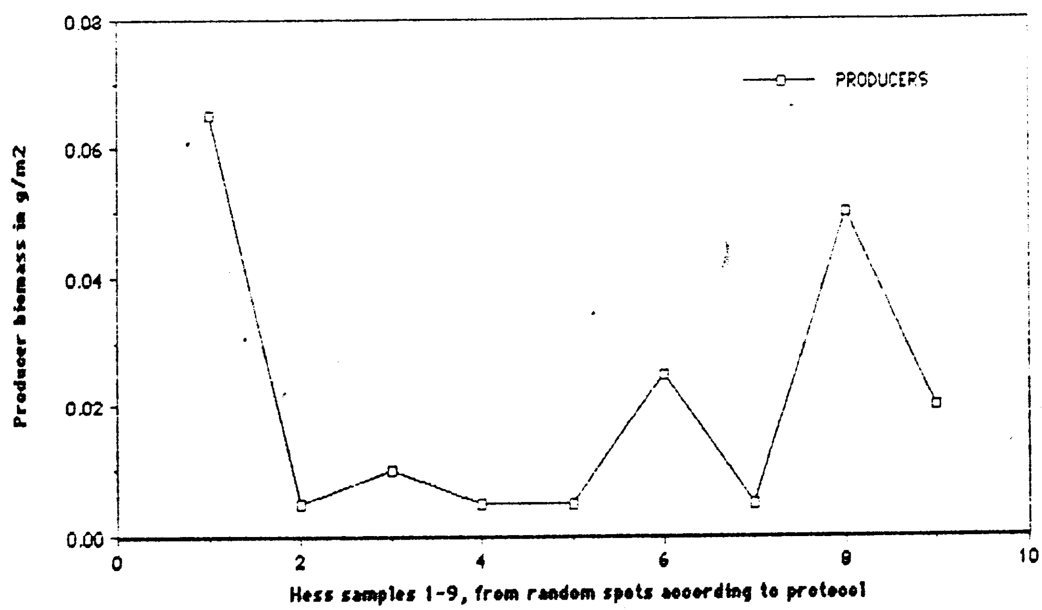

FIGURE 4B- TRANSECT MULTIPLE ERROR SAMPLES FOR PRODUCERS-HAVASU CREEK-1991

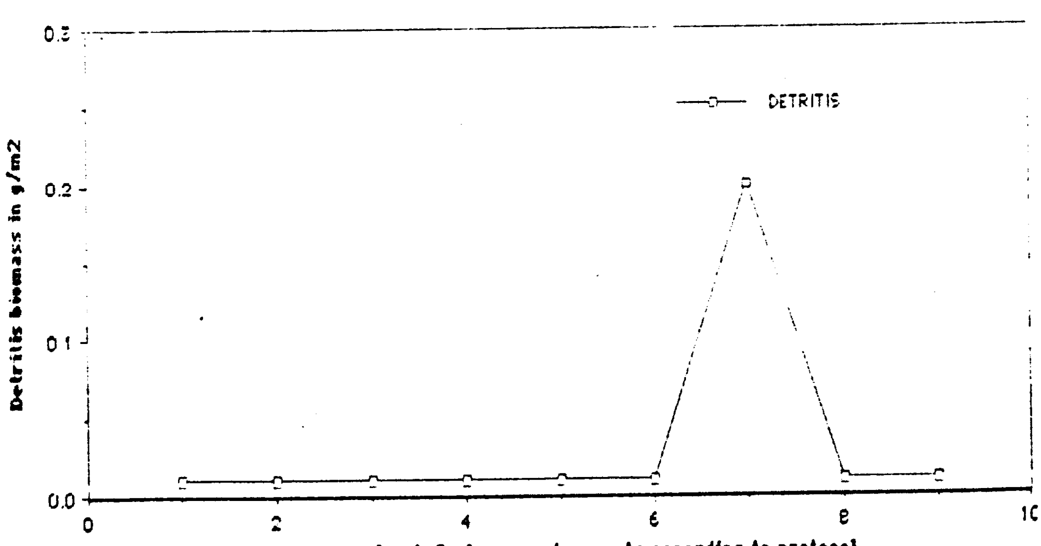

FIGURE 4C- TRANSECT MULTIPLE ERROR SAMPLES FOR DETRITIS- HAVASU CREEK-1991

AQUATIC DIPTERA BENTHIC DATA SHEET EPIC ______

SITE ______________ MILE ______________ DATE ______

COLLECTORS ______________ MAIN STEM CFS ______________ TIME ______

SAMPLE TYPE PONAR HESS PETERSON

PAN ______

TRANSECT	DEPTH	DISTANCE VELOCITY	TOTAL SEDIMENT	SORTING BAG/VIAL# 1	2	3	4	5	6	7	8	9	10
2 BIO													
2 TAX													
4 BIO													
4 TAX													
6 BIO													
6 TAX													

NOTES
DATA8

Figure 5

Chapter 6

RODENT DISTRIBUTION WITHIN THE COLORADO RIVER CORRIDOR

Nancy Garavito and Garry Mowery

INTRODUCTION

Impoundment of desert rivers may profoundly affect riparian habitat (Smith and Prokopich 1989). Since the construction of the Glen Canyon Dam, maximum river flows are now less than one-third those of predam years (Carothers and Dolan 1982). With the threat of annual scouring gone and a more stable substrate in place, vegetation has rapidly colonized previously inhospitable river banks (Fig. 1 Zone 4), resulting in rapid colonization by animal species (Carothers 1982). The overall effect of the dam on several species of mice and woodrats has been positive (Carothers 1991). Small mammal populations have been studied since the completion of the Glen Canyon Dam (Hoffmeister 1971; Ruffner and Carothers 1975; Ruffner and Tomko 1976; Ruffner et al. 1978).

This study was a continuation of a longitudinal investigation of the distribution, abundance, and density of terrestrial rodents in the two most distinct beach zones (2 and 4), as described by (Carothers et al. 1976 Fig. 1). Zone 4 was the last zone to form but it appears to have had adequate time to be well established, often producing the greatest biomass. We hypothesized significantly more rodents should occur in the biologically more productive zone 4.

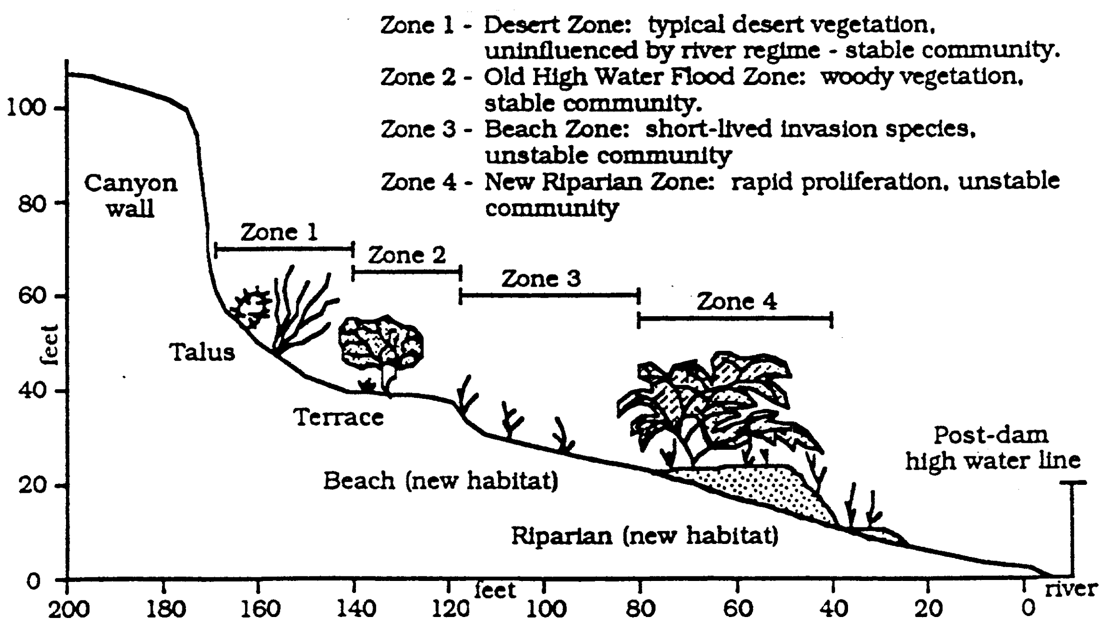

Figure 1. Diagrammatic cross-section of vegetation zones in the Inner Gorge of the Colorado River in Grand Canyon after construction of Glen Canyon Dam (adapted from Carothers, et. al., 1979).

METHODS

Trapping was carried out on nine beaches from mile 31, elevation 3,000 ft., to mile 224.5, elevation 1,335 ft. (Table 1). The study area included a short section of the sagebrush and shadscale community typical of the Great Basin Desert, the catclaw and mesquite trees of the Sonoran Desert, and finally the plants characteristic of the Mohave Desert. The river plant community was dominated by tamarisk and willows (Stevens 1983).

Approximately 50 Sherman live traps were baited each evening with oatmeal and a raisin and set in a transect, 5 meters apart, in each of zones 2 and 4. Each day at dawn, the trapped rodents were identified, sexed, and weighed. The captured animals were then released unharmed into the zone from which they were captured.

There was some concern that the aging traps may have not all functioned properly. The bait used was different from that used the previous year but the same as that used for most of the other years. Field identification of some of the species of the genus *Peromyscus* is somewhat difficult and there may be some inconsistentcies in identification by different researchers. Tail-hair features may lead to misidentification (Smith and Prokopich 1989). For example, *P. boylii* made up 4% of trapped species in 1987 (Rotstein 1987), 33% in 1988 (Kendall et al. 1988), and 1% in 1989 (Smith 1989). It seems unlikely that the assemblage would have fluctuated so quickly. Since species identification is difficult, this report pooled all species of the genus *Peromyscus* together.

RESULTS

Table 1 shows the total number of captured animals at each site. In Table 2 the various species that were captured in each zone are listed. Table 3 indicates species trends from 1987 - 1991. The percent of rodents caught in each zone is illustrated in Fig. 2 and trap success by zone is shown in Fig. 3. Figs. 4 and 5 demonstrate the ratio of males and females caught in the respective zones. Fig. 6 illustrates trap success over the past seven years. The percentage of rodents captured in zones 2 and 4 ,for the past seven years ,is depicted in Figs. 7 and 8.

This year, Peromyscus represented 80% of the total trapped animals, in accord with past results. Ruffner and Tomko (1976) found P. eremicus to be dominant as early as 1976. Eleven percent of this year's total was Perognathus formusus, a significant rise from the past two years. This apparent change in population may be due to a misidentification of P.formusus for P. intermedius in 1989 and 1990 (L. Stevens personal communication). Two species of Neotoma were captured: N. albigula - 2% and N. lepida - 7% (Table 2). A comparison of all trapped animals by zone shows that there was no dramatic difference in distribution between zones 2 and 4 (Fig. 2). Trap success was also very comparable in both zones (Fig. 3). Apparently the habitat in zone 4 has developed and stablizied adequately to support a population equal to that of zone 2. It should be noted, however, that there was an unequal distribution of members of the genus Neotoma - 8 were found in zone 2 but only 3 were found in zone 4. The rocky substrate and woody legume vegetation of zone 2 probably provides a more suitable environment for these larger animals.

Butler et al. (1990) indicated a significant difference in distribution by sex in zones 2 and 4. This unequal distribution did not appear in this year's findings (Figs. 4,5). Additionally, those animals identified as being in a reproductive state were equally distributed in both zones.

DISCUSSION

Past researchers have expressed considerable concern over variables that could significantly affect data. Examples of these variables are weather conditions during trappings (Rotstein et al. 1987; Kendall et al. 1988), negative correlations between ant and rodent populations (Rotstein et al. 1987; Kendall et al. 1988; Smith and Prokopich 1989; Butler et al. 1990), and inconsistencies in beach selection for trappings (Rotstein et al. 1987; Kendall et al. 1988; Butler et al. 1990). In light of these variables and other unknowns, which either have not yet been eliminated or are impractical to control, it seems prudent to look at three general sets of data over the past five to seven years. Total trap success is considered first. Figure 6 shows that the overall percent trapping success has remained mostly constant the past five years, especially in light of potential variables. Second, Table 3 suggests that total population trends have remained relatively stable over the last five years. Finally, Figure 7 shows that even though the seven year trend of percent captured in zone 4 shows some inconsistencies, it now appears to be well established as a rodent habitat. The decline in 1983 was due to flooding (Spears and Spears 1983). Zone 2 has shown a gentle steady increase in percent captured over the past seven years and has always, if only minimally, out performed zone 4 (Figure 8).

CONCLUSION

The dam has created additional habitat (zone 4) for rodents along the river corridor. This zone is now sufficiently established and stabilized so that it supports a rodent population nearly equal to that of the predam high water zone (zone 2). This year's investigation suggests that the rodent population in the canyon has undergone relatively minor damges during the past several years.

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TABLE I. RODENTS CAPTURED BY BEACH AND HABITAT ZONE

Date	Beach	Traps	Zone 2	Zone 4	Total
7/25/1991 R	Lower South Canyon 31	100	4	5	9
7/26/1991 R	Nankoweap 52.5	100	15	10	25
7/27/1991R	Carbon Creek 63.5T	96	9	4	13
7/28/1991 L	Hance76.5	96	5	2	7
7/29/1991 L	Granite93.5	96	8	11	19
7/30/1991 R	Lower Blacktail 20.1	96	5	6	11
7/31/1991 L	Poncho's137	96	15	15	30
8/1/1991 L	National166.5	96	7	7	14
8/3/1991 R	Mile224.5	92	3	0	3
Total		868	71	60	131

TABLE 2. RODENTS CAPTURED BY SPECIES AND HABITAT ZONE

Species	zone 2	% by sp.	Zone 4	% by sp.	Total
Peromyscus sp.	56	78.8	50	83.3	106
Perognathus formosus	7	9.8	7	11.6	14
Neotoma albigula	2	2.8	0	0	2
Neotoma lepida	6	8.4	3	5	9
Totals	71	99.8	60	99.9	131

TABLE 3. SPECIES TREND 1987-1991.

Species	1987	1988	1989	1990	1991
Peromyscus sp.	91	93	62	63	80
Perognathus formosus	1	0	0	1	11
Perognathus intermedius	4	0	24	24	0
Neotoma albigula	1	3	6	8	2
Neotoma lepida	2	4	8	4	7
Total	99	100	100	100	100

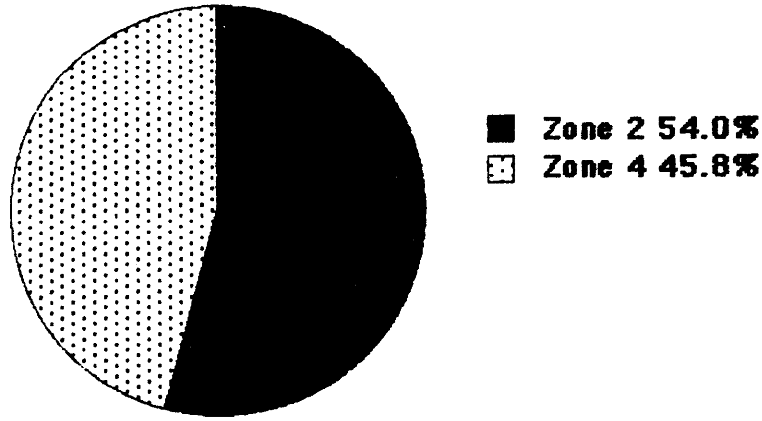


Fig. 2 Percentage of Rodents by zone

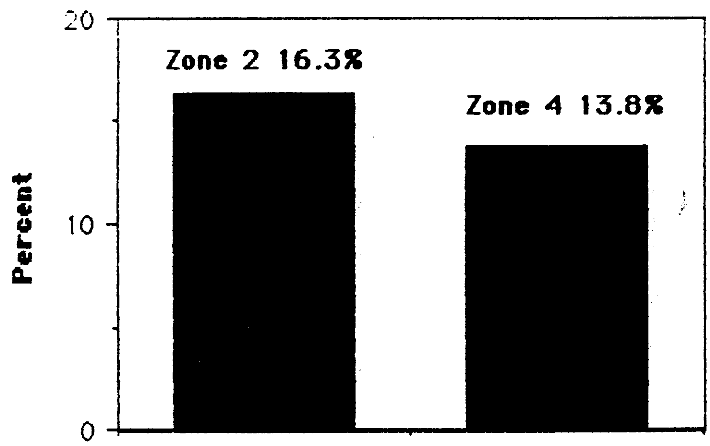


Fig. 3 Trap Success by zone

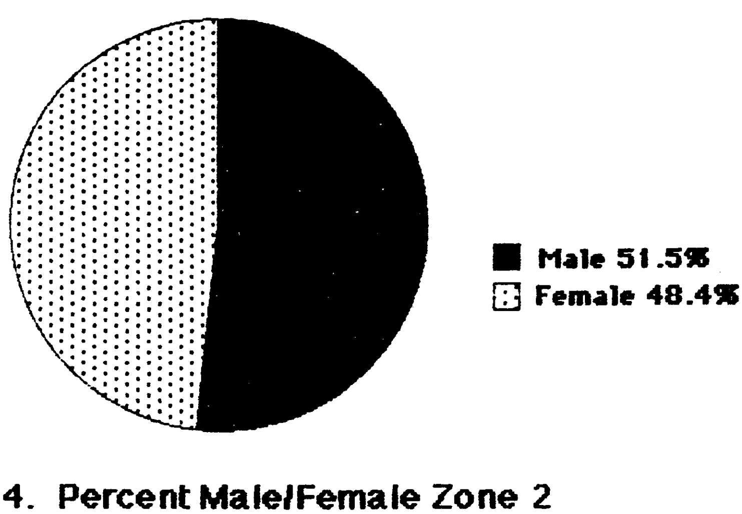


Fig. 4. Percent Male/Female Zone 2

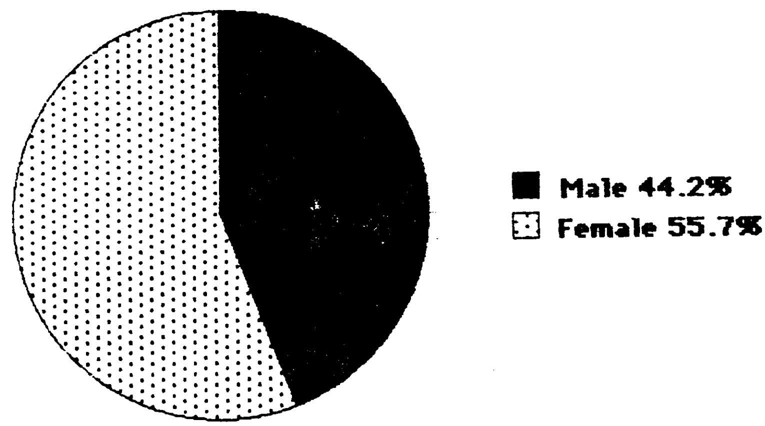


Fig. 5 Percent Male/Female Zone 4

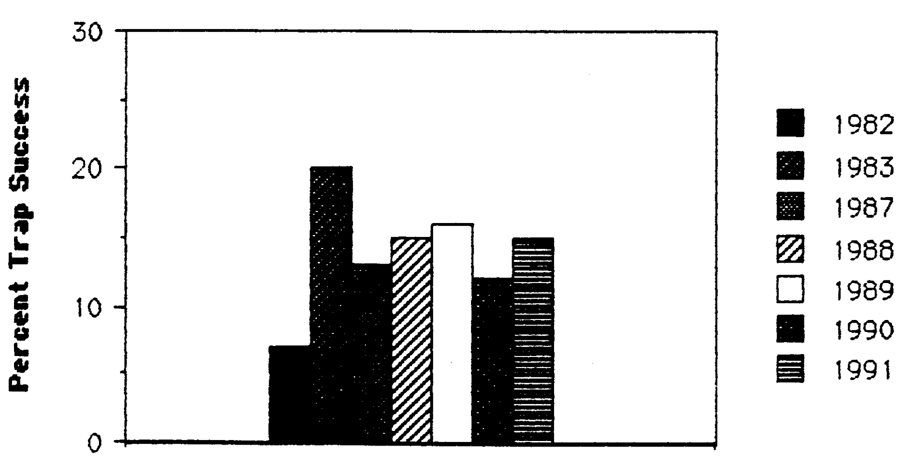


Fig. 6 Trap Success Over Seven Years

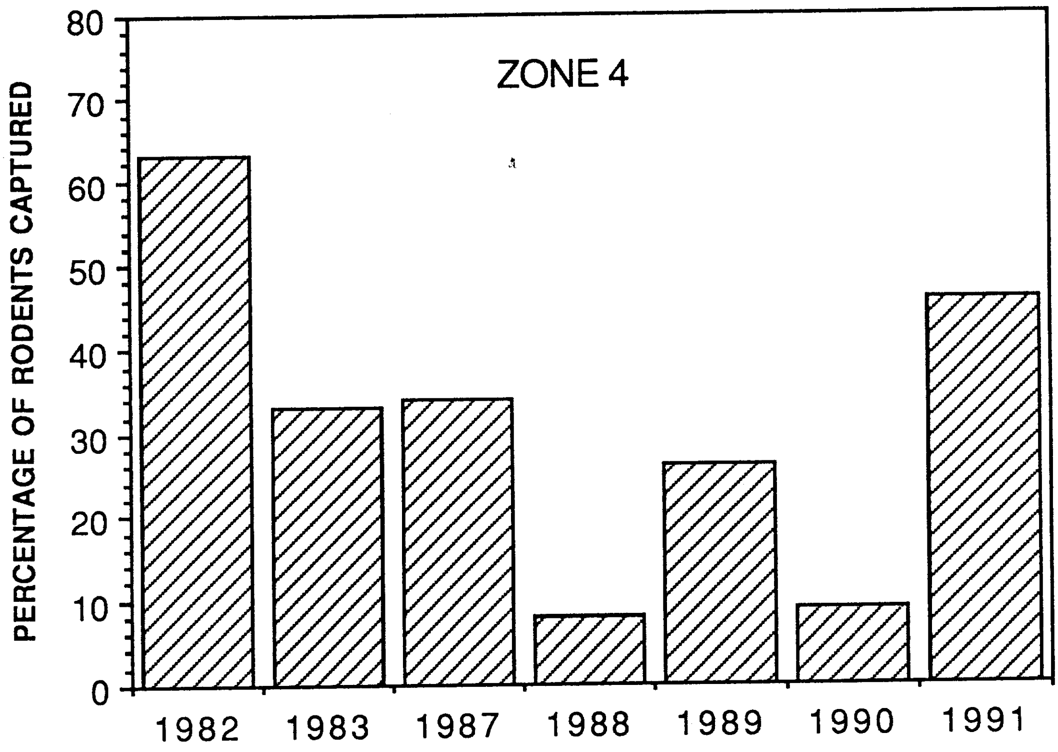


FIGURE 7. PERCENTAGE OF RODENTS CAPTURED

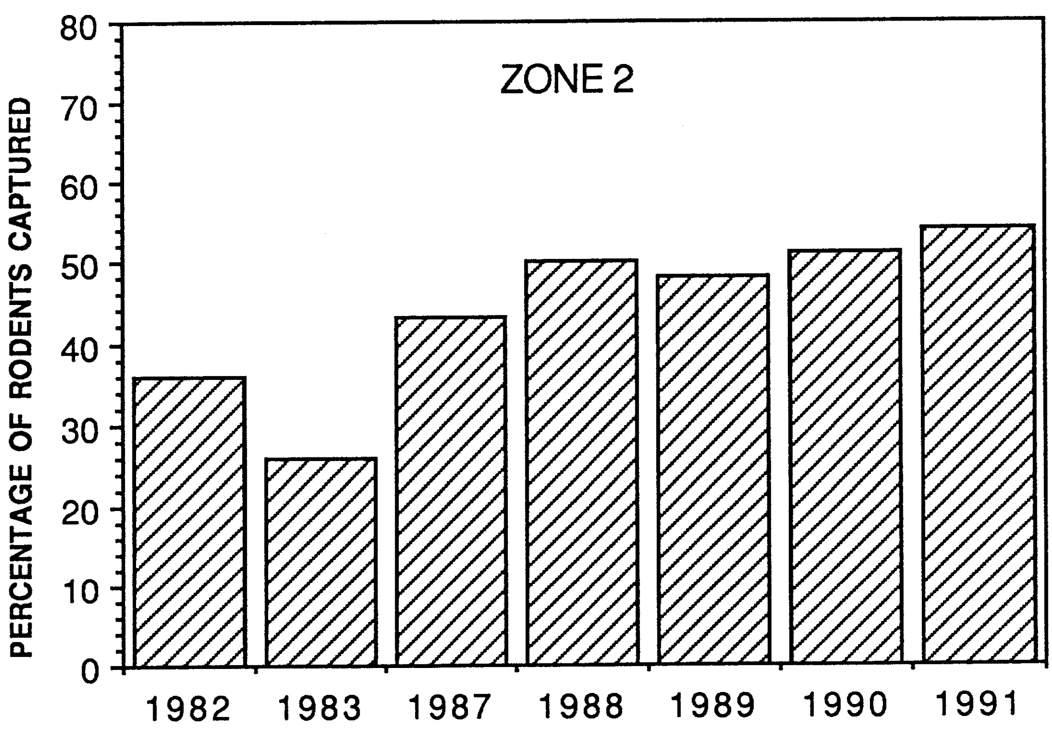


FIGURE 8. PERCENTAGE OF RODENTS CAPTURED

CHAPTER 7: Lizard Diets and Density in the Riparian Zone of the Colorado River, Grand Canyon National Park.

Jodee Janda and Carolyn Jones

INTRODUCTION

We examined density and diet of four common lizard species along the riparian zone of the Colorado River in the Grand Canyon National Park. The research focused on two main topics. First, density studies were conducted to augment previous studies correlating lizard distribution with physical factors and flora in the riparian Zone 4 (Carothers et al, 1979). Second, diet was investigated to determine whether lizards rely on aquatic-derived or terrestrial invertebrates.

Past research has shown that the riparian zone contains the highest concentration of all four species of lizards. (Lew and Welden 1990). It has been suggested that increased food resources in this zone probably account for the higher density of lizards. (Warren and Schwalbe 1988). To date, little research has been done regarding lizard diets, especially in respect to the newly established riparian habitat which has resulted from the construction of the Glen Canyon Dam. The specific objectives of the study were :

1. To compare lizard density with ambient temperature, time of day, and substrate.
2. To catch as many lizards as possible and take weight and snout-to-vent measurements.
3. To collect the stomach contents of at least one lizard of each of the four species from nineteen different beach beach (zone 4) sites.
4. To determine whether the insect/invertebrate components the lizard diets are terrestrial, aquatic, or both.
5. To sweep net each zone 4 beach site to determine predominant terrestrial invertebrates.

METHODS

In this study the riparian zone 4 was examined at 18 different sites along the Colorado River. At each site the following procedure was used:

1. General data was recorded: site, mile and side of river, ambient temperature, vegetation, substrate., time and weather; Figure 1.
2. An area was randomly chosen, measured, and marked off.

3. Researchers systematically walked through the area and recorded the number and types of lizards seen. (Four species were recorded: Uta stansburiana, Sceloporus magister, Cnemidophorus tigris, and Urosaurus ornatus)
4. Using the noose method, as many lizards as possible were caught and the following data was recorded for each catch: (Figure 1)
   a. species (replication #)
   b. weight in grams
   c. snout to vent length in centimeters
   d. sex
5. One lizard of each species caught was sacrificed so that stomach contents could be examined. Specimens were processed in 70% EtOH and stomach contents were inspected in the labortory under a dissecting microscope. Identification was to family taxonomic level where possible. Larry Stevens, project director, has a permit for these collections from the Grand Canyon National Park.
6. At each site, a 50X sweep sample was taken using an insect net. Insects were killed with ethyl acetate, the contents removed and placed in EtOH for later identification.

Materials:

Data sheet (Figure I)	Clip board
0.5 mm pencil	Willow poles
Ambient thermometer (celcius)	Monofilament line
Clipboard	50g Hanging balance
3 ring notebook	100g Hanging balance
Ruler (cm)	Petri dishes
Zip lock bags (quart size)	Calibration weights
Muslin butterfly net	Forceps
70% Ethyl Alcohol	Tuperware containers
Ethyl Acetate	Dissecting Microscope
Small whirl pack bags	Sharpee Marker
Labels	Bucket

Figure I

DATA SHEET: GRAND CANYON HERPETOFAUNAL DIET STUDY

KEY: *Uta stansburiana* - Utst; *Urosaurus ornatus* - Uror; *Sceloporus magister* - Scma; *Cnemidophorus tigris* - Cnti; *Bufo cognatus* - Buco; *Bufo woodhousei* - Buwo

DATE:__________ MILESIDE:________ NAME OF BEACH:______________ RECORDERS:_______________

SITE CONDITIONS: TEMPERATURE:___________; WIND SPEED:____________; CLOUDS:_______________

SUBSTRATE TYPE:________________________; VEGETATION:____________________

INSECTS IN 50 SWEEPS SAMPLE:____

COMMENTS INCLUDING DENSITY:____

SPECIES	SEX	TIME	BAG + LIZARD MASS (G)	BAG MASS (G)	LIZARD MASS (G)	SNOUT TO VENT LENGTH (CM)	STOMACH CONTENTS

Table I is a brief description of the four common lizards found in the Colorado River corridor (Lew and Welden 1990).

Table I Description of Lizard Species

Side-blotched Lizard (Uta stansburiana)

The side-blotched lizard is one of the most abundant lizards in the arid and semiarid regions of the Western United States (Stebbins, 1966). This small (less than 10 centimeters) brownish lizard is characterized by an oval black or blue-black spot on its side. According to Pianka (1986), the side-blotched lizard is frequently found under shrubs, however Stebbins (1966) indicated a varied habitat which includes sand, rock, bushes or scattered trees.

Desert Spiny/Yellow-Backed Spiny Lizard (Sceloporus magister)

The desert spiny is a relatively large (9 to 30 centimeters) lizard with yellow-brown to grey-brown scales on its dorsal and lateral surfaces. It has an incomplete black collar and a banded tail (Miller et al. 1982). Tomko (1976) noted the highest densities of this lizard were in areas of Acacia, Tamarix, and Salix flora. It is arboreal and seeks shelter in crevices, under logs, and covered areas (Stebbins 1966). The spiny uses a "sit and wait" foraging technique, feasting on insects (Coleoptera, Diptera, Hymenoptera) and occasionally on lizards and vegetation (Tomko 1976). Stebbins (1966) issues a warning that the spiny lizard often bites when captured.

Northern Whiptail (Cnemidophorus tigris)

The Northern Whiptail is also know as the Western Whiptail. The whiptail is easily identified by the pale yellow, white or green longitudinal stripes on its ventral surface and its overall streamlined-snakelike appearance (Miller et al. 1982).

Tree Lizard (Urosaurus ornatus)

The tree lizard is slender with a long tail. The chevron-shaped markings on its dorsal side provide for easy identification. The adult male has a blue-green belly and a blue or yellow throat patch. This lizard is usually found on dark vertical surfaces of rocks near water, not trees as his name suggests. When approached, the tree lizard will cock its head before retreating. (Miller et al. 1982).

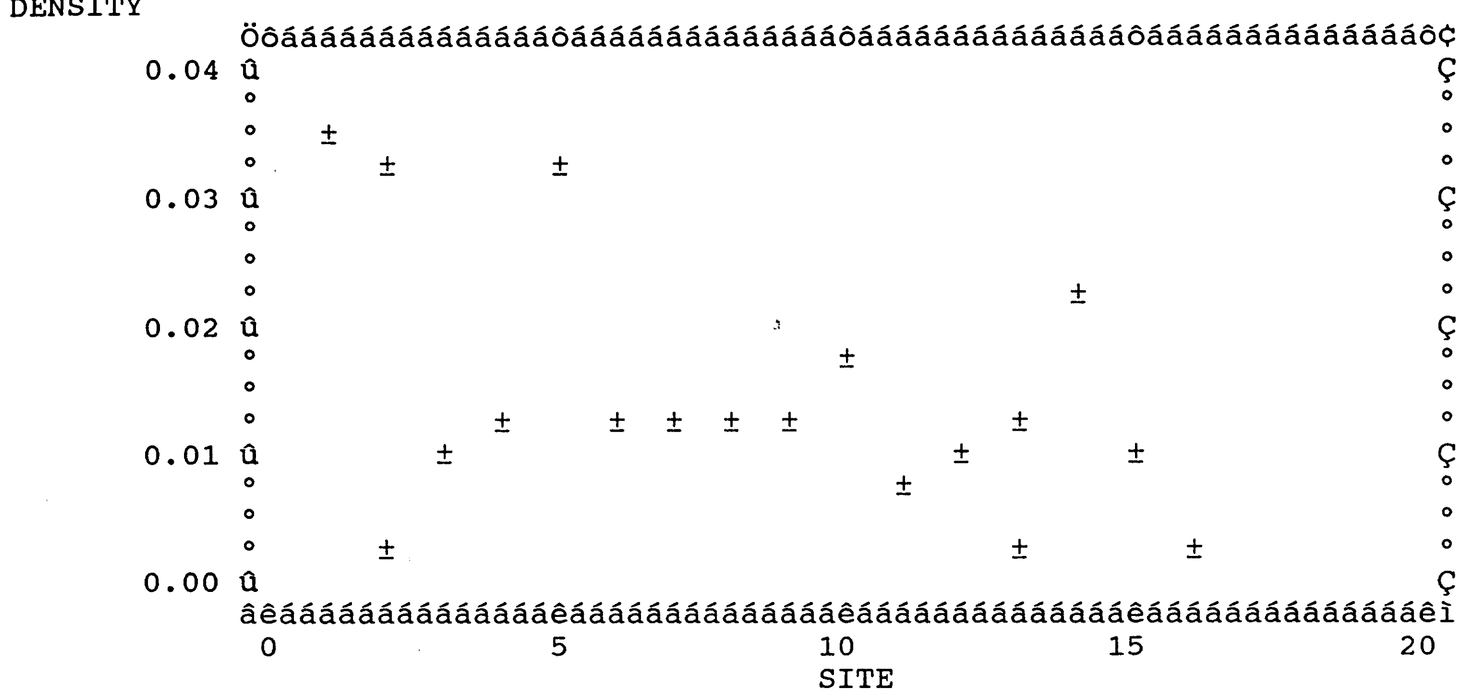
Results

In reviewing the data from seventeen beaches, a total of thirty-five lizards were collected and their stomach contents analyzed. Table II presents the raw data for the lizard diets. This table indicates the types of invertebrates the lizards are eating, and whether the invertebrate source is aquatic or terrestral. Table III presents the percentages of lizards in each species with presence/absence of aquatic invertebrates in their diet.

Table III Lizard diets- aquatic or nonaquatic percentages based on presence/ absence of dietary items per individual

	UTST	UROR	CNTI	SCMA
Aquatic Diet	7 (63.6%)	5 (71.4%)	6 (54.5%)	1 (16.7%)
Nonaquatic Diet	4 (36.4%)	2 (28.6%)	5 (45.5%)	5 (83.3%)
Totals	11	7	11	6

A density analysis was also performed; raw data is presented in Table IV. From 19 surveys, a total of 72 lizards were counted with representatives from all 4 species. Lizard densities decreased as we moved down the river. At mile l72, no lizards were recorded during our density check, nor in the following density studies. After mile 122.8, no Urosaurus ornatus were seen or captured. Likewise, after mile 143.5, there was an absence of Uta stansburiana. Univariate analysis revealed that lizard density was significantly negatively correlated with distance downstream from Lees Ferry (Y= -.001x + 0.022, F= 4.621, P= 0.047, df= 1,16; Figure II).



2 CASES WITH MISSING VALUES EXCLUDED FROM PLOT

Figure 2: Lizard density was negitively correlated with distance downstream. Sites on Table IV. Regression equation is: Y= 0.01x + 0.022, F= 4.621, p=0.047, df=1.16

Our analysis of the lizards also included weighing each lizard and measuring their snout to vent length. Table V summarizes all data collected. We are unable to draw any conclusions from these measurements at this point, but these data may be used for future reference.

Discussion

Lizard diet analysis revealed that lizards display significant use of river-derived aquatic invertebrates. Of the thirty-five lizards studied, nineteen obtained part of their diet from the river. The remaining sixteen obtained food exclusively from the land. Of the four species studied, only Sceloporus magister showed little use of river-derived invertebrates (16.7%), while more than 50% of the individuals of the other species had consumed riverine macroinvertebrates. From our own observations and past research (Stebbins, 1966), Sceloporus magister is often found in arboreal areas, which tend to be a relatively greater distance from the river. This may account for the lower percentage of aquatic invertebrates in their diet. On the other hand, Uta stansburiana, Cnemidophorus tigris, and Urosaurus ornatus tend to be found in areas closer to the river (Stebbins, 1966), (Lew and Welden, 1990), which could account for the aquatic invertebrates in their diets.

Table II Lizard Diet

	INVERTEBRATE																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Sample#																			
1	-	+	+	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-
2	-	+	-	-	+	-	-	-	-	-	-	+	+	-	-	-	-	-	-
3	-	+	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-
4	-	+	+	-	+	+	-	-	+	-	-	+	-	-	-	-	-	-	-
5	-	+	+	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-
6	-	+	-	-	+	+	-	+	-	+	-	+	+	-	-	-	-	-	-
7	-	+	-	-	+	-	+	+	-	+	-	+	-	-	-	-	-	-	-
8	-	-	-	-	+	-	-	-	-	+	-	+	+	-	-	-	-	-	-
9	-	-	-	-	+	-	-	+	+	+	-	+	+	-	-	-	-	-	-
10	-	+	-	-	+	+	-	-	-	-	-	+	-	-	-	-	-	-	-
11	-	+	-	-	-	+	-	-	-	+	-	+	-	-	-	-	-	-	-
12	+	+	-	+	+	+	-	+	-	-	-	+	-	-	-	-	-	-	-
13	-	-	-	-	+	+	-	+	-	-	-	+	-	-	-	-	-	-	-
14	-	+	-	-	+	+	-	-	-	-	-	+	+	-	-	-	-	-	-
15	-	-	-	-	-	+	-	-	-	+	-	+	-	-	-	-	-	-	-
16	-	+	-	+	+	+	-	-	+	-	+	+	-	-	-	-	-	-	-
17	-	+	+	+	-	+	+	+	-	-	-	+	-	-	-	-	-	-	-
18	-	+	+	-	+	+	-	-	-	-	-	+	-	-	-	-	-	-	-
19	-	-	-	-	+	+	-	-	+	-	-	+	+	-	-	-	-	-	-
20	-	-	-	-	-	+	-	+	-	+	-	-	-	-	-	-	-	-	-
21	-	-	-	-	+	+	-	-	-	+	-	+	-	-	-	-	-	-	-
22	-	+	-	-	+	+	-	+	+	+	-	+	-	-	-	-	-	-	-
23	+	-	+	-	+	+	-	-	-	+	-	+	-	-	-	-	-	-	-
24	+	+	+	-	+	+	-	+	-	-	-	+	-	-	-	-	-	-	-
25	-	+	-	-	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-
26	-	-	-	+	+	-	-	-	+	-	-	+	-	-	-	-	-	-	-
27	-	-	+	-	+	+	-	+	-	+	-	+	-	-	-	-	-	-	-
28	-	+	-	+	+	+	-	+	+	-	-	+	+	+	-	-	+	-	+
29	-	+	-	-	+	-	-	+	-	-	-	+	-	-	-	+	-	-	-
30	-	-	+	-	+	+	-	-	+	-	-	+	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	+	-	+	+	-	-	-	-	-	-
32	+	-	-	-	+	+	-	+	-	-	-	+	-	-	+	-	-	-	-
33	+	-	-	-	+	+	-	+	+	-	-	+	-	-	-	-	-	+	-
34	-	-	-	-	-	+	-	-	-	+	-	+	+	-	-	-	-	-	-
35	-	-	-	-	+	+	-	-	+	+	-	+	-	-	-	-	-	-	-

	KEY TO LIZARD DIETS (INVERTEBRATES)
1	Orthoptera
2	Diptera (aquatic)
3	Diptera (terrestrial)
4	Neuroptera
5	Coleoptera
6	Hymenoptera
7	Amphipoda (aquatic)
8	Homoptera
9	Lepidoptera
10	Terrestrial Hemiptera
11	Acarina
12	Unknown Terrestrial Invertebrate
13	Arachnid
14	Dragonfly\ Damselfly
15	Diplopoda
16	Megaloptera
17	Ephemeroptera
18	Chiloptera
19	Aquatic Heiptera

Table IV

LIZARD DENSITY

DATE	MILE	SITE	SUBSTRATE	TEMP (°C)	TIME	VEGETATION	AREA (m)	UTST	UROR	SCMA	CNTI
25-Jul	35L	Nautiloid	Debris fan and sand	29.5°	11:30 AM	Brickellia, Tamarisk	49x13	0	7	0	14
25-Jul	43.7L	Anasazi Bridge	Debris fan and Sand	31°	3:15 PM	Willow	22x32	0	0	0	0
25-Jul	43.7L	Anasazi Bridge	Debris fan and sand	31°	3:20 PM	Willow	25x22	4	13	1	0
26-Jul	61.0L	LCR Confluence	Sloped terrace Rocky debris	32°	1:50 PM	Tamarisk Acacia, Snakeweed	18x30	0	2	1	2
27-Jul	71.0L	Cardenas	Sandy beach	34°	1:00 PM	Tamarisk, Camel thorn	12x47	0	0	0	7
27-Jul	75.5L	Nevills	Debris fan and sand	38°	3:00 PM	Tamarisk, Grasses	15x32	8	3	0	4
28-Jul	81.1L	Grapevine	Sand and Boulders	36.5°	1:45 PM	Mormon Tea, Acacia Brickle bush	13x28	0	4	0	0
28-Jul	87.8R	Phantom Rch	Debris fan and sand		4:45 PM	Tamarisk	16x16	1	1	1	0
29-Jul	93.2L	Granite Rpds	Sand	28°	7:35 AM	Tamarisk, Arrow Weed, Bricklebush	14x18	0	0	3	0
29-Jul	108.0R	Lower Bass	Sand and Boulders	41.5°	12:00 PM	Tamarisk	22x22	1	4	1	0
29-Jul	120.0R	Blacktail	Sand and Rocks	34.5°	6:15 PM	Bricklebush, Grasses	25x13	4	0	0	1

Table IV

LIZARD DENSITY

DATE	MILE	SITE	SUBSTRATE	TEMP (°C)	TIME	VEGETATION	AREA (m)	UTST	UROA	SCMA	CNTI
30-Jul	122.8L	Forester	Debris fan and sand	35°	10:05 AM	Tamarisk Willow	27x13	0	1	1	0
30-Jul	134.0R	Tapeats	Sand and Boulders	35°	3:00 PM	Bricklebush, Grasses	12x19	1	0	0	1
31-Jul	143.5R	Kanab	Debris fan and sand	33.5°	10:00 AM	Tamarisk, Willow, Camel Thorn	24x30	0	0	0	0
31-Jul	143.5R	Kanab	Cobble Bar	33.5°	10:15 AM		20x35	2	0	0	6
31-Jul	156.8L	Havasu Creek	Sand and Boulders	36.5°	2:15 PM	Acacia, Willow, Cottonwood	9x25	0	0	3	2
1-Aug	166.4L	National	Debris fan and sand	29.5°	9:45 AM	Tamarisk, Arrow Weed	22x37	0	0	1	6
2-Aug	172.0L	unnamed	Sand, Rocks, Boulders	32°	8:15 AM	Tamarisk, Grass	13x27	0	0	0	0
2-Aug	194.0L	unnamed	Sand, Rocks	41°	12:25 PM	Tamarisk, Acacia		0	0	0	0

EXPLANATION:

UTST = Uta stansburiana
UROR = Uarosaurus ornatus
SCMA = Sceloporus magister
CNTI = Cnemidophorus tigris

Table V

LIZARD WEIGHT, LENGTH, AND STOMACH CONTENT

Date	Mile	Site	Substrate	Temp °C	Vegetation	Time	Lizard Species	weight (gm)	Snout-vent (cm)	Sample #	Stomach Content
24-Jul	8.0L	Jackass	Cobbles, boulders	35.5°	Brickellia	2:15 PM	UTST 1	4.2	-	-	-
							UTST 2	4.7	-	1	A,T
							UTST 3	3.1	-	-	-
							UTST 4	2.5	-	-	-
							UTST 5	3.9	-	2	A,T
							UTST 6	4.4	-	3	A,T
							UROR 1	1.1	-	-	-
24-Jul	31.0R	S. Canyon	Debris fan and sand	-	Tamarisk, Mixed Native	6:45 PM	SCMA 1	11.5	6.3	-	-
						7:08 PM	SCMA 2	30.9	9	-	-
25-Jul	35.0L	Nautiloid	Debris fan and sand	29.5°	Tamarisk	11:40 AM	CNTI 1	13.5	7.9	7	A,T
						11:45 AM	CNTI 2	14	7.8	8	T
						11:55 AM	CNTI 3	9.8	6.3	9	T
						12:00 PM	CNTI 4	11.4	7.1	-	-
						11:40 AM	UROR 1	4	5.3	4	A,T
						11:45 AM	UROR 2	3	5	5	A,T
						12:18PM	UROR 3	3.5	5.6	6	A,T
						12:23 PM	UROR 4	1	4.6	-	-
25-Jul	43.7L	Anasazi Bridge	Beach sand	31°	Willow	3:45 PM	UROR 1	4	4.4	-	-
						3:48 PM	UROR 2	3.9	4.5	11	A,T
						4:05 PM	UROR 3	3.6	4.7	-	-
						3:51 PM	UTST 1	3.5	4.8	10	A,T
						3:57 PM	UTST 2	3.6	4.8	-	-
						3:52 PM	SCMA 1	12.4	6.7	35	T
						3:55 PM	SCMA 2	32.9	8.6	-	-
26-Jul	61.0L	LCR Confluence	Sloped, Rocky Terrace	32°	Tamarisk, Acacia	2:15 PM	CNTI 1	17	7.9	12	A,T
						2:22 PM	SCMA 1	32.1	8.3	13	T
						2:45 PM	UROR 1	1.5	3.7	14	A,T

Table V

LIZARD WEIGHT, LENGTH, AND STOMACH CONTENT

Date	Mile	Site	Substrate	Temp °C	Vegetation	Time	Lizard	weight	Snout-vent	Sample #	Stomach
26-Jul	64.6R	Carbon Creek	Debris fan and sand	26.5°	Tamarisk	6:28 PM	UTST 1	4	5.2	15	T
						7:00PM	UTST 2	4	5.5	-	-
						7:02 PM	UTST 3	1.5	4.3	-	-
						7:04 PM	UTST 4	3.8	4.8	-	-
						7:05 PM	UTST 5	2.5	4.2	-	-
						7:06 PM	UTST 6	3.1	4.5	-	-
						6:35 PM	SCMA 1	48.5	9.4	-	-
						6:40 PM	SCMA 2	30	8.9	-	-
						7:08 PM	SCMA 3	8	5.9	-	-
27-Jul	71.0L	Cardenas	Sandy beach	34°	Tamarisk, Camelthorn	1:28 PM	CNTI 1	9	6.9	-	-
						1:30 PM	CNTI 2	12.75	8.4	-	-
						1:33 PM	CNTI 3	11	7.3	-	-
						1:35 PM	CNTI 4	10	7.1	16	A,T
27-Jul	75.5L	Nevills	Debris fan and sand	38°	Tamarisk	3:15 PM	UTST 1	4.4	4.9	-	-
						3:24 PM	UTST 2	3	4.7	18	A,T
						3:30 PM	CNTI 1	11.5	7.2	17	A,T
28-Jul	81.1L	Grapevine	Sand, Boulders	36.5°	Mormon Tea, Acacia, Bricklebush	2:00 PM	UROR 1	0.5	3.2	-	-
						2:20 PM	UROR 2	4	5.2	-	-
						2:24 PM	UROR 3	3.5	5.1	-	-
						2:26 PM	UROR 4	5	6	-	-
						2:28 PM	UROR 5	4.5	5.4	20	T
						2:31 PM	SCMA 1	14.75	7.2	19	T
29-Jul	93.2L	Granite Rapids	Sand	28°	Tamarisk, Arrow Weed, Bricklebush	7:35 AM	SCMA 1	40	9.7	-	-
						7:38 AM	SCMA 2	41	9.8	-	-
						7:40 AM	SCMA 3	46.25	10.6	-	-
29-Jul	108.0R	Lower Bass	Sand, Rocks Boulders	41.5°	Tamarisk	12:52 PM	UTST 1	3.5	4.6	22	A,T
						1:03 PM	UROR 1	5.75	5.8	21	T
29-Jul	120.0R	Blacktail	Sand, Rocks	34.5°	Grass, Bricklebush	6:45 PM	UTST 1	4	4.8	23	T
						6:48 PM	UTST 2	3	4.6	-	-

Table V

LIZARD WEIGHT, LENGTH, AND STOMACH CONTENT

Date	Mile	Site	Substrate	Temp °C	Vegetation	Time	Lizard	weight	Snout-vent	Sample #	Stomach
30-Jul	122.8L	Forester	Debris fan and sand	35°	Tamarisk, Willow	10:25 AM	SCMA 1	35.5	9.9	-	-
						11:15 AM	CNTI 1	14.5	7.4	24	A,T
30-Jul	134.0R	Tapeats	Debris fan and sand	35°	Grass, Bricklebush	3:10 PM	UTST 1	3.5	4.6	25	A,T
						3:52 PM	UTST 2	2.5	4.5	-	-
						3:30 PM	CNTI 1	2.5	4.5	26	T
31-Jul	143.5R	Kanab	Debris fan and sand	33.5°	Tamarisk, Willow, camelthorn	10:40 AM	UTST 1	2.75	4.5	27	T
31-Jul	156.8	Havasu Creek	Sand, Boulders	36.5°	Acacia, Willow Cottonwood,	2:35 PM	SCMA 1	10	6.7	28	A,T
						2:45 PM	CNTI 1	13.5	8.6	29	A,T
1-Aug	166.4L	National	Debris fan and sand	29.5°	Tamarisk, Arrow weed	10:15 PM	SCMA 1	14.25	7.1	30	T
						10:25 PM	CNTI 1	1.25	3.7	31	T
2-Aug	172.0L	unnamed	Sand, Rocks, Boulders	32°	Tamarisk, Grass	9:00 AM	SCMA 1	9.25	6.2	32	T
						9:10 AM	SCMA 2	22.5	8.2	-	-
						9:15 AM	SCMA 3	9.5	6.3	-	-
						9:45 AM	CNTI 1	10.5	7.7	33	T
						9:55 AM	CNTI 2	11	6.6	-	-
2-Aug	194.0L	unnamed	Sand, Rocks	41°	Tamarisk, Acacia, Grass	1:45 PM	UTST 1	2	4.2	34	T

EXPLANATION:
A = Aquatic Invertebrates
T = Terrestrial Invertebrates
UTST= Uta stansburiana
UROR = Urosaurus ornatus
CNTI = Cnemidophorus tigris
SCMA = Sceloporus magister

Data gathered on lizard densities indicates a negative correlation between density and distance downstream. As we moved downstream the lizard densities decreased. This could be due to a decrease in the abundance of food. As noted by Carothers, there is a decrease in Cladophora in the river as one moves downstream due to silt/sediment contributed by tributaries. This decrease in Cladophora causes a decrease in the population of aquatic invertebrates, which directly effects the lizards diet. Lizard density was not correlated with time of day or temperature (p in both cases > 0.150, df=2, 14); however, this finding may reflect the small sample size, highly variable weather conditions, or factors such as vegetative cover or substrate.

RECOMMENDATIONS

1. For subsequent years, we suggest that the group consists of at least 3 people: 1 person to process the lizards, and 2 to catch lizards.
2. Density surveys should be more consistent in terms of distance from the river, and the area surveyed.
3. Researchers should be more specific as to what substrate the lizards are caught in.

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Chapter 8

Photographs of the Colorado River Reaches

Dorothy St. Clair

Introduction

The geomorphological processes occurring along the Colorado River through the Grand Canyon are continual. Since 1983, the Northern Arizona University, Grand Canyon Experience expeditions have accumulated photographic records of specific beaches. These photographs are readily available to analyze erosional and depositional features of the sites. In an attempt to expand the data base available to scientists a new project was developed for this years expedition. The photographic records of the beaches were still acquired.

The objective of the project was to record with photographs the eleven Grand Canyon reaches at half mile intervals. The reaches (Figure 1), identified by Schmidt and Graf (1986) were defined by channel geometry and rock type. The Colorado River in Grand Canyon: A Guide, by Larry Stevens aided in locating each half mile interval.

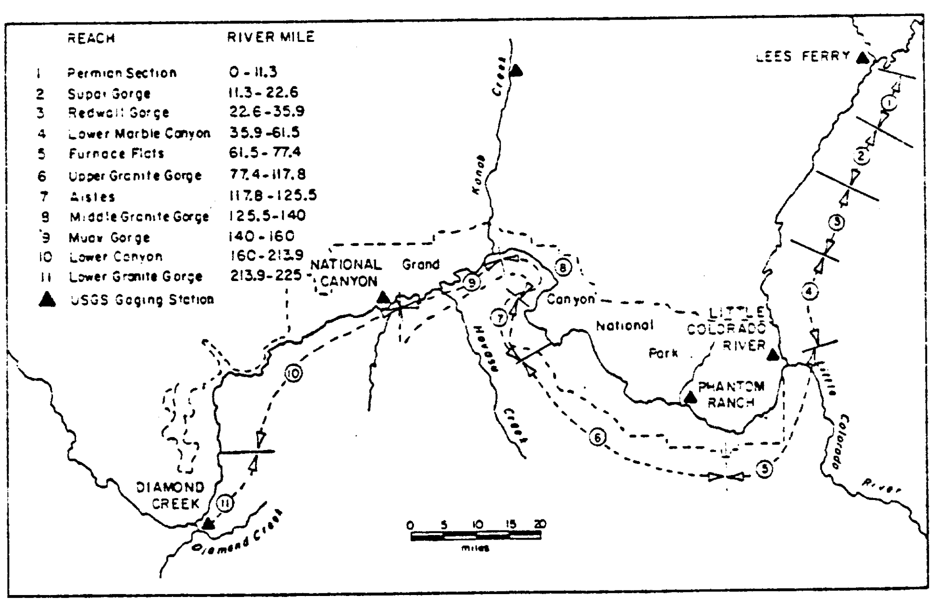

Figure 1. Map of the Colorado River through Grand Canyon National Park and reaches within the study area.

Methods

The baseline study involved taking photographs of the left and right sides of the Colorado river corridor every half mile. The eleven reaches represented are located between Lees Ferry, mile 0 and Diamond Creek, mile 225.

The photographs were taken on TMax 400 black and white film. Using a 35 mm camera with a 28 mm wide angle lens, optimal beach coverage could be accomplished. The photographs taken horizontally would represent the beach and water interface. Pictures were taken to river left with the mileage written on a chalkboard. The chalkboard was held in position by an assistant. The river right photograph did not include the chalkboard.

A problem associated with this project was delaying photographs which were to be shot while in the middle of a large rapid. To prevent water damage, the camera was placed in an ammo box until it was relatively safe to remove it. Unavoidably a few photographs may have one-tenth of a mile error.

Results

The effort to photographically record the reaches required 28 rolls of 36 exposure film. The film has been developed and printed into contact sheets. The sheets are available for analysis at Northern Arizona University.

Recommendations

With any new project, the learning process begins again. Suggestions to improve the outcomes readily become available:

1. A 35 mm camera should be used with a 28 mm lens.
2. The photograph should be taken horizontally to allow for the most beach coverage.
3. The photographer should safely stand and shoot photographs from the right rear of the boat, to the left and then pivot to the right.
4. An umbrella should be taken to protect the camera from rain.
5. People should not be seen in the photograph taken to the left as it obstructs the interface to be recorded.

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CHAPTER 9

SOCIOLOGICAL DATA

Nancy Brookes

INTRODUCTION

Each day the National Park Service permits up to 150 commercial visitors, 16 to 32 private individuals and varying numbers of researchers access to the Grand Canyon on the Colorado River. At the present time, the Park Service does not control or monitor the progress of these parties along the river, and thus has little data on the frequency of contact between groups.

This report is a continuation of Colorado River Investigations Sociological Data collection which began in 1982. The purpose of the report is to provide ongoing data related to recreational experiences of river visitors. Attitude surveys given to Grand Canyon Experience participants over the past few years indicates that the water level and contact with other boats and aircraft have an impact on the quality of the river trip. It is therefore important for the Park Service to review contact information to insure that the quality of a Grand Canyon river trip remains high and meets visitors' expectations.

METHODS

Participants of the Grand Canyon Experience travelled on 2 Canyoneers, Inc. commercial, motor-powered rafts from Lee's Ferry to Pierce Ferry. Research was conducted between Lee's Ferry and Diamond Creek, a distance of 225.5 miles, from July 24, 1991 to August 3, 1991. Each stop was logged for the day, mile, name of location, reason for the stop and time. Each departure was logged for the day, mile, name of location and time. The Colorado River in Grand Canyon, A Guide (Stevens 1983) was used to determine mileage and location names. Contacts with other boats, aircraft and hikers were also logged for the day, mile, description of contact and time. Data was collected in a small water-resistant notebook at the time of contact. The river trip from Diamond Creek to Pierce Ferry was a contingency plan due to washed-out roads at Diamond Creek which prevented pull-out. No research was conducted during this part of the trip.

In addition, after the project participants returned to Northern Arizona University, they were given a questionnaire regarding the quality of their experience.

RESULTS

During the 11-day Grand Canyon Experience river trip 38 stops were logged. 9 stops were made for overnight camping, 28 stops included beach research and 13 stops included attraction points. 18 stops had multiple purposes. A summary of stops is shown on Table I.

A total of 10 hikers was encountered during the trip. These contacts did not have a significant effect on the quality of the river experience.

255 boats were contacted with a mean of 23.3 boat contacts per day. Boat contacts were separated into power boats and oar boats and included repeat contacts. It should be noted that all power boats contacted were inflatable rafts. All oar boats were either inflatable rafts or kayaks. Boat contacts are shown on Table II and Figure I. 1991 boat contacts represent a 60% decrease from last year's total of 638 boat contacts. Boat contacts were divided into upper half and lower half of the river trip by mileage at mile 113 to correlate with the questionnaire. 99 boats were contacted in the upper half and 162 boats were contacted in the lower half. In the upper half, 70% were oar boats and 30% were motor rafts. In the lower half, oar boats increased to 73% and motor rafts decreased to 27%. It should be noted that 61 out of 118 oar boats (52%) were kayaks in the lower half compared to 10 kayaks out of 30 oar boats (33%) in the upper half. Questionnaire responses to items 5 and 6 indicate that while participants were sensitive to the increase in number of boats between the upper and lower halves of the trip, the size and type of boat did not seem to be a factor (Table IV).

Aircraft contacts totalled 293, a 381% increase over the 1990 total of 77. The mean was 26.6 aircraft contacts per day. Aircraft contacts were divided into low-flying airplanes, high-altitude jets, and helicopters. Aircraft contacts are shown on Table III and Figure II.

Results of the River Trip Experience Questionnaire, given after the completion of the trip, are summarized in TableIV. 93% of participants indicated that the water level affected their enjoyment of the trip, 58% said that the number of boat contacts in the upper river affected their experience, and 68% indicated that the number of boats in the lower half of the river affected their experience. Additionally, 72% said that research trips are best served by motorized boats, but 68% said that oar boats are preferable for recreational trips.

DISCUSSION

The data and observations collected during the 11-day river trip indicate that perceptions of the quality of contacts with boats and aircraft varied widely throughout the trip and are affected by location and circumstances as well as numbers of contacts. Most participants, when interviewed informally, indicated that contact with other boats was pleasant or neutral. Contact with other boats was viewed as negative only when multiple groups were stopped at the same beach or when there was competition for campsites.

During the 11 day trip, we experienced above average numbers of boat contacts on 4 days. These occurred on the 1st, 5th, 8th and 10th days. On each of these days, circumstances worth mentioning affected our group's perception of the high levels of contact.

Most boats contacted on our first day were research groups that had put in for the 4-day 5000 CFS controlled flow which began at 1AM on 7/26. We spent the first day making repeat contacts with these boats between research stops. We were unable to use our planned campsite on the 1st night because another group was camped there. During the 2nd through 4th days we had below-average contacts with other boats due to the low flow which commercial river trips were avoiding.

On our 5th morning, due to the low water level, one of our boats became stuck on a rock in Hance Rapids for almost 4 hours . During that time 13 boats backed up behind us. We experienced repeat contact with these boats for several hours afterward, including lunch at Grapevine which was especially crowded. These contacts were generally regarded as negative because they interfered with our research and we interfered with their activities.

The 8th day we visited Havasu Creek where we encountered 19 other boats. This location was viewed as overcrowded which diminished the quality of the attraction.

The 10th night was viewed by the group as our most frustrating experience with other boats because we were unable to find a suitable campsite. As we got closer to Diamond Creek, all regular campsites were taken by other groups preparing for take-out the following day. We camped 16 miles downriver from our intended campsite which extended our day and gave us a poor location for our last night. Comparing contacts this year and last year from Havasu Creek to Diamond Creek shows a similar pattern of high contact and an increase in negative attitudes toward these contacts during the lower half of the trip.

Aircraft contacts were generally not regarded as negative except in high density corridors. Contacts on the 3rd, 4th, 9th and 10th days accounted for 89% of all aircraft contacts. These contacts occurred over 81.5 miles or 36% of the distance between Lee's Ferry and Diamond Creek. Although this distance represented slightly more than one third of the trip, it was sufficient to cause 55% of project participants to say that planes affected the enjoyment of the Canyon. Low-flying aircraft were generally viewed as the most negative aircraft contacts. They also accounted for the most frequent contacts.

SUMMARY

Contacts with aircraft and other boats are an inevitable part of experiencing the Grand Canyon on the Colorado River. If the attitudes of Grand Canyon Experience participants can be considered representative of visitors to the river, perception of these contacts is to a great extent, controlled by how much it inconveniences a group in finding campsites and visiting attraction points. If the Park Service intends to maintain the quality of river trip experiences, it should continue to monitor not only the number of boats that are allowed on the river, but also the contact that these boats have with each other at key locations.

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TABLE I. GRAND CANYON EXPERIENCE 1991 SUMMARY OF STOPS

DAY	MILE	BEACH	REASON	TIME
1	0.00	LEE'S FERRY	DEPART	1128
1	8.00	BADGER CANYON	LUNCH, BR	1244
1	8.00	BADGER CANYON	DEPART	1349
1	8.00	JACKASS CREEK	BR	1353
1	8.00	JACKASS CREEK	DEPART	1504
1	31.50	SOUTH CANYON	CAMP, BR	1745
2	31.50	SOUTH CANYON	DEPART	954
2	33.00	REDWALL CAVERN	AP	1005
2	33.00	REDWALL CAVERN	DEPART	1025
2	34.70	NAUTILOID CANYON	LUNCH, BR,AP	1037
2	34.70	NAUTILOID CANYON	DEPART	1347
2	43.60	ANASAZI BEACH	BR	1500
2	43.60	ANASAZI BEACH	DEPART	1530
2	53.00	LOWER NANKOWEAP	CAMP, BR,AP	1640
3	53.00	LOWER NANKOWEAP	DEPART	1005
3	58.00	AWATUBI BEACH	BR	1058
3	58.00	AWATUBI BEACH	DEPART	1135
3	61.40	LITTLE COLORADO RIVER	LUNCH, BR,AP	1211
3	61.40	LITTLE COLORADO RIVER	DEPART	1528
3	64.60	CARBON CREEK	CAMP,BR,AP	1556
4	64.60	CARBON CREEK	HIKE TO CHUAR	745
4	65.40	CHUAR BEACH	AP	1100
4	65.40	CHUAR BEACH	DEPART	1115
4	71.00	CARDENAS CREEK	LUNCH, BR	1217
4	71.00	CARDENAS CREEK	DEPART	1401
4	75.40	NEVILL'S BEACH	BR	1446
4	75.40	NEVILL'S BEACH	DEPART	1555
4	76.50	HANCE BEACH	CAMP, BR	1630
5	76.50	HANCE BEACH	DEPART	815
5	76.50	HANCE RAPIDS	STUCK ON RAPIDS	830
5	76.50	HANCE RAPIDS	DEPART	1213
5	81.10	GRAPEVINE	LUNCH, BR	1325
5	81.10	GRAPEVINE	DEPART	1428
5	88.00	PHANTOM RANCH	AP	1556
5	88.00	PHANTOM RANCH	DEPART	1700
5	93.50	GRANITE BEACH	CAMP, BR	1800
6	93.50	GRANITE BEACH	DEPART	842
6	98.40	CRYSTAL RAPIDS	SCOUT RAPIDS	929
6	98.40	CRYSTAL RAPIDS	DEPART	959
6	108.80	LOWER BASS & SHINUMU	LUNCH, BR, AP	1146
6	108.80	LOWER BASS & SHINUMU	DEPART	1411
6	116.00	ELVES' CHASM	AP	1520

DAY	MILE	BEACH	REASON	TIME
6	116.00	ELVES' CHASM	DEPART	1658
6	120.10	BLACKTAIL CANYON	CAMP, BR, AP	1733
7	120.10	BLACKTAIL CANYON	DEPART	729
7	122.80	FORSTER BEACH	BR	747
7	122.80	FORSTER BEACH	DEPART	1129
7	130.40	BEDROCK BEACH	BR	1229
7	130.40	BEDROCK BEACH	DEPART	1326
7	133.75	1/4 MI. UPRIVER OF TAPEATS CREEK	LUNCH	1347
7	133.75	1/4 MI. UPRIVER OF TAPEATS CREEK	DEPART	1446
7	134.00	TAPEATS CREEK	BR	1450
7	134.00	TAPEATS CREEK	DEPART	1601
7	136.30	DEER CREEK	BR, AP	1621
7	136.30	DEER CREEK	DEPART	1745
7	137.00	PONCHO'S KITCHEN	CAMP, BR	1800
8	137.00	PONCHO'S KITCHEN	DEPART	852
8	143.50	KANAB CREEK	BR	940
8	143.50	KANAB CREEK	DEPART	1018
8	147.80	MATKATAMIBA CANYON	AP	1045
8	147.80	MATKATAMIBA CANYON	DEPART	1144
8	150.00	LAST CHANCE BEACH	LUNCH	1200
8	150.00	LAST CHANCE BEACH	DEPART	1308
8	156.60	HAVASU CREEK	BR, AP	1352
8	156.60	HAVASU CREEK	DEPART	1519
8	166.60	NATIONAL CANYON BEACH	CAMP, BR	1622
9	166.60	NATIONAL CANYON BEACH	LAYOVER DAY	
10	166.60	NATIONAL CANYON BEACH	DEPART	731
10	172.00	172L BEACH	BR	821
10	172.00	172L BEACH	DEPART	1007
10	194.00	194L BEACH	LUNCH, BR	1237
10	194.00	194L BEACH	DEPART	1452
10	204.00	SPRING CANYON BEACH	BR	1555
10	204.00	SPRING CANYON BEACH	DEPART	1654
10	224.50	224.5R BEACH	CAMP, BR	1903
11	224.50	224.5R BEACH	DEPART	825
11	225.50	DIAMOND CREEK/FLOODED	TAKEOUT ABORTED	837
11	225.50	DIAMOND CREEK	DEPART	1013
11	280.00	PIERCE FERRY	TAKE-OUT	1708

EXPLANATION:

BR= Beach research
AP = Attraction point

TABLE II. BOATS CONTACTED BY DAY

Date	Day	Mi. Travelled	Power Boats	Oar Boats	Total Boats
7/24/91	1	31.5	6	30	36
7/25/91	2	21.5	7	8	15
7/26/91	3	11.6	1	0	1
7/27/91	4	11.9	0	2	2
7/28/91	5	17	8	29	37
7/29/91	6	26.6	10	0	10
7/30/91	7	16.9	4	6	10
7/31/91	8	29.9	3	59	62
8/1/91	9	0	7	6	13
8/2/91	10	57.9	27	38	55
8/3/91	11	1	5	9	14

TABLE III. AIRCRAFT CONTACTS BY DAY

Date	Day	Total Aircraft	Airplanes	Jets	Helicopters
			(low-flying)	(high-altitude)	
7/24/91	1	3	3	0	0
7/25/91	2	2	2	0	0
7/26/91	3	62	41	7	14
7/27/91	4	42	29	9	4
7/28/91	5	3	1	1	1
7/29/91	6	20	3	5	12
7/30/91	7	2	0	2	0
7/31/91	8	7	6	1	0
8/1/91	9	78	73	5	0
8/2/91	10	72	51	18	3
8/3/91	11	2	1	1	0

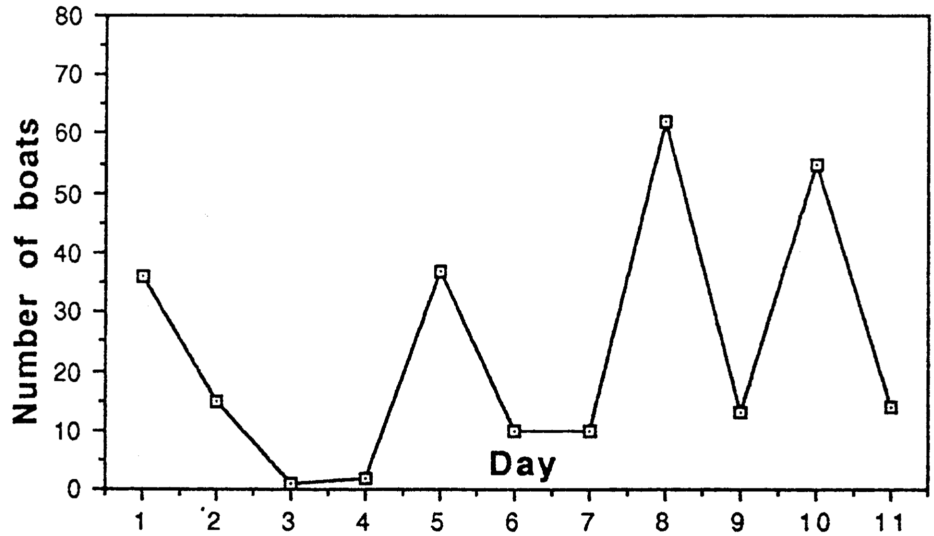

FIGURE 1. NUMBER OF BOATS CONTACTED PER DAY

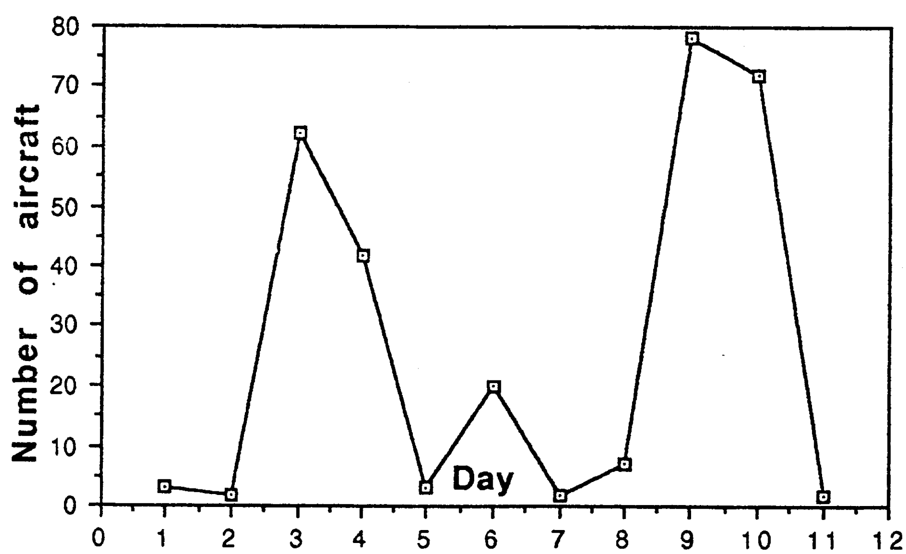

FIGURE 2. NUMBER OF AIRCRAFT CONTACTED PER DAY

TABLE IV. RESULTS OF THE RIVER TRIP EXPERIENCE QUESTIONNAIRE

1. Has the low water level affected your enjoyment of the river trip?

a. strongly agree	11
b. agree	16
c. disagree	2
d. strongly disagree	0
e. no opinion	0

2. Did the presence of planes over the canyon affect your overall enjoyment of the canyon?

a. strongly agree	5
b. agree	11
c. disagree	9
d. strongly disagree	2
e. no opinion	2

3. Do you think research trips are best served with motorized vehicles like the Canyoneers boats?

a. strongly agree	6
b. agree	15
c. disagree	7
d. strongly disagree	1
e. no opinion	0

4. Do you think oar-powered boats like the Havasu enhance the recreational river trip?

a. strongly agree	11
b. agree	8
c. disagree	5
d. strongly disagree	0
e. no opinion	4

5. Did the number of boat contacts in the upper half of the river trip affect your experience on the river?

a. strongly agree	7
b. agree	10
c. disagree	11
d. strongly disagree	0
e. no opinion	1

6. Did the number of boat contacts in the lower half of the river trip affect your experience on the river?

a. strongly agree	5
b. agree	14
c. disagree	8
d. strongly disagree	1
e. no opinion	0

CHAPTER 10: RADIOACTIVITY IN TRIBUTARY SAMPLES

by Phyllis Hochstetler

I. INTRODUCTION

In the Grand Canyon National Park, sedimentary rocks may have higher-than-normal levels of radioactive uranium since uraniferous breccia pipes are common in this region of Arizona. The level of radioactive uranium tends to increase as the percentage of silica increases in the rock, and tends to be higher in low temperature igneous rocks. The breccia pipes supply natural uranium source for the Colorado River sediments. An alternative source of uranium could be man-made through surface spill, mining activity, or other surface disruptive activity of the natural uranium ores.

Due to this possibility of contamination, research continued for the third year to determine the levels of radioactive uranium in the Colorado River system within the Grand Canyon National Park. Since radioactive isotopes precipitate out of water, mud deposits were collected as samples. The data gathered from these samples will be used to compare with 1989 and 1990 data as well as future comparisons.

Hypothesis: The levels of radioactive uranium in the Colorado River sediments are within a normal range as expected for sediments sourced from locally uraniferous sediment rocks and low temperature igneous rocks.

Objectives:
1. To resample 1989 & 1990 beach sites near stream tributaries and to establish new sites in the Colorado River corridor of the Grand Canyon.
2. To analyze river sediment samples and measure the concentration of radioactive uranium.

II. METHOD

A. Study Site--The 1991 sample area on the Colorado River was between the Little Colorado River (mile 61.4) and Granite Park (mile 204). Approximately 1 kilogram of fine sand was taken from near the water/sand interface at selected beaches. The samples were put into whirlpak bags, double-bagged, and labeled by location with a permanant marker. Color

TABLE 1. PERCENTAGE OF SAND, SILT, AND CLAY

Date	Site/mile	Coarse sand		Medium sand		Fine sand		Very fine sand		Silt and clay	
		0	0.5	1	1.5	2	2.5	3	3.5	4	Pan
7/26/91	L.Colorado #2/61.4	0%	0%	0%	0%	0%	1%	1%	1%	1%	96%
7/26/91	L.Colorado #3/61.4	0%	0%	0%	5%	23%	28%	23%	16%	3%	2%
7/26/91	Carbon Creek/64.6	0%	2%	3%	5%	8%	14%	25%	22%	4%	17%
7/28/91	Phantom Rch/87.6	0%	4%	6%	8%	6%	6%	8%	9%	10%	43%
7/29/91	Granite Rap/93.5	0%	0%	1%	1%	2%	2%	11%	24%	22%	37%
7/29/91	Bass/108.8	0%	0%	0%	0%	2%	13%	31%	32%	12%	10%
7/29/91	Shinumo/108.8	0%	2%	4%	8%	9%	11%	19%	19%	7%	21%
7/29/91	Blacktail/120.1	0%	0%	0%	3%	13%	27%	28%	17%	3%	9%
7/30/91	Forster Crk/122.8	0%	0%	5%	3%	3%	5%	11%	18%	10%	45%
7/30/91	Forster-Tam/122.8	0%	0%	0%	0%	1%	2%	4%	18%	26%	49%
7/30/91	Deer Creek/136.3	0%	1%	1%	4%	6%	10%	19%	28%	11%	20%
7/31/91	Kanab-mth/143.5	0%	0%	0%	1%	2%	3%	4%	7%	10%	73%
7/31/91	Kanab-lwr/143.5	0%	0%	0%	0%	0%	7%	25%	41%	15%	12%
7/31/91	Kanab-upr/143.5	0%	1%	1%	7%	12%	15%	18%	19%	4%	23%
7/31/91	Matkatamiba/147.8	0%	1%	1%	1%	3%	16%	17%	44%	12%	5%
7/31/91	Havasu/156.6	0%	1%	1%	4%	4%	5%	14%	18%	17%	36%
8/1/91	Nat'l-lower/166.5	0%	0%	0%	0%	0%	4%	33%	43%	6%	14%
8/1/91	Nat'l-200/166.5	0%	0%	0%	1%	3%	6%	18%	27%	21%	24%
8/1/91	Nat'l-500/166.5	0%	0%	0%	1%	0%	0%	16%	18%	26%	39%
8/1/91	Nat'l-mid/166.5	0%	0%	2%	2%	2%	4%	6%	18%	19%	47%
8/2/91	M. 194-lwr/194	0%	0%	0%	1%	6%	20%	26%	18%	13%	16%
8/2/91	M.194-upr/194	0%	0%	0%	0%	0%	1%	6%	26%	31%	36%
8/2/91	Granite Pk/204	0%	0%	0%	0%	0%	1%	5%	20%	24%	50%

photographs of the the 1989 sample sites were used to resample the same location and some new sample site photographs were taken for future use.

B. Sample Preparation--At N.A.U. the samples were air-dried for 24 hours. About 100 grams of each sample were then separated and were mechanically sieved by an automatic shaking apparatus. The percentages of sand and silt/clay were established. (See Table 1.)

The remainders of the samples were weighed and placed in individual plastic containers.

C. Gamma Ray Spectrometric Analysis--The samples were analyzed for radioactive uranium and thorium using in-house passive gamma ray techniques at the NAU laboratories. Natural radioactive gamma ray spectra were measured for each sample using a shielded activated NaI crystal, photomultiplier tube and pulse analyzer. The spectra were then compared with the spectra from reference samples of known concentrations of uranium and thorium. The concentrations of uranium and thorium in the samples were computed from the relative sizes of their energy peaks relative to the reference samples.

The samples were analyzed again in 30 days to compare the results.

III. RESULTS

Results of this year's analysis are pending completion of tests. In the previous studies, the areas of Kanab Creek, National Canyon (Taylor, et al, 1989) and North Canyon (Bates, et al, 1990) have shown higher-than-normal concentrations of uranium while the other areas have been within normal range.

References:

Bates, B., Martin, S., Stock, M. (1990) Level of Radioactive Uranium in Colorado River Sediments, Colorado River Investigation #9, Northern Arizona University, 119-122.

Taylor, C., Vasavez, K., Shannon, J. (1989) Level of Gamma Radiation in Colorado River Sediments, Colorado River Investigations VIII, Northern Arizona University, 130-136.

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