COLORADO RIVER INVESTIGATIONS VIII
July - August, 1989

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Northern Arizona University

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INTRODUCTION

This report presents results of a graduate course on the geology, hydrology, and biology of the Grand Canyon offered through Northern Arizona University with support and cooperation from the National Science Foundation and the National Park Service, Grand Canyon National Park. Conducted during July and August, 1989, this program involved classroom instruction, short field trips, and an 11-day river trip through the Grand Canyon. During that trip, each student participated in a research project under the supervision of either Dr. Stanley Beus or Dr. Lawrence Stevens. The data collected and the conclusions presented contribute to several ongoing studies and questions of concern to the National Park Service in management of the resources in Grand Canyon.

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 (organic as well as inorganic) there existed the potential for popular beaches to fill "cat box style" with any number of 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. Since 1976, the original Grand Canyon sites have been monitored and re-evaluated several times (Carothers, et al. 1984). In 1982, human impact data for 35 beach sites in Glen and Grand Canyons were presented and compared with the results of previous sampling efforts.

In 1983, human impact data for 22 Grand Canyon beach sites, including seventeen of the beaches evaluated in 1982 and five new beaches, were compared to the 1982 data. Eleven of the original beaches were no longer comparable in 1983 and were dropped from the study. In 1984, two previously studied beaches were not included. However, seven new beaches were added. The beaches which were deleted or added in the 1985, 1986, 1987, 1988, and 1989 studies are indicated in Table I-1.

OBJECTIVES

The objectives of this 1989 study are to:

1. Collect data on the degree of sand discoloration on 21 previously sampled beaches along the Colorado River corridor (1984-1988),

2. Collect data on the incidence of charcoal greater than or equal to 1 cm and human litter on 21 previously sampled beaches along the Colorado River corridor (1984-1988),

3. Compare data from objectives 1 & 2 with the findings from studies conducted in 1984-1988 to assess human impact on beaches after they were cleaned in the 1983 flood.

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.

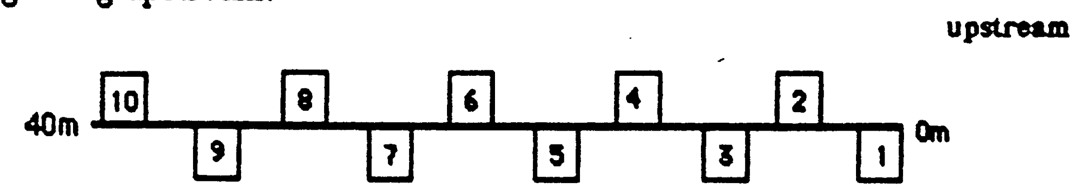
METHODS

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 river mile number and the side of the river was written on a chalkboard and included in the photograph. Ex:

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 the 1988 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 upstream.



5. Sand samples were also collected at the sand/water interface and from the terrace above the beach at the old high water line. On several beaches sand samples were taken under the canopy of a mature tamarisk tree.

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.

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, and stored in a labeled petri dish. The apparatus was then cleaned by swirling sand around inside the

containers and discarding the sand. The wire mesh was cleaned with a toothbrush after each sample was shaken.

9. When all of the samples from a transect were shaken, 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 standardized prior to each series of readings against a white standard and a gray standard to calibrate the instrument. The reflectivity of the filter paper should be measured and recorded each time the reflectometer is calibrated.

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 1984-1988. T-score calculations at a 0.05 level of significance were used to compare the 1988 reflectometer readings with the 1989 reflectometer readings.

RESULTS

Twenty-one beaches were sampled in 1989. Twenty of these were compared to 1988. The levels of sand discoloration as measured by reflectometer readings are presented in Table I-1. For purpose of comparison, this data is presented with equivalent figures from 1988. Due to lack of available time or erosion three beaches were deleted from the study. One beach was added to the study and no transect lines were changed.

In comparing the 1989 and 1988 sand analyses, four beaches showed an increase in sand discoloration but not at a 0.05 level of significance, and seven showed an increase in sand discoloration at a 0.05 level of significance. Seven beaches showed a decrease in sand discoloration at a 0.05 level of significance and two showed a decrease in sand discoloration, but not at a 0.05 level of significance. There was no data with which to compare Hance Rapid in 1988. (see data sheets for each beach).

Results of the charcoal and human litter accumulation are summarized in Table I-2 for the years 1984-1989. In comparing the 1988-1989 data, ten beaches showed an increase in incidence of charcoal greater than 1 cm, three beaches showed no change in incidence of charcoal, and seven showed a decrease. In comparing 1988-1989 data, thirteen beaches showed an increase in the amount of human litter, four showed a decrease, and three showed no change. These comparisons of human litter and charcoal debris were not analyzed using T-score calculations to determine what, if any, level of significance existed.

CONCLUSIONS

The Colorado River beaches in 1989 appear to have suffered a deterioration in cleanliness compared to the previous year. The results of the sand discoloration tests show a slow but steady deterioration from 1984 through 1989. Based on this data it is concluded that human impact is a factor in increased sand discoloration on the beaches.

The study indicates that the levels of charcoal and human litter found on the beaches increased from 1988 to 1989. The levels of charcoal found are considerably greater than the amount of human litter found for 1989. These data indicate that the increasing levels of charcoal may be responsible for the increased sand discoloration. It is also possible that discoloration may be due to organic materials such as tamarisk duff.

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 changing use patterns on the beaches.

The results of this study support the initial hypothesis that selected Grand Canyon camping beaches have shown an increase in both sand discoloration and the incidence of charcoal and human litter since the 1983 flood scoured them clean.

RECOMMENDATIONS

Perhaps factors other than human use are influencing the data obtained in this study. In order to better differentiate between human impact and other factors on the sand discoloration levels we recommend: 1) samples be taken under established tamarisk trees or other vegetation, 2) samples of sifted sand with low reflectometer readings be saved and brought back for laboratory analysis.

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. We also recommend the beach data sheets be revised so that beach, terrace, and vegetation samples will not be accidentally included in the calculations for mean and standard deviation.

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Table I-1 Results of sand discoloration analysis of beach campsites in Grand Canyon, 1984-1989 (means only)

Site No.	Campsite Name	River Mile	Sand Discoloration (Standard Deviation) 1984 (S.D.)	1985 (S.D.)	1986 (S.D.)	1987 (S.D.)	1988 (S.D.)	1989 (S. D.)
1	Badger Rapid	8.0	69.69 (2.52)	70.55 (1.82)	59.65 (5.59)	69.03 (3.95)	68.76 (2.86)	73.42 (1.43)
2	20 Mile	20.0	68.78 (3.14)	64.29 (3.07)	67.47 (4.54)	69.20 (2.19)	deleted	
3	Shinumo Wash	29.0	69.10 (3.16)	68.62 (3.03)	68.24 (5.14)	72.57 (1.95)	67.42 (3.22)	64.64 (0.69)
4	Anasazi Bridge	43.5	70.55 (1.83)	71.13 (1.80)	71.61 (1.79)	72.72 (2.24)	deleted	
5	Lower Nankoweap	53.0	64.91 (3.16)	69.33 (2.66)	66.67 (3.51)	71.36 (1.85)	65.67 (2.73)	62.28 (1.73)
6	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)
7	Lava Canyon (Chuar)	65.5	65.91 (4.05)	68.56 (3.81)	67.24 (2.87)	beach gone	beach gone	
8	Unkar	72.2	67.70 (2.28)					
9	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)
10	Hance Rapid	76.5	66.87 (5.14)	63.82 (2.92)	65.00 (4.12)	69.12 (3.56)		67.62 (1.96)
11	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)
12	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)
13	Lower Bass Camp	108.5	63.38 (5.69)	64.46 (1.69)	67.87 (3.71)	70.31 (3.46)	63.00 (2.56)	61.56 (1.09)
14	114 Mile	114.0	69.22 (2.06)	63.77 (2.39)	71.44 (2.30)	deleted		
15	122 Mile	122.0	71.16 (2.15)	68.55 (2.65)	71.44 (2.30)	beach gone	69.47 (2.28)	69.87 (2.47)
16	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)
17	Bedrock	131.0	70.54 (3.40)	68.20 (2.02)	71.50 (1.64)	69.49 (1.68)	68.19 (2.55)	
18	Dubendorff	132.0	70.22 (2.51)	69.63 (2.35)	69.62 (1.76)	71.07 (2.51)	71.83 (1.50)	river protocol
19	Deer Creek	136.0		65.46 (1.38)	66.68 (2.16)	65.43 (2.30)	68.43 (3.70)	63.96 (1.18)
20	Pancho's Kitchen	137.0	65.90 (3.79)	67.20 (3.81)	69.43 (3.04)	69.32 (2.00)	66.35 (2.32)	62.19 (1.46)
21	Upper National	166.5	68.95 (3.00)	73.31 (0.98)	beach gone	beach gone		
22	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)
23	Upper Lava	179.0					71.73 (1.70)	
24	Lower Lava Falls	180.0		67.74 (1.65)	67.63 (2.92)	72.87 (3.17)	69.43 (1.56)	69.32 (1.45)
25	186 Mile	186.0	72.06 (1.50)	70.95 (2.18)	69.54 (1.23)	71.43 (1.11)	64.65 (1.51)	70.87 (2.39)
26	Helicopter Pad	187.2					63.53 (2.07)	
27	194 Mile	194					66.69 (1.56)	71.99 (1.45)
28	195 Mile	195				71.91 (1.71)		
29	Parashant	198.5	63.94 (4.77)	68.39 (2.68)	beach gone	beach gone		
30	Indian Canyon	207.0			71.09 (1.52)	72.18 (2.11)	69.17 (2.85)	70.06 (1.21)
31	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)
32	Pumpkin Bowl	213.0	70.83 (1.75)	68.63 (2.41)	69.54 (1.81)	69.17 (2.60)	66.52 (2.25)	72.32 (1.31)
33	Trail Canyon	219.0	72.18 (1.45)	68.78 (3.38)	beach gone	beach gone		
34	220 Mile	220.0	67.71 ( )	66.93 (2.28)	68.67 (1.74)	69.18 (1.94)	64.97 (1.51)	70.30 (1.91)

Table I-2 Results of charcoal and human litter accumulations analysis of beach campsites in Grand Canyon 1984-1989 (means only).

Site No.	Campsite Name	River Mile	Charcoal cm/m2 1984	1985	1986	1987	1988	1989	Human Litter m2 1984	1985	1986	1987	1988	1989
1	Badger Rapid	8.0	2.5	0.2	0.2	10.4	5.7	9.6	0.2	0.0	0.3	0.4	0.2	0.7
2	20 Mile	20.0	0.0	0.3	0.0	0.2			0.2	0.2	0.0	0.0		
3	Shinumo Wash	29.0	0.0	0.0	0.0	0.6	0.7	0.4	0.1	1.0	0.1	0.5	0.1	0.2
4	Anasazi Bridge	43.5	0.0	0.0	0.2	0.2			0.0	0.0	0.0	0.1		
5	Lower Nankoweap	53.0	0.2	0.6	0.6	6.9	4.8	1.5	0.4	0.0	0.0	0.8	0.2	0.5
6	Awatubi	58.1	0.0	0.0	0.0	1.3	0.8	0.3	0.0	0.3	0.1	0.5	0.2	0.1
7	Lava Canyon (Chuar)	65.5	1.6	1.3	4.5	beach gone		0.3	0.0	0.2	beach gone			
8	Unkar	72.2	0.2	beach gone					0.1	beach gone				
9	Nevills Rapid	75.5	0.3	0.0	0.0	0.0	0.8	0.6	0.0	0.0	0.0	0.1	0.0	0.1
10	Hance Rapid	76.5	0.2	0.9	1.5	3.6		3.1	0.0	0.0	0.0	0.2		0.0
11	Grapevine	81.1	0.0	0.0	0.0	0.5	0.6	0.2	0.0	0.0	0.0	0.0	0.2	0.4
12	Granite Rapid	93.2	0.0	0.0	0.0	2.1	0.8	1.08	0.0	0.0	0.4	0.2	0.6	1.9
13	Lower Bass Camp	108.5	1.5	0.4	0.5	3.8	3.5	2.67	2.2	0.0	0.5	0.6	0.3	1.22
14	114 Mile	114.0	0.2	0.0	0.1	delete			0.0	0.5	delete			
15	122 Mile	122.0	0.0	0.0	1.0		0.0	0.0	0.2	0.1			0.0	0.7
16	Forster	122.8	0.0	0.0	0.6	0.0	0.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0
17	Bedrock	131.0	0.0	0.3	0.5	0.0	0.9		0.1	0.0	0.1	0.0	0.1	
18	Dubendorff	132.0	0.0	0.5	0.0	0.0	0.0		0.0	0.0	0.0	0.3	0.0	
19	Deer Creek	136.0		2.0	1.8	1.0	1.1	1.7		0.0	0.6	0.4	0.4	0.4
20	Pancho's Kitchen	137.0	0.0	0.1	1.3	0.8	0.0	0.8	0.4	0.1	0.8	0.4	0.0	0.7
21	Upper National	166.5	0.0	0.0	beach gone				0.2	0.2	beach gone			
22	Lower National Canyon	166.6	0.0	0.0	0.2	1.3	0.1	0.5	0.0	0.2	0.7	0.5	0.1	0.0
23	Upper Lava	179.0						0.0					0.3	
24	Lower Lava Falls	180.0		0.7	1.6	3.7	0.5	1.8		0.0	0.9	0.0	0.1	0.3
25	186 Mile	186.0	0.2	0.6	0.8	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.4	0.1
26	Helicopter Pad	187.2					0.0						0.0	
27	194 Mile	194.0					0.2	0.3					0.0	0.0
28	195 Mile	195.0												
29	Parashant	198.5	0.0	0.0	beach gone				0.2	0.3	beach gone			
30	Indian Canyon	207.0				0.0	0.0	0.2			0.0	0.1	0.1	0.0
31	Granite Park	208.8	0.1	0.0	1.2	1.9	0.8	2.2	0.1	0.0	0.1	0.1	0.3	0.6
32	Pumpkin Bowl	213.0	0.0	0.2	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.4
33	Trail Canyon	219.0	0.1	0.0	beach gone				0.0	0.0	beach gone			
34	220 Mile	220.0	0.4	0.0	0.0	1.4	2.1	1.1	0.2	0.0	0.0	0.4	0.0	0.9

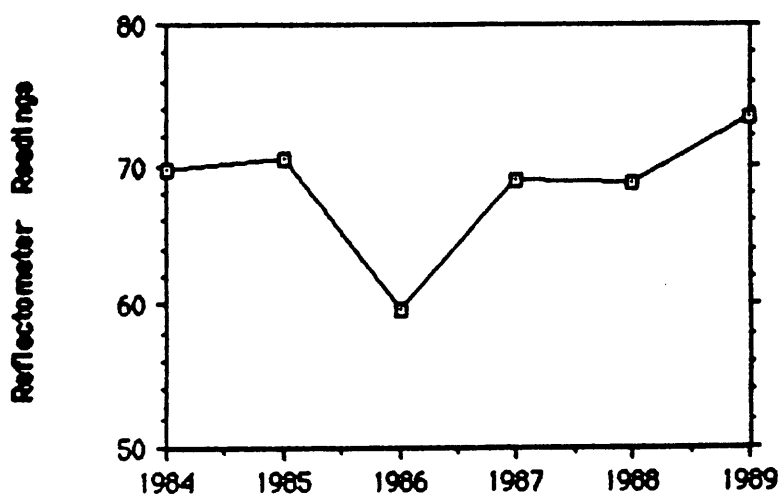
Beach name: Badger
River mile: 8.0

Sample #	Sand Discoloration (reflectometer reading)
1	73.1
2	70.8
3	73.5
4	71.7
5	72.9
6	74.1
7	75.7
8	74.9
9	73.8
10	73.7
Mean	73.42
Std. Deviation	1.43

+4.63 t-value found in analysis of 1988 and 1989 mean scores. Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS

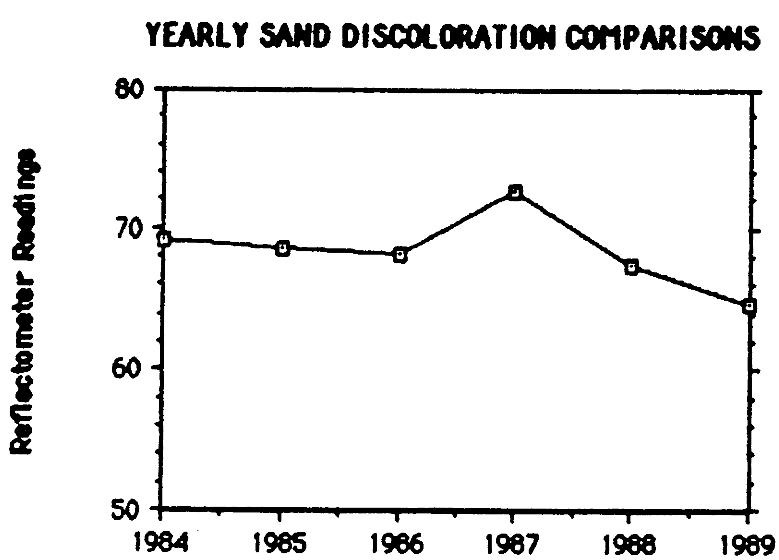


Beach name: Shinumo Wash
River mile: 29

Sample #	Sand Discoloration (reflectometer reading)
1	63.3
2	64.8
3	64.5
4	65.2
5	66.1
6	64.3
7	65.0
8	64.4
9	64.5
10	64.0
Mean	64.64
Std. Deviation	.69

-2.71 t-value found in analysis of 1988 and 1989 mean scores.
Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988



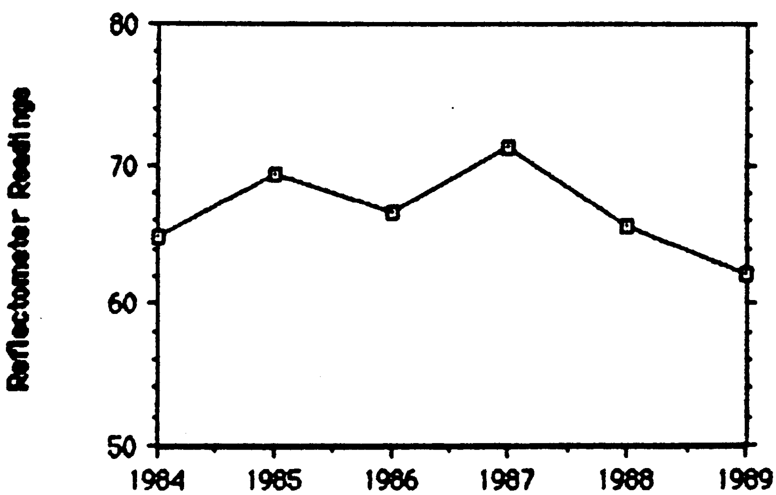
Beach name: Lower Nankoweap
River mile: 53.0

Sample #	Sand Discoloration (reflectometer reading)
1	60.8
2	63.2
3	62.7
4	64.9
5	62.0
6	60.3
7	63.7
8	60.6
9	64.3
10	60.3
Mean	62.28
Std. Deviation	1.73

-2.95 t-value found in analysis of 1988 and 1989 mean scores. Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS

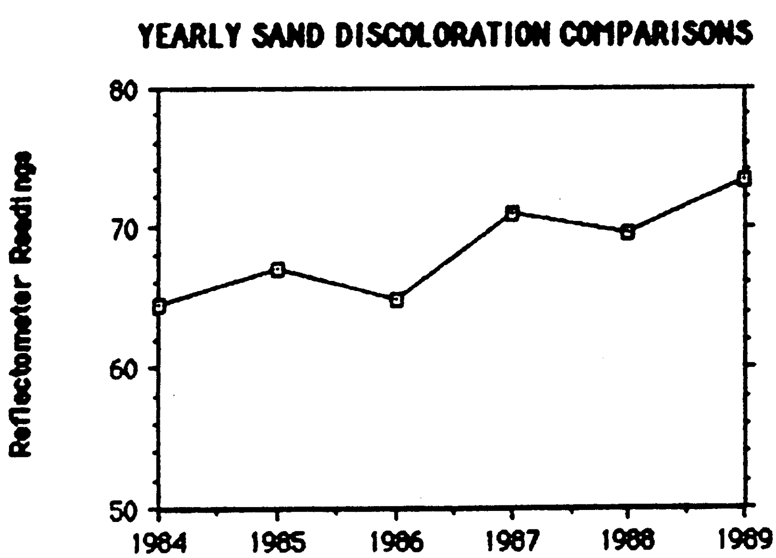


Beach name: Awatubi
River mile: 58.1

Sample #	Sand Discoloration (reflectometer reading)
1	74.7
2	77.7
3	76.0
4	70.5
5	72.3
6	71.8
7	69.5
8	70.7
9	74.6
10	74.3
Mean	73.21
Std. Deviation	2.66

+ 2.84 t-value found in analysis of 1988 and 1989 mean scores. Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988



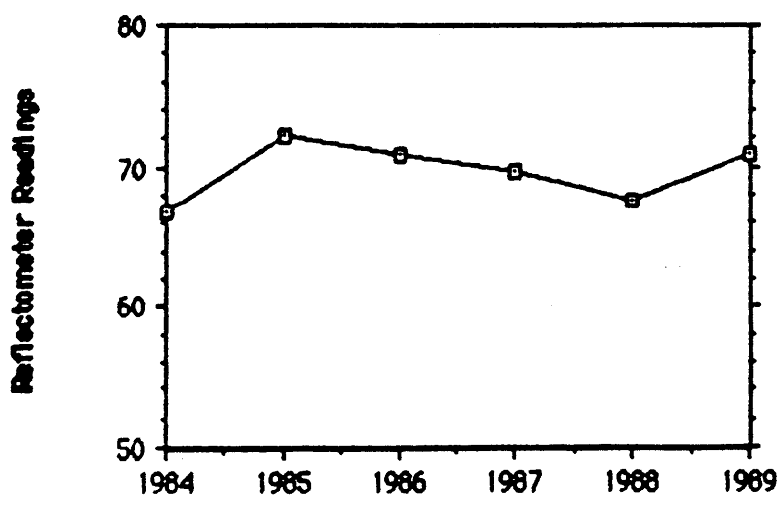
Beach name: Nevills Rapid
River mile: 75.5

Sample #	Sand Discoloration (reflectometer reading)
1	73.4
2	69.0
3	72.1
4	71.5
5	71.6
6	70.8
7	69.0
8	69.6
9	67.6
10	75.2
Mean	70.98
Std. Deviation	2.28

+4.41 t-value found in analysis of 1988 and 1989 mean scores.
Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS

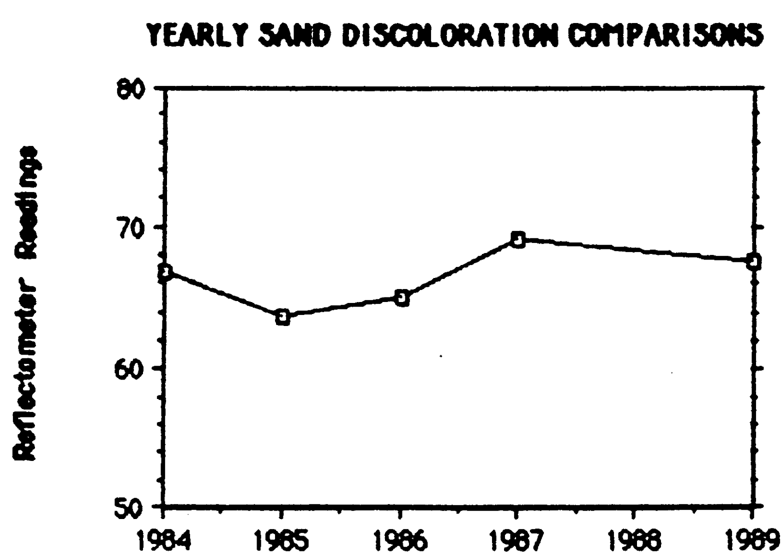


Beach name: Hance Rapid
River mile: 76.5

Sample #	Sand Discoloration (reflectometer reading)
1	67.3
2	68.3
3	71.2
4	64.8
5	68.0
6	68.4
7	68.0
8	65.4
9	65.5
10	69.3
Mean	67.62
Std. Deviation	1.96

NOTE: Beach was not done in 1988.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988



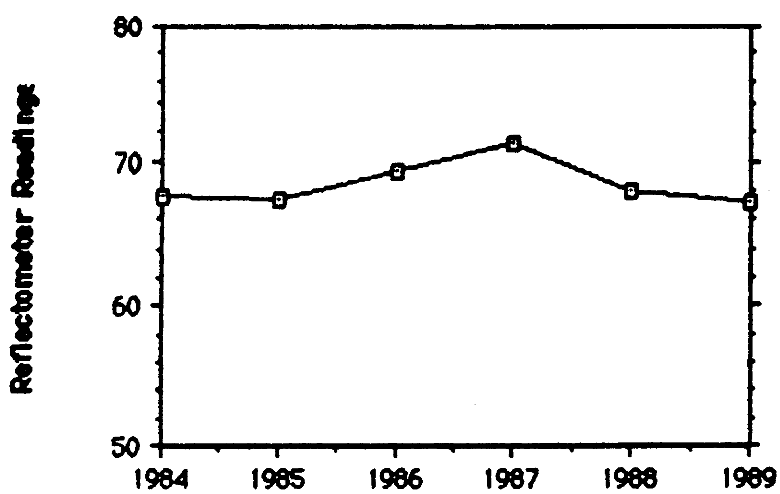
Beach name: Grapevine
River mile: 81.1

Sample #	Sand Discoloration (reflectometer reading)
1	67.0
2	67.2
3	68.0
4	67.1
5	67.7
6	65.5
7	66.2
8	67.6
9	67.5
10	67.7
Mean	67.15
Std. Deviation	.77

-1.67 t-value found in analysis of 1988 and 1989 mean scores.
Not Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS



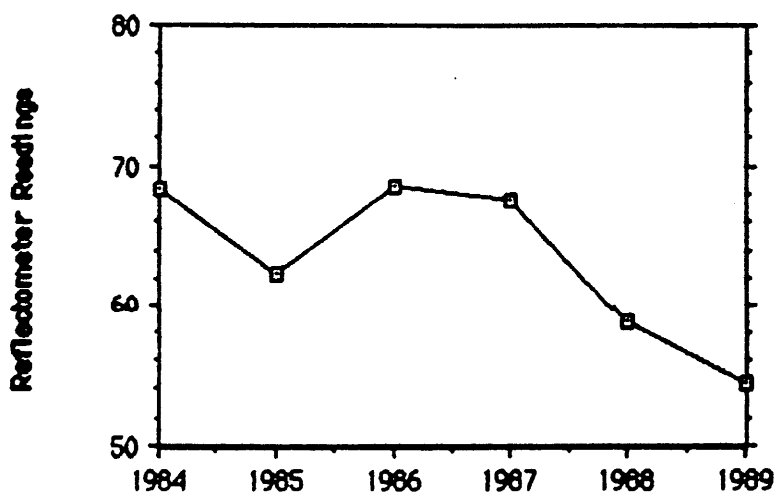
Beach name: Granite Rapid
River mile: 93.2

Sample #	Sand Discoloration (reflectometer reading)
1	57.0
2	53.8
3	51.2
4	52.0
5	54.6
6	52.3
7	59.3
8	58.0
9	51.2
10	no sample
Mean	54.38
Std. Deviation	3.08

- 3.43 t-value found in analysis of 1988 and 1989 mean scores. Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
\+ = greater reflection of light in 1989
\- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS



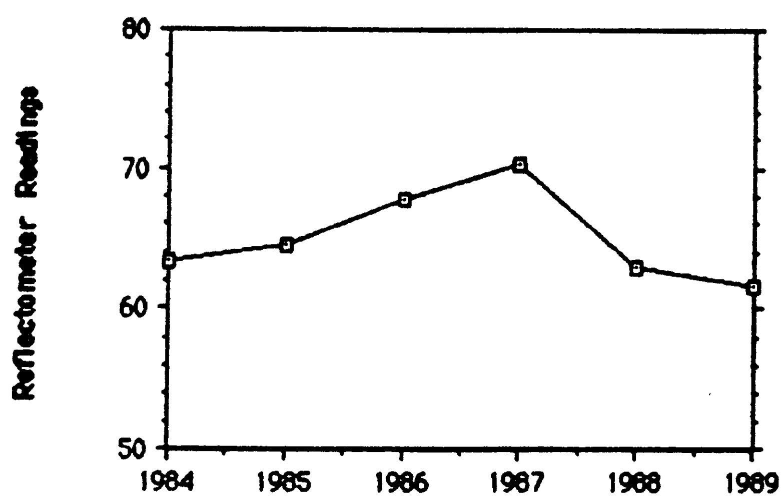
Beach name: Lower Bass Camp
River mile: 108.5

Sample #	Sand Discoloration (reflectometer reading)
1	61.2
2	61.0
3	61.2
4	59.6
5	63.2
6	60.9
7	61.9
8	62.3
9	62.7
10	no sample
Mean	61.56
Std. Deviation	1.09

- 1.83 t-value found in analysis of 1988 and 1989 mean scores.
Not Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS



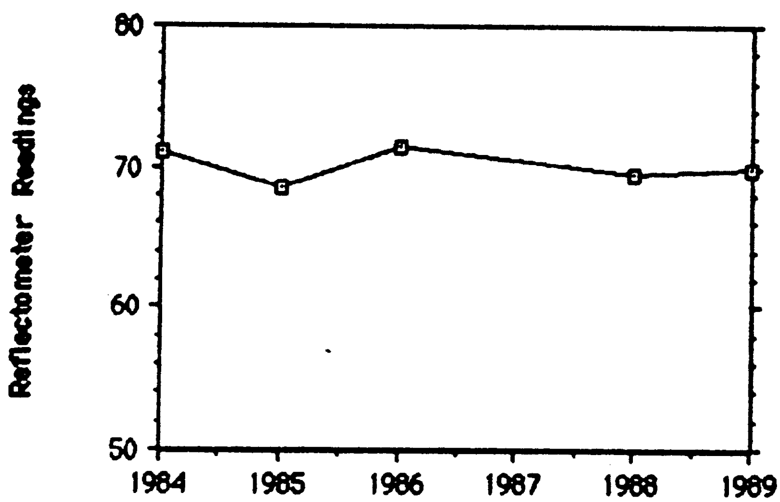
Beach name: 122 Mile
River mile: 122

Sample #	Sand Discoloration (reflectometer reading)
1	73.8
2	72.1
3	71.0
4	70.6
5	70.0
6	70.2
7	70.1
8	67.4
9	64.9
10	68.8
Mean	69.87
Std. Deviation	2.47

+ .32 t-value found in analysis of 1988 and 1989 mean scores. Not Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS



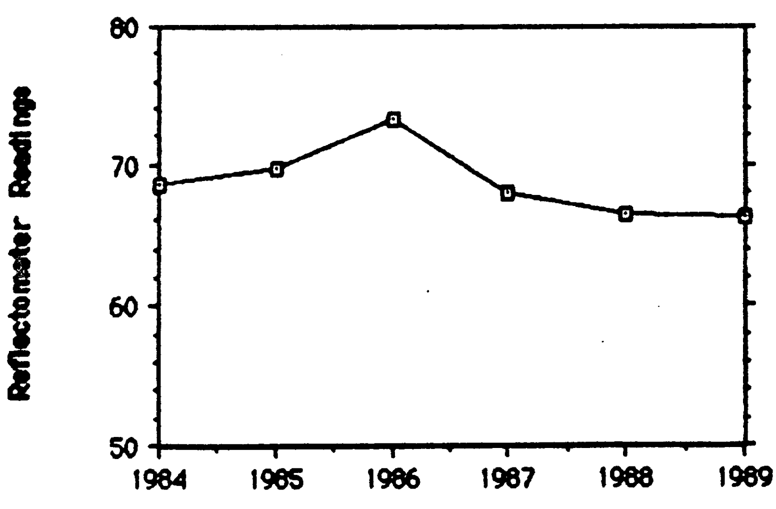
Beach name: Forster
River mile: 122.8

Sample #	Sand Discoloration (reflectometer reading)
1	67.8
2	66.4
3	64.3
4	68.8
5	65.0
6	64.9
7	66.4
8	65.8
9	67.2
10	66.3
Mean	66.29
Std. Deviation	1.38

-.17 t-value found in analysis of 1988 and 1989 mean scores.
<u>Not Significant</u> at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS



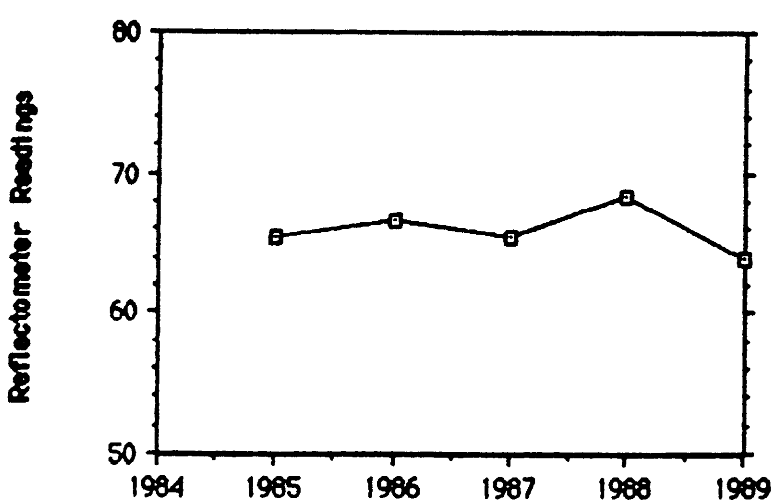
Beach name: Deer Creek
River mile: 136

Sample #	Sand Discoloration (reflectometer reading)
1	64.5
2	64.8
3	64.2
4	63.6
5	64.1
6	65.3
7	65.1
8	63.9
9	62.7
10	61.4
Mean	63.96
Std. Deviation	1.18

-3.81 t-value found in analysis of 1988 and 1989 mean scores.
Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS



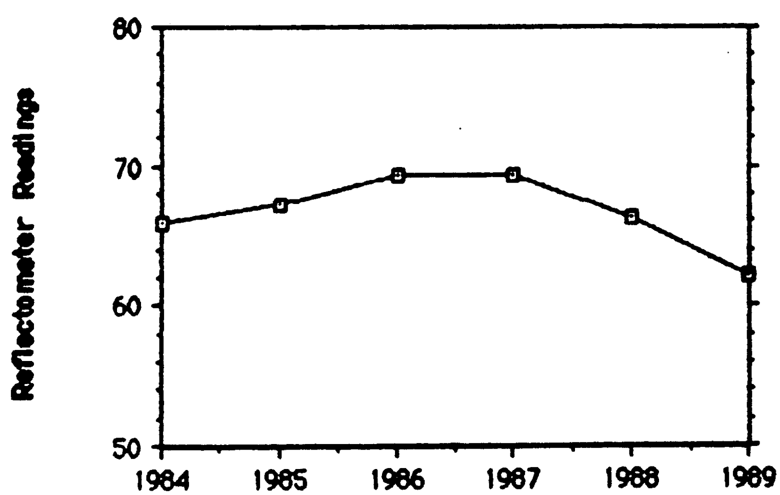
Beach name: Pancho's Kitchen
River mile: 137.0

Sample #	Sand Discoloration (reflectometer reading)
1	62.0
2	59.3
3	61.7
4	61.2
5	61.4
6	64.6
7	63.6
8	62.2
9	63.0
10	62.9
Mean	62.19
Std. Deviation	1.46

-5.99 t-value found in analysis of 1988 and 1989 mean scores.
Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS



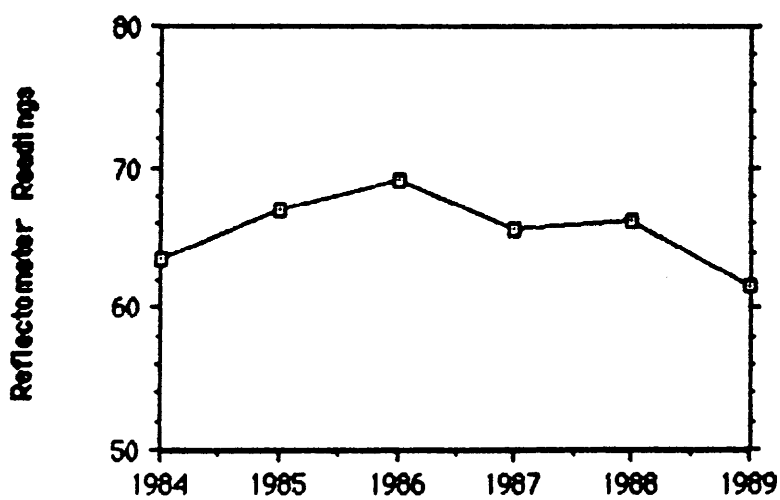
Beach name: Lower National Canyon
River mile: 166.6

Sample #	Sand Discoloration (reflectometer reading)
1	63.1
2	62.2
3	61.0
4	61.9
5	61.5
6	60.9
7	62.4
8	59.5
9	61.8
10	62.0
Mean	61.63
Std. Deviation	.99

-6.74 t-value found in analysis of 1988 and 1989 mean scores.
Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS

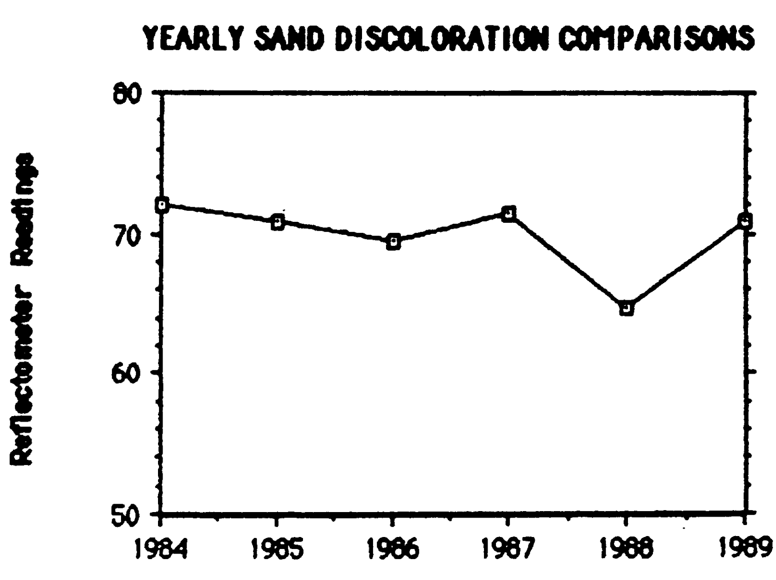


Beach name: 186 Mile
River mile: 186.0

Sample #	Sand Discoloration (reflectometer reading)
1	71.6
2	68.6
3	68.4
4	68.8
5	70.9
6	70.9
7	70.3
8	72.5
9	70.2
10	76.5
Mean	70.87
Std. Deviation	2.39

+9.87 t-value found in analysis of 1988 and 1989 mean scores.
Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988



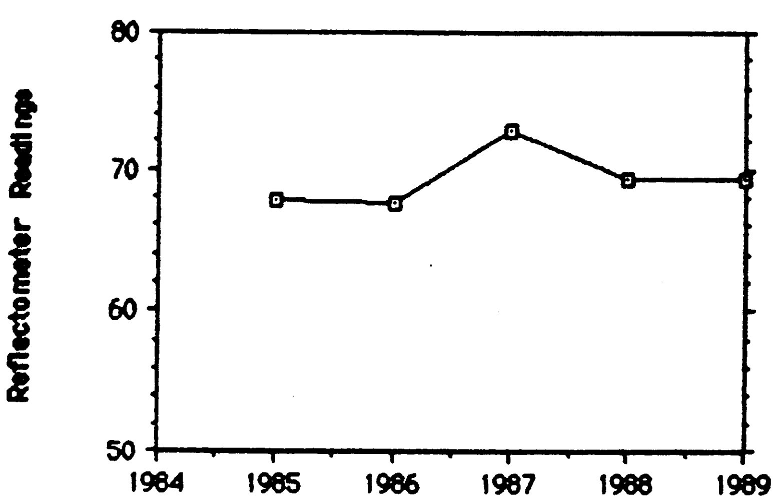
Beach name: Lower Lava Falls
River mile: 180.0

Sample #	Sand Discoloration (reflectometer reading)
1	67.0
2	68.5
3	69.1
4	68.1
5	71.2
6	70.6
7	70.9
8	70.0
9	67.7
10	70.1
Mean	69.32
Std. Deviation	1.45

-.19 t-value found in analysis of 1988 and 1989 mean scores.
Not Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS



Beach name: Helicopter Pad
River mile: 187.2

Sample #	Sand Discoloration (reflectometer reading)	
1	65.2	(on the helicopter pad)
2	61.6	(below the helicopter pad)
3	66.7	(upper trail to helicopter pad)
4	69.1	(lower trail to helicopter pad)
5		
6		
7		
8		
9		
10		
Mean	65.6	
Std. Deviation	2.73	

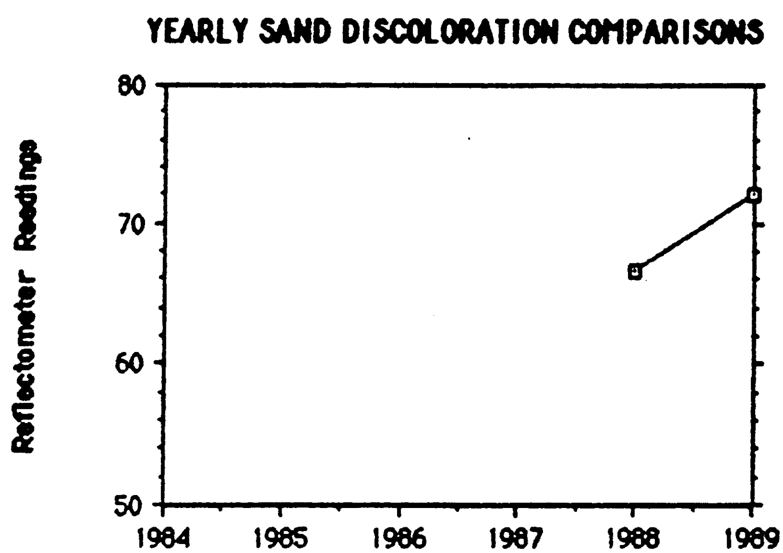
Note: A transect was not set up and a t-value was not calculated due to different sample sizes in 1988 and 1989.

Beach name: 194 Mile
River mile: 194.0

Sample #	Sand Discoloration (reflectometer reading)
1	70.1
2	72.5
3	70.7
4	69.9
5	72.4
6	73.5
7	71.3
8	73.4
9	74.0
10	72.1
Mean	71.99
Std. Deviation	1.45

+10.43 t-value found in analysis of 1988 and 1989 mean scores. Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988



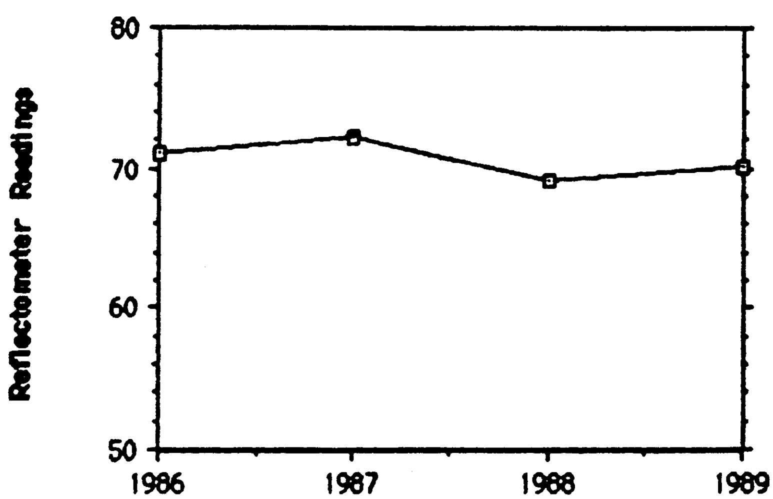
Beach name: Indian Canyon
River mile: 207.0

Sample #	Sand Discoloration (reflectometer reading)
1	69.9
2	69.4
3	71.9
4	69.2
5	69.4
6	70.2
7	72.3
8	68.5
9	70.5
10	69.3
Mean	70.06
Std. Deviation	1.21

+.81 t-value found in analysis of 1988 and 1989 mean scores.
<u>Not Significant</u> at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS

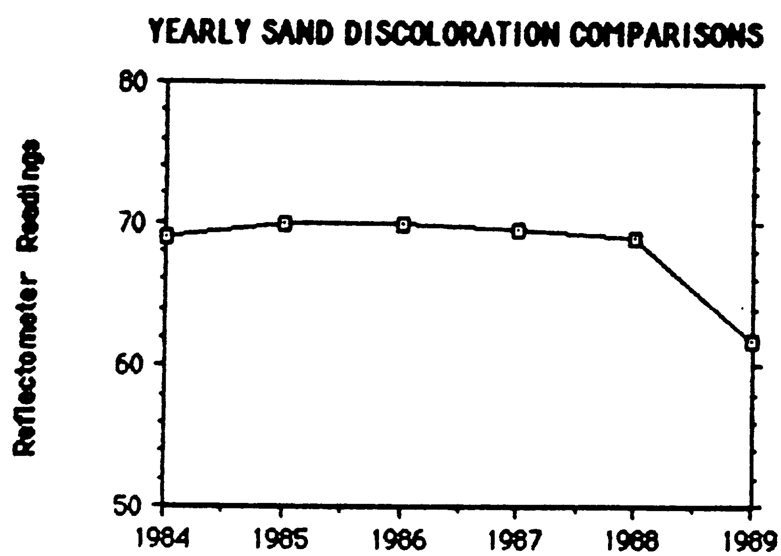


Beach name: Granite Park
River mile: 208.8

Sample #	Sand Discoloration (reflectometer reading)
1	60.1
2	60.5
3	60.6
4	59.2
5	61.9
6	60.0
7	65.3
8	60.6
9	63.3
10	65.6
Mean	61.71
Std. Deviation	2.27

-6.37 t-value found in analysis of 1988 and 1989 mean scores. Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988



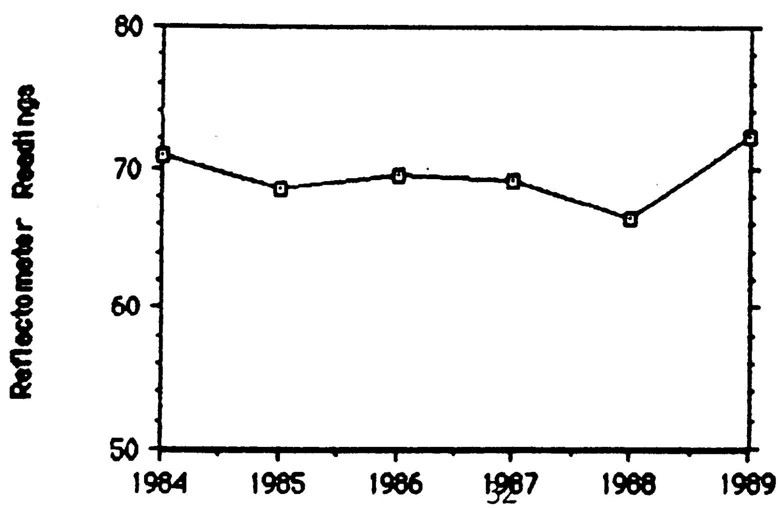
Beach name: Pumpkin Bowl
River mile: 213.0

Sample #	Sand Discoloration (reflectometer reading)
1	71.7
2	72.3
3	69.9
4	72.0
5	72.3
6	73.6
7	73.7
8	72.4
9	74.3
10	71.0
Mean	72.32
Std. Deviation	1.31

+2.13 t-value found in analysis of 1988 and 1989 mean scores. Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988

YEARLY SAND DISCOLORATION COMPARISONS

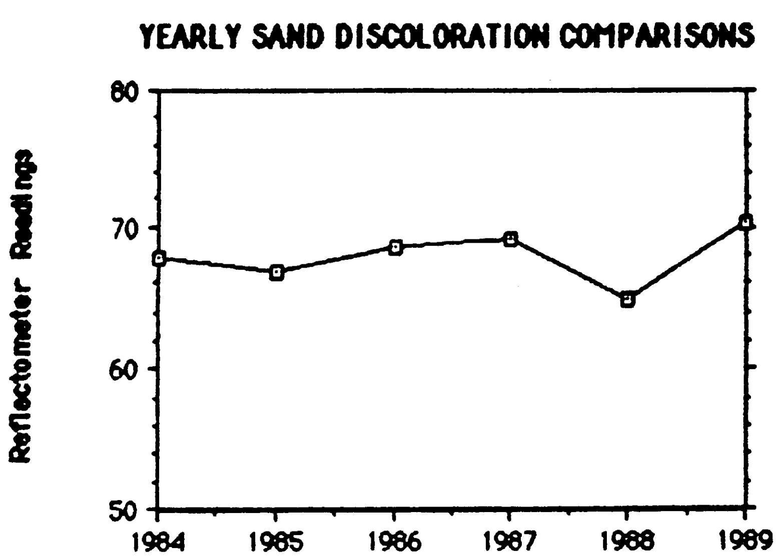


Beach name: 220 Mile
River mile: 220.0

Sample #	Sand Discoloration (reflectometer reading)
1	72.3
2	72.7
3	72.2
4	69.5
5	70.4
6	71.6
7	69.4
8	69.1
9	69.2
10	66.6
Mean	70.3
Std. Deviation	1.91

+6.28 t-value found in analysis of 1988 and 1989 mean scores. Significant at the .05 level.

NOTE: Less reflection indicates more discoloration
+ = greater reflection of light in 1989
- = greater reflection of light in 1988



Equipment List

Reflectometer II + battery; (extra battery)
500-1000 small whirl packs
Transect line (40 meter tape)
2 magic markers (waterproof)
3- one m2 frames, collapsible
5 plastic sand sifters
filter paper (#7 coarse grade) 12 per beach
24 petri dishes (to place filter paper in while awaiting testing; to use to dry sand)
5 tweezers (to pick up filter paper)
5 toothbrushes (to clean stainless steel mesh apparatus)
12 large sample bags (to store sand samples)
5-150 micron stainless steel mesh apparatus
1 table with legs
calculator with statistical mode
pad for writing; pencils; pencil sharpener
table of T-scores
1 clip board
chalkboard to record location, chalk
black & white film, camera
umbrella
previous year's beach sand contamination report, including data sheets of each beach
photos of previous year's transect lines
epoxy glue to repair mesh screens
computer diskettes
blank data sheets
Apple StatPak program to calculate t scores
Cricket graphing program to display data
previous years report and tables on Macintosh diskettes

CHAPTER 2

TOPOGRAPHIC CHANGES ON SELECTED BEACHES IN THE GRAND CANYON, 1988-89

Linda Brogdon, Mark Gilbreath, Martha Hermanson, Mary Lou Rankin, Susan Robertson

INTRODUCTION

The Colorado River beaches are one of the most important elements of the recreational value of the Grand Canyon National Park. These beaches have been altered considerably since the 1963 addition of the Glen Canyon Dam on the Colorado River. This alteration is of national concern, resulting in the commencement of a five-year environmental impact study under the National Environmental Policy Act, as announced on July 28, 1989 by the US Secretary of the Interior, Manuel Lujan.

On July 25, 1989, a research team of five Arizona science teachers began a twelve-day investigation of campsite beaches along the Colorado River in the Grand Canyon. This study, a continuation of work initiated in 1974 and conducted annually since 1982, was implemented to determine the direction, degree and speed of the alteration of the 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 on the Colorado River beaches as a result of the control of river flow by the Glen Canyon Dam, and should serve as a data base for the environmental impact study.

The investigation involved a transit survey along previously fixed profile lines from established benchmarks and the establishment of two new benchmarks at L19.3 with two cross-sections. The research team surveyed a total of 35 cross-sections on 17 beaches (Table 2-I). Lower Lava Falls (R180.9) was not surveyed due to lack of time. The Ledges beach (L151.6) was not surveyed again this year because all that remained was exposed rock, nor were L18.2, Nankoweap (R53.0), Mouth of the Little Colorado beach (R61.8), Tanner (L65.5), L87.1 and the remaining beaches on Table 2-1 labeled as "gone".

OBJECTIVES

The flows of the Colorado River as regulated by the Glen Canyon Dam are expected to contribute to topographic changes on the surface of selected beaches throughout the river corridor in Grand Canyon National Park as compared to previously recorded measurements. This study is designed to measure and monitor these changes on an annual basis.

METHODS

Previously established benchmarks were located (one to three per beach) and two new benchmarks were set at L19.3. Instrument stations were set (as per historical data) from which horizontal sight rod 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. Materials

1. 1 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. length)
7. 1 - 18 ft survey rod
8. 2 hand lens
9. 2 benchmark nails
10. 1 roll orange flag tape
11. graph paper
12. clipboard (metal)
13. machete
14. 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 & white film (1-20 exposures per beach)

B. Procedures

Legend: Benchmark or Base Station = BS (numbered)
Cross Section = CS (numbered)
Instrument Station, once located, is referred to as CS
Height of instrument (transit barrel) = HI

1. Locate all BSs as noted in historical data record (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 BSs; 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 CS onto (toward) whichever BS is to be used for elevation data.
5. Take and record HI.
6. Orient transit barrel along 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, at arbitrarily selected positions based on topography (e.g. change in slope, or change in composition of beach).
   Note:
   If horizontal sight rod readings cannot be taken due to extreme slope of beaches or excessive, non-removable 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 barrel downward, record 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 same CS onto (toward) any other available BS.
9. Repeat steps #4 through #8 with transit set on sucessive Cross Sections.
10. 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)

RESULTS

Since 1988, most beaches have essentially remained the same or lost sediment (see Table 2-2; Figures 2-1 to 2-37). Some beaches gained sediment in one area and lost in another.

Comparison of inner beaches (first half of each beach profile) since 1988:

- 33.0% lost sediment
- 35.5% remained the same
- 25.6% gained sediment

Comparison of outer beaches (second half of each beach profile) since 1988:

- 50.0% lost sediment
- 16.7% remained the same
- 33.3% gained sediment

Comparison with original survey - inner beaches:

- 44.8% lost sediment
- 13.8% remained the same
- 41.4% gained sediment

Comparison with original survey - outer beaches:

- 80.8% lost sediment
- 0.0% remained the same
- 19.2% gained sediment

CONCLUSION

Glen Canyon Dam closed in 1963 and sediment, originally deposited during annual floods on Grand Canyon beaches, was trapped behind the dam. Most of the over 200 beaches in the Grand Canyon gained sand in 1983 after an unexpected high-water spill. Since 1983, these same beaches have been gradually eroding.

Beaches in this year's survey essentially remained the same or lost sediment, compared to 1988. Slight gains on inner beaches could be due to blowing dunes. Gains and losses on the outer beaches are caused by the river and/or flash flooding and, perhaps, human use (see Recommendation section below). On balance, these processes have taken away more than they have put back on most beaches being monitored. A summary of gain or loss of sand on the beaches surveyed this year is given in Figures 2-38 and 2-39.

DISCUSSION/RECOMMENDATIONS

A comparison of each beach with its original survey is difficult, since some surveys were conducted during 1975 whereas others were not begun until after the 1983 flood. This team of investigators recommends that future comparisons of all monitored beaches be made to the post-1983 flood surveys.

As mentioned in the Conclusion above, the effect of human use of the beaches on the gain and/or lost of sedimentation needs to be quantified and incorporated into this investigation.

We further recommend that all profiles include points at regular intervals that will be measured annually as well as points at current topographic changes, and consistently extend the profiles to the water-line or beyond (in the case of high flow rate). A measured distance from the transit should be established as the inner/outer beach demarcation at each beach and used in future comparisons.

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ADDENDUM 2-1

To Beach Profile Survey Team:

1. To increase speed and accuracy of data collection, we recommend training a crew and sticking to specific job assignments while in the field. Rotating tasks in order to learn various roles, and discovering 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 measuring tape, etc.).

3. Rod Person:
    a. Watch Transit Person for directions at all times during readings.
    b. Pick or plant two points (a stick, soneone'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 Section.
    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" on top.
    b. Have old report, old photos, 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; locations for each rod reading.

BEACH PROFILE LOCATION SHEET

Site L 19.8 Mile Post 19.9

Date established 7/26/89

Base station #1 LS boulder Photo ✓ Perm. mark X at hi[illegible]

Base station #2 ~~Sandstone~~ Boulder against cliff Photo ✓ Perm. mark X " " "

Base Station #3 ______ Photo ______ Perm. mark ______

Elevation datum ______ Photo # ✓

Length of base line #1 96.5 from BS[1] to BS[2]
Base line orientation S56°E from BS[1] to BS[2]

Length of base line # 2 ______ from ______
Base line orientation ______ from ______

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

Cross section #1: 32 ft. from BS1 toward BS2
at an angle of 93° (~~counter~~) clockwise from direction of Toward BS1

Cross section #2: 64 ft from BS1 towards BS2
at an angle of 93° (~~counter~~) clockwise from direction toward BS1

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

Comments

CROSS-SECTION DATA SHEET

MILE: L 19.9 CAMPGROUND NAME: ?

CROSS-SECTION NO. 1 & 2 SURVEY DATE: 4/25/89

ORIGINAL SURVEY? ✓ RESURVEY NO.

ED = BS2

FROM	TO	ROD READING (feet)	SLOPE DISTANCE (ft/in)	VERTICAL ANGLE (deg)	HORIZONTAL DISTANCE	COMMENTS
CS2	BS2	1.88		0	0	
CS2	CS2	5.12 HI				
CS2	1	5.25			19'8"	
CS2	2	7.12			53'1	[illegible]
CS2	3	11.33			73'	on rocks
CS2	4	14.49			79'3"	on sand
CS2	5	16.88			104'5"	on flat sand beach
CS2	6	18.50			141'3"	wet sand
CS2	7	17.00 (18.02)		2° down	160'4"	waters edge
CS2	BS1	2.90				
CS1	BS1	4.58			32'1"	
CS1	C[illegible]	[illegible]				
CS1	CS2	4.80 HI			0	
CS1	1	7.25			19	[illegible]
CS1	2	7.93			39.1	on big rock
CS1	3	12.42			62.9	on rocks
CS1	4	16.41			84.1	On Sand
CS1	5	17.50 (19.79)		1°10" down	112.6	Wet Sand
	6	17.00 (24.66)		3° down	146.3	water's Edge

COMMENTS:

Much of beach is boulder rubble

May be adding sand at lower level.

CS1 L 19.9

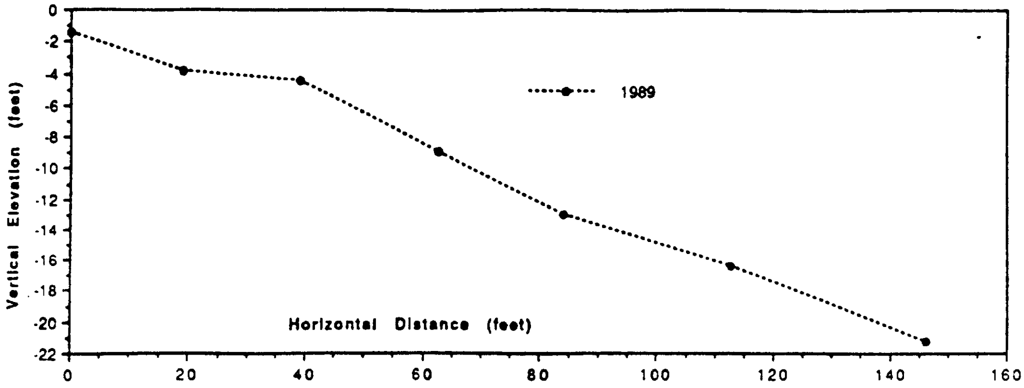

Figure 2-1 Beach Profile

CS2 L19.9

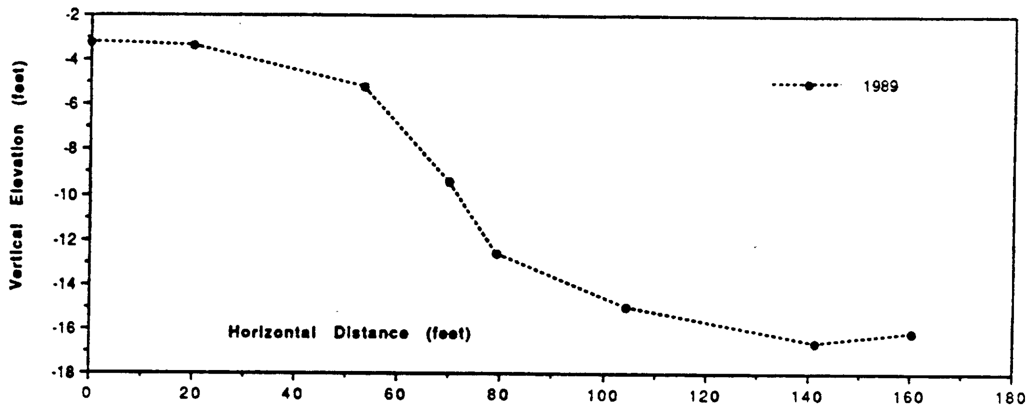

Figure 2-2 Beach Profile

CS1 Nautiloid L 34.7

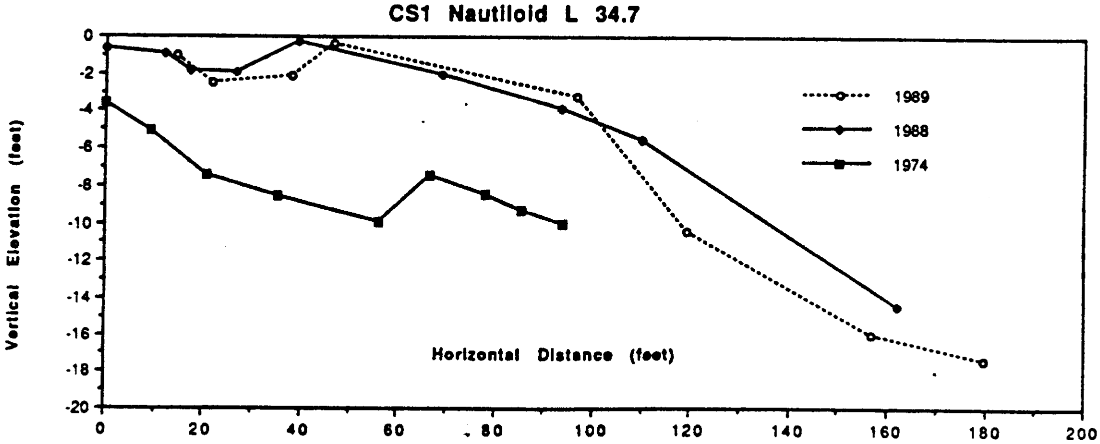

Figure 2-7. Beach profiles.

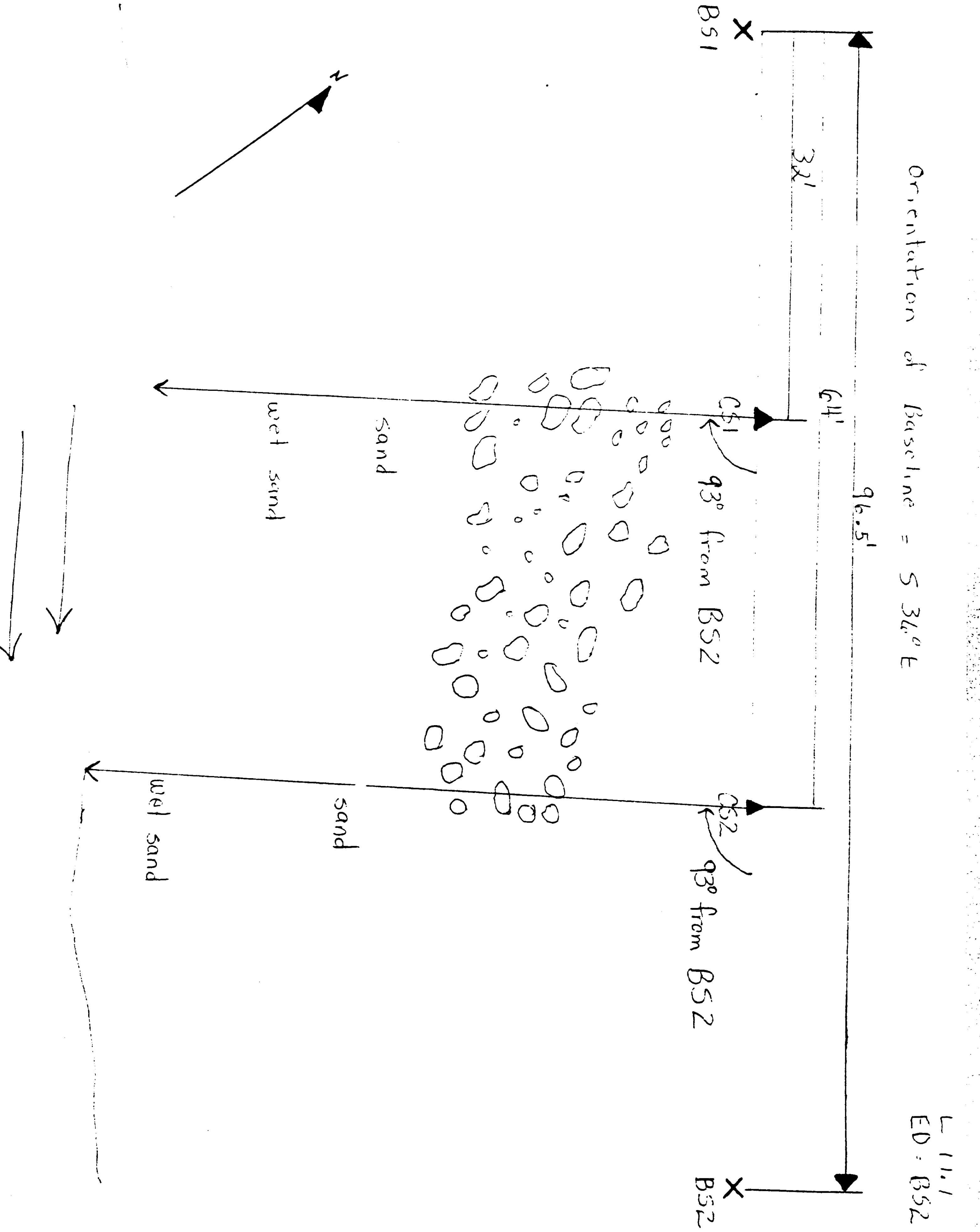

Figure 2-3. Sketch map of 19.9 - Mile Beach.

Figure 2-4 L19.9 Mile Beach BSI

Figure 2-5 L19.9 Mile Beach BS2

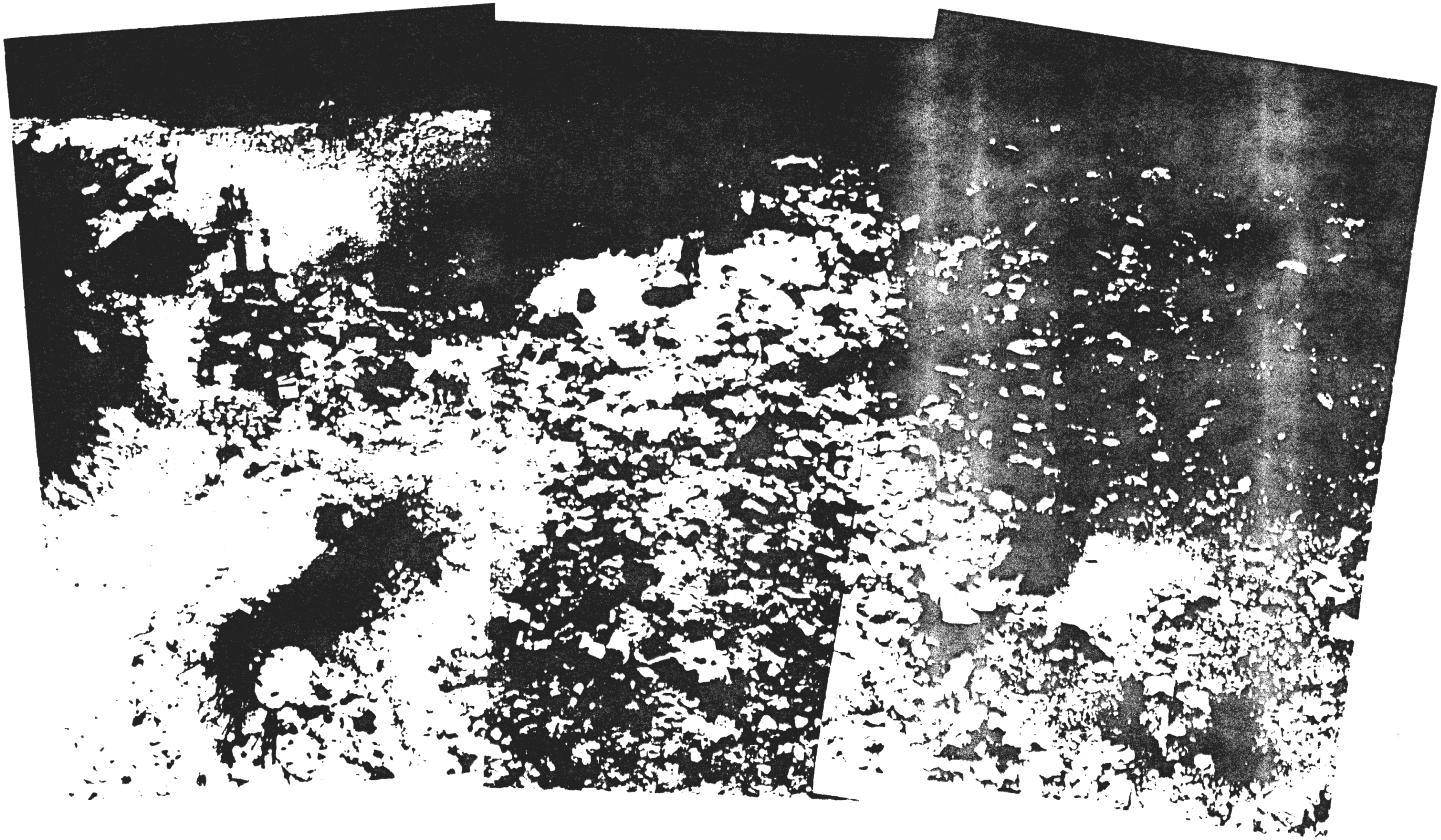

Figure 2-6 L19.9 Beach

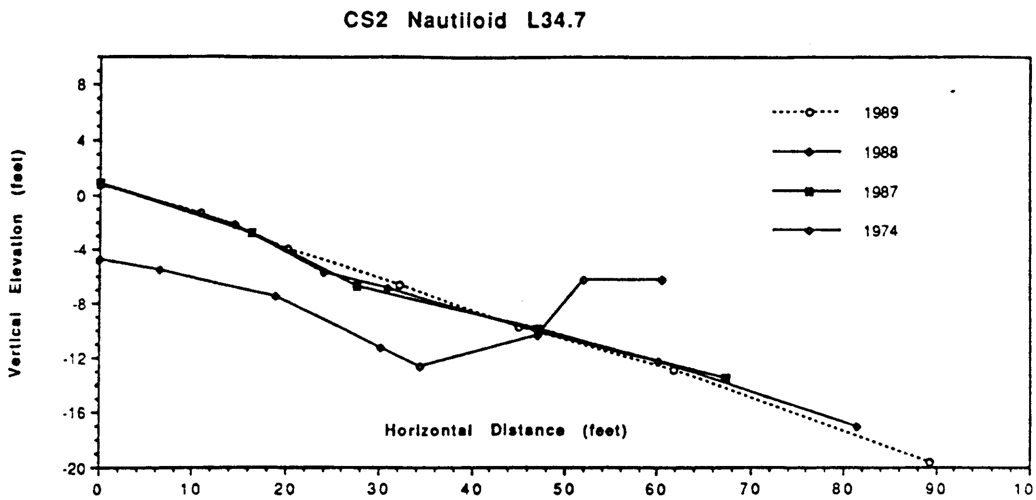

Figure 2-8 Beach Profiles

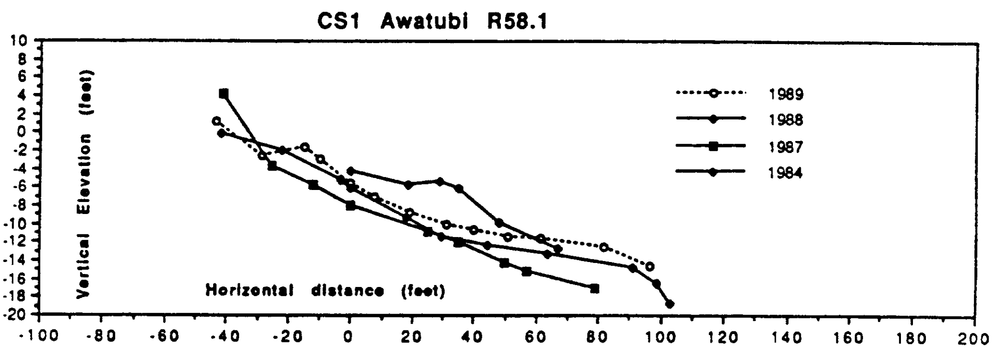

Figure 2-9. Beach profiles, Awatubi

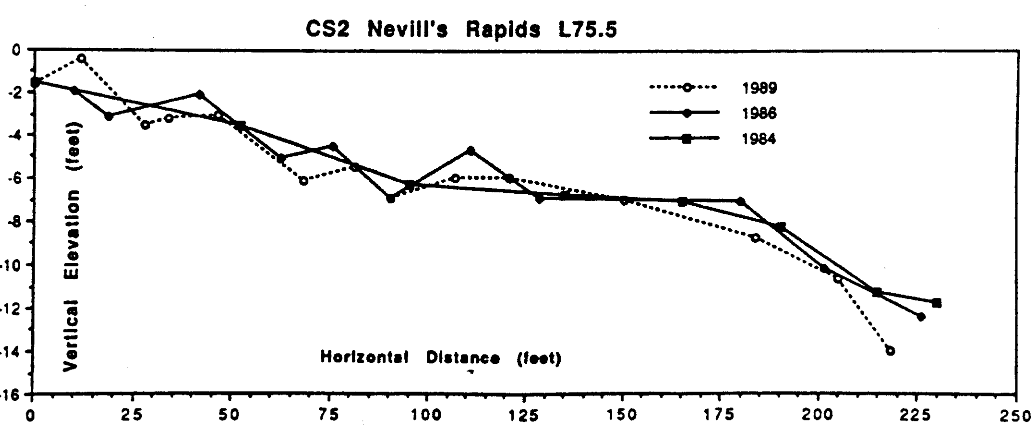

Figure 2-10. Beach profiles

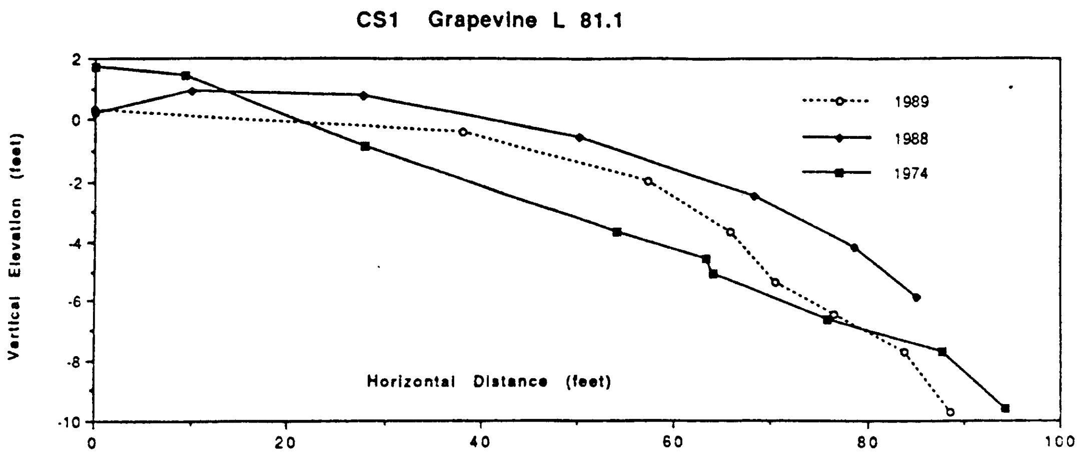

Figure 2-11. Beach profiles.

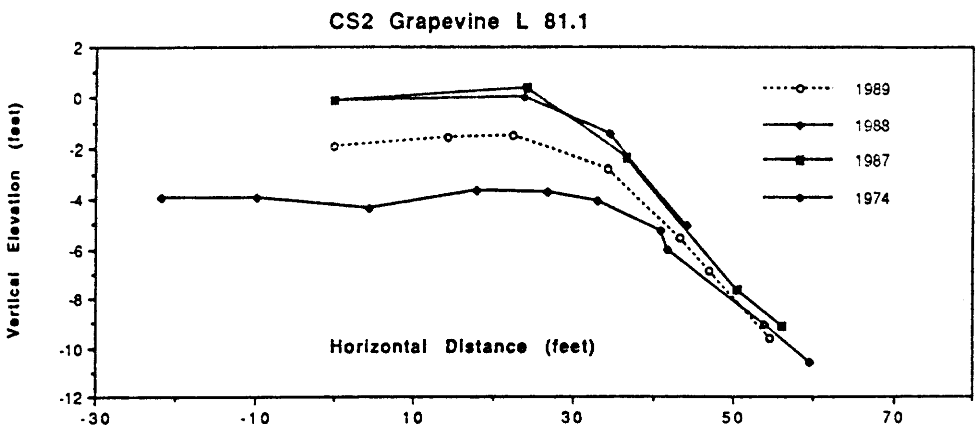

Figure 2-12. Beach profiles.

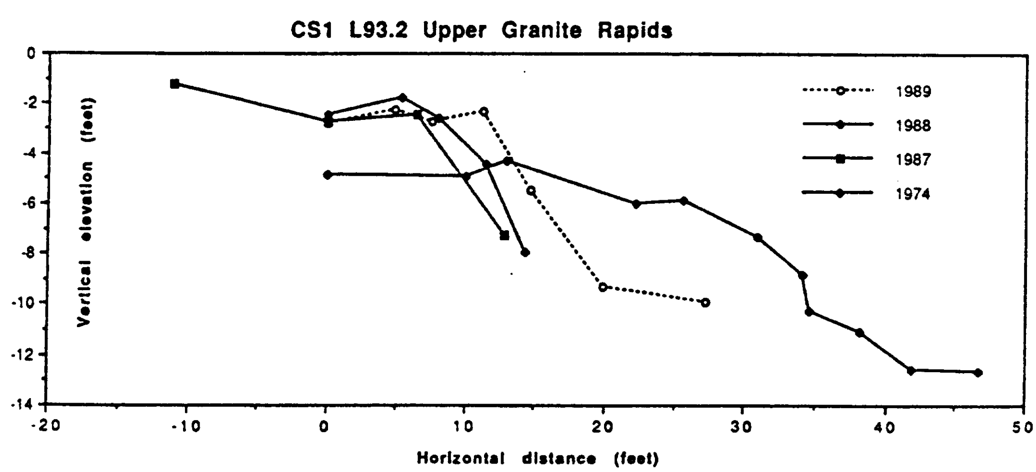

Figure 2-13. Beach profiles

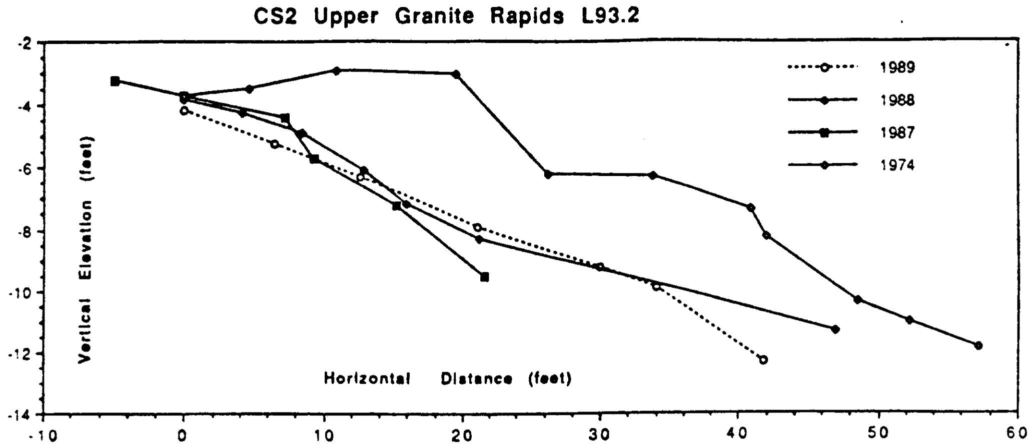

Figure 2-14 Beach Profiles

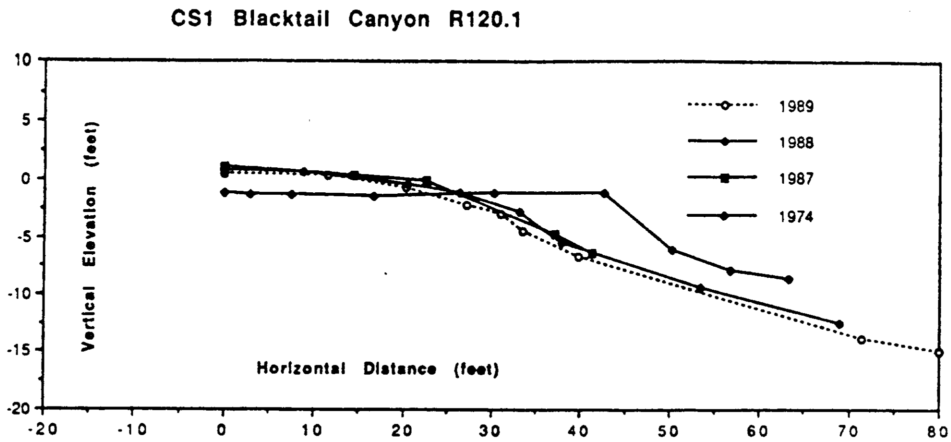

Figure 2-15. Beach profiles.

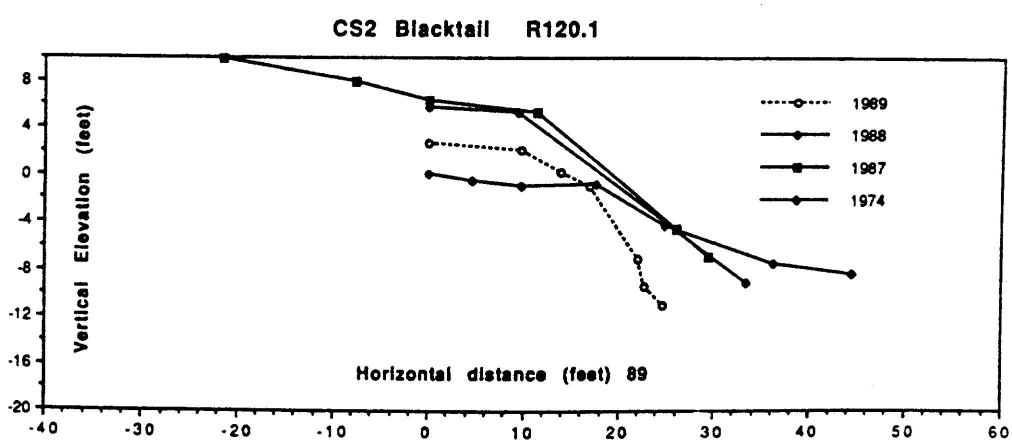

Figure 2-16

CS1 122 - Mile Beach R 122.0

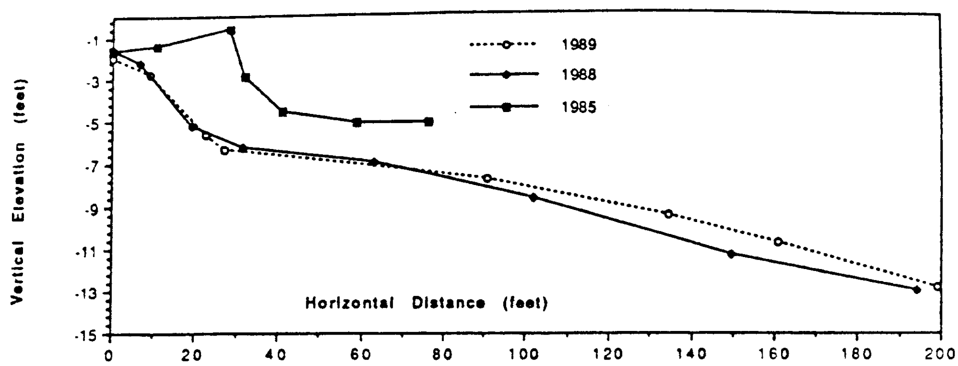

Figure 2-17. Beach profiles.

CS2 122 - Mile Beach R 122.0

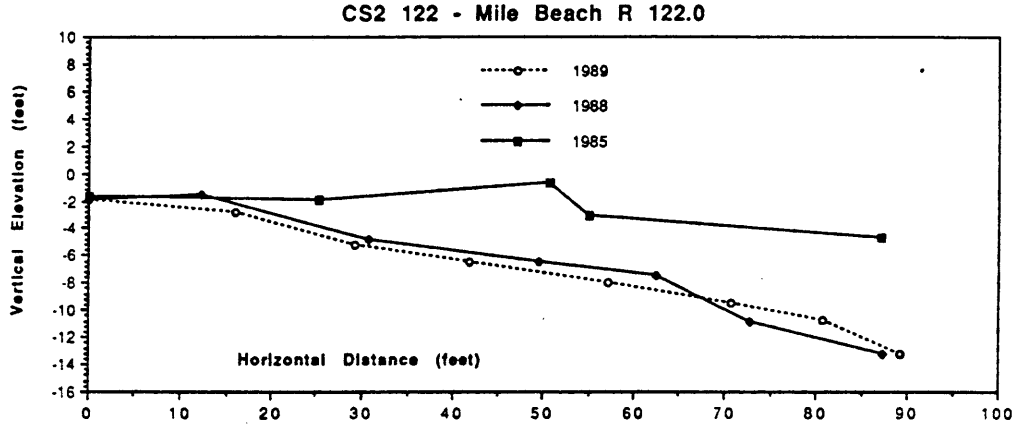

Figure 2-18. Beach Profiles.

CS1 Forster Canyon R 122.8

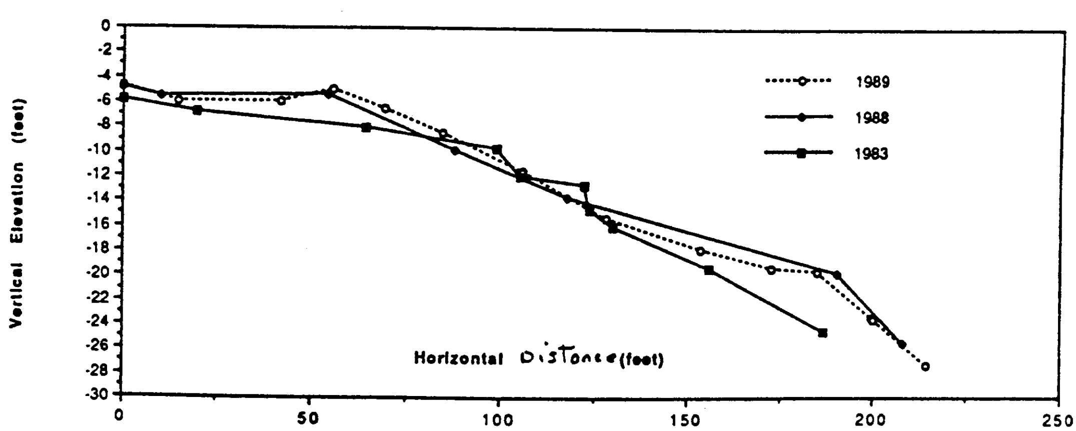

Figure 2-19. Beach profiles.

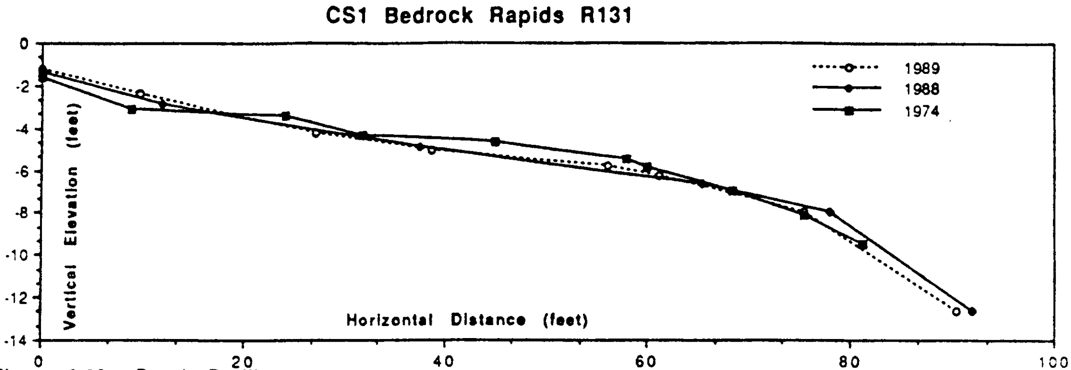

Figure 2-20 Beach Profiles

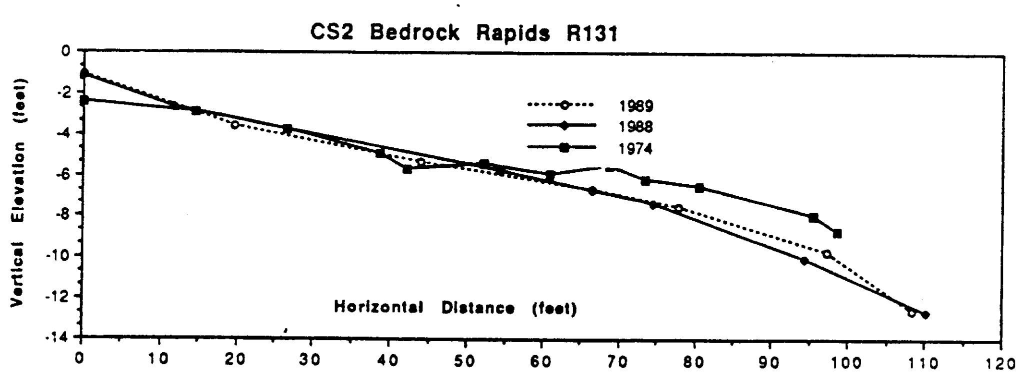

Figure 2-21 Beach Profiles

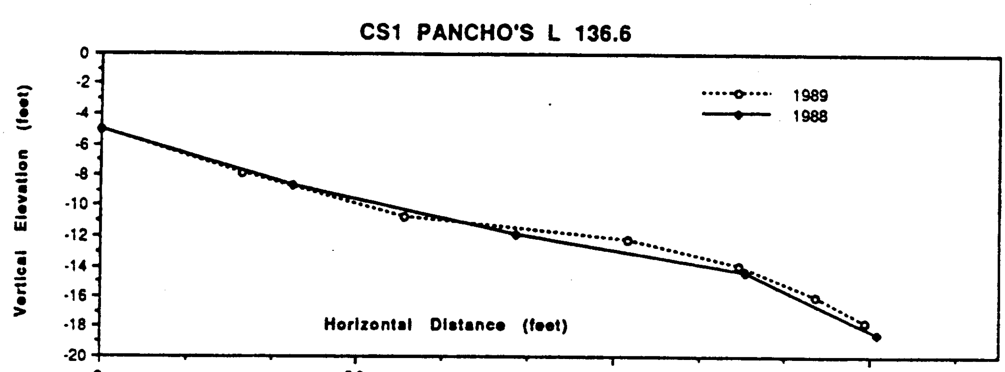

Figure 2-22 BEACH PROFILES

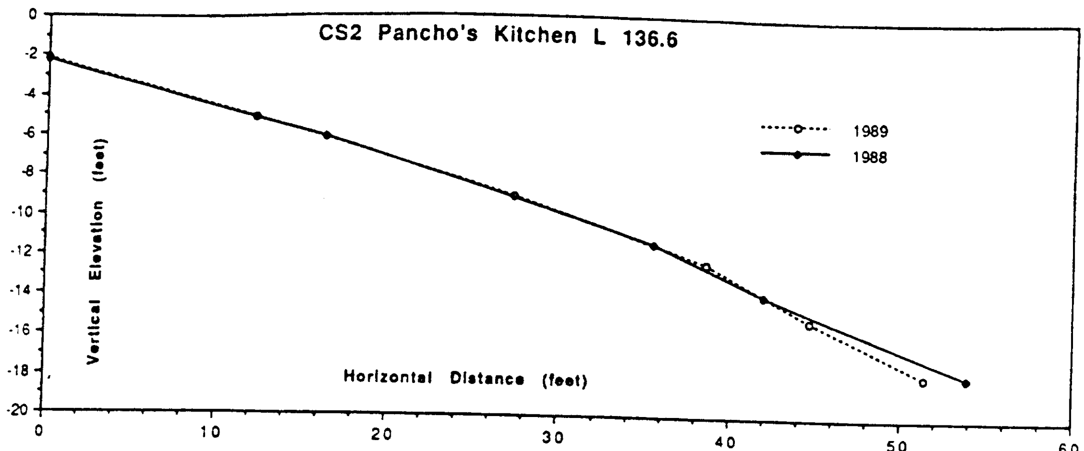

Figure 2-23 Beach Profiles

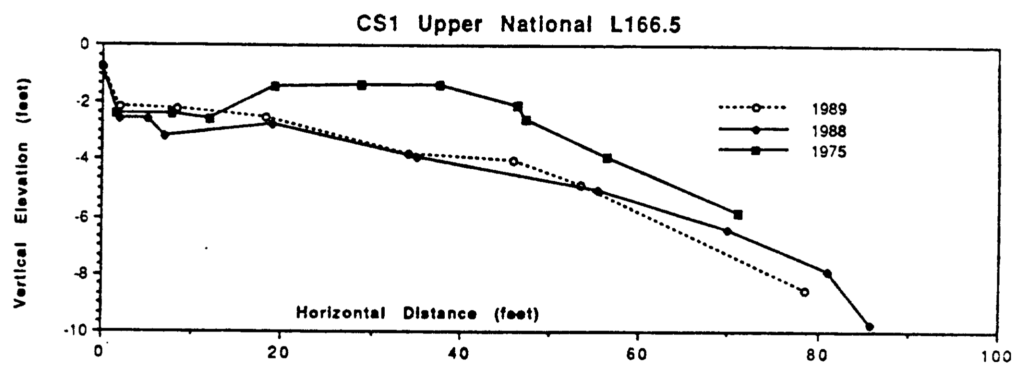

Figure 2-24 Beach Profiles

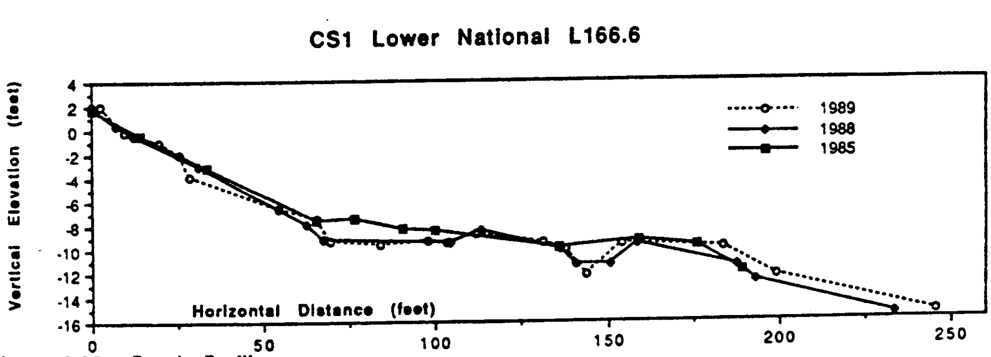

Figure 2-25 Beach Profiles

CS2 Lower National L166.6

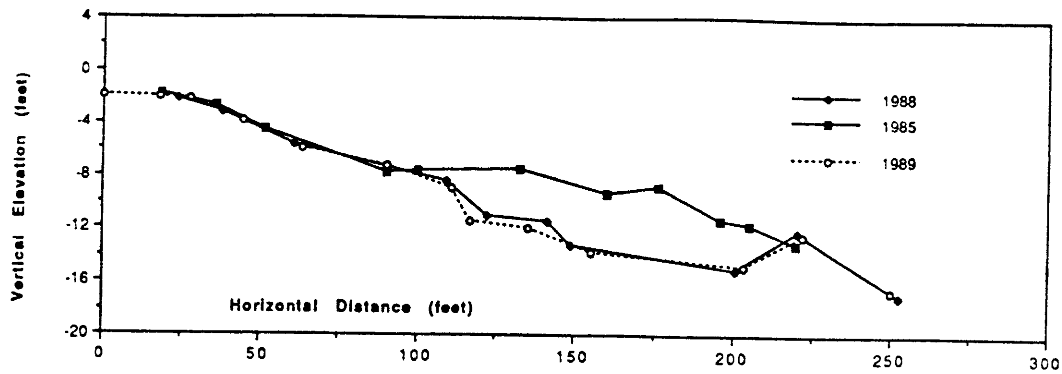

Figure 2-26 Beach Profiles

CS3 Lower National L166.6

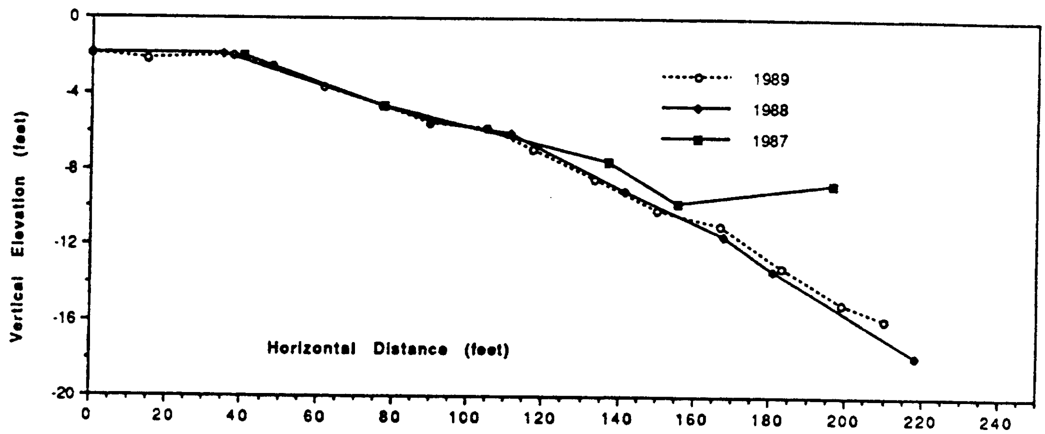

Figure 2-27 Beach Profiles

CS4 Lower National L166.6

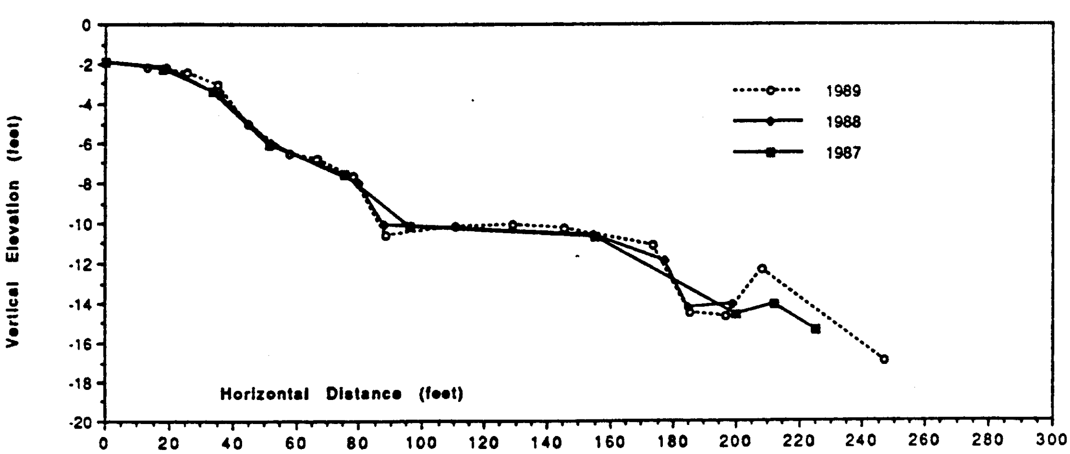

Figure 2-28 Beach Profiles

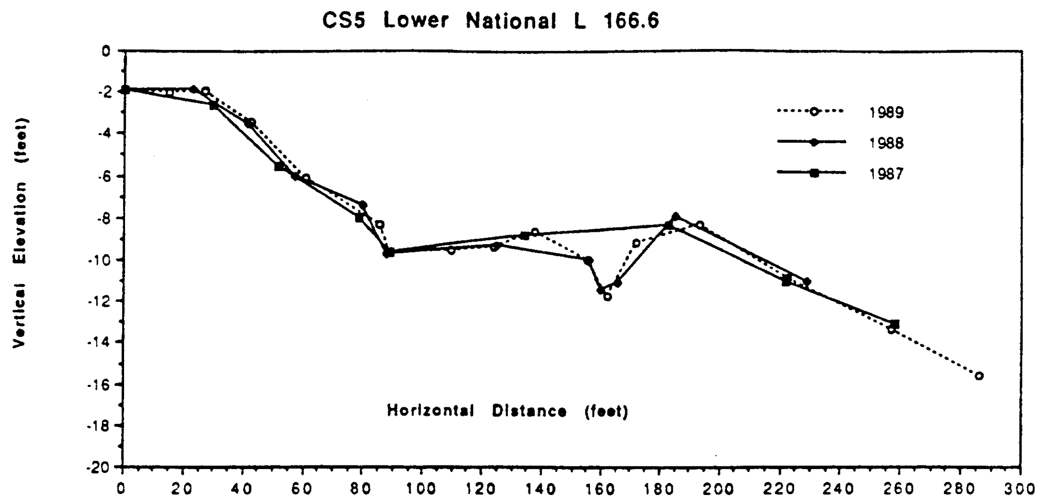

Figure 2-29 Beach Profiles

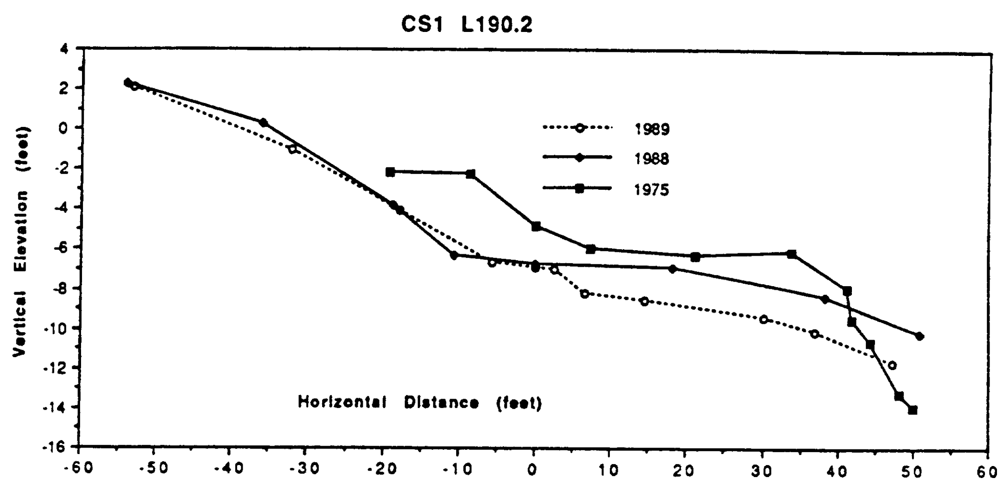

Figure 2-30 Beach Profiles

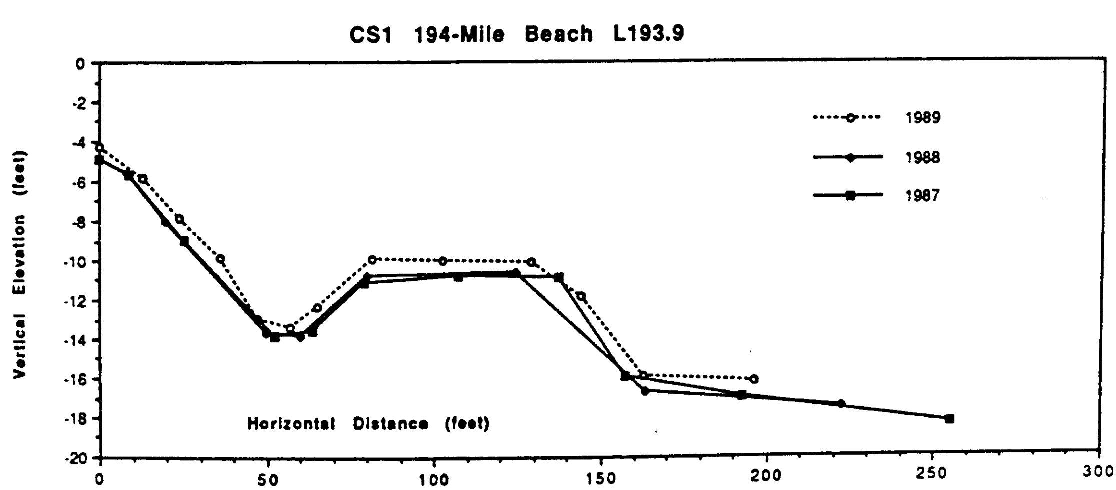

Figure 2-31. Beach profiles

CS2 194 - Mile Beach L193.9

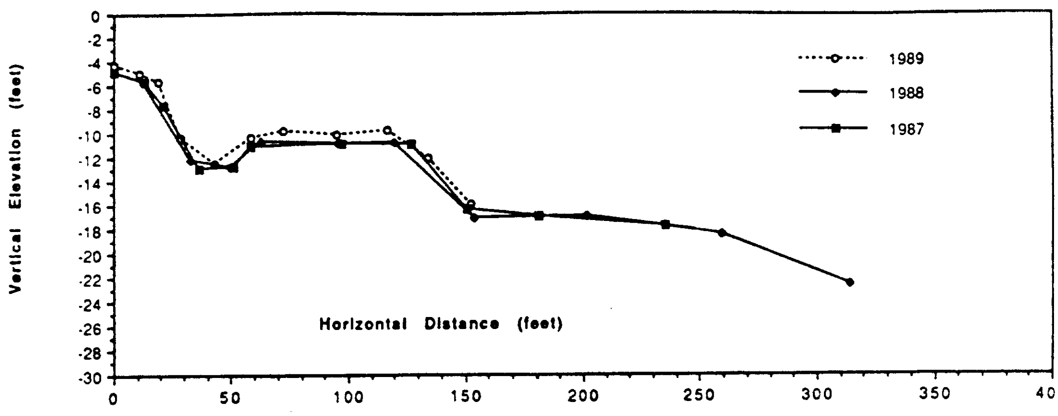

Figure 2-32. Beach profiles

CS3 194 - Mile Beach L193.9

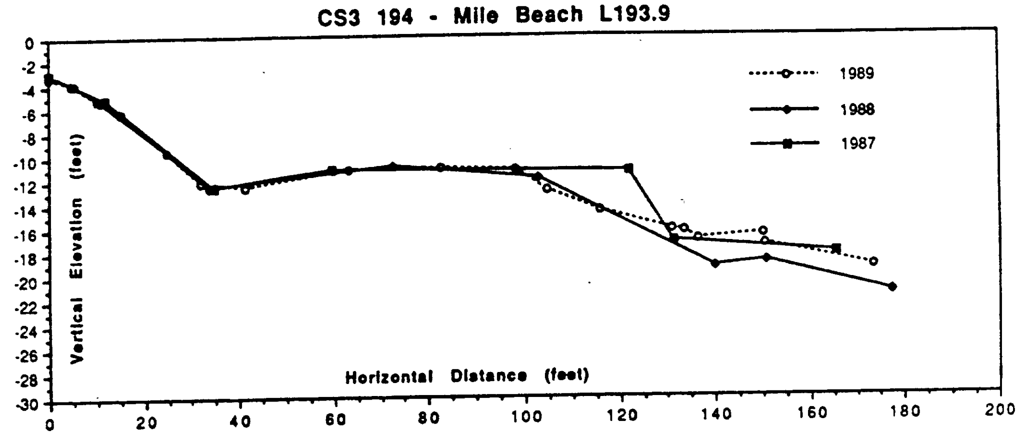

Figure 2-33. Beach Profiles

CS1 Granite Park L208.8

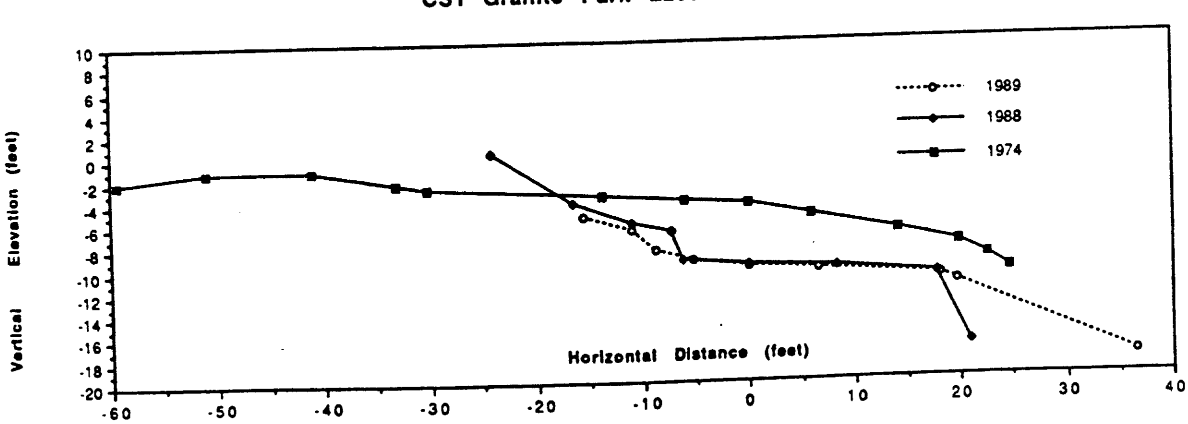

Figure 2-34

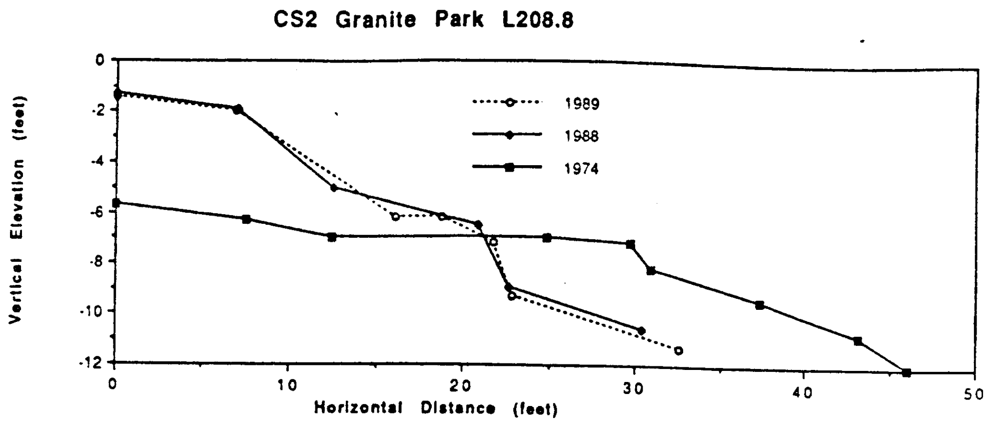

Figure 2-35

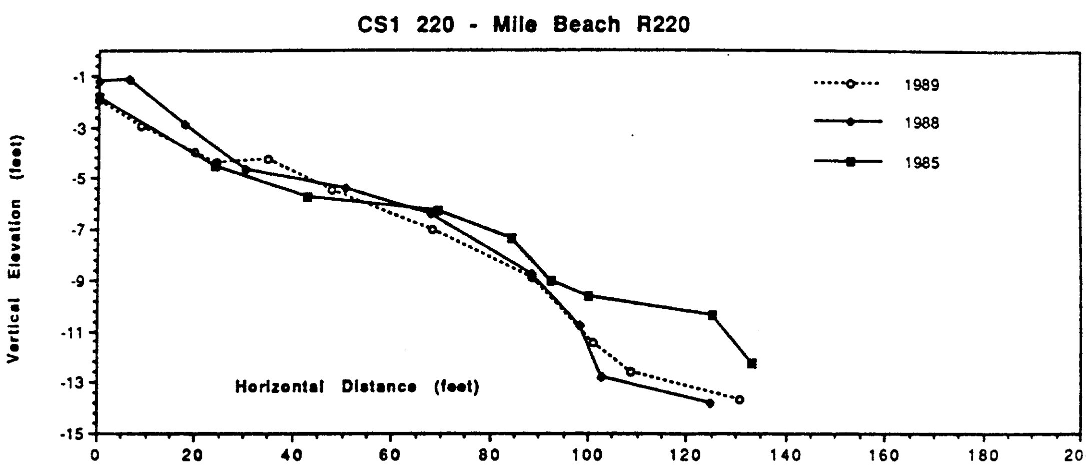

Figure 2-36. Beach profiles

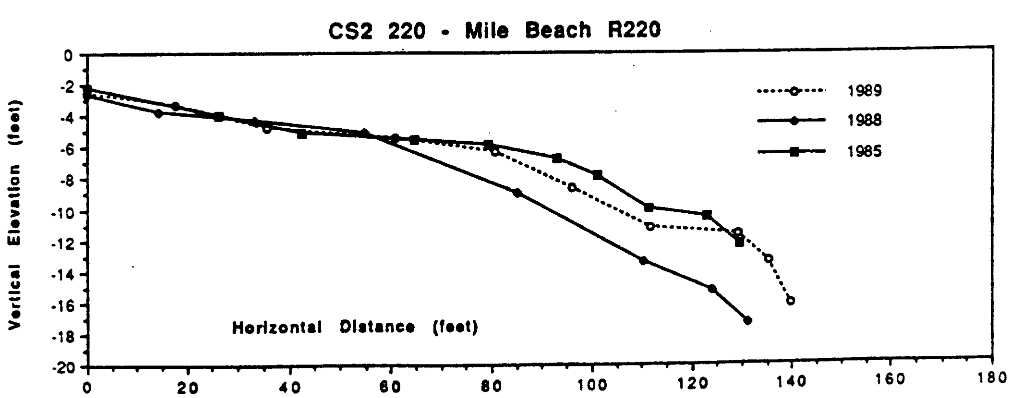

Figure 2-37. Beach profiles

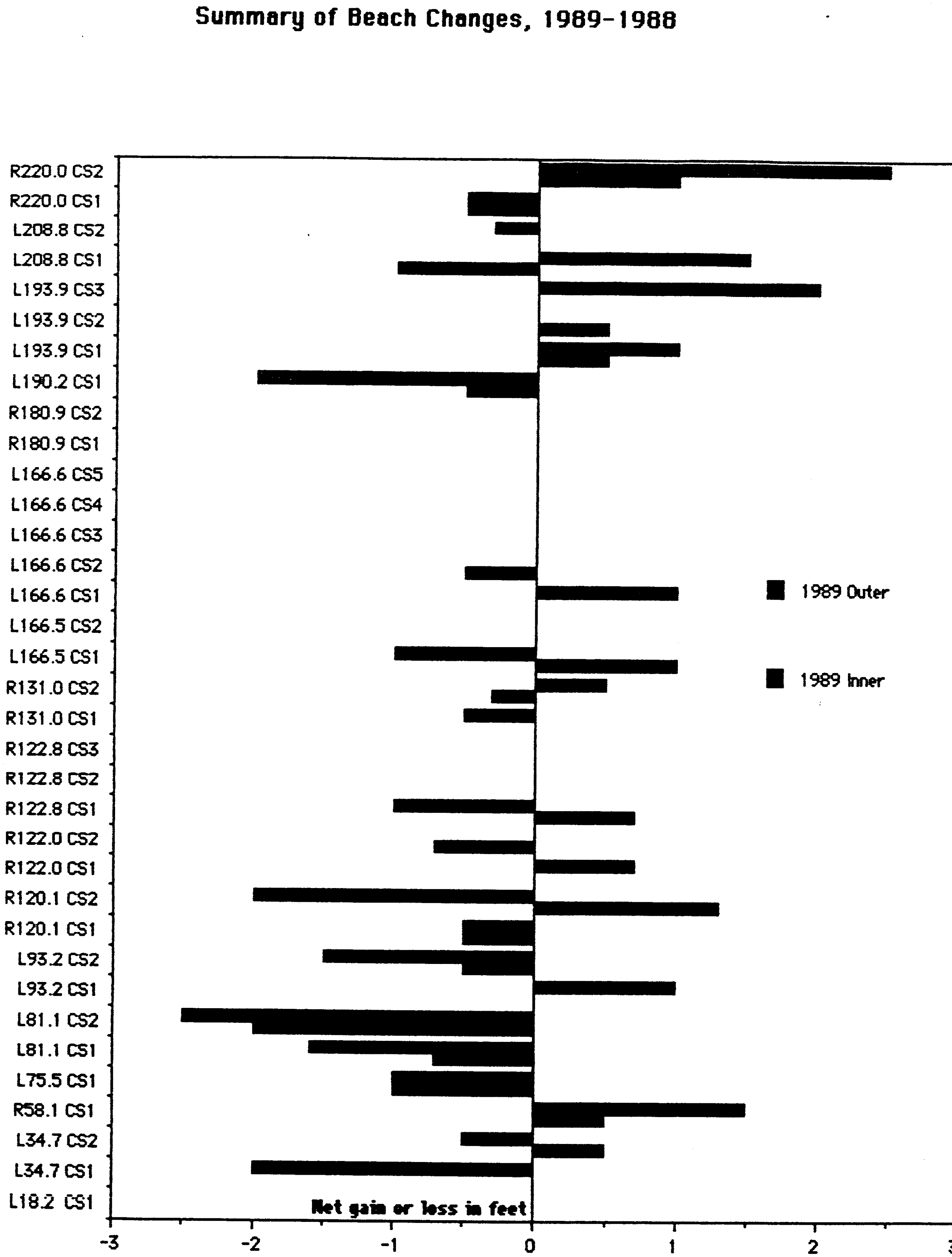
Summary of Beach Changes, 1989-1988
R220.0 CS2
R220.0 CS1
L208.8 CS2
L208.8 CS1
L193.9 CS3
L193.9 CS2
L193.9 CS1
L190.2 CS1
R180.9 CS2
R180.9 CS1
L166.6 CS5
L166.6 CS4
L166.6 CS3
L166.6 CS2
L166.6 CS1
L166.5 CS2
L166.5 CS1
R131.0 CS2
R131.0 CS1
R122.8 CS3
R122.8 CS2
R122.8 CS1
R122.0 CS2
R122.0 CS1
R120.1 CS2
R120.1 CS1
L93.2 CS2
L93.2 CS1
L81.1 CS2
L81.1 CS1
L75.5 CS1
R58.1 CS1
L34.7 CS2
L34.7 CS1
L18.2 CS1
1989 Outer
1989 Inner
Net gain or loss in feet
-3
-2
-1
0
1
2
3

Fig 2-33

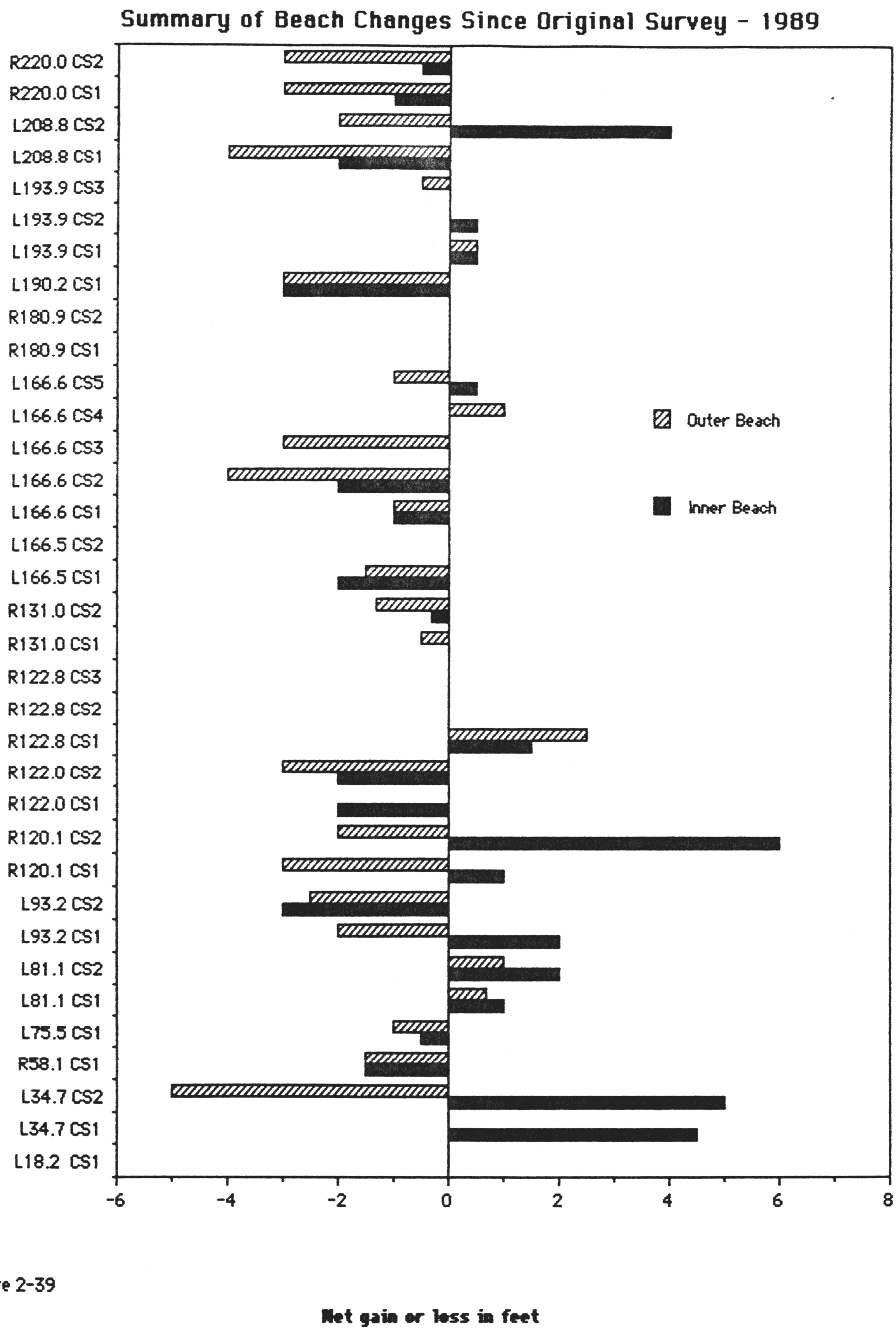
Summary of Beach Changes Since Original Survey - 1989
R220.0 CS2
R220.0 CS1
L208.8 CS2
L208.8 CS1
L193.9 CS3
L193.9 CS2
L193.9 CS1
L190.2 CS1
R180.9 CS2
R180.9 CS1
L166.6 CS5
L166.6 CS4
L166.6 CS3
L166.6 CS2
L166.6 CS1
L166.5 CS2
L166.5 CS1
R131.0 CS2
R131.0 CS1
R122.8 CS3
R122.8 CS2
R122.8 CS1
R122.0 CS2
R122.0 CS1
R120.1 CS2
R120.1 CS1
L93.2 CS2
L93.2 CS1
L81.1 CS2
L81.1 CS1
L75.5 CS1
R58.1 CS1
L34.7 CS2
L34.7 CS1
L18.2 CS1
Outer Beach
Inner Beach
-6
-4
-2
0
2
4
6
8
Net gain or loss in feet

Figure 2-39

Table 2-1. Beach Profiles Surveyed.

River Mile	Beach Nam	1974	1975	1980	1982	1983	1984	1985	1986	1987	1988	1989
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
L34.7	Nautiloid Canyon	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
R61.8	Mouth of the Little Colorado	1		1		1	1	1	2	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
L81.1	Grapevine	2		2		2	1	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
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
R122.0	122 Mile Beach (new 1985)							2	2	2	2	2
R122.8	Forster Canyon (new 1983)					3	3	3	3	2	3	1
L124.4	Upper 124 1/2 Canyon (gone)	2			X	1						
R131.0	Bedrock Rapid	2		2		2	2	2	2	2	2	2
L136.6	Pancho's Kitchen (new 1988)										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
L166.6	Lower National (new 1985)							2	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
L208.8	Granite Park	2	2	2	1	2	2	2	2	2	2	2
R220.0	220 Mile Beach (new 1985)							2	2	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)
1987 data from Beus and others (1988)
1988 data from Beus and others (1989)
1989 data from this report

Table 2-2. Summary of loss or gain of beach sand.

Beach	Profile	1989 Inner	1989 Outer	Original Inner	Original Outer
L34.7	CS1	0.0	-2.0	4.5	----
	CS2	0.5	-0.5	5.0	-5.0
R58.1	CS1	0.5	1.5	-1.5	-1.5
L75.5	CS1	-1.0	-1.0	-0.5	-1.0
L81.1	CS1	-0.7	-1.6	1.0	0.7
	CS2	-2.0	-2.5	2.0	1.0
L93.2	CS1	0.0	1.0	2.0	-2.0
	CS2	-0.5	-1.5	-3.0	-2.5
R120.1	CS1	-0.5	-0.5	1.0	-3.0
	CS2	1.3	-2.0	6.0	-2.0
R122.0	CS1	0.0	0.7	-2.0	----
	CS2	-0.7	0.0	-2.0	-3.0
R122.8	CS1	0.7	-1.0	1.5	2.5
R131.0	CS1	0.0	-0.5	0.0	-0.5
	CS2	-0.3	-0.5	-0.3	-1.3
L136.6	CS1	-0.3	0.7	---	---
	CS2	0.0	-0.5	---	---
L166.5	CS1	1.0	-1.0	-2.0	-1.5
L166.6	CS1	0.0	1.0	-1.0	-1.0
	CS2	-0.5	0.0	-2.0	-4.0
	CS3	0.0	0.0	0.0	-3.0
	CS4	0.0	0.0	0.0	1.0
	CS5	0.0	0.0	0.5	-1.0
L190.2	CS1	-0.5	-2.0	-3.0	-3.0
L193.9	CS1	0.5	1.0	0.5	0.5
	CS2	0.5	---	0.5	---
	CS3	0.0	2.0	0.0	-0.5
L208.8	CS1	-1.0	1.5	-2.0	-4.0
	CS2	0.0	-0.3	4.0	-2.0
R220.0	CS1	-0.5	-0.5	-1.0	-3.0
	CS2	1.0	2.5	-0.5	-3.0

CHAPTER III

GRAND CANYON BEACHES: A STUDY OF SELECTED CAMPSITES FOR SUITABILITY

Robert LaChat
and
Chris Pike

INTRODUCTION

The beaches within the Grand Canyon represent a major recreational resource for the river runners and backpackers of the Grand Canyon. During the summer of 1989 selected Campsites were classified according to camper capacity, shoreline composition, degree of active and inactive erosion, flash flood potential and professional boatmen's overall opinion of campsite suitability.

Before 1963 and the completion of Glen Canyon Dam, the yearly floods from the Rocky Mountains would bring sediment into the Grand Canyon and replenish the eroded campsites. Since 1963 this sediment has been trapped in Lake Powell, leaving the campsites to be eroded by flash floods, wind and human contact (Kalinowski, Spencer and Staats 1987). Also contributing to erosion of the beaches is the daily fluctuation of the Colorado River due to operations at Glen Canyon Dam. "Current operations will result in loss of some beaches in the long term" (Glen Canyon Environmental Studies Final Report Jan. 1988).

This report presents the results of the 1989 Campsite Inventory of beaches from Lee's Ferry to Diamond Creek in Grand Canyon National Park. The research was conducted as part of the annual Northern Arizona University Research Expedition which ran from July 25th through August 5th 1989.

METHODS

This investigation followed guidelines and used campsite survey sheets designed during the 1987 inventory (Kalinowski, Spencer and Staats, 1987). In addition to this a boatmen survey was added (see table 3-1). Our research team felt that the boatmen were a neglected resource in the past. We felt they should be surveyed as they are the ones that determine if a campsite is suitable for a group or not. Two experienced boatmen on the trip, Brian Dierker and Pete Resnik were surveyed along with an outside boatman from Grand Canyon Expeditions. The data collected from these boatmen has been added to this report as a point of comparison with observations made by previous researchers and our selves. Phase two of the inventory will be completed when surveys are returned by al commercial companies that run the Colorado river through the Grand Canyon. This data will be available to future campsite researchers.

Although the observations are subjective the following guidelines were used during the on site inspection of the beaches to help insure consistency.

1. Campsite Location

   Camps were identified by name and river mileage (The Colorado River in Grand Canyon A Guide, Stevens 1983). In some cases beaches are identified only as river mileage, with an accuracy of plus or minus one tenth of a mile. An "L" represents the left side of the river when looking downstream and an "R" represents the right side of the river when looking downstream.

2. Campsite Capacity

   Campsite size or capacities were broken into three groups. Small 15-20 people, Medium 21-30 groups, and Large 31 to 40+. The maximum size of parties is limited by the Park Service to 16 for private groups and 36 (not including crew) for commercial ventures.

3. Shoreline Composition

   To determine shoreline composition it is necessary to find a high spot (rock or ledge) on the beach where the researchers can get a good view of the entire shoreline. By using two researchers more accurate approximations of percentages can be achieved through discussion and compromise. The researchers assessed the percentage of shoreline covered by rock armoring, sand, and vegetation. rock armoring was broken into three groups: rock, boulder, and ledges. Vegetation was noted by the dominant specie or species.

4. Erosion of Shoreline

   Shoreline erosion was determined by walking along the beach shoreline. Shoreline erosion was placed into three categories, active cutbanks, inactive cutbanks and no apparent erosion. Measurements were also made in meters of the height of the active and inactive cutbanks. It should be noted here that river flow greatly affects what is observable to the researchers. During our river trip the flow fluctuated between 7,000 C.F.S. and 30,000 C.F.S. When the river was low more erosional cutbanks were visible, when the river was high much of the erosion features were hidden under the water.

5. <u>Beach Equilibrium</u>

Beach equilibrium is a prediction of what the beach will be doing in the future. We divided these predictions into three categories: stable, influx, and unstable.

A stable beach is one that has reached stability and is not eroding. Beaches which are stable show characteristics of no active cutbanks, have a lower profile at shoreline and usually are protected by rock armoring or vegetation.

An influx beach was a beach where some active erosion was visible but partial stabilizing was apparent. Characteristics of this beach type were a moderate beach angle, inactive cutbanks and semi protection by rock armoring and or vegetation.

An unstable beach was one showing much active erosion. Characteristics of this beach type are a high angle at the shoreline active cutbanks and many times an active shoreline current.

6. <u>Flash Flood Potential</u>

Flash flood potential was determined by locating side canyon washes if any and overhanging cliffs and their proximity to campsites. We broke these down into four groups. High flash flood areas were ones in which the side canyon emptied directly through the camp area. Medium flash flood areas were ones contained in channel but heavy flows could cause problems. Low flash flood meant wash area was far enough away that only a major flow would mean trouble. Beaches listed as having none meant that there were no wash areas or cliff overhangs n the area.

7. <u>Boatmen Survey</u>

Boatmen were surveyed (see 3-1). They were asked their opinions or what makes a beach suitable, if campsite suitability has improved or decreased, what the biggest threat to campsite suitability is. They were also asked to name their favorite beaches in each of eight reaches described by Staats 1987. Finally, boatmen were asked to rate 25 of the 37 beaches we inventoried as to suitability with a number 1-5 with 1 being the most suitable and 5 being the least.

8. <u>Beach Angle</u>

A Bruton Compass was used to determine the beach angle at the shoreline. Place a clipboard at the same angle as the beach sand at water's edge then determine the angle with a Bruton Compass.

RESULTS AND DISCUSSION

During the 1989 trip we were able to survey 37 of the 49 beaches surveyed by Kalinowski, Spencer, and Staats in 1987. We used 1987 as a comparison because we had more matched beaches than in 1988. Our results show a marked change in capacity of the beaches from the 87 surveys (3-2). The beach capacity was rated upward in each area with our survey indicating an increase from 37% for large capacity beaches in 1987 to 67% in 1989. We felt this large change was due to the bias inherent in the researchers. When looking at a beach for capacity we decided capacity should be how many campers an area can possibly hold. For instance we had a large group (40+) when the crew was included and we were able to camp at mile 20.0--a beach indicated by Kalinowski, Spencer and Staats to be only a medium capacity beach. This would seem to explain our decrease in small and medium beaches--35% to 11% and 28% to 22% respectfully.

The left side of the corridor yielded 51% of the beaches surveyed and the right side 49% (3-3). This is consistent with the 87 surveys that indicated 53% of the beaches surveyed were on the left side and 47% on the right side.

The shoreline composition data indicated no accountable change in vegetation--14% in 87 to 13.5% in 89. One beach (194) did show a huge increase in vegetation as Tamerisk has taken over a large tidal flat. Our studies did record a trend from sand shoreline which was 49% in 87 and 43% in 89 to rock shoreline of 35% in 87 to 43% in 89.

Erosion type is where the largest changes seemed to occur. In 1987 the survey indicated only 28% of the beaches showed any signs of active erosion. Our studies indicate a huge jump to 70%. Much of this change may be assumed to come from surveys at different water levels of the river. We also marked a drop in inactive cutbanks from 35% in 87 to 8% in 89. This indicates inactive banks recorded in 87 had become active once again. We also see that beaches that showed no erosion in 87 decreased from 37% to 22% in 1989.

When we look at Beach Equilibrium, and the prediction of future beach erosion we see a decrease in both stable and unstable beaches and an increase in beaches that were influx. Stable beaches fell from 43% to 22%, unstable beaches fell from 51% to 41% while influx beaches increased from 6% to 38%. This indicates many of the stable beaches have begun to become less table and are influx, while many of the unstable beaches have become more stabilized.

Flash flood potential on beaches showed much consistency with the 1987 data except for the area of medium and high areas. Medium flash flood areas dropped from 22% to 8% from 87 to 89 and high areas increased from 10% in 87 to 24% in 89. The change in the medium and high flash flood areas may be due to the fact that the Canyon was experiencing flash flooding during the time of the trip and recent flooding was more evident to the researchers. Also both researchers had been on earlier trips and could remember instances of flooding on certain beaches.

The addition of the beach survey by boatmen add their opinions for the first time. The boatmen seem to be in agreement that camp suitability has decreased over the past few years. Their statements indicate they believe that rapid water flow fluctuations has removed beach sands and therefore camping area and the overuse of beaches has also decreased the suitability (3-1; 3-4).

CONCLUSIONS

From comparing the 1987 data of matched beaches to 1989 data we see that the majority of the beaches have become less suitable due to more evident erosion of the shoreline. Only 22% of the beaches appear to be in the stable category. This indicates that erosion is continuing to remove needed sand from the beaches. These researchers observed that during times of rapid water drop "false springs" would form when trapped water in the sand would escape back to the river. Much sand was seen leaving the beaches in these "water gullies." Our studies show 78% of the beaches are undergoing some kind of change and a marked increase from previous surveys. Beaches overall have become less stable, indicating problems in the future for river runners finding suitable campsite locations for their groups.

In our results we indicated that we had a large increase in the large capacity sites and a drop in small and medium sites. We feel this is due to the fact boatmen are now using small and medium sites to replace previous large sites that are being lost to erosion. As a result campsite comfort is being lowered along the river corridor as usable space decreases.

Beaches that seem to be most stable are the ones that are protected by either rock armoring or vegetation. Beaches on the back side of eddies are the only ones that appear to be building.

It is our opinion that when phase two of the boatmen survey is completed a better idea of the problems facing campsite suitability will be realized. With this data, to begin with future inventories will be more complete and realistic. We will then have a better idea as to what really constitutes beach suitability to the people who utilize the campsites most often--the boatmen.

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Bureau of Reclamation Air Photos Colorado River Beaches1988

TABLE 3-1 FILLED OUT BOATMAN SURVEY

SITE SUITABILITY BOATMAN SURVEY

HOW LONG HAVE YOU BEEN A BOATMAN ON THE COLORADO RIVER? 32 years

APPROXIMATELY HOW MANY TRIPS THROUGH GRAND CANYON HAVE YOU TAKEN? 200 + ??

WHAT IS THE AVERAGE GROUP SIZE YOU RUN THROUGH THE CANYON? 20-25

WHAT DO YOU LOOK FOR AS A BOATMAN FOR A SUITABLE CAMPSITE?

a) Good spot for boats.
b) enough room for group.
c) Not overused (clean)
d) Good hiking or points of interest
e) Good location for making the next days points of interest or camp.

IN YOUR OPINION HAVE THE BEACHES BECOME MORE OR LESS SUITABLE OVER

TIME? PLEASE STATE REASONS. Less Suitable mainly because of the loss of beach sand.

IN YOUR OPINION WHAT IS THE BIGGEST THREAT TO CAMPSITE SUITABILITY IN THE GRAND CANYON? Peaking Power Water Flows

IDENTIFY YOUR FAVORITE BEACH IN EACH REACH?
R-1 MILE 0-11.3 House Rock
R-2 MILE 11.3-61.2 S. Canyon
R-3 MILE 61.3-91.1 75 Mile
R-4 MILE 91.1-121.1 First Left below Hermit Rapid
R-5 MILE 121.1-143.5 Stone Canyon
R-6 MILE 143.5-179.4 Ledges 151
R-7 MILE 179.5-213.8
R-8 MILE 213.9-225.7 220

TABLE 3-1 BOATMAN SURVEY

[illegible]
[illegible]
[illegible]

[illegible]	4
[illegible]	3
[illegible]	3
[illegible]	4
[illegible]	2
[illegible]	3
[illegible]	3
[illegible]	3
[illegible]	2
[illegible]	2
[illegible]	3
[illegible]	3
[illegible]	3
[illegible]	2
[illegible]	4
[illegible]	No Camping
[illegible]	3
[illegible]	2
[illegible]	2
[illegible]	2
[illegible]	3
[illegible]	3
[illegible]	3
[illegible]	3
[illegible]	3

[illegible] TIME TO FILL OUT THIS SURVEY.

In my mind many of these beaches are not all that suitable any more because they get used all the time. In general we try to find new camps when possible in some areas.

TABLE 3-2 COMPARISON OF 1987 AND 1989 BEACH CAMPSITES

	NUMBER		PERCENT		TOTAL	
	87	89	87	89	87	89
Capacity						
small	17	4	35%	11%		
medium	14	8	28	22		
large	18	25	37	67	49	37
Shoreline Composition (by top percent)						
vegetation	7	5	14	14		
rock	18	16	37	43		
sand	24	16	49	43	49	37
Erosion type						
active	14	26	28	70		
inactive	17	3	35	8		
none	18	8	37	22	49	37
Beach Equilibrium						
stable	21	8	43	22		
influx	3	14	6	38		
unstable	25	15	51	41	49	37
Flash Flood Potential						
none	14	9	29	24		
low	19	16	39	43		
medium	11	3	22	8		
high	5	9	10	24	49	37

TABLE 3-3 CAMPSITE DATA

CAMPSITE	RIVER MILE BANK	CAPACITY	SHORELINE COMPOSITION	EROSION	BEACH EQUILIBRIUM	FLASH FLOOD	BEACH SLOPE	BOATMEN ASSESSMENT	REACH	HUMAN IMPACT	BEACH PROFILE
ADGER	8.0L	3	B60%	3	1	L	10%	3	1	Y	N
18.mile	18.3L	1	L100%	2	1	M	5%	-	1	N	Y
9.9 mile	19.9L	2	S50%	1	2	L	10%	-	1	N	N
.CANYON	20.0R	1	B85%	1	1	H	5%	-	1	Y	N
SHINUMO	29.0L	3	B55%	3	1	L	18%	2	1	Y	N
NAUTALOID	34.7L	2	S50%B50%	3	3	H	15%	3	2	N	Y
UCKFARM	41.0R	3	B50%	1	2	M	11%	3	2	Y	N
PPER NANKOWEAP	52.0R	3	R85%	1	2	H	4%	3	2	N	N
MIDDLE NANKOWEAP	52.5R	3	T80%	1	2	0	14%	2	2	N	N
OWER NANKOWEAP	53.0R	3	T40%S40%	1	2	L	13%	2	2	N	N
WATUBI	58.1R	3	S60%	3	2	L	14%	2	2	Y	N
LOWER L.C.R.	61.8R	3	S90%	3	2	L	7%	-	2	N	N
CARBON CREEK	64.6R	3	B60%	1	2	L	11%	2	3	N	N
AVA CANYON	65.2R	2	W40%T40%	1	2	0	10%	-	3	N	N
NEVILLS	75.5L	3	R80%	3	1	L	12%	2	3	Y	Y
HANCE RAPID	76.5L	3/S	B85%	1	2	L	15%	4	3	N	N
RAPEVINE	81.1L	3	S90%	1	3	0	15%	2	3	Y	Y
RANITE RAPID	93.2L	2	S65%	1	3	L	14%	2	4	Y	Y
LOWER BASS	108.3R	3	B70%	1	2	H	5%	2	4	Y	N
PPER BLACKTAIL	120.1R	3	B/L95%	1-2	2	L	5%	3	4	N	Y
OWER BLACKTAIL	120.2R	2	B85%	1	2	L	8%	3	4	N	N
119.5 BEACH	119.5L	3	S80%	1	3	0	15%	-	4	N	N
122 BEACH	122.0R	3	S80%	1	2	L	8%	2	4	Y	Y
FORESTER	122.8L	3	S70%	1	3	H	9%	2.5	5	Y	N
BEDROCK	131.0R	1	L/B70%	1	3	H	3%	3	5	Y	Y
DEER CREEK	136.0L	1	R50%S50%	1	3	L	3%	2	5	N	N
ANCHO,S KITCHEN	136.0L	3	S90%	1	3	0	20%	2	5	Y	Y
PPER NATIONAL	166.5L	2	S100%	3	3	H	2%	2	6	N	N
LOWER NATIONAL	166.6L	3	B/R80%	3	1	H	11%	1	6	Y	Y
FERN GLEN	168.0R	3	S95%	1	1	L	6%	1	6	N	N
ILE 186	186.0L	3	S65%	3	3	0	5%	3	7	Y	N
MILE 190.2	190.2L	1	B60%	3	3	L	7%	-	7	N	Y
MILE 194	194.0L	3	S70%	3	3	0	20%	-	7	Y	Y
PARASHANT	198.5R	2	R75%	3	3	H	14%	3	7	N	N
RANITE PARK	208.8L	2	TWA60%	3	3	0	10%	-	7	N	N
UPPER 220	220.0R	3	T50%	2	1	0	14%	1	8	Y	Y
OWER 220	220.0R	3	S80%	3	3	M	15%	-	8	Y	Y

TABLE 3-4 Legend for Table 3-3

River mile	= distance downstream form Lee's Ferry (miles)
Side	= side of river when viewed downstream : "L" = left, "R" = right
Size	= camp area large enough to accommodate a river party 1 = small 15 - 20 person group 2 = meduim 21 - 30 person group 3 = large 31 - 40+ person group /s = split campsite
Actual Erosion	= type of erosion present 1 = active = cutbanks, unstable 2 = inactive = cutbanks, stabilized 3 = none = no erosion apparent
Beach Equilibrium	1 = stable = no erosion apparent 2 = influx = limited erosion or deposition 3 = unstable = erosion noticeable
Sand Discoloration Study	
Human impact	Y = Yes survey took place N = No did not survey
Beach Profile Study	Y = yes N = no
Reach	= which of 8 - 30 mile reaches beach was in.
Flash Flood Potential	0 = none, L = low, M = medium, H = high
Shoreline composition	= highest % of shoreline covering = Rock Armoring (3 types) R = rocks, B = boulders L = ledges = Vegetation (3 types) T = tamerisk, W = willow, A = arroweed = sand = S

TABLE 3-5 Boatman Survey General Information

The 3 boatmen surveyed fit the following profile :

1. Average of 23.3 years of running the Colorodo River
2. Average of 183 trips down the Colorodo River
3. 27.3 people was the average size group these boatmen took down the river.

I. The order of what these boatmen look for in a suitable campsite:

1. A good spot for mooring the rafts. (Easy access for getting equipment in and out of the rafts.)
2. Enough room for the group
3. Clean beach - low human impact
4. Points of interest such as side hikes
5. Morning and evening shade
6. Set-up point for the following days agenda

II. When asked if the beaches were more or less suitable then years ago all three boatmen felt the beaches had become less suitable.

III. When asked what they felt was the number one threat to campsite suitability all three boatmen sited rapid flucuations of water level in the river as their biggest concern. Another concern listed by two of the boatmen was the overuse of many of the beaches.

CHAPTER IV

LIZARD DENSITY AND HABITAT STUDIES ALONG THE COLORADO RIVER IN GRAND CANYON NATIONAL PARK

JOANNE DOMBROWSKI, SUSIE SMITH

INTRODUCTION

This project attempted to quantify the preferred lizard habitat and temperature, as well as the density of lizards in the four environmental zones of the Colorado River. Zone I, farthest from the river, featured typical desert scrub vegetation. Zone II was a stable community of woody vegetation dominated by acacia and mesquite. This zone marked the old high water flood zone (OHWZ). The river reached the OHWZ for the first time since dam construction during the high water releases from Glen Canyon Dam in 1983. Zone III, a sandy beach area, was an unstable vegetative zone populated by short-lived invasion species. Zone IV marked the new high water zone (NHWZ), and was populated primarily by exotic tamarisk (<u>Tamarix chinensis</u>) and the native arrowweed (<u>Tessaria sericea</u>) (Figure IV-1). The proliferation of this riverside vegetation was a direct result of controlled river flows from Glen Canyon Dam that prevented floods which scoured away the vegetation. Until recently, it was thought that the tamarisk located in the NHWZ was of little or no value. However, findings by Warren and Schwalbe (1988) indicated that this NHWZ was not only richly inhabited by reptiles, but may be the preferred habitat.

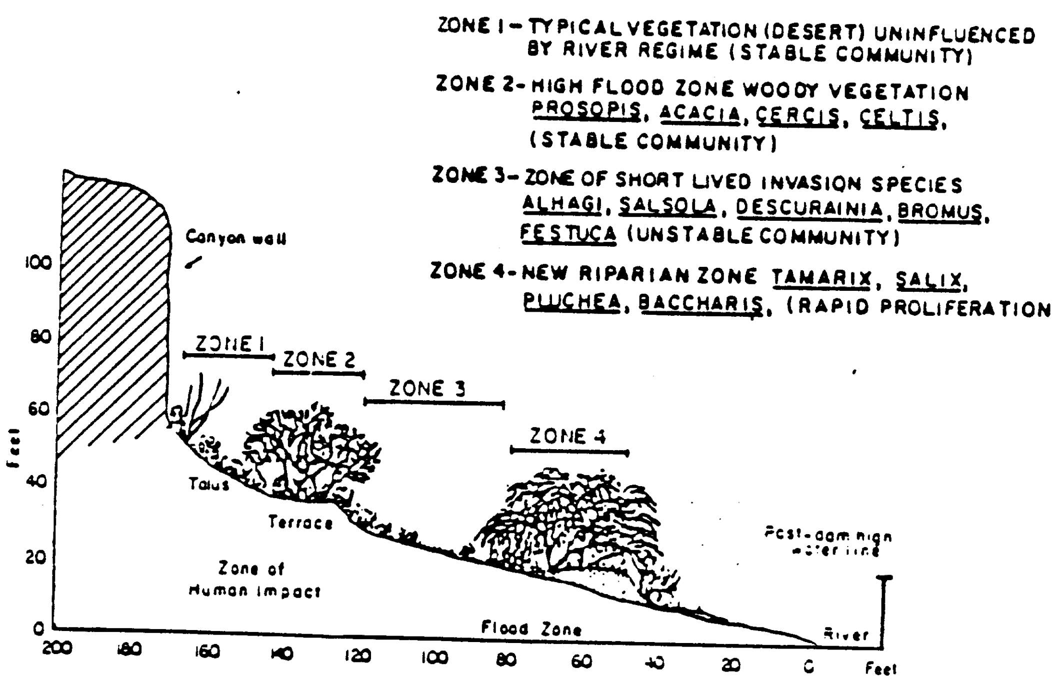

Figure IV-1. Vegetative Zones

OBJECTIVES

The objectives of this project are as follows:

1. To compare lizard densities in all four zones
2. To compare lizard species densities in all four zones
3. To compare habitat substrate texture and vegetation in all four zones
4. To compare relationships between plant species diversity and lizard species
5. To determine the types of substrate or vegetation most inhabited by different lizard species
6. To compare types of substrate or vegetation inhabited by different lizard species
7. To determine if there is a relationship between ambient and soil temperatures and the density of lizards.

HYPOTHESIS

Previous research from the course "Geology of the Grand Canyon" and as reported by Warren and Schwalbe (1988) indicated that Zone IV provided more shelter for protection and greater food source, and therefore should have a greater density of lizards and plant species than the other zones.

Since lizards are poikilothermic, rocks and vegetation cover would provide shelter from heat and predators. Therefore, lizard density should increase with abundant cover. Also, highest lizard density should occur within a narrow, optimal temperature range.

METHODS

Twenty beaches were sampled using the techniques discussed below. The four zones were visually identified by using key plants and terraces formed by the river. Zone I was located by the presence of the talis slope near the canyon walls and presence of desert plants such as agave and broom. Zone II occupied a terrace formed by the river and was inhabited by plants such as acacia, mesquite, and hackberry. Zone III was identified as approximately 10 meters behind the riparian habitat distinguishing Zone IV. Zone IV was identified by locating the stands of tamarisk and willows.

Using a data record sheet (Figure IV-2), starting time was recorded. A shaded ambient temperature and a soil temperature were taken after three minutes and recorded, along with other pertinent data (location, date, etc.).

Beach ____
Zone ____
Date ____

REPTILE PROJECT DATA SHEET

Observer ______________ Beach Name (river mile) ______________

Date ______________ Time Start ________(A)(P) Time Stop ________(A)(P)

Ambient Temperature ________ Soil Temperature ________ Lapsed Time ________

	Vegetation Zone				Species Reptile									Habitat Characteristic			
	1	2	3	4	1	2	3	4	5	6	7	8	9	1	2	3	4
Total Number																	
Percent																	
TOTAL INDIVIDUALS PER MINUTE																	

KEY TO ZONES

1 - Desert Vegetation
2 - Old High Water Zone
3 - Back beach
4 - New High Water Zone

KEY TO REPTILES

1 - side blotched lizard
2 - desert spiny lizard
3 - western whiptail
4 - tree lizard
5 - desert collared lizard
6 - chuckwalla
7 - juvenile
8 -
9 -

KEY TO CHARACTERISTICS

1 - plant
2 - Rock
3 - sand
4 - other

Figure IV-2. Reptile project data sheet.

HABITAT CHARACTERISTICS

	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
<u>Texture</u>																														
Fine																														
Coarse																														
Other																														
<u>Ground Cover</u>																														
Plant																														
Shrub																														
Bare																														
Other																														

NOTES:

Figure IV-2. continued.

An arbitrary starting point roughly parallel to the shore was selected in a zone with a visual point of reference determined for use in maintaining an unbiased walk through a quadrant. Thirty steps were paced off, 21.3m in length, and 9.1m in width for a total of 194m^2 per quadrant, recording the substrate and vegetation cover encountered at the tip of the foot for each step.

Plant species located in the transect were identified and recorded with unknowns carefully collected, labeled, and bagged for later identification.

Lizards spotted 4.5 meters on either side of the transect line were identified and recorded, along with information on the substrate or plants they were associated with. Ending time was recorded after the transect survey was completed. The process was repeated for the remaining zones. The sampling process was carried out by a minimum of two people at a time in a zone.

MATERIALS

Clipboards
Data sheets (4/beach)
Sharpened pencils/sharpener
Plant press
Note paper
Zip-lock, sandwich size bags
Soil thermometer
Ambient thermometer
Rubber bands (for clipboard)
Calculator
Graph paper
50 m tape
Reptile identification books

RESULTS

Table IV-1 presents the density of lizards observed in each zone. The highest frequency was in Zone IV (OHWZ) with 30.9%. There was little difference in the density of lizards observed between Zones I, II, and III. When comparing lizard density by species, the side blotched (Uta stansburiana) were the most observed lizards in each of the 4 zones, constituting 45% of all lizards observed. The whip tailed (Cnemidophorus tigris) was the second highest in Zones I, II, and IV, but the least dense in Zone III, followed in density by the tree lizard (Urosaurus ornatus) in Zones I, II, and III.

The density of lizards observed per meter square is shown. The quadrants in each zone were 195m^2. Zone IV had a frequency of .103 side blotched/M^2. This is equivalent to .196 lizards/minute in Zone IV. Figure IV-3 compares the lizard density between zones. Zone II had the highest density.

In Table IV-2 fine substrate included silt, sand, and fine gravel. Zone III had the highest percent of fine substrate at 78%. Zone I had the least fine substrate at 52%. Coarse substrate included coarse gravel, pebbles, and boulders. Zone I had the highest percent of coarse substrate at 48% and Zone III the least at 22%. Ground cover included two categories: low growing plants and grass, and shrubs. The least cover was found in Zones III and IV

Table IV-1. Lizard species observed.

Species	Zone I (N=20) No. Obs. (1%) Density/M^2(No./Min.)	Zone II (N=16) No. Obs. (1%) Density/M^2(No./Min.)	Zone IIII (N=17) No. Obs. (1%) Density/M^2(No./Min.)	Zone IV (N=16) No. Obs. (1%) Density/M^2(No./Min.)	Total No. Dbs. (%)
Side Blotched	9(36.0) .0023(.05)	9(40.9) .0029(.058)	9(36.0) .0027(.054)	20(64.5) .006(.196)	47(45.63)
Desert Spiney	4(16.0) .001(.022)	1(4.55) .0003(.006)	8(32.0) .0024(.048)	2(6.45) .0006(.096)	15(14.56)
Western Whiptail	7(28.0) .0018(.038)	7(31.82) .0018(.045)	2(8.0) .0023(.012)	8(25.8) .0006(.078)	24(23.3) .0026
Tree	5(20.0) .0013(.027)	5(22.73) .0013(.03)	5(24.0) .0016(.036)	1(3.23) .0018(.010)	17(16.5) .0003
Total	25(24.27)	22(21.35)	25(24.27)	31(30.9)	103(100.0)

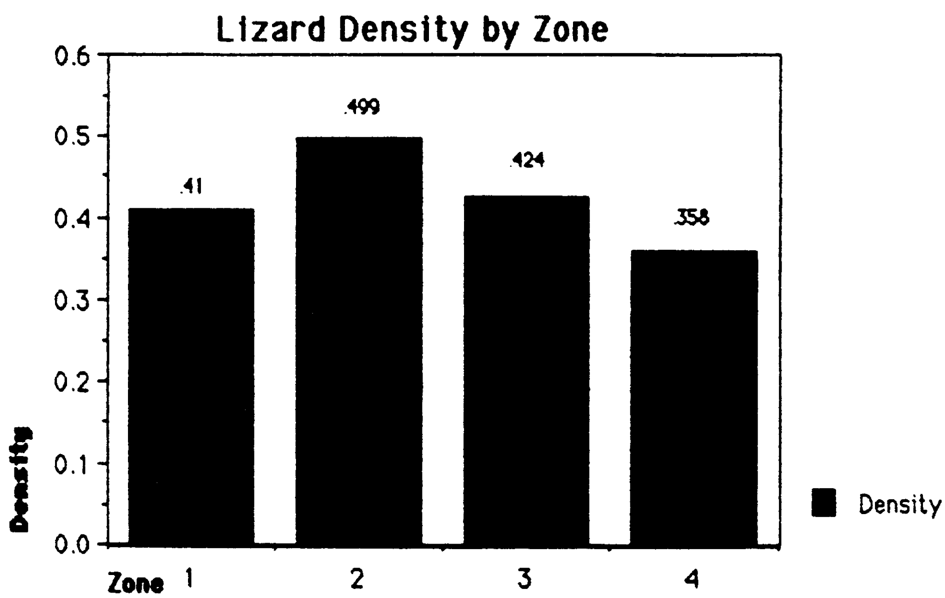

Figure IV-3. Total Lizard Density by Zone with Standard Error

Table IV-2. Habitat texture and cover.

Characteristic	% of Habitat Charcteristic Zone 1 (N=20)	Zone II (N=16)	Zone III (N=17)	Zone IV (N=16)
Fine	52	63	78	70
Course	48	37	22	30
Ground Cover	12.5	12.08	8.63	7.5
Shrub Cover	1.8	2.29	1.96	4.38

at 8.63% and 7.5% respectively. Shrub cover included all overhanging branches and shrubs of .05 meter and taller. Zone IV had the most cover at 4.4% and Zone I the least at 1.8%.

Table IV-3 reports the plant species richness found in the zones and the average number of lizards seen. Zone IV had the largest number of different plant species with an average number of 8.31 and the largest average number of lizards sighted. Zone I also had a high average plant diversity with an average of 8.05, but the smallest average number of lizards.

Table IV-3. Plant species diversity mean/quadrant.

Species	Zone 1 (N=20)	Zone II (N=16)	Zone III (N=17)	Zone IV (N=16)
Plants	8.05	7.94	7.06	8.31
No Lizards	1.25	1.38	1.47	1.94

Table IV-4 shows the relationship between lizards observed and the environment of the zones. More lizards were observed in rocks and sand with 43% and 37% respectively. There was variability in lizard/substrate association between the zones. More lizards were found on rocks in Zone I, more on sand in Zone II. In Zone III, plant/lizard associations were the most frequent, and in Zone IV, lizard/rock association were the most frequent. The most frequent association found in all zones was lizards and rocks.

Table IV-4. Lizard habitat association.

Habitat Association	Zone 1 (N=20) No. Obs.	(%)	Zone II (N=16) No. Obs.	(%)	Zone III (N=17) (No. Obs.	(%)	Zone IV (N=16) No. Obs.	(%)	All Zones No. Obs.	(%)
Rock	13	(52)	7	(29)	8	(33)	16	(53)	44	(43)
Plant	1	(4)	5	(21)	9	(38)	6	(20)	21	(20)
Sand	11	(44)	12	(50)	7	(29)	8	(27)	38	(37)
Total	25	(100)	24	(100)	24	(100)	30	(100)	103	(100)

Table IV-5 shows the relationship between lizard species and habitat. Side blotched lizards were most frequently found on rocks, as compared to sand and plants, at 59%. Whip tailed lizards were most frequently seen on sand at 50%, and spiney lizards were most seen on rocks.

Table IV-5. Habitat association by Lizard species.

Species	Rock	(%)	Plant	(%)	Sand	(%)	Total	(%)
Side Blotch	28	(59)	6	(13)	13	(28)	47	(46)
Desert Spiny	9	(60)	6	(40)	0	(0)	15	(14.5)
Western Whiptail	5	(21)	7	(29)	12	(50)	24	(23)
Tree	8	(47)	5	(29)	4	(24)	17	(16.5)
Total	50		24		29		103	

Figure IV-4 through 7 reports the temperature ranges at which lizards were observed. No lizards were sighted below 27.5°C ambient and soil temperature. No lizards were observed above 40.5°C ambient temperature and 49°C soil temperature. The ambient temperature range with the most lizards observed was 33-35°C. This range was where 38.8% of all lizards observed occurred. The soil temperature range with the most lizards observed was 33-35°C with 37.86% of all lizards. There was a sharp decrease in the number of lizards observed above and below the range of 30-38°C.

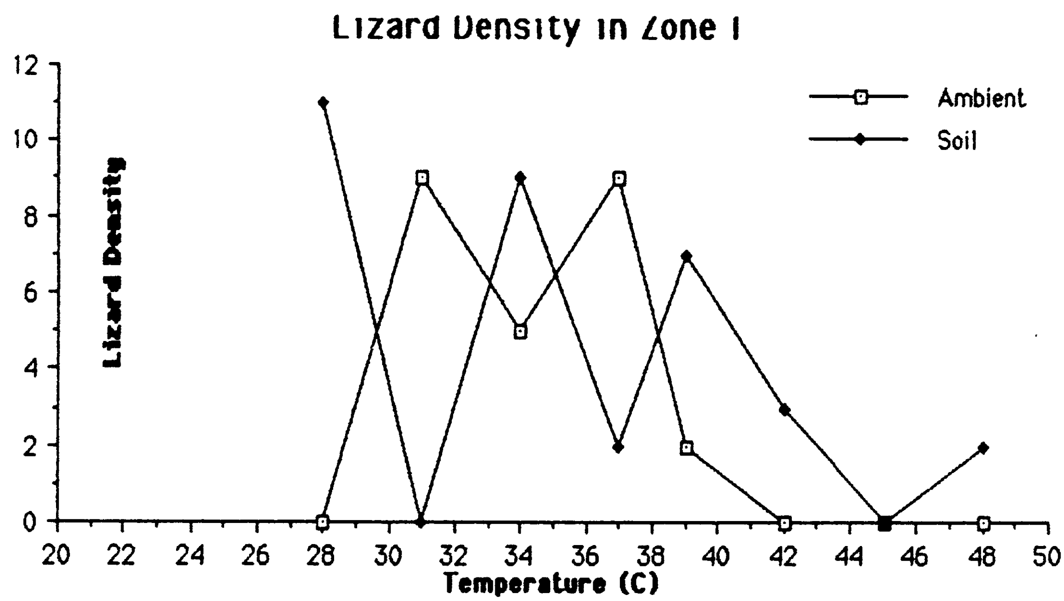

Figure IV-4. Lizard Density and Temperature Relationships, Zone 1

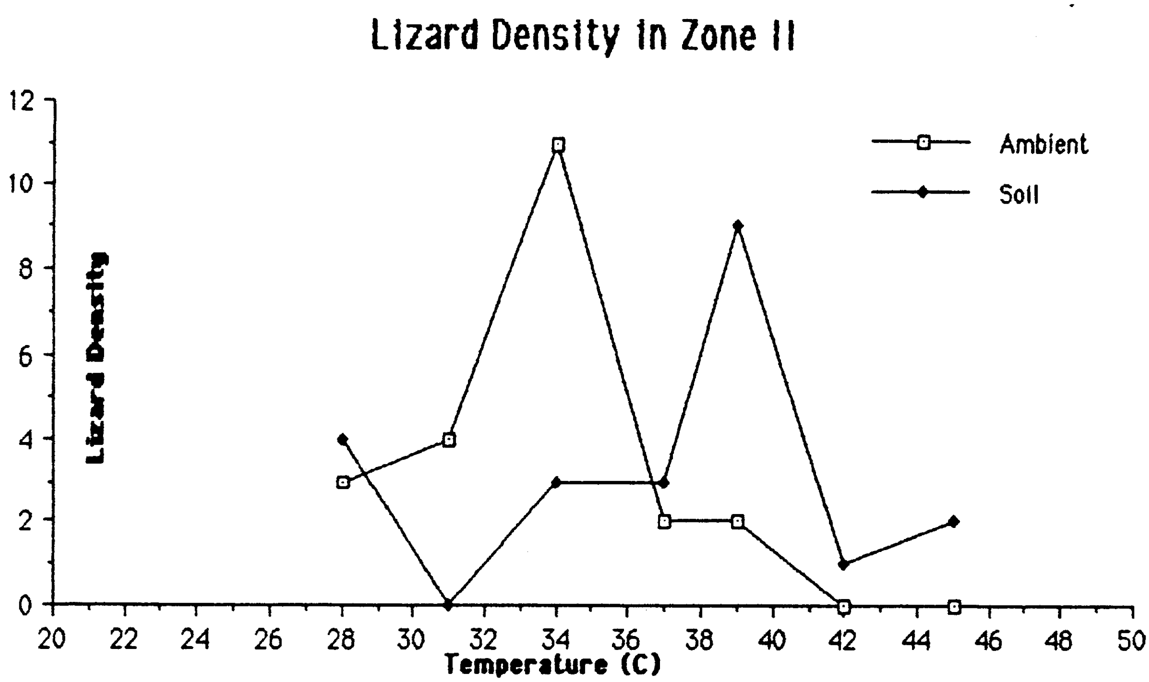

Figure IV-5. Lizard Density and Temperature Relationships, Zone II

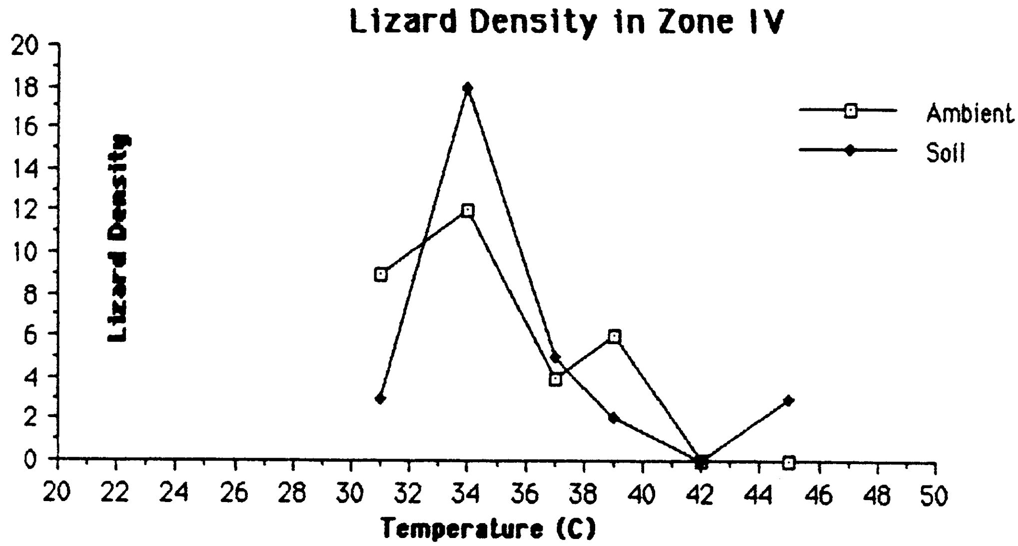

Figure IV-6. Lizard Density and Temperature Relationships, Zone IV

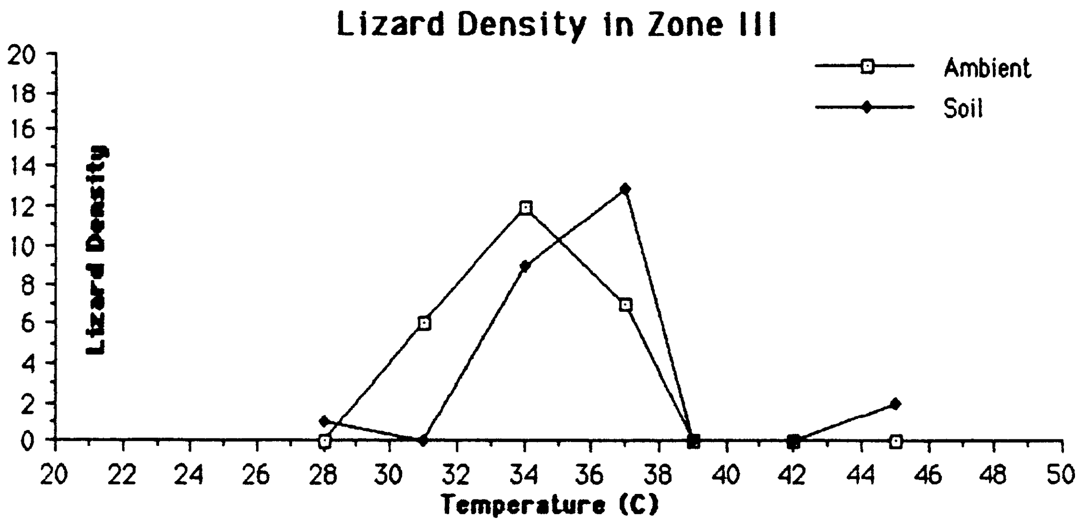

Figure IV-7. Lizard Density and Temperature Relationships, Zone II

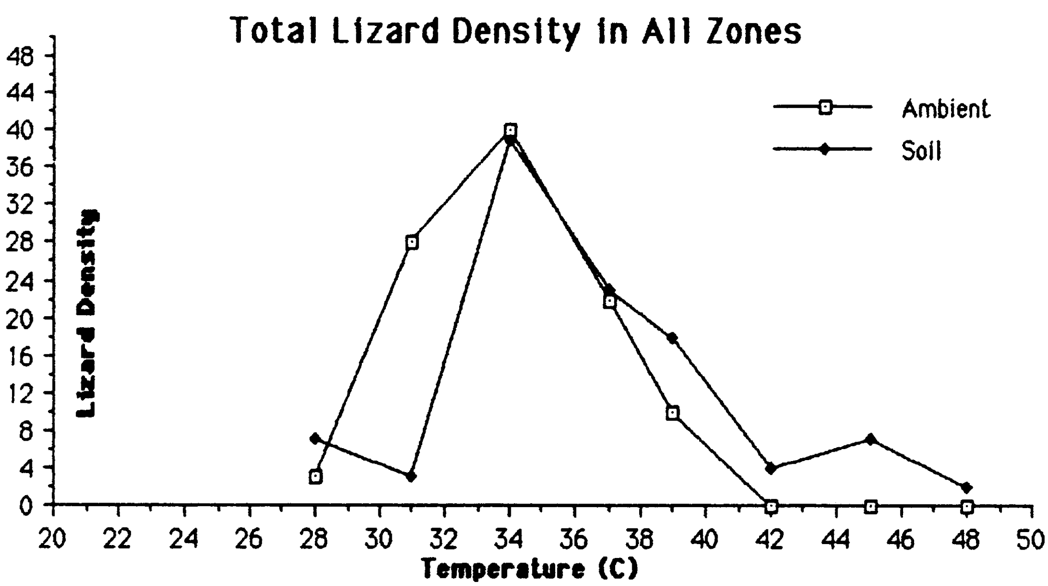

Figure IV-8. Lizard Density and Temperature Relationships, All Zones

DISCUSSION

Spacial and temporal differences limited the frequencies of inter species encounters between lizards and thus affected competition for food and habitat (Pianka, 1986). Due to the limitations posed by the time schedule, time of day of sampling was not constant from beach to beach. Because of this factor it was not possible to identify specific lizard species time preferences. The data does indicate that the time of day did affect the number of lizards observed as a factor related to temperature. Another variable in this study which may have affected the number of lizards observed was the amount of disturbance by people walking through the study site prior to the observations.

In comparing lizard densities in all zones, the riparian habitat of the NHWZ contained the highest density of lizards. This may be due to the higher abundance of food and plant cover. Pianka, 1986, lists shrubs as the preferred habitat of side blotched lizards and there were more shrubs in this zone than in the other 3 zones. The side blotched lizards had the highest density of all lizards in zone 4 (NHWZ). In comparing the densities of lizard species in the zones, it can be seen that side blotched lizards were the most abundant, followed by western whip tailed lizards. The side blotched lizards seem to be the most versatile in habitat requirements. Warren and Schwalbe, 1988, reported side blotched lizards occurring in open areas, and Pianka, 1986, reported them by shrubs. This study found a higher incidence of side blotched lizards on rocks. This would indicate that they successfully inhabited varied environments.

In comparing the habitat substrate texture and vegetation, zone 1, desert, contained the highest percentage of coarse substrate. This included pebbles and boulders. The make-up of zone 1 was approximately half coarse and half fine substrate. Zone 1 also contained the lowest percentage of shrub cover and a high percentage of ground cover, including grass and dead plant matter (duff).

There was approximately the same number of plant species in each zone. No apparent differences were noted in plant species richness. All 4 lizard species were sighted in each of the 4 zones.

In general, zone 4 had the highest lizard count, with side blotched prevaling, and also the greatest percentage of fine substrate (approximately 70%). The desert (zone 1) had 48% coarse substrate mostly composed of boulders. Relationships could not be drawn on other zones since the coarse substrate count in zones 1, 2, and 3 were basically the same, and the number of lizards were also nearly the same. The lizard species having the greatest density was the side blotched lizard. It was found in all zones and habitats. However, it was most often seen in association with rocks. Desert spiney lizards were observed most often on rocks, but Warren and Schwalbe, 1988, reported rocks and trees as the preferred habitat. Pianka, 1986, discussed the desert spiney as a climbing, ground feeding lizard. The tree lizards were most often seen in association with plants and were reported by Pianka, 1986, as inhabiting small branches of trees. Stebbins, 1985, reported tree lizards in tamarisk trees and in open areas, especially associated with river courses. Whip tailed lizards were most observed under plant cover in contrast to bare soil as reported by Warren and Schwalbe, 1988.

In comparing types of substrate or vegetation inhabited by different lizard species, the following was found: More side-blotched and tree lizards were observed on rocks, whereas there was a larger number of whiptails found on the sand. Thus the two most inhabited substrates were rock and sand.

Optimal ambient temperature for all lizards appears to be in a range of 30 - 38 degrees Celsius in the 4 zones. The soil temperature range of 33 - 40.5 degrees Celsius showed the highest number of lizards observed in all zones. The range of ambient and soil temperatures as recorded in this study, is narrow. The number of lizards in all 4 zones show a marked decrease above and below the optimal levels.

Results from this study indicate that the preferred habitat appears to be at an optimal ambient temperature range of 30 to 38 degrees Celsius, and a soil temperature of 33 to 40.5 degrees Celsius. The preferred habitat appears to be rock closely followed by sand.

RECOMMENDATIONS

1. Add a "Juvenile" category for young lizards which are difficult to accurately identify by species.

2. The lizard study team should observe the beach before other people move about on it, disturbing the lizards and preventing an accurate count.

3. Survey quadrants for lizards before collecting other data to increase sighting ability.

4. All equipment used should be calibrated in metrics.

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CHAPTER V

WATER CHEMISTRY OF THE COLORADO RIVER AND IT'S TRIBUTARIES FROM LEES FERRY TO DIAMOND CREEK

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INTRODUCTION

The Colorado River watershed is the single most important natural resource to the inhabitants of the arid Southwest. Due to the large size of this magnificant catch basin, 250,000 square miles, the Colorado and it's tributaries provide a valuable ecological barometer of it's surroundings (Stevens, 1987). Public and governmental attention over environmental concerns such as mining and agricultural methods in the Colorado River watershed area have created the need to qualify these impacts.

Accumulative ionization of the Colorado River by it's tributary streams and springs was analyzed from Lees Ferry to Diamond Creek, Arizona. It is suspected that the river has the capacity to neutralize the effects of the high total dissolve solids concentration of the Grand Canyon Drainage Basin. Field chemistry consisted of salinity, pH, conductivity, titration for alkalinity and the temperature at time of testing. Laboratory chemistry was done to check the presence of micronutients; zinc, calcium, manganese and copper.

Water chemistry analysis done on this expedition has further expanded the salinity counts found on the River Investigation Report,1988 thus increasing the amount of base line data for future use. The most significant result obtained showed a drop in the main stem pH from 8.2 in 1978 to 7.8 in 1989 (Brickler and Tunnicliff, 1980).

METHODS AND MATERIALS

Water samples were collected from 43 sites from the Colorado River and it's tributaries as shown on Figure 5-1. Sample 38 was considered an invalid collection due to the small amount collected and the large amount of sediment present. Samples were taken from three different sources as noted on Table 5-1.

Mainstem river collection was random with attention given to the primary tributary, the Little Colorado River. For this sample sites were above at the 56 mile mark. This marsh area was selected to be above any back eddies created by the Little Colorado River. The other sites were directly at the Little Colorado, at it's confluence with the Colorado, and with the mainstem at mile 81.1.

Tributary collections were taken at both creeks and springs. Direct spring sampling, without substrate contamination was noted. Drought conditions were prevalent this summer in Northern Arizona, so not all tributaries were running. Standing water and femoral stream descriptions were also noted.

Bank storage collections were done at low river pulse, less than 5.000 CFS, from natural seep unless otherwise noted. The exceptions were samples collected from hand dug holes located 0.5 meters above the present water level. This type of sampling was included due to the irregular departure times from beaches, not coinciding with the low river pulse. Main stem samples were taken nearby for comparison.

Collection analysis was performed within 24 hours for pH, conductivity, salinity, and percent milliequivalents per liter of calcium carbonate. The analysis procedure started with mouth pippeting 50 ml. of the sample into a 50 ml. plastic beaker.

Electrodes from a YSI Model 33 SCT meter were suspended in the beaker with temperature, salinity, and conductivity recorded. The meter was calibrated between each sample and the probe was rinsed into the beaker with distilled water after the data was gathered.

A ring stand, 10 ml. buret, and clamp were next set up for the titration of milli-equivalents of calcium carbonate. The initial pH was recorded, with the electrodes remaining in the sample solution for monitoring throughout the titration. Recordings of pH were made while constantly swirling the sample until a value was found to hold steady for 10 seconds. Water samples were titrated with hydrochloric acid, molarity of 0.1082, to an end point of pH 4.2 to 4.0. Titration volumes and corresponding pH values were recorded for graphing purposes.

All glassware was consistently rinsed with distilled water after each usage. The pipet and the contaminated sample bottles were flushed with chloroform and rinsed throughly with distilled water. Collected water samples were stored in a raft cooler to reduce bacteria and algae blooms and to retard the corresponding uptake of nutrients.

Upon returning to the laboratory, the samples were analyzed with a Perkin-Elmer Model 2380 atomic absorption spectrum instrument. Concentrations of calcium, manganese, copper, and zinc were determined using absorbance values verus parts per million linear graphing techniques. Standard solutions were prepared that would encompass sample absorbance values and produce a linear graph.

Statistical analysis consisted of the mean, standard deviation, and the standard error values. Due to the small sample size, standard error values and means were used for graphing.

RESULTS

Water chemistry parameters tested for in the field are graphed on Figure 5-2 thru 5-6. Tributary collection sites were further divided into standing water and true spring categories. Standing water data may vary from running water due to evaporation and settling of dissolved solids. True spring samples were taken immediately at the source before the water could make contact with the surface substrate and be contaiminated. All samples collected were taken from the surface and main stem samples were highly turbid after mile 53.

Conductivity values are graphed on Figure 5-2. Tributary samples showed the highest resistance to electrical flow, 2802μohms, therefore has the most total dissolved solids (Wetzel, 1975). Main stem or Colorado River samples were the lowest at 445μohms. Lava Creek at mile 65.5 inputs the highest amount of total dissolved solids with a conductivty reading of 28,000μohms.

Figure 5-3 depicts the high percentage of salinity found in the tributaries, 2.7%. Bank storage samples were also relatively high, 2.0%, even though these beaches are routinely soaked at high river pulse from the main stem which had an average salinity of 0.3%. Salinity values appear to be low but consistent and should be taken with a "grain of NaCl".

The logarithum of the reciprocals were used to calculate the mean ph values, Figure 5-4. These values are very consistent throughout the drainage system. True springs being slightly more acidic than the other categories at a ph of 7.39. Peggy's Pot at mile 192R, a spring that has emerged in the past 4 years and only at low river flows, had a ph of 6.83.

Alkalinity concentrations were determined in milliequivilents per liter of calcium carbonate, Figure 5-5 (Wetzel, 1975). True springs overall are adding the most amount of $CaCo_3$, 8.48 meq/L, to the river. Main Stem concentrations are the lowest, 3.75 meq/L, which is 29% of the total average tributary input.

Calcium and trace metal concentrations are listed on Table 5-2. Manganese, copper and zinc are described as trace if the concentration was less than one tenth part per million (ppm). This interval was choosen as the point of least confidence from linear graphing for results. Calcium concentrations mean comparisons were plotted on Figure 5-6. Standing water had the lowest at 29.5 ppm, again attributed to settling. Bank storage contained 49.9 ppm on the average, which is 7% greater than the main stem value of 45.5 ppm Ca. True spring and tributary amounts were nearly identical at 41.5 ppm and 40.0 ppm Ca.

CONCLUSIONS

Watershed influnce on the river appears to be complex, varied and can supersede the limits of the river corridor. Tributary input to the river is pronounced during the summer monsoon season and may have multiple impacts on the river water quality (Brickler and Tunnicliff, 1980).

The main stem of the river remained remarkably consistent for the parameters monitored through the Grand

Canyon. Capacity of the river to neutralize the effects of the tributary at first appears evident. We experienced many adiabatic cooling showers through out our expedition and encountered a flash flood of Tanner Wash at Shearwall Rapid. Localized contamination is very evident at these events as the debris within the drainage is flushed into the river. Eventually it would seem that the river's flow capacity simply dilutes the influx of material to keep the river so constant.

Our data supports the theory that the beaches deposited in the corridor may provide the buffering mechanism. A simple comparison of all the mean values examined for at bank storage and main stem sites shows that the beaches have a 29% higher average concentration overall. Considering that these alluvial deposits are soaked with river water reguarly, this difference is significant.

Further support of this idea is the fact that the rivers ph has lowered from an average of 8.2 to 7.8 from 1978 to 1989 (Brickler and Tinnicliff, 1980). The most dramatic change in the river during this time were the flooding events of 1983-84 (Stevens, 1987). These discharge rates of up to 98,600 cfs scoured out the old beaches and depoisted new or recharged sediments. Along with the recreational importance of these beaches, the integrity of the water chemistry may be influnced, further indicating the need to maintain them at historical size and replacement interval.

Trace metals in our enviornment, released by major industries, now exceed all radioactive and organic pollution combined (Weisbub, 1988). Power production plants which are abundant throughout the Colorado River watershed are point sources for nickle, selenium and cadmium. Coal fired power plants, through coal ash release, deposit copper, zinc and mercury into the soil. Several of these metals were tested for and currently are found in trace amounts. Future analysis should be continued, due to the location of the Navajo Generation Plant in Page, Arizona.

Calcium concentrations are high throughout the system and are important as a micronutrient for primary producers and root growth in higher plants (Smith, 1974). Manganese, copper and zinc are also important for photosynthesis and enzyme production (Smith, 1974). Aquatic life is too dependent on these minerals. Trout require calcium for skeletal growth, it's uptake may be blocked by zinc, and result in improper development or death (Spry and Wood, 1988). Therefore terrestrial and aquatic life, as well as human, are dependent on survalence of these minerals.

Table 5-1 Grand Canyon Water Quality Collection Sites

No.	Site	Mile	Temp.	Cond.	Sal.	pH	Alkal.	Comments
1	Badger Creek	8.0	11.5	65	0.4	7.46	3.12	Mainstem
2	20 Mile Creek	20.0	29	99	0.9	7.70	3.29	Bank Storage
3	North Canyon	20.5	21.5	450	0.5	7.52	3.61	Standing Water
4	Nautiloid Canyon	34.7	38	1150	0.7	8.54	1.88	Standing Water
5.	Vassey's Spring	31.7	32	180	0.0	8.40	3.79	True Spring
6.	Nankoweap Point	53	32	660	0.7	8.06	NA	Bank Storage*
7	Awatubi	58	32	800	8.0	8.0	4.11	Bank Storage
8	Marsh on R	56	32	81	0.1	7.63	5.32	Mainstem
9	Little Colorado	61.5	28	3980	32	7.74	7.55	Tributary
10	Little Colo/Col	61.5	28	3100	2	7.86	9.74	Confluence/Trib
11	Kwagunt Marsh	56	28	3800	31	7.83	3.48	Bank Storage
12	Nankowkeap	53	23	438	0.2	8.50	4.85	Tributary
13	Lava Creek	65.5	30	28,000	14	4.12	38.3	Tributary
14	Grapevine	81.1	29.5	400	0.1	7.63	5.32	Mainstem
15	Nautiloid Canyon	34.7	38	400	0.0	7.87	3.09	Tributary^
16	Carbon Creek	64.6	32	750	0.5	7.99	3.77	Tributary
17	Hermit Creek	95	32	500	0	8.42	3.92	Tributary
18	Crystal Creek	98.2	34	1,000	0.3	8.68	3.55	Tributary
19	Shinumo Creek	108	35	200	0	8.32	3.48	Tributary
20	Elves Chasm	116.5	34	1100	0.5	8.17	2.90	Tributary
21	Beach 119.5	119.5	34	700	0.3	8.13	3.51	Bank Storage
22	Blacktail	120.1	36	2,000	1.0	8.01	4.37	Tributary
23	Blacktail	120.1	34	750	0.3	7.70	3.44	Mainstem
24	Blacktail	120.1	35	800	0.3	7.70	5.15	Bank Storage
25	122 Mile Creek	122.1	25	890	0.6	7.49	3.31	Bank Storage
26	Tapeats Creek	133	25	268	0.4	8.45	3.52	Tributary
27	Thunder/Tapeats	133	25	179	0.1	8.47	3.54	Confluence/Trib
28	Thunder River	133	26	226	0.2	8.29	3.52	Tributary
29	Deer Creek	136.1	25	238	0.2	8.17	3.77	Tributary
30	Stone Creek	139.9	31	212	0.1	7.73	4.56	Tributary
31	Kanab Creek	143.4	26	680	0.6	8.23	2.71	Tributary
32	Matkatamiba	148	26	1300	1.1	7.90	2.19	Tributary
33	Havasu Creek	156.9	25	430	0.6	8.13	5.00	Tributary
34	National Creek	166.5	26.5	10,000	1.1	8.00	2.68	Tributary^
35	Lower Lava Falls	180	31	800	0.3	7.45	13.29	True Spring
36	Peggy's Pot	192	29	1250	0.03	6.83	13.10	True Spring
37	Mile 194	194	27	478	0	8.05	3.98	Mainstem
39	Spring Canyon	204.4	26	390	0	8.29	4.03	Tributary
40	Pumpkin Springs	212	28	8300	5.7	6.89	3.72	True Spring
41	3 Springs	215.5	27	550	0_	7.46	5.50	Tributary
42	Diamond Creek	222	23	60	0.1	8.35	6.90	Tributary
43	Diamond Creek	222	23	890	0.2	8.06	3.18	Mainstem
	Units Used		°C	ohms	%		meq/L	

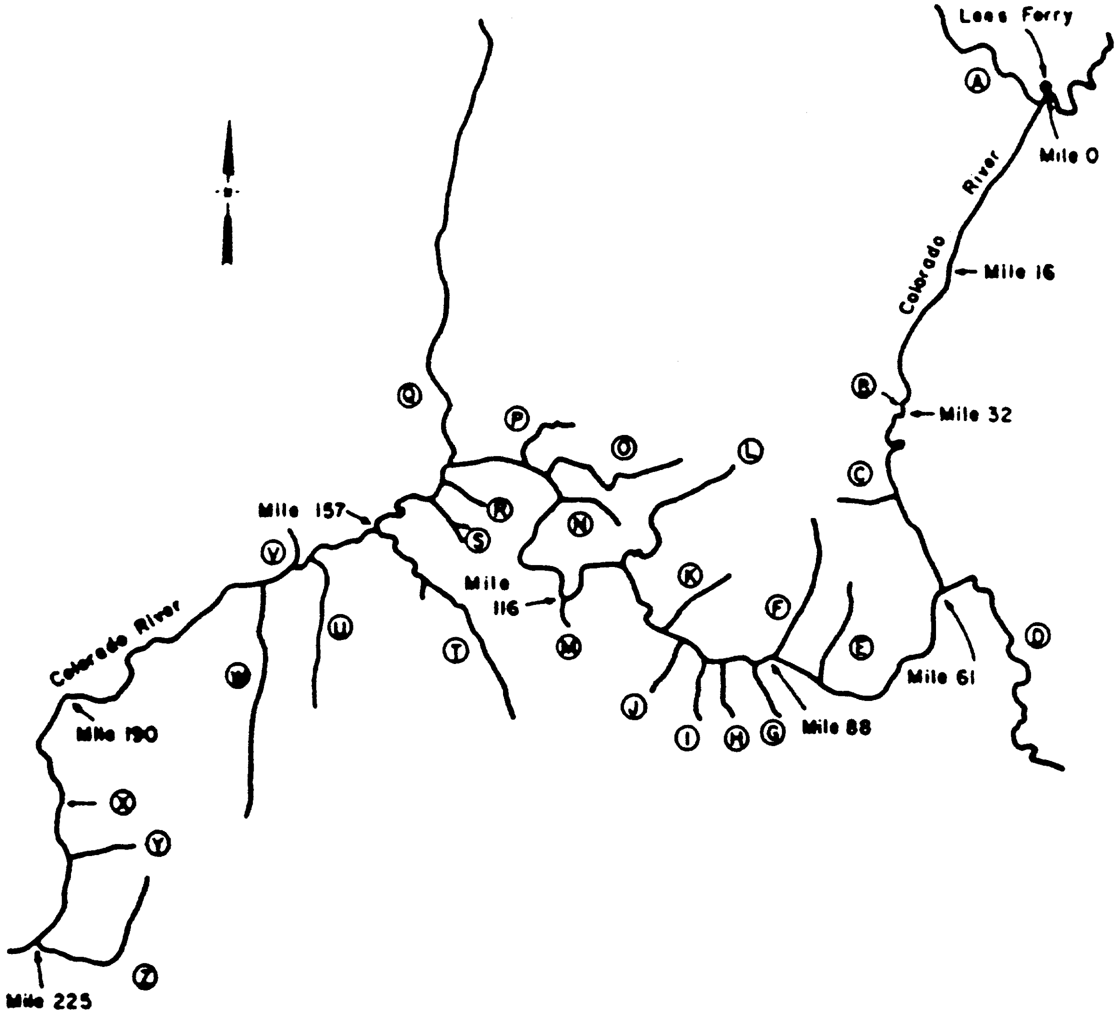
*Hand dug seep
^Direct sample, no substrate content
Sample 38 - invalid collection

Table 5-2. Calcium and trace metal concentration

No.	Site	Mile	Calcium	Manganese	Copper	Zinc
1	Badger Creek	8.0	47	0.5	0	0
2	20 Mile Creek	20.0	48	0.1	0	0
3	North Canyon	20.5	16	0.25	Trace	Trace
4	Nautiloid Canyon	20.5	20	0	0	0
5	Vassey's Spring	31.7	25	0	0	0
6	Nankoweap Point	53	55	0	0	0
7	Awatubi	58	41	0	0	0
8	Marsh on R	56	42	0	0	0
9	Little Colorado	61.5	57	0	Trace	0
10	Little Colo/Col	61.5	52	0	Trace	0
11	Kwagunt Marsh	56	47.5	0.1	0	0
12	Nankowkeap	53	13.5	0	0	Trace
13	Lava Creek	65.5	105	0	Trace	0
14	Grapevine	81.1	71	0	0	0
15	Nautiloid Canyon	34.7	43	0.15	Trace	Trace
16	Carbon Creek	64.6	47.5	Trace	0	Trace
17	Hermit Creek	95	27	0	Trace	0
18	Crystal Creek	98.2	12.5	Trace	Trace	0
19	Shinumo Creek	108	16	0.5	Trace	Trace
20	Elves Chasm	116.5	42	0	Trace	0
21	Beach 119.5	119.5	49	0.15	0	Trace
22	Blacktail	120.1	92	0	Trace	0
23	Blacktail	120.1	41.5	0.1	0	0
24	Blacktail	120.1	63	0	Trace	0
25	122 Mile Creek	122.1	40	0	0	0
26	Tapeats Creek	133	2	Trace	0	Trace
27	Thunder/Tapeats	133	2	0	Trace	0
28	Thunder River	133	1.5	0.2	0	Trace
29	Deer Creek	136.1	0.2	0	Trace	Trace
30	Stone Creek	139.9	5	0.45	0	0
31	Kanab Creek	143.4	77	0	0	0
32	Matkatamiba	148	88	0.1	0	0
33	Havasu Creek	156.9	11	0.1	Trace	0
34	National Creek	166.5	0.01	Trace	Trace	
35	Lower Lava Falls	180	53	0	Trace	0
36	Peggy's Pot	192	88	0	Trace	Trace
37	Mile 194	194	29	0.29	0	0
39	Spring Canyon	204.4	49	0	0	0
40	Pumpkin Springs	212	0.1	0	Trace	Trace
41	3 Springs	215.5	56	0	Trace	Trace
42	Diamond Creek	222	13	0	0	0
43	Diamond Creek	222	49	0	Trace	Trace
	Units Used		ppm	ppm	ppm	ppm

Sample 38 - Invalid Collection

Site	Mile
Badger Creek	8.0
20 Mile Creek	20.0
North Canyon	20.5
Nautiloid Canyon	34.7
Vassey's Spring	31.7
Nankoweap Point	53
Awatubi	58
Marsh on R	56
Little Colorado	61.5
Little Colo/Col	61.5
Kwagunt Marsh	56
Nankowkeap	53
Lava Creek	65.5
Grapevine	81.1
Nautiloid Canyon	34.7
Carbon Creek	64.6
Hermit Creek	95
Crystal Creek	98.2
Shinumo Creek	108
Elves Chasm	116.5
Beach 119.5	119.5
Blacktail	120.1
Blacktail	120.1
Blacktail	120.1
122 Mile Creek	122.1
Tapeats Creek	133
Thunder Tapeats	133
Thunder River	133
Deer Creek	136.1
Stone Creek	139.9
Kanab Creek	143.4
Matkatamiba	148
Havasu Creek	156.9
National Creek	166.5
Lower Lava Falls	180
Peggy s Pot	192
Mile 194	194
Spring Canyon	204.4
Pumpkin Springs	212
3 Springs	215.5
Diamond Creek	222
Diamond Creek	222



LEGEND

A. Paria River
B. Vasey's Spring
C. Nankoweap Creek
D. Little Colorado River
E. Clear Creek
F. Bright Angel Creek
G. Garden Creek
H. Monument Creek
I. Hermit Creek
J. Boucher Creek
K. Crystal Creek
L. Shinumo Creek
M. Elves Chasm
N. Stone Creek
O. Tapeats Creek
P. Deer Creek
Q. Kanab Creek
R. Ole Creek
S. Matkatamiba Creek
T. Havasu Creek
U. National Creek
V. Fern Glen
W. Mohawk Creek
X. Pumpkin Spring
Y. Three Springs
Z. Diamond Creek

Figure 5-1 Colorado River and Tributaries Through The Grand Canyon, With Collection Sites

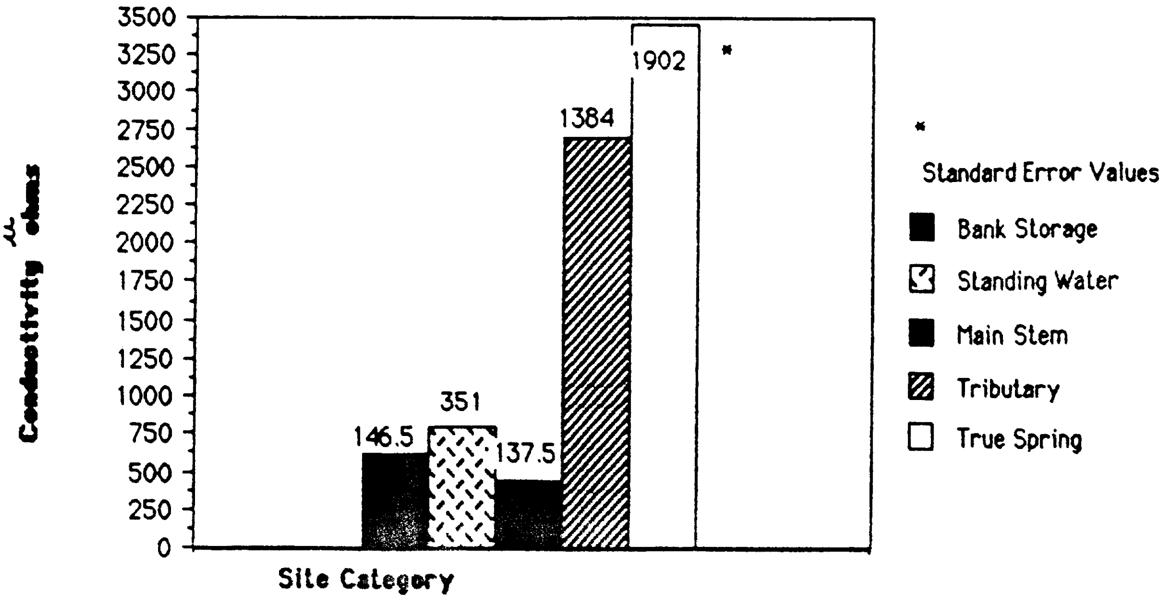


Figure 5-2 Mean Conductivity Comparison For 5 Site Catagories

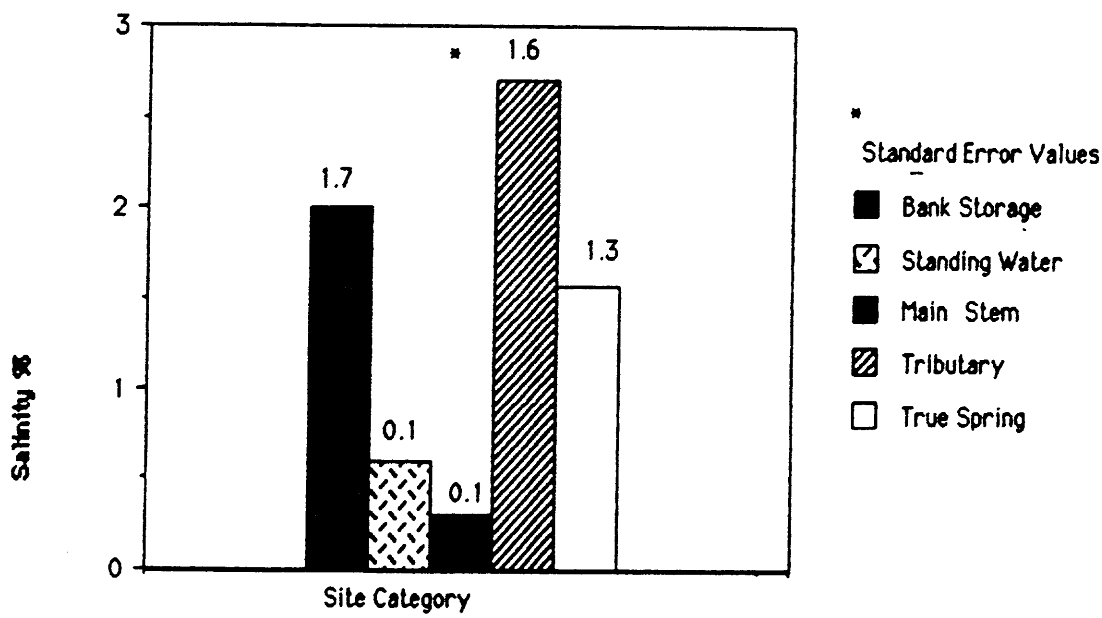


Figure 5-3 Mean Salinity Comparison For 5 Site Catagories

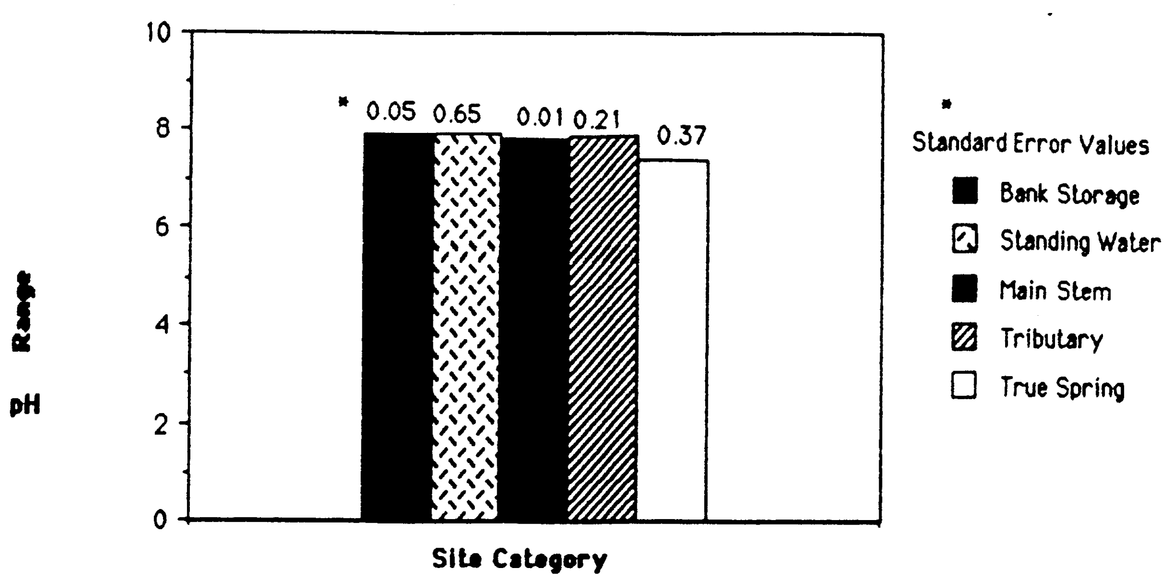


Figure 5-4 Mean pH Comparison For 5 Site Categories

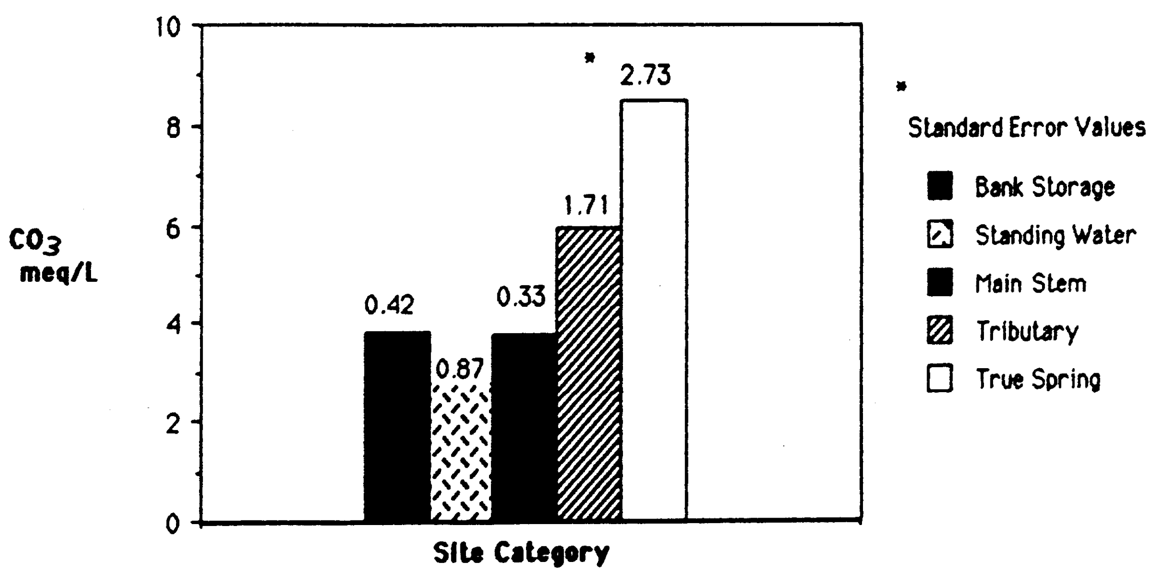


Figure 5-5 Mean Alkalinity [ ] Comparison For 5 Site Categories

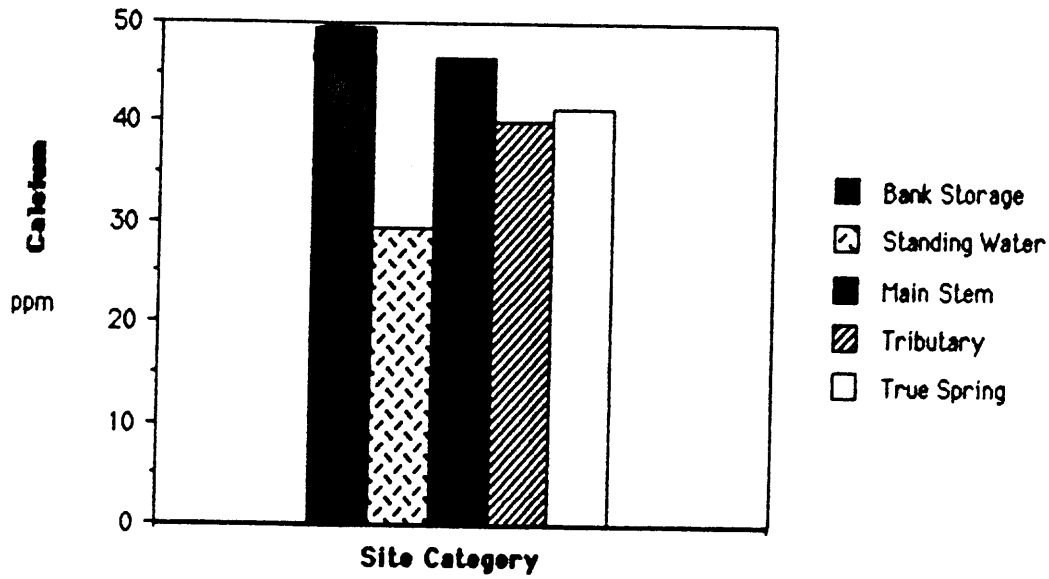


Figure 5-6 Mean Calcium [ ] Comparison For 5 Site Categories

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ADDENDUM

This year's chemistry group would like to make the following suggestions to future groups reseaching the same material.

1. Special durable plastic containers should be made for the pipets and burets.
2. Sample bottles should have labels on them prior to leaving, then when the label has been written on in field it should be covered with transparent tape.
3. A cooler with dry ice should be provided just for chemistry water samples.
4. A small board should be included as chemistry supplies, so a table can be made to work on.
5. As much on site testing should be done as possible.
6. Testing for phosphates, nitrates, and heavy metals would be recommended.

CHAPTER VI

CONTINUED STUDIES ON THE RED HARVESTER ANT: DENSITY AND FORAGING ACTIVITIES ON HUMAN IMPACTED, COLORADO RIVER BEACHES IN GRAND CANYON NATIONAL PARK, SUMMER 1989

Chris Pike, Robert LaChat
and
Cathy O'Rourke Taylor, Asst.

INTRODUCTION

Red harvester ants (Pogonomyrex californicus) are found on every human impacted beach on the Colorado River between Lee's Ferry and Diamond Creek. This concolorous medium large ferruginous red ant is a health safety concern to the hikers and 21,500 river rafters who access these beaches and therefore the National Park Services. The sting of these ants is severe, but they must be provoked. Stings are typically sustained by getting too close to their nests, physically harming them, or interrupting their forage routes. The ants have the greatest impact on humans from early spring through late fall when they are most active. Persons hypersensitive to ant venom or subjected to multiple stings may collapse from anaphylactic shock (Cole 1968 p. 4).

OBJECTIVE

The current study is designed to continue the examination of long term densities, distribution, and food habits of californicus. Beaches were divided into the four post dam vegetation zones of the inner gorge (from Carothers, 1976, Figure VI-1). Efforts were also made to determine the usage of the beach, the boatmen's opinions were invaluable for this. The beach is then classified high, medium, or low.

The hypothesis tested in this investigation is are the ants hive populations increasing, since the 1983 flood. We also looked at human impact effecting hive numbers. Methods were also used to study the hives' food sources.

Control beaches were picked to have as little impact by man as possible. Lower Little Colorado (L.C.R. 61.8) where camping is not permitted within 1/4 mile of the confluence because of the endangered humpback chub (Gila cypha). Buck Farm 40.5 and new Kwagunt Marsh Island (result of 1983 flood) are also good controls.

METHODS

A typical post-Glen Canyon Dam beach has four fairly distinct vegetation zones determined by indicator plant species (Carothers et al., 1976). The zone measurements are subjective due to varying physical factors like slope, rock outcrops, water level, rock type, sun exposure, washes, and surveyor.

Once plant zones are determined and paced for area, hive surveys can be made. Hive counts per zone are done by observers walking a zig-zag pattern through zones. Area of zone and hive sightings are recorded on data log sheets (Fig. VI-2). Field notes and 10 minutes foraging data are also recorded on data log sheets. Much of the beach is very hot (sand 140°F) and the ants do bite, so researchers must be wary and physically fit.

A typical Grand Canyon beach will take about 40 minutes including a 10 minute foraging count or 20-30 minutes with no foraging count. Zone 1 Desert will often be too large to survey, so use length of beach by 10 meters. All three other zones should be surveyed in entirety. Surface temperatures are taken by shading sand with clipboard and Taylor lab thermometer. Two inch temperatures are taken by soil thermometer. Six inch hive temperatures are taken by meat thermometer. Taylor sling psychrometer and distilled H_2O should be used for relative humidity. Tables to convert wet and dry bulb temperatures to relative humidity are usually with psychrometer. This study requires two to three observers with good near vision. Observers must be able to pick out the various foraging food types by sight, so practice before leaving on the expedition is essential. Grease and/or sugar sand and water sand can be determined by its origin or if this fails, by smelling and rubbing between the fingers. Hives are dinural and will not be active in the middle of the day unless it is cloudy. When active foraging routes will help in determining location of hives, follow the ants with food back to the nest. Flipping rocks ants commonly nest under will give some insights to hive architecture. There is a very good one upriver from kitchen at Carbon Creek. Knowing your pace in varying terrain is also extremely important and should be standardized before the expedition. Backup instruments, hand lenses, shovels, pry bars, collecting vials, and stop watches will be extremely useful to have with you.

RESULTS AND DISCUSSION

Only one beach was found to be devoid of Pogonomyrmex californicus--Kwagunt Marsh Island (Table VI-1). This is a new beach created in the 1983 flood from a beaver marsh, mile 55.5. Since their is no Harvester ant population this location will give some insight into new beach colonization by the ants. There are populations above at Nankoweap mile 52.5 .86 hives/100 meters and Awatubi mile 58.1 .05 hives/100 meters (Tables VI-1 and VI-2). All other beaches surveyed have healthy hive populations.

Our 1989 numbers of hives per/100 sq. meters are slightly lower this year (Figure VI-3, Table VI-2). We attribute these lower numbers to less expertise of surveyors, Steve Ward was on the 1986, 1987, and 1988 expeditions. Also less desert area was surveyed this year due to time limitations on beach and/or time of day (Table VI-1). Another possible factor was the monsoon season had not really broken this year at the time of the expedition (Table VI-1).

We don't see the large numbers found of 2.40 ant hives per 100m found on some beaches studied by Hayden, Dolan, Carothers (1977). However, both our numbers and personal observations Pike 1986/1989 and LaChat 1987/1989 expedition members show hives numbers are up from our last trips. Slight decrease in overall numbers is probably due to sampling biases.

Our foraging data shows a large decrease in blackfly utilization--5.7% (Table VI-3) versus 40% on last year's expedition (Ward and Honahni 1988). Our highest beach utilization only reached 48% (Figure VI-4) bedrock and were not seen at all on 12 beaches of the 20 food surveyed. The blackflies (Simulium sp) probably could not have existed in the Colorado River in any great numbers prior to the dam closure in 1963 because they require clear running water with high dissolved oxygen content for their larval cycle (Laird 1981). The Colorado was very muddy, the Paria and a side canyon from the Navajo Nation made Secchi disks readings down to less than 1 foot by our second day. Our team members noticed a large decrease in the number of blackflies seen on the river's edge and no sightings in depressions as in 1986 (Pike and Ward). One possible explanation is this large sediment load interfered with the blackflies' life cycle. The data also shows that Harvester ants will access the most concentrated food within their foraging range. This means first choice is human deposited 44%, then inspects 20%, and finally plant material, 33% (Table VI-3, VI-4, VI-5) wet sand is theorized to be used for humidity control probably in the larva and egg portion of hives. We noted two separate rooms of dead ants, two of seeds, and one of plant parts at Carbon Creek 64.6 7/28/89. Hives do seem to have separate rooms for storage. We do not know if dead ants were own hives burial or vanquished enemy to be used as a food source. We did see vanquished enemy hive adults being transported in an ant war at lower National 166.6. See 10 minute counts below.

Date	Time	Larvas	Pupa	Ants	Plant Parts	Insects	Wet Sand	Oatmeal
8/1	6:45 PM	123 = 79%	14 = 9%	17 = 11%	0	0	0	0
8/1	7:03 PM	62 = 56%	34 = 31%	14 = 13%	0	0	0	0
8/2	8:59 AM	4 = 14%	0 = 0%	4 = 14%	10 = 34%	1 = 3.5%	1 = 3.5%	9 = 31%
8/2	6:42 PM	0 = 0%	0 = 0%	5 = 25%	6 = 30%	3 + 15%	1 = 5%	5 = 25%

One can see that the younger members of the vanquished hive were the ones taken first. Most of the adult ants taken were the orangish colored ones we call juveniles. Some juveniles were carried to winning hive looking dead and then were observed working on winning hive. Vanquished hive entrances were covered about 10:00 PM, perhaps to keep winning hives foraging workers from going down wrong hive. VAnquished hive was opened and accessed for stored food and hive members again the next morning. Winning hive excavated till after 10:00 PM on 8/1 and all day 8/2 even after other hives in area stopped work. We feel this was to store ill-gotten gains from vanquished hive. We noted ants fighting several times along foraging routes. This was especially true near kitchen or disturbed areas. We therefore feel inter-hive competition may help limit hives on a beach. Our two warring hives were within 8 meters of each other. A short video was made of some of the fighting 8/1.

The mammal study was responsible for the oatmeal and rice found at hives. These two studies are not compatible. We found the ants would ignore natural foods and access oatmeal and rice first every time. Interestingly the rice seemed to be preferred.

CONCLUSIONS AND RECOMMENDATIONS

The Harvester ants were most aggressive when in close proximity to other hives, common kitchens, or areas that flooded. Those areas with greater food sources and stable substrate seem to have greatest number and size of hives. One method to get a better idea of hive size might be using a piece of bread and counting workers after a few minutes. Grand Canyon Harvester ants do enslave others of their own species. Food sources of these ants will be the highest concentrated available within their range 100m (Pike and Ward, 1986). Overall ants are still probably increasing. We do not feel extermination is possible or preferred. The ants are replacing the floods in keeping the sand clean.

To do a better job at least one experienced ant researcher should be present. Also a fixed flagged hive beach repeatedly visited several times a year would be of immense value. Working only during mating season is a problem. If inexperienced team researchers are used, practice with and experienced one should be mandatory. Finally take more than one of each instrument as breakage is high.

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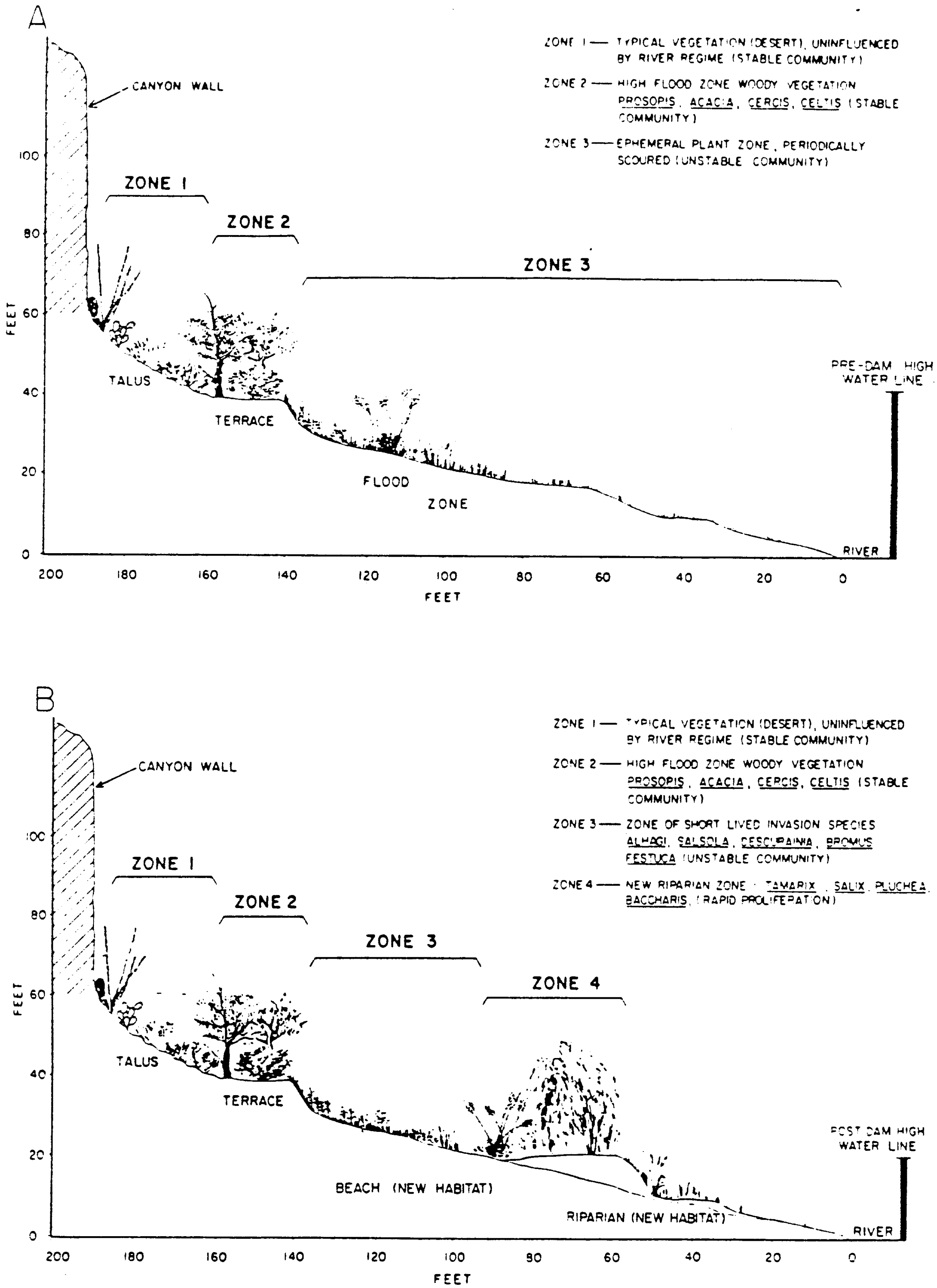
Figure 6-1



Diagrammatic cross-section of vegetation zones in the Inner Gorge of the Colorado River in Grand Canyon before (A) and after (B) the construction of Glen Canyon Dam (from Carothers et al., 1976).

Figure 6-2

LOG 1

RED HARVESTER ANT DENSITY AND FORAGING DATA

Beach & L/R r.m ______________________
Date: __________ Time begin ______ end ______
Human usage: LOW ----- HIGH

I. RIPARIAN ZONES DENSITY (TICK MARK COUNT)	# OF HIVES	AREA SIZE L X M = M	DENSITY/100 M
1-			
2-			
3-			
4-			
TOTALS.			

Zone Key: 1 - desert; 2 - OHWL; 3 - camp; 4 - NHWL

II. FORAGED ITEMS DELIVERED TO HIVE:

Zone: 3-4 observation
Sand surface temp. ______________
6" soil temp. at hive ______________
Distance to common kitchen ______________
T1 _____ T2 _____ Time ______________
(+/- 10 min)

(TICK MARK COUNT)	% OF TOTAL
Plant parts	
Seeds	
Blackflies	
Insects (other)	
Food scraps	
Grease sand	
Wet sand	

Zone: 1-2 observation
Sand surface temp. ______________
6" soil temp. at hive ______________
Distance to common kitchen ______________
T1 _____ T2 _____ Time ______________
(+/- 10 min)

	% OF TOTAL
Plant parts	
Seeds	
Blackflies	
Insects (other)	
Food scraps	
Grease sand	
Wet sand	

Ambient Temp: ______ % Rel Humidity: ______ Wet Bulb: ______ Dry Bulb: ______

COMMENTS:

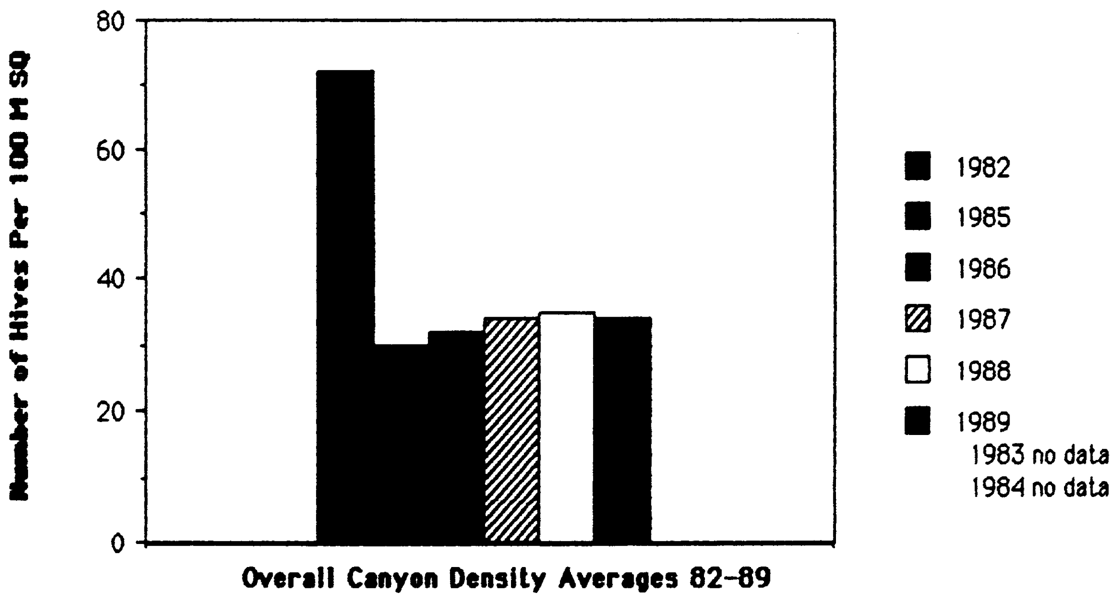
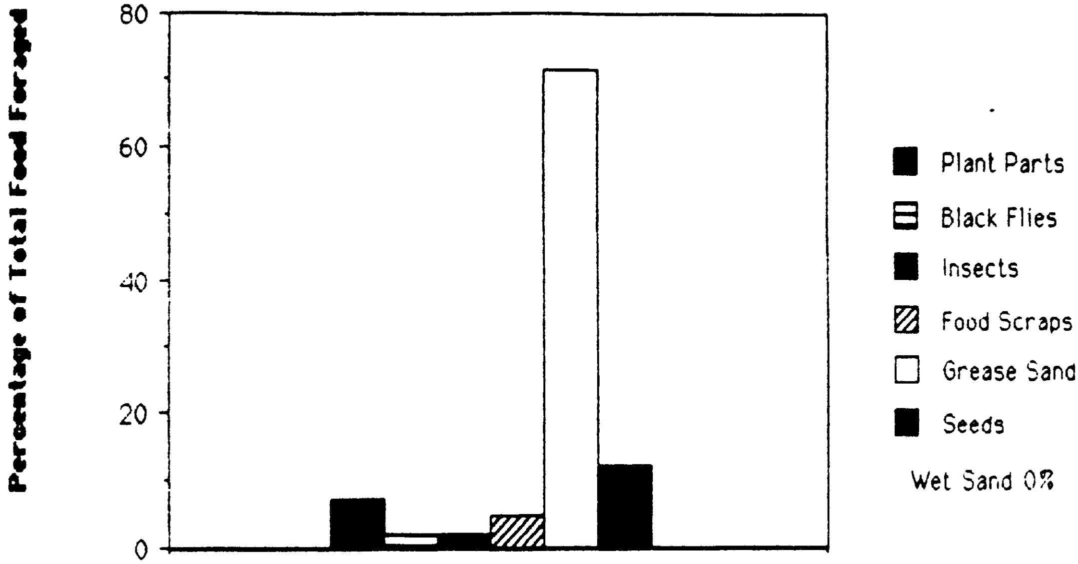
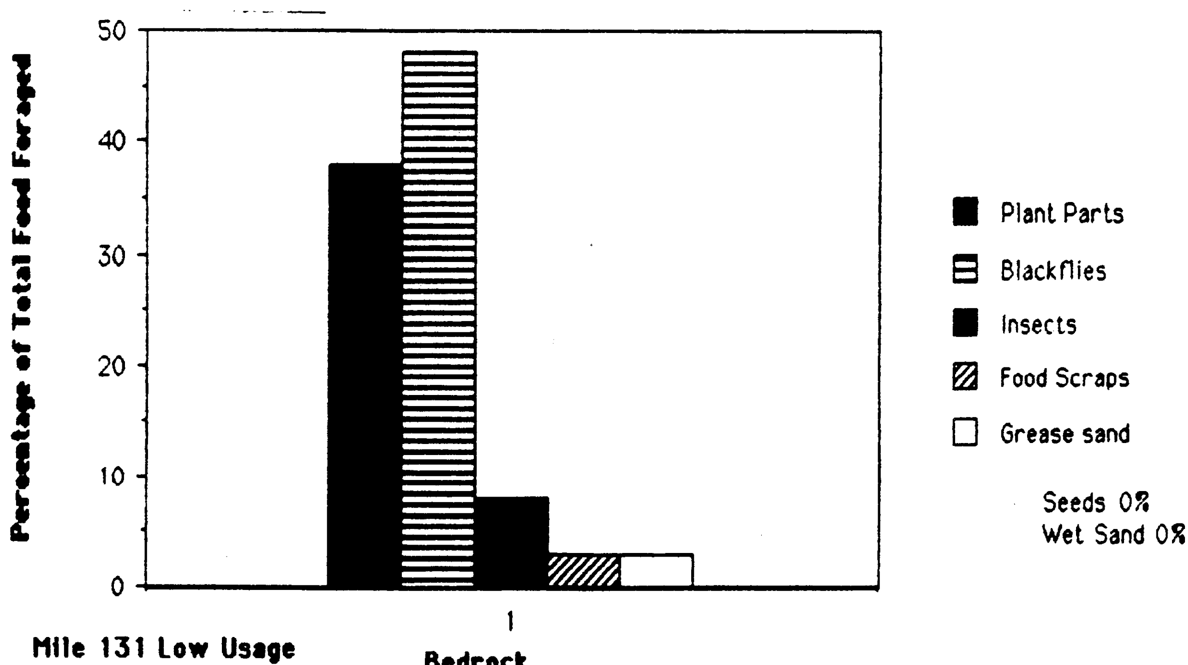

Number of Hives Per 100 M SQ
80
60
40
20
0
1982
1985
1986
1987
1988
1989
1983 no data
1984 no data
Overall Canyon Density Averages 82-89

Figure 6-3



Middle Nankoweap Mile 52
High Usage
Figure 6-4



Mile 131 Low Usage
Figure 6-5

Table 6-1 1989

Beach	Mile	Date	Time	Temp.Air	Humidity	2inTemp.	6inTemp	Density	Usage
Badger	8	7/25	3:18pm	88F	30%	104F	108F	.05	H
20 Mile	20	7/25	7:30am	72F	52%	78F	80F	.09	H
North Canyon	20.5	7/26	9:37am	76F	56%	108F	88F	.29	H
Shinumo Wash	29	7/26	12:30pm	83F	43%	94F	80F	.03	H
Nautiloid	34.7	7/26	2:54pm	94F	--	95F	92F	.12	H
Buck Farm	41	7/26	5:06	85F	57%	88F	90F	.14	H
(U) Nankoweap	52.3	7/27	10:00am	--	--	--	--	.24	H
(M) Nankoweap	52.5	7/27	10:27am	84F	44%	90F	83F	.01	H
(L) Nankoweap	53	7/27	7:41am	69F	81%	78F	60F	.86	H
Kwagunt Marsh	55.5	7/27	12:00	--	--	--	--	--	L
desert only at L.C.R.									
Lower L.C.R.	61.8	7/27	4:17	83F	--	--	--	.72	L
Carbon Creek	64.6	7/28	7:55am	75F	78%	75F	78F	.19	H
Lava canyon	65.5	7/28	10:43	--	--	--	--	.26	H
Nevils Rapid	75.5	7/28	12:17pm	83F	46%	90F	86F	.21	M
Hance	76.5	7/28	3:00pm	--	--	--	--	.60	H
Grapevine	81.1	7/29	8:00am	82F	59%	86F	91F	.15	H
Granite Rapids	93.2	7/29	12:03pm	93F	34%	110F	98F	1.4	H
Bass	108	7/29	5:08pm	95F	35%	92F	95F	.09	H
(U)Blacktail	120	7/30	9:30am	90F	44%	89F	86F	.15	M
(L)Blacktail	120	7/30	12:15pm	--	--	126F	100F	--	M
122 Mile	122	7/31	9:10am	96F	33%	102F	95F	.67	M
Forster	122.8	7/31	10:20am	--	--	--	--	.07	H
Bedrock	131	7/31	12:28pm	92F	43%	91F	92F	.18	L
Deer Creek	136	7/31	3:39pm	--	--	88F	92F	.14	H
Pancho's Kitchen	136.6	8/1	7:40am	85F	42%	76F	85F	.16	H
(L) National	166.6	8/1	6:40pm	91F	32%	81F	88F	--	H
(L) National	166.6	8/2	8:55am	78F	57%	72F	80F	--	H
(L) National	166.6	8/2	3:05pm	101F	22%	103F	100F	--	H
(L) National	166.6	8/2	6:42pm	92F	26%	84F	94F	.38	H
(U) National	165.5	8/2	7:15am	--	--	--	--	.08	M
Fern Glen	168	8/3	9:40am	85F	45%	82F	93F	.17	H
186 beach	186	8/3	3:00pm	95F	28%	112F	113F	.09	H
190.2 beach	190.2	8/3	4:45pm	--	--	115F	115F	.33	M
194 beach	194	8/4	7:10am	85F	42%	80F	80F	1.4	H
Parashant	198.5	8/4	9:56 am	96F	31%	93F	86F	.60	M
Granite Park	208.8	8/4	1:50pm	107F	22%	118F	122F	.07	H
220 beach	220	8/4	7:10 pm	83F	43%	75F	81F	.75	H
220	220	8/5	6:12 am	101F	20%	98F	106F	.91	H

H=high
M=medium
L=low

Table 6-2

List of sampled beaches 1982-1989 for Harvester Ant densities.

Beach Mile bank	1982	flood	1984	1985	1986	1987	1988	1989	Usage
Jackass 7.8 L	--	--	.00	--	.09	.27	.23	--	H
20 mile 20 L	.00	--	.07	.37	.19	--	--	.09	H
Shimumo 29.0L	--	--	--	--	.06	.13	--	.03	H
Nautiloid 34.7L	--	--	.00	.13	--	.30	.30	.12	H
Buck Farm(C)40.5R	--	--	--	--	--	.06	.26	.14	H
Nankoweep 53.0R	1.10	--	.00	--	.09	.64	--	.86	H
Awatubi 58.1R	--	--	.00	.26	.12	--	.30	.05	H
LCR (C) 61.8R	--	--	--	--	.04	.21	.22	.72	L
Carbon 63.5R	--	--	--	--	.92	.68	--	.19	H
Nevills 75.5L	.56	--	--	.09	.14	.27	.30	.21	M
Hance 76.5L	--	--	--	.32	.17	.31	--	.60	H
Grapevine 81.1L	--	--	.00	.29	.20	.38	.38	.15	H
Granite 93.2L	.56	--	--	--	.29	.97	.50	1.4	H
Bass 108.5R	.00	--	.00	.55	.81	.51	.46	.09	H
Upper 120.1R Blacktail	.49	--	.00	.31	.21	.19	.39	.15	M
Lower 120.3R Blacktail	--	--	--	--	--	--	.58	--	M
Mile Creek 122.0R	--	--	--	.41	.33	.29	.43	.67	M
Forster 122.8L	--	--	.00	--	.30	.28	.23	.07	H
Bedrock 131.0R	--	--	.00	--	--	.40	.47	.18	L
Deer creek 136.0L Falls	2.5	--	--	--	--	.43	.33	.14	H
Pancho's 137.0L	--	--	--	--	.31	.25	.30	.16	H
National 166.6L	--	--	--	.04	.06	.38	.42	.38	H
Fern Glen 168.0R	--	--	--	--	--	.52	.29	.17	H
Lower Lava 180.9R	--	--	.00	.03	.05	.10	--	--	H
Mile Beach 186.0R	--	--	.00	--	--	.25	.27	.09	M
Mile Beach 190.2L	--	--	.00	.04	--	.33	--	.33	H
Mile Beach 194.0L	--	--	--	.15	--	.09	.29	.33	M
[illegible]ont 198.6R	2.3	--	--	--	.13	.29	.28	.60	M
Granite 208.9L Park	.67	--	.00	.70	.50	.64	--	.07	H
Middle 220R	--	--	--	.77	.51	.54	.55	.91	H
Averages	.994	--	.00	.277	.271	.345	.354	.342	

(--)=not surveyed
(H)=high usage
(M)=medium usage
(L)=low usage
(C)=control

Table 6-3

Beach	plants	seeds	FORAGED ITEMS % blackflies	insects	food scraps	greasesand	wetsand
L20	0	3%	0	22%	35%	39%	0
North 20.5	49%	0	0	6%	28%	14%	0
Buck farm	85%	0	0	10%	0	0	5%
Nevils	35%	1.5%	0	0	1.5%	92%	0
Awatubi	44%	11%	28%	16%	0	0	0
Carbon creek	0	0	0	7%	32%	50%	11%
Carbon Creek	6%	0	0	3%	52%	39%	0
Grapevine	5%	0	9%	0	86%	0	0
Granite rapids	50%	0	0	25%	0	0	25%
Upper blacktail	54%	8%	15%	23%	0	0	0
122 mile	3%	0	2%	2.5%	2.5%	90%	0
Bedrock	38%	0	48%	8%	3%	3%	0
Deercreek	21%	11%	0	21%	5%	42%	0
Pancho's	50%	2%	2%	6%	38%	0	0
Lower National	0	0	0	100%	0	0	0
Lower National	20%	15%	0	5%	25%	35%	0
Fern Glen	9%	2%	5%	13%	23%	48%	0
194 Mile	5%	0	0	0	74%	21%	0
220 mile	86%	8%	0	6%	0	0	0
Averages	29.5	3.2	5.7	14.4	21.5	22.8	2.2

CHAPTER VII

WATER TURBIDITY AND TEMPERATURE OF THE COLORADO RIVER IN GRAND CANYON

Mark Gilbreath

INTRODUCTION

Much of the Colorado River drainage area is arid land with scant vegetation cover to inhibit sediment loss during heavy run-off. In pre-Glen Canyon Dam days, the Colorado River in the Grand Canyon carried large sediment loads and was reddish in appearance. Since the building of the dam upstream, sediment has been trapped in Lake Powell. Water of the Colorado River entering the canyon since the construction of Glen Canyon Dam is clear with low turbidity. Sediments in the river now come only from tributaries and side canyons below the dam, generally as a result of heavy summer rains and melting snow.

River temperature has also been affected by the Glen Canyon Dam. Pre-dam water temperatures varied from winter lows near 32 degrees F. to summer highs in the mid 80 degree range. Dam-released water from Lake Powell comes from the lake's hypolimnetic zone, a region of sediment-free, cold water with a constant temperature (45 degrees) approximately 200 feet below the surface. As a result, river water temperatures neither reach the yearly extremes the pre-dam river did, nor fluctuate seasonally.

A knowledge of the temperature and turbidity of the Colorado River below Glen Canyon Dam and in the Grand Canyon is important in understanding the resulting biological community. Clear, sediment free water allows a euphotic zone to develop where light can penetrate. The absence of sediments reduces scouring of the river bottom. Plants such as Cladophera can photosythesize in this zone and grow on the bottom. The algae provide food for amphipods and diatoms, which are eaten by trout. The low turbidity of the water allows for the growth, reproduction, and survival to these and other aquatic species of plants and animals. The restricted temperature range of the water has a limiting effect on the variety of fish able to breed and flourish. Some native species have continued to inhabit the river, spawning in the warmer water side canyons, while other species have disappeared.

OBJECTIVES

With the use of Secchi Disc and surface temperature readings, the turbidity and water temperature can be determined at various locations along the Colorado River between Lees Ferry and Diamond Creek. These data will record any changes in turbidity and temperature resulting from inflow from side canyons and tributaries into the Colorado River in the Grand Canyon.

METHODS

Water temperature in degrees Fahrenheit were collected using a glass, mercury thermometer held 1 foot below the surface. A round, 8-inch diameter, black and white disk suspended on a rope (a Secchi Disc) was lowered into the river at designated locations, which generally bracketed major tributaries and side canyons. The disc was lowered into the water until it disappeared from sight when observed from a distance of 3 feet above the water. The depth of the descent was measured by the rope marked in feet.

RESULTS

Figures VII-1 and VII-2 and Table VII-1 present the turbidity and temperature results. The turbidity data showed a large decrease in clarity after passing the Paria River confluence, decreasing from 12 feet to 2.75 feet. Later the same day , after passing a flash flood in progress at Tanner Wash, the clarity approached near zero at 0.125 feet. On day two, the river had cleared to 2.75 feet, returning to the turbidity seen below the Paria River confluence. By the morning of the third day the turbidity was very high and never significantly lowered. Rain fell the second, third, and fourth nights, and large thunderstorms upriver occurred those same nights. By the afternoon of the third day visibility had reached zero (maximum turbidity) , and with slight fluctuations, never appreciably increased. All flowing tributaries, including the Little Colorado River, were less turbid than the Colorado River at corresponding points.

Temperature of the river increased 13.5 degrees F. betwwen Lees Ferry and Diamond Creek (Table VII-1). The temperature gain averaged 1 degree gain per 16 miles. The most rapid rise in temperature was at the confluence of the Little Colorado River, with a rise of 1.5 degrees.

CONCLUSIONS

Turbidity of the river showed sharp increases past the Paria River, after the flash flood at Tanner Wash (mile 14.5) and below the Little Colorado, after which turbidity remained extremely high for the continuation of the trip. Summer rainstorms in the area and upstream likely added increased sediment loads from tributaries and normally dry canyons to produce high turbidity for most of the trip.

Water temperature rose gradually throughout the trip. The fastest rise in temperature occurred from Lees Ferry to Phantom Ranch, with a more gradual rise of less gain fro the remainder of the trip.

Table VII-1. Table showing the day, time, mile, temperature, and turbidity of data collection sites.

Day	Time	Mile	Temperature (degrees F)	Turbidity (feet of visibility)
1 7/25/89	12:30 pm	0.5	46	12
	12:35 pm	1.1	46	2.75
	2:48 pm	8	46	1.25
	5:37 pm	14.5	46	0.125
2 7/26/89	6:00 am	20	47	2.75
	11:26 am	21.5	46	2.75
	4:25 pm	48	48	2.25
3 7/27/89	7:25 am	53	49	0.125
	1:20 pm	58	50.5	0.75
	4:15 pm	61.8	52	0.0
	5:06 pm	65.2	52	0.0
4 7/28/89	10:40 am	65.4	52	0.0
	2:15 pm	75.5	52	0.0
5 7/29/89	7:32 am	81.1	53	0.125
	10.33 am	87.5	54	0.0
	4:14 pm	108.5	54.5	0.0
	6:30 pm	116.5	55	0.0
6 7/30/89	7:30 pm	120	55	0.25
7 7/31/89	1:32 pm	131	56	0.0
	1:40 pm	132	56	0.0
	2:10 pm	133	56	0.0
	2:20 pm	134	57	0.0
8 8/01/89	8:19 am	136	56	0.0
	4:22 pm	156.9	57	0.0
9 8/02/89	11:45 am	166.5	58	0.0
10 8/03/89	7:27 am	166.6	58	0.0
	1:07 pm	180	58	0.125
	4:23 pm	190.2	58.5	0.0
11 8/04/89	7.08 am	194	58	0.0
	7:33 pm	220	59.5	0.0

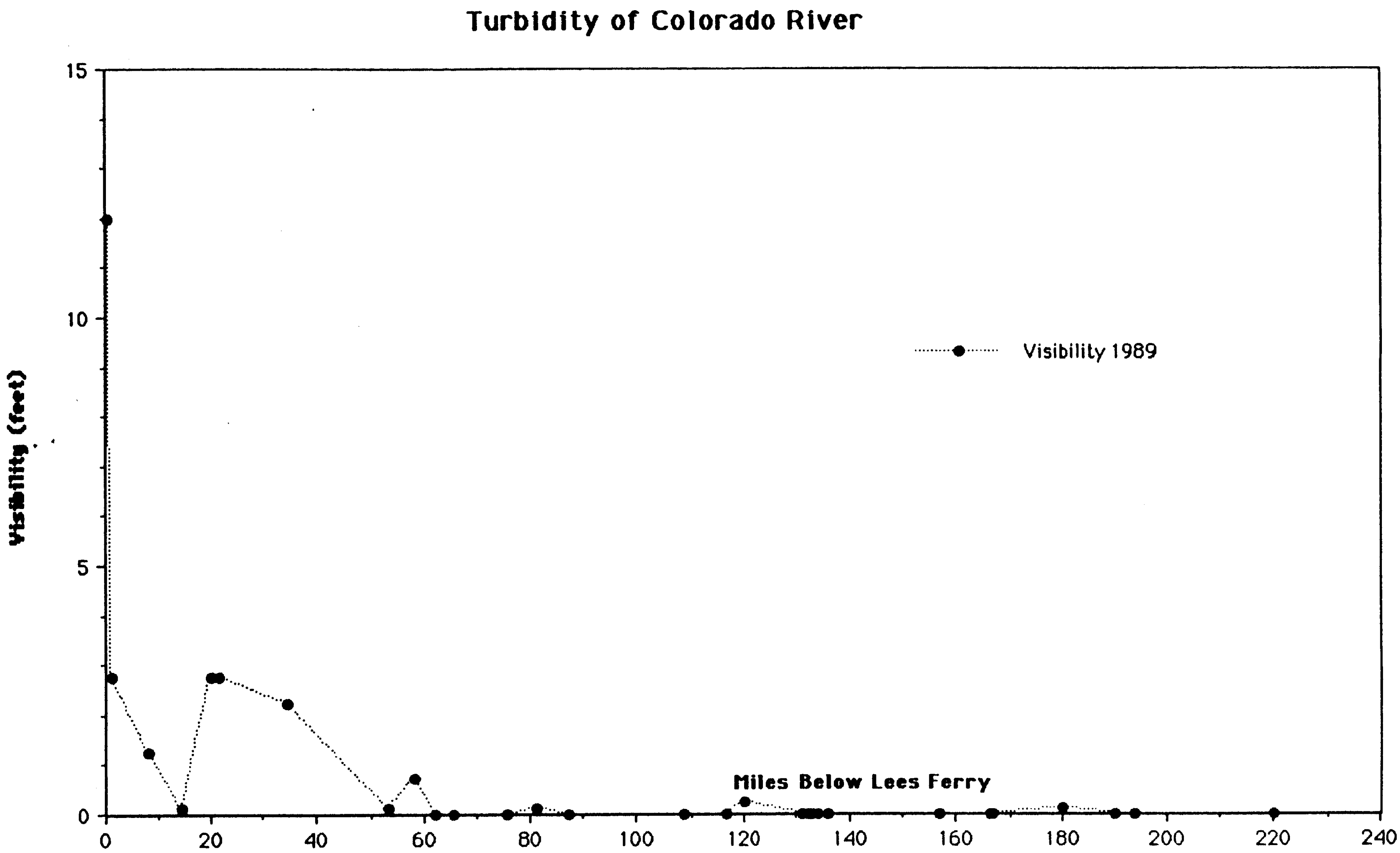

Turbidity of Colorado River
Visibility (feet)
15
10
5
0
Visibility 1989
Miles Below Lees Ferry
0
20
40
60
80
100
120
140
160
180
200
220
240

Figure VII-1

Surface Water Temperature, Colorado River

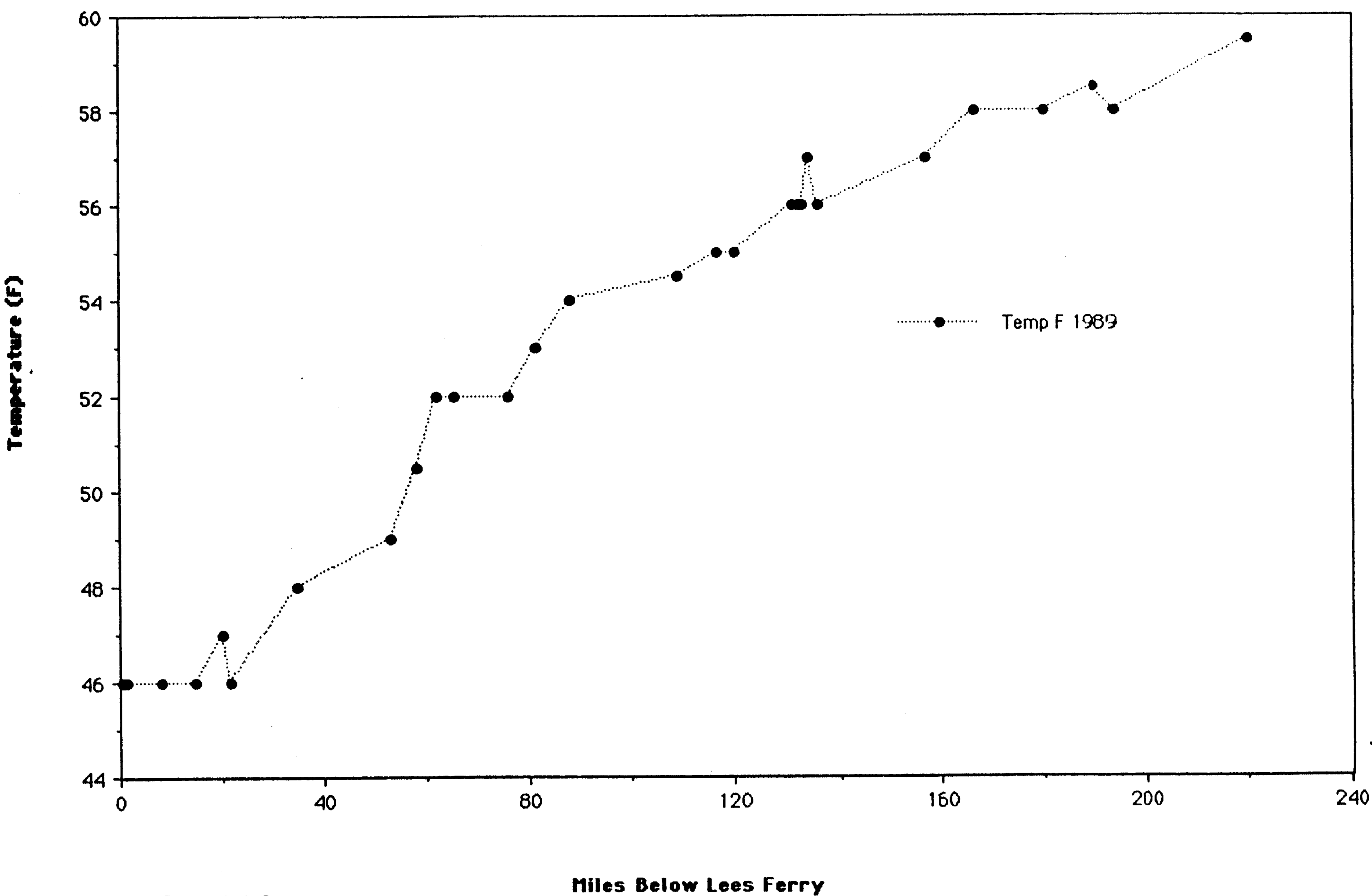


Figure VII-2

CHAPTER VIII

SMALL MAMMAL POPULATIONS WITHIN THE COLORADO RIVER CORRIDOR

Jay Smith and Virgil Prokopich

INTRODUCTION

Impoundment of desert rivers may profoundly affect riparian rodent community composition and structure. Small mammal populations in the Colorado River corridor have been studied since the completion of Glen Canyon Dam (Hoffmeister, 1971; Ruffner, 1975, 1976, 1978). Four distinct habitat zones were described by Carothers (1976), (Figure VIII-1). Limited trapping of small mammals was done before and after the post-dam flood of 1983 (Trimble, 1982; Spears, 1983, Rotstein 1987, Kendall, 1988).

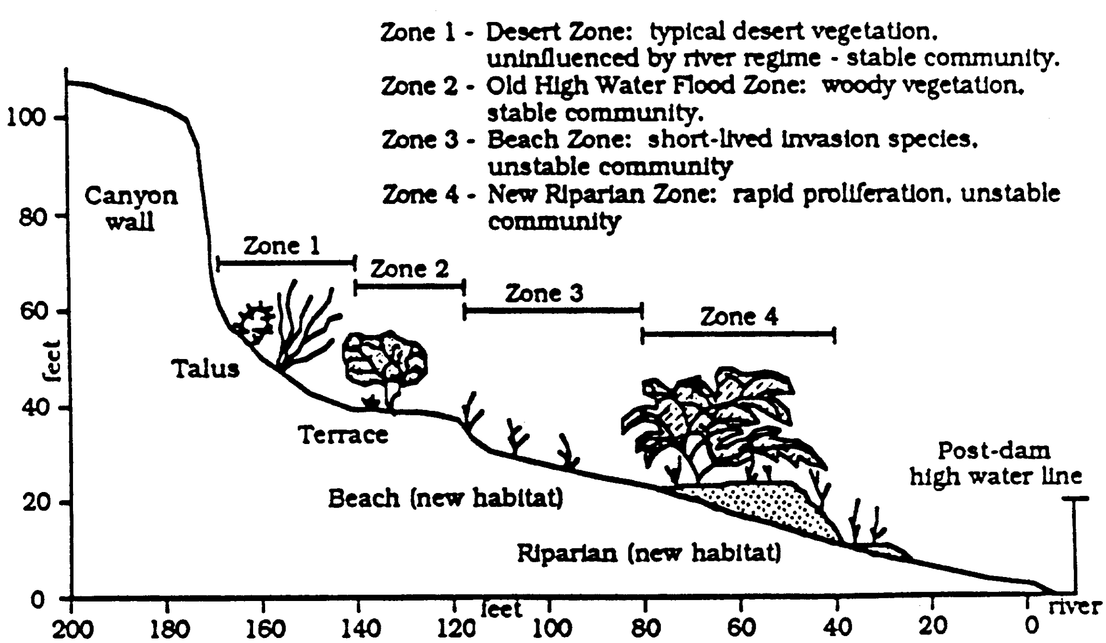
The purpose of this study was to sample the small mammal populations in the Colorado River corridor in three of the four habitat zones.

Hypotheses

1. More mammals were expected in the highly productive new riparian zone (Zone 4) than in the old high water flood zone (Zone 2) or the desert zone (Zone 1).

2. On the basis of previous surveys Peromyscus eremicus and Peromyscus boylii were expected to numerically dominate the small mammal population.

Figure VIII-1 Habitat zones along the Colorado River corridor. Carothers (1976)



METHODS

Each night during the 11 day river trip, in July-August, 1989 small mammals were live trapped on ten different beach sites. (Mile 119 was trapped on the right side on 07/29 and on the left side on 07/30. Lower National (166.5 L) was trapped on 08/1 and Upper National (166.4 L) on 08/2). In 3 of the 4 zones an attempt was made to evenly space the 32 traps, baited with oatmeal, granola and rice. Traps were set in zones 1,2 and 4. It was decided that a more accurate sample would be obtained if there was a higher concentration of traps in each zone. The traps were collected at dawn. Trapped mammals were weighed, sexed, identified by species and released unharmed into the zone from which they were captured.

ABBREVIATIONS USED

Peromyscus boylii = Pb
Peromyscus eremicus = Pe
Perognathus intermedius = Pi
Neotoma albigula = Na
success rate = sr
Peromyscus crinitus = Pc
Perognathus formosus = Pf
Peromyscus maniculatus = Pm
Neotoma lepida = Nl
zone = z

RESULTS

Table VIII-1 shows the number of mammals trapped on each beach. The table compares the number of mammals trapped in each zone to the number of traps set in each zone per night. Table VIII-2 shows the distribution of species in each zone. The totals of mammals trapped by zone from Table VIII-1 and VIII-2 are compared with data from previous years in Figure VIII-2. Figure VIII-3 compares percentage of small mammal species trapped in years 1982, 1983, 1987, 1988, and 1989. Figure VIII-4 shows the distribution and number per species, on each beach. Table VIII-3 compares the mean mass of the seven species trapped.

Table VIII-1. Number of small mammals captured and trapping success (%) by beach and habitat zone.

Date	Beach	ZONE 1	ZONE 2	ZONE 3	ZONE 4	TOTAL/ SITE
7/25	19.5 (L 19.5)	00/23	00/00	00/00	00/22	00/45
7/26	Nankoweap (R 53)	00/00	04/25	04/22	00/00	08/47
7/27	Carbon Ck (R 64.7)	00/26	00/32	00/00	00/31	00/89
7/28	Grapevine (L 81.1)	00/23	02/32	00/00	02/32	04/87
7/29	119 (L 119)	02/32	11/28	00/00	07/32	20/92
7/30	119 (R 119)	04/27	04/30	00/00	00/29	08/86
7/31	Pancho's Kitchen (L 137)	04/24	05/23	00/00	02/22	11/69
8/01	Lower National (L 166.8)	03/24	09/30	00/00	05/30	17/84
8/02	Upper National (R 166.6)	11/30	07/30	00/00	08/30	26/90
8/03	194 (L 194)	05/29	18/30	00/00	08/30	31/89
TOTAL / ZONE		29/238	60/260	04/22	32/258	125/778
SUCCESS RATE		12%	23%	18%	12%	16%

Table VIII-2. Number of mammals captured and success rate (sr=%) by species and habitat zone.

Species	z1	sr1	z2	sr2	z3	sr3	z4	sr4	TOTAL	% OF TOTAL
Pm	00	0.0%	00	0.0%	00	0.0%	00	0.0%	00	00%
Pe	13	5.5%	30	12.5%	01	4.5%	25	9.7%	69	55%
Pc	02	0.8%	04	1.5%	00	0.0%	01	0.4%	07	06%
Pb	00	0.0%	00	0.0%	01	4.5%	00	0.0%	01	01%
Pf	00	0.0%	00	0.0%	00	0.0%	00	0.0%	00	00%
Pi	09	3.8%	17	6.5%	00	0.0%	04	1.6%	30	24%
Na	01	0.4%	06	2.3%	00	0.0%	01	0.4%	08	06%
Nl	04	1.7%	03	1.2%	02	9.1%	01	0.4%	10	08%
TOTAL/ ZONE	29		60		04		32		125	
TOTAL sr/ ZONE		12.2%		23%		18%		12.5%	16%	
% TOTAL/ ZONE	23%		48%		03%		26%		100%	

Figure VIII-2 Percentage of mammals captured by zone.

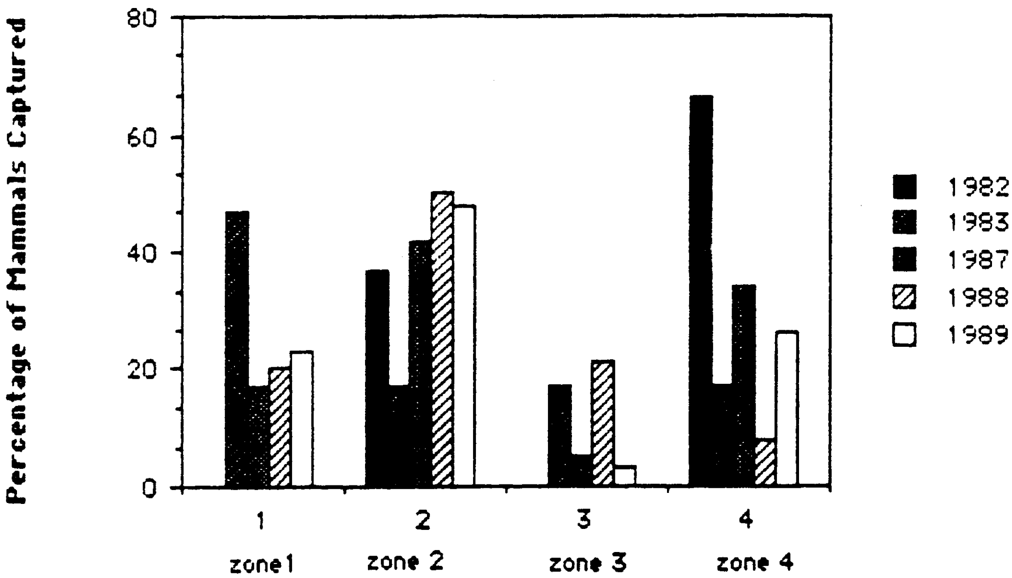


Figure VIII-3A. % Species by Year

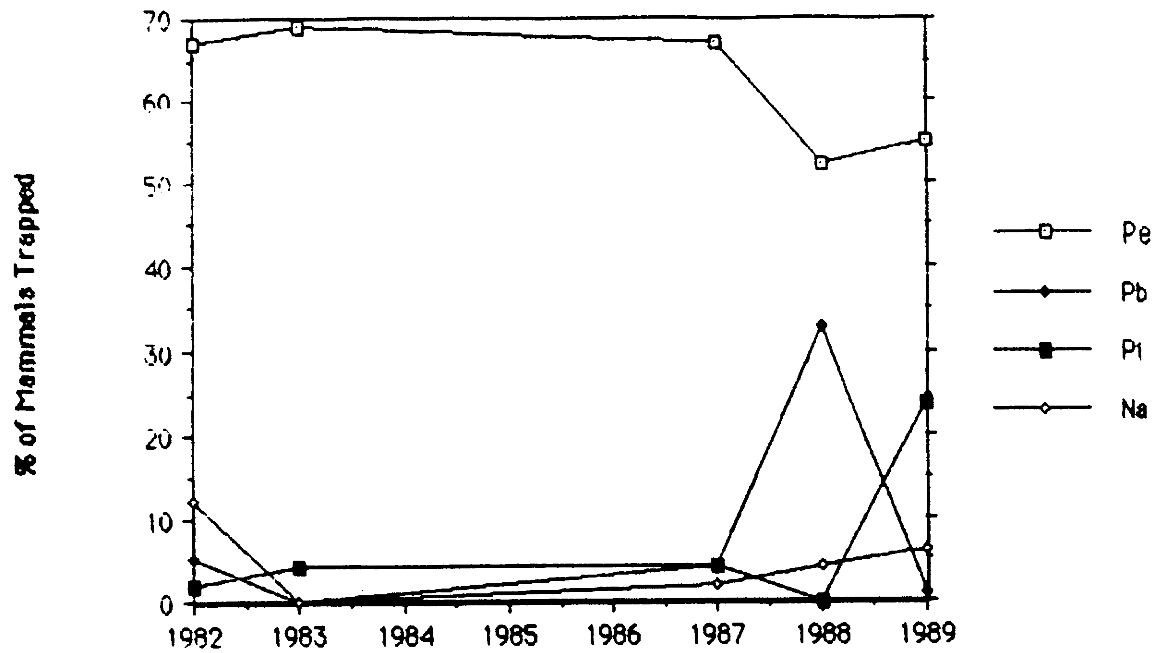


Figure VIII-3B. % Species by Year

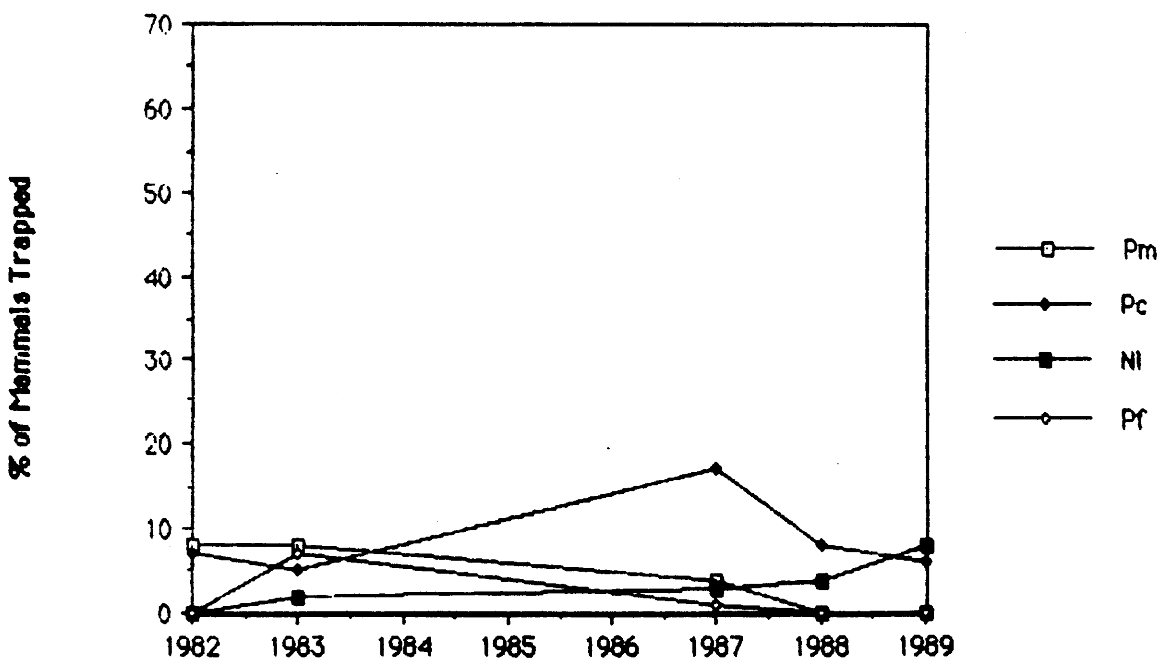


FIGURE VIII-4 Species Distribution and Number Per Beach

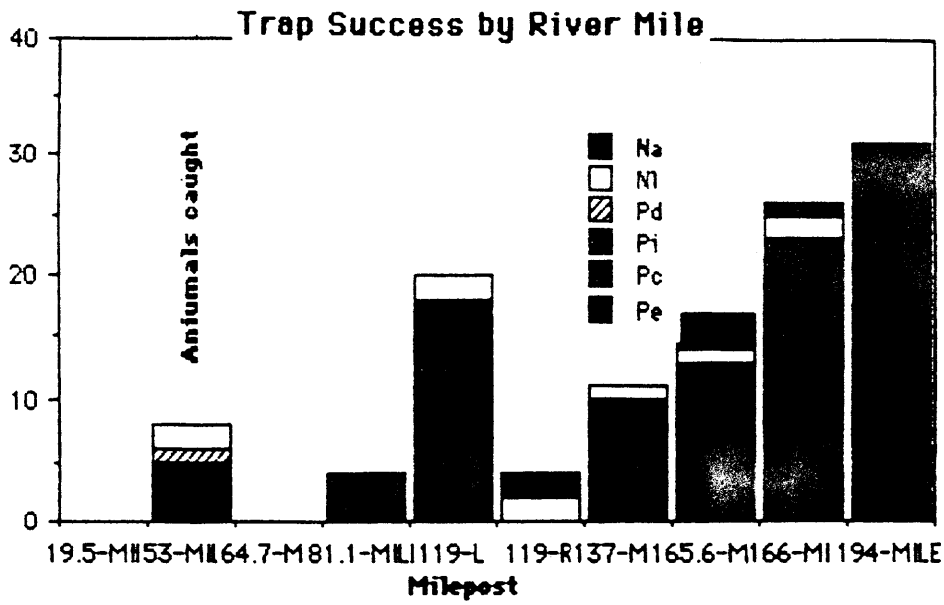


TABLE VIII-3. MEAN MASS, STANDARD DEVIATION (S), NUMBER OF MAMMALS/SPECIES

SPECIES	MEAN MASS	S	N#
Pm	0.0g	+-0.0	00
Pe	16.8g	+-2.2	69
Pc	14.7g	+-1.4	07
Pb	25.5g	+-0.0	01
Pf	0.0g	+-0.0	00
Pi	15.0g	+-1.7	30
Na	106.3g	+-5.8	08
Nl	85.7g	+-4.4	10

Total # trapped = 125

DISCUSSION

This survey of small mammals from 3 habitats in the Colorado River corridor in Grand Canyon National Park revealed differences between years in trapping success, dominance, zone distribution, species distribution, and the effects of distance downstream from Lee's Ferry on relative abundance. In the 1989 study 125 small mammals were caught on ten consecutive nights, from a total of 778 traps set. The trap success rate increased to 16%, as compared to 1988, (15%) (Kendall 1988) and 1987, (13%) (Rotstein 1987).

P. eremicus continued to dominate (55%) of the total mammals trapped. In the 1988 study, P. boylii was stated to have a surprising increase from the 1987 study (from 3% to 33%). The 1989 data shows P. boylii at 1% of rodents trapped. The 1988 study records no trappings of P. intermedius, while 1989 shows 24% of rodents trapped were P. intermedius. Due to similarities in tail-hair features, a misidentification of P. intermedius as P. boylli may have occured in the 1988 study.

Forty percent of mammals trapped were caught in zone 2, while zone 4 produced 26% and zone 1 yielded 23%. The success rate (based on successful trappings per number of traps/set in a zone) was also highest in zone 2 (23%) Zones 1 and 4 both had success rates of 12%. Zone 3 was mistakenly trapped on one beach and yielded an 18% success rate. Zone 4 shows a substantial increase in trappings from the 1988 study (from 7% to 26%). In 1982 (pre-flood) zone 4 yielded 63% of mammals trapped and dropped to 16% in 1983 (post-flood). This may indicate an increase in use of zone 4 compared to pre-flood conditions.

When comparing the percentage of species trapped by year, a few changes were evident. P. eremicus was dominant over P. intermedius in zones 1 and 2 and P. eremicus was overwhelminly dominant over P. intermedius in zone 4. Competitive interaction maybe reducing P. intermedius populations in zone 4.

No P. maniculatus were trapped in 1989. This was not surprising as P. maniculatus were not usually found in the Grand Canyon Colorado River corridor, perferring rim habitats (Hoffmeister 1971). No P. formosus were trapped either. P. formosus are only found on the north and west side of the Colorado River (Hoffmeister 1986). P. formosus also prefer the rocky slopes of zone 1 for habitat (Hoffmeister 1986). Only three of ten trap sites were north/west side beaches, thus limiting successful trappings of P. formosus. To further decrease the success, one north beach was not trapped for zone 1, another north/west beach yielded no rodents in 89 traps because of rain. This left one north/west beach to yield P. formosus.

N. albigula occur only on the south side of the Colorado River (Hoffmeister 1986). The 1989 data showed two N. albigula identified on the north side of the river. This may be interpreted either as a migration across the natural barrier of the Colorado River or a misidentification of N. lepida as N. albigula. N. lepida can be found on both sides of the Canyon (Hoffmeister 1986).

There continues to be a relationship between the number of mammals trapped and the number of ant nests (Kendall 1988) The higher the ant population the lower the success rate of the traps. This may represent competitive interaction between ants and rodents. Future studies may want to identify the number of traps per site which have been infested with ants to see if there is competitive interaction between ants and rodents.

Figure VIII-4 strongly suggests a negative correlation between elevation and rodent population density. The figure also suggested that wider corridor reaches had higher populations of rodents. Future studies should increase the number of traps and maintain constant numbers of traps in each zone on each sight, to determine if these patterns are real. Higher rodent populations in the lower corridor may occur in response to resource availability and/or predation pressure.

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CHAPTER 9

LEVEL OF GAMMA RADIATION IN COLORADO RIVER SEDIMENTS

CATHERINE O'ROURKE TAYLOR, KRIS VASQUEZ, JOE SHANNON

INTRODUCTION

At present, little information exists on background gamma radiation in the Colorado River corridor in Grand Canyon National Park. Above normal amounts of radioactivity in sediment deposits in the Grand Canyon would diminish the value of the Colorado River system for biological resources, recreational users and for the Lower Colorado River Basin states that depend on the river as a water source. Higher than normal amounts of radiation in this system could be due to contamination from uranium mining spills at Church Rock Mill in 1979 on the Rio Puerco (Little Colorado River) drainage (Shuey, 1982) and one at Kanab Creek in 1983. Due to the mining spills, the amount of gamma radiation in Colorado River mud may increase below the Little Colorado and below Kanab Creek.

On July 16, 1979, an estimated 1,100 tons of tailings and 94 Mgal of liquid were released into the Puerco River when a tailings pond dam failed at Church Rock, New Mexico (Webb et al., 1987). After the spill occurred, greater than 30 pCi/g of thorium-230 was found as far down as 40 miles from the dam. The concentration eventually decreased with time until it reached a level of 9 pCi/g (Webb et al., 1987). Since the Puerco River empties into the Little Colorado River which meets the Colorado River at river mile (RM) 61 in the Grand Canyon, the spill may have a significant impact on sediments, water quality, and rare and endangered humpback chub breeding habitat in the Grand Canyon. Little information is available on the Hacker Canyon spill in Kanab Creek. Apparently, an Energy Fuels Nuclear uranium mine released some radioactive substances into the drainage but the amount and the exact date could not be determined.

Ours was the first study of its type done in the Grand Canyon by this group. Since radioactive isotopes precipitate out of water (Webb et al., 1987), sampling mud deposits should give an indication of the amount of radioactivity present. The amount of background activity can be measured by using mud deposits from above the Paria River confluence (RM 1). Since this was a baseline study, we attempted to collect samples from pre-dam, pre-Puerco River spill, pre-1983 flood deposits, and post-1986 aggraded sediments. The data obtained should serve not only to determine the effect of Rio Puerco on the Colorado River, but also to serve as a base for future studies.

METHODS

We collected mud samples from various points along the Colorado River from July 25 - August 5, 1989 over a 225-mile route from Lee's Ferry to Diamond Creek. One kg. samples were collected from back eddies or other sources of fluvial silt using a small hand-held trowel. Silt was important because radionuclides precipitate out of water and cling to silt and clay particles (Landa, 1980). Care was taken to insure that the samples consisted of mud with little or no vegetation. Each sample was double bagged in 4 L. size zip-loc bags and labeled as to site location using a waterproof marker. Sample locations are listed in Table 9-1, along with percent silt and clay. For a control below the Little Colorado

River, samples were taken from older deposits at Parashant Canyon. These samples are noted in Table 9-1.

We took 3-4 color polaroid pictures of various views from the sample collection site in most cases. One picture always consisted of a team member standing on the exact site. A compass reading was taken using a Bronstead compass and this reading was recorded on each photograph.

Upon returning to Northern Arizona University, the samples were dried in an oven at 60°C. At this point, 100 g. of each sample was mechanically phi sized to determine the percentage of silt and clay using a "soil tester" apparatus. The greater the percentage of silt and clay in a sample, the higher the quality.

DISCUSSION OF SAMPLE SITES

At Blacktail Rapid, samples were taken from two different deposits both of which were pre-1983 because there was tamarisk trees growing above them. According to Larry Stevens, the tamarisks germinated sometime between 1965 and 1973. Whether or not the deposits were pre-dam could not be determined.

At Kanab Creek, four different samples were taken. Kanab Creek #1 was a surface deposit slightly upstream from the confluence of Kanab Creek and the Colorado River. Kanab Creek #2 was a river deposit at the mouth of Kanab Creek. Kanab Creek #3 was a tributary deposit one-quarter mile up Kanab Creek. Kanab Creek #4 was a tributary deposit on a debris bar downstream of the creek mouth.

Thirteen different deposits were found at a cutbank at Parashant Canyon. Due to color differences, Ted Melis was able to determine that seven of the deposits were from river flooding events and six deposits were from tributary flooding events. We labeled the youngest deposits river #1 and tributary #1 and progressed down the profile with the bottom-most deposit being river #7. The numbers in Table 9-1 and Table 9-2 represent the specific deposits each sample was taken from.

RADIOACTIVITY STUDY

Selected samples were analyzed for radioactive uranium, thorium, and potassium using passive gamma-ray techniques. Samples approximately 1 kg in weight were sealed in plastic containers and stored for one month to allow parent and daughter products in the radioactive decay series to equilibrate. Natural radioactive gamma-ray energy spectra were then measured for each sample using a shielded activated NaI crystal, photomultiplier tube, and pulse height analyzer. These spectra were then compared with the spectra from standards containing known concentrations of U, Th, and K, and the unknown concentrations of U, Th, and K in the samples were computed from the relative sizes of the energy peaks from the standards and samples. Results are given in part per million (ppm) for uranium and thorium, and in percent of <u>total</u> potassium, the conversion from radioactive potassium being made using the cosmic abundance ratios of the potassium isotopes. Standard deviations of the element abundances are also given, based upon the goodness of fit of the sample spectral peaks with the standard spectral peaks. Natural heat generation from the sum of the radioactive isotopes is given in both HGU units (10^{-13} calories/cubic centimeter/second), and in S.I. units (microwatts per cubic meter).

The analyses can be evaluated both in terms of the absolute abundances of the radioactive elements, and in terms of the concentration ratios of these elements. Absolute abundances are typically in the following ranges for crystalline rocks:

Thorium:	1-30 ppm
Uranium:	0.1-10 ppm
Potassium:	0.1-5%

Concentrations tend to increase with increasing silica int eh rocks as these elements are incompatible and tend to be concentrated in low temperature igneous rocks. Cosmic concentration ratios of these elements, based upon meteorite studies, are generally taken to have the following values:

Th/U:	3.8
K/U:	10,000

These ratios ±50% are typically found in crystalline rocks unless there is evidence for selective remobilization of one of more of the incompatible radioactive elements.

Selective remobilization of the incompatible radioactive elements most commonly occurs in low temperature aqueous processes. Potassium is easily transported in aqueous solution, uranium is soluble under reducing conditions only, and thorium has a very low solubility. Typically, these processes lead to a decrease in both the Th/U and the K/U ratios in sediments.

RESULTS

The Grand Canyon samples mostly show radioactivity trends expected in normal sedimentary processes (Table 9-3, Figure 9-1). Most absolute abundances are within the normal crystalline rock range, and there is no evidence for major radioactive element enrichment. The concentration ratios indicate slight potassium depletion in most of the samples relative to uranium and thorium, and minor uranium enrichment relative to thorium. These depletions and enrichments are thought to result from normal low temperature aqueous processes.

Two samples show significant uranium enrichment relative to thorium; sample number 1581689 at Kanab Creek and sample number 1681689 at National Canyon. In these samples the absolute uranium concentrations are marginally higher than concentrations typical of crystalline rocks, indicating uranium enrichment rather than thorium depletion. Sedimentary rocks with very high uranium concentrations are common in the Grand Canyon region (the uraniferous breccia pipes), so a natural source for the higher uranium sediments is possible. Alternatively, the source could be man-made through surface spill, mining activity, or other surface disruptive activity of the natural uranium ores. Whatever the source, the concentrations or uranium sampled in this study are no cause for alarm, but they provide a useful baseline data set against which future sediments can be compared, to evaluate the impact of development on the margins of the Grand Canyon.

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TABLE 9-1 PERCENT SILT AND CLAY OF COLORADO RIVER SAMPLES

SAMPLE SITE	RIVER MILE	PERCENT SILT AND CLAY
Lee's Ferry	0	52.4
Paria confluence	0.5	47.6
Badger Rapids	8.0	1.7
Shinumo	29.0	19.9
Nankoweap	52.0	2.6
Mile 56 Emarsh #1	56.5	46.5
Mile 56 Emarsh #2	56.5	36.7
Little Colorado Confluence	61.8	13.3
Lava Canyon #1	65.2	36.2
Lava Canyon #2	65.2	36.1
Upper Granite	93.2	39.7
Blacktail Canyon	119.1	51.1
Blacktail Rapid #1	120.0	49.0
Blacktail Rapid #2	120.0	20.6
122 Mile Canyon	122.0	58.5
Fishtail Rapid	139.0	61.8
Kanab Creek #1	143.5	60.7
Kanab Creek #2	143.5	54.0
Kanab Creek #3	143.5	70.4
Kanab Creek #4	143.5	35.1
National Canyon	166.5	71.4
194 Mile	194.0	26.5
Parashant Canyon River	198.5	61.9
Parashant River #2	198.5	83.5
Parashant Trib #3	198.5	28.1
Parashant Trib #6	198.5	56.6
Parashant River #7	198.5	83.6

TABLE A-2 Phi Size Data

Sample Site	1400	707	500	351	250	177	125	88	63	PAN
					PHI SIZE (MICRONS)					
Lees Ferry	0.01	0.01	0.03	0.05	0.71	1.16	1.17	[illegible]	33.11	[illegible]
Paria Confluence	0.33	1.11	1.43	1.27	1.64	1.16	11.79	[illegible]	[illegible]	[illegible]
Badger Rapids	0.02	0.19	0.49	3.24	13.13	37.33	21.33	7.94	3.03	1.69
Shinamu Creek	0	0.05	0.16	2.83	11.12	15.41	24.00	13.40	10.33	[illegible]
Nankoweap	0.05	0.40	0.13	0.46	15.51	37.51	36.31	4.13	1.39	1.63
Ft F marsh #1	0	0.01	0.02	0.06	0.13	0.32	4.07	19.67	13.63	46.11
Ft F marsh #2	0	0.01	0.01	0.01	0.02	0.04	6.07	26.50	30.31	36.61
Little Colorado	0.56	2.43	1.07	2.03	9.46	19.21	31.26	11.33	5.77	13.14
Lava Canyon #1	0	0.01	0.04	0.06	0.21	0.41	6.69	26.44	24.13	34.41
Lava Canyon #2	0.14	1.37	1.07	[illegible]	0.66	0.81	7.69	25.24	[illegible]	[illegible]
Upper Granite	0.01	0.02	0.03	0.17	1.04	2.62	16.53	21.41	17.71	39.19
Blacktail Canyon	1.81	3.72	2.16	0.95	1.66	3.00	15.98	11.16	6.53	50.60
Blacktail Rapid#1	0	0.01	0.01	0.01	0.29	1.81	15.11	17.56	15.13	48.49
Blacktail Rapid#2	0	0.01	0.04	0.59	6.85	9.37	14.20	11.76	14.32	30.17
122 Mile Canyon	0	0.01	0.01	0.02	0.02	0.16	15.62	14.00	11.43	55.24
Fishtail Rapids	0.01	0.01	0.01	0.02	0.10	0.35	11.63	15.10	10.69	61.46
Kanab Creek #1	0	0.01	0.01	0.01	0.08	0.33	6.53	13.94	16.54	60.55
Kanab Creek #2	0.01	0.04	0.03	0.17	0.91	1.20	21.00	12.69	9.14	55.01
Kanab Creek #3	0.03	0.09	0.11	0.21	0.45	0.56	7.40	10.55	10.26	70.39
Kanab Creek #4	2.35	3.75	2.48	4.00	6.31	6.17	19.15	13.53	6.87	34.63
National Canyon	0.06	0.16	0.06	0.03	0.04	0.03	8.62	10.70	5.66	70.71
Mile 194	0	0.04	0.03	0.19	1.01	1.92	24.91	28.46	15.57	[illegible]
Parashant River	0.59	6.61	4.54	3.12	2.51	1.47	3.35	6.16	3.77	61.56
Para River #1	0.47	0.15	0.36	0.73	1.04	0.61	1.44	3.59	7.67	[illegible]
Para Trib #5	0	0.40	1.32	2.91	5.27	3.88	12.85	21.78	22.39	[illegible]
Para Trib #6	0	0.02	0.03	0.10	0.37	0.72	3.97	17.36	24.27	[illegible]
Para River #7	0.02	0.02	0.03	0.01	0.02	0.02	1.24	4.60	10.59	[illegible]

TABLE 9-3. PROPORTIONS OF URANIUM, THORIUM AND POTASSIUM IN COLORADO RIVER SAMPLES

NO.	SAMPLE SITES	Th ppm	Std D	U ppm	Std D	K %	Std D	HGU	Std D	K/U *3	Std D
1	Paria # 1 1381689	7.13	1.53	3.58	0.62	0.44	0.14	3.53	0.68	1.48	0.28
2	Paria River 781489	4.93	1.37	2.54	0.55	0.56	0.12	2.53	0.60	1.06	0.25
3	Paria # 3 981489	3.10	0.73	1.02	0.28	0.64	0.09	1.30	0.32	0.55	0.13
4	Shinumo Cr 2081789	4.52	1.27	2.49	0.51	0.20	0.11	2.35	0.56	0.98	0.23
5	Nankoweap 1781789	3.37	0.94	1.39	0.36	0.80	0.12	1.62	0.41	0.55	0.13
6	LCR 1481689	5.56	1.61	3.11	0.64	0.31	0.14	2.94	0.71	1.23	0.30
7	LCR # 1 2581889	5.35	1.62	2.93	0.65	0.27	0.14	2.79	0.71	1.17	0.30
8	LCR # 2 481489	7.32	1.50	2.80	0.61	0.40	0.14	3.07	0.66	1.28	0.28
9	LCR 2 881489	6.77	1.45	2.75	0.58	0.39	0.13	2.94	0.64	1.23	0.27
10	LCR # 2 581489	7.22	1.46	2.83	0.59	0.42	0.13	3.07	0.65	1.28	0.27
11	L Co R 2761889	5.77	1.67	3.06	0.67	0.25	0.15	2.93	0.73	1.23	0.31
12	LCR # 3 2281789	5.77	1.69	3.10	0.67	0.32	0.15	2.97	0.74	1.24	0.31
13	Upper Granite 1081489	7.07	1.58	2.98	0.64	0.35	0.14	3.13	0.70	1.31	0.29
14	Blacktail Cn 2381789	6.51	1.61	3.88	0.65	0.37	0.14	3.59	0.71	1.50	0.30
15	Blacktail Cn 1281589	5.73	1.60	3.38	0.64	0.25	0.14	3.12	0.70	1.31	0.29
16	Blacktail Cr 1 1181489	7.64	1.56	3.46	0.63	0.37	0.14	3.52	0.69	1.47	0.29
17	Mile 122R 2881889	11.08	1.65	3.45	0.67	0.42	0.15	4.11	0.73	1.72	0.31
18	Fishtail Cr 1981789	7.45	1.54	3.68	0.62	0.40	0.14	3.63	0.68	1.52	0.29
19	National Cn 1681689	4.29	2.32	10.78	0.96	0.34	0.20	7.47	1.04	3.13	0.43
20	Kanab Cr # 1 1881789	13.40	1.71	4.18	0.69	0.52	0.15	4.98	0.76	2.08	0.32
21	Kanab Cr 15816891	4.20	1.81	11.22	0.76	0.97	0.23	7.87	0.83	3.29	0.35
22	Kanab Cr 2481789	7.80	1.79	5.52	0.72	0.39	0.16	4.83	0.79	2.02	0.33
23	Kanab Cr # 4 2981889	5.10	1.40	3.22	0.56	0.20	0.13	2.90	0.62	1.21	0.26
24	Mile 194L 2691889	6.65	1.46	2.85	0.59	0.37	0.13	2.98	0.65	1.25	0.27
25	Parashant Trib 381489	4.11	1.03	1.31	0.39	0.94	0.13	1.73	0.45	0.72	0.19
26	Parashant Trib 6 781489	4.93	1.37	2.54	0.55	0.56	0.12	2.53	0.60	1.06	0.25
27	Parashant Cn 7 681489	9.64	1.67	2.98	0.67	0.52	0.15	3.60	0.74	1.50	0.31
28	Parashant Cn 2181789	9.35	1.67	4.14	0.67	0.44	0.15	4.25	0.74	1.78	0.31
29	Parashant Cn 281489	10.16	1.71	3.15	0.69	0.57	0.15	3.80	0.76	1.59	0.32

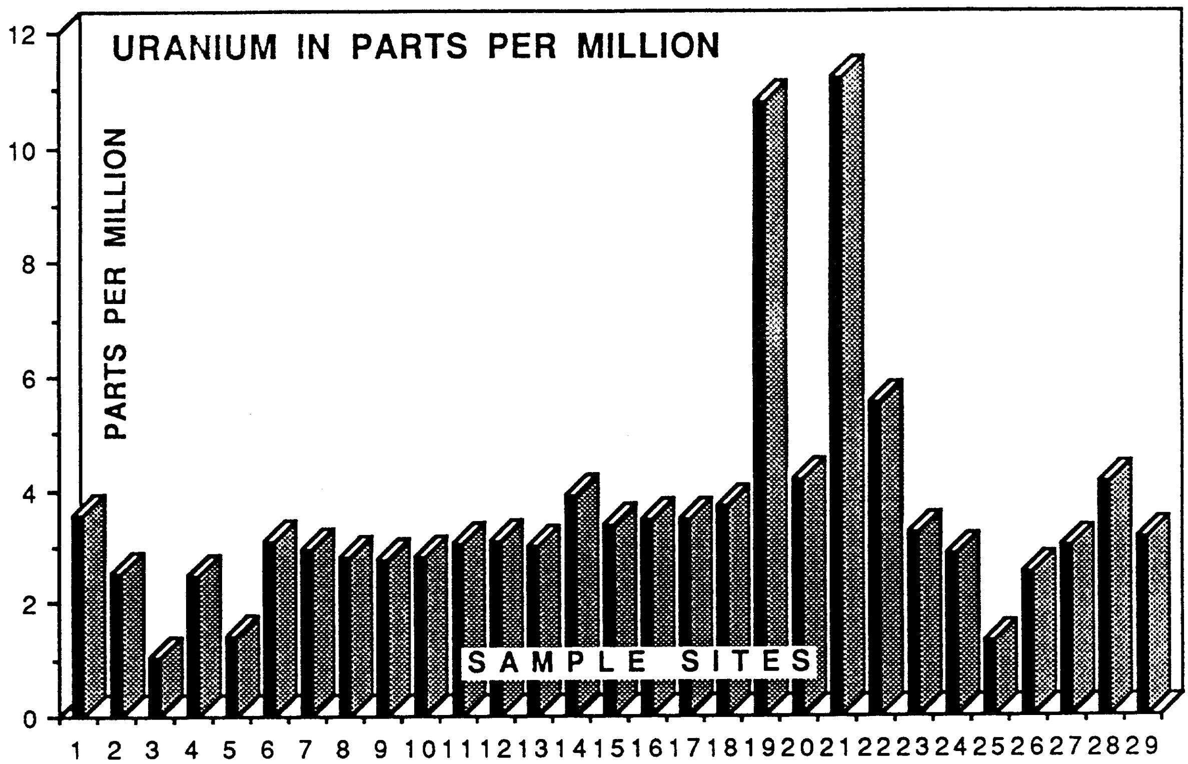


Figure 9-1. Uranium present in selected Colorado River sediment samples. Data are from Table 9-3.

CHAPTER X

PERCOLATION RATES BENEATH CANOPIES OF THREE DOMINANT RIPARIAN PHREATOPHYTES IN THE COLORADO RIVER CORRIDOR, GRAND CANYON NATIONAL PARK

Peggy L. Benenati
Graciela Rendon-Coke
Lawrence E. Stevens

INTRODUCTION

One biotic mechanism responsible for perennial riparian plant succesion in dam-controlled environmentS is canopy induced soil hydrophobicity. Resin, sugars and other plant by products accumulate and waterproof the soil surface (Stevens and Waring 1985). Hydrophobic soils inhibit seedling establishment by preventing root development in desiccated soil. Clonal species are capable of rhizomally colonizing the waterproofed soil beneath the canopy. The combination of these mechanisms and strategies may result in succession in a dam-controlled environment (Stevens 1989).

METHODS

Field and laboratory experiments in the Grand Canyon and at Northern Arizona University were conducted to determine if tamarisk (*Tamarix ramosissima*), coyote willow (*Salix exigua*) and arrow weed (*Tessaria sericea*) are using direct interference competition to prevent seedling establishment under their canopies.

Sixty-nine percolation runs and soil collections were conducted at sites with dense canopy cover under *Tamarix*, *Salix*, *Tessaria* and unvegetated (open) soil sites. The open soil sites were selected from undisturbed areas and used as a control.

An 8 cm. diameter ABS plastic pipe was beveled at one end to facilitate soil penetration. The pipe was inserted 5 cm. into the soil with minimal disturbance. One half litre of water was poured into the tube and timed with an stop-watch until completely absorbed. A hand trowel was used at each site to collect superficial soil samples of 100-200 Grams at 1.0 cm depth. The samples were weighed immediately with a 300 g Pesola spring balance.

The sixty nine soil samples were returned to the laboratory and dried at 60 degrees Celsius and re-weighed to determine moisture content. Each was sifted through screens of diameters of 1.000mm. and 0.0625 mm. for 15 minutes in a mechanical shaker,and weighed to determine percent silt+clay content.

Data were analyzed using analysis of variance and covariance,and multiple linear regression.

RESULTS

Raw data presented in Table X-1.

Table X-1: Raw data by river mile; CANOPY: 1= *Tamarix*, 2= *Tessaria*, 3= *Salix*, 4= Unvegetated soil. PERCRATE= Percolation rate. PSLT= Percent silt. ASPSC= Arcsine sqare root percent silt+clay. PWATER= Percent moisture. ASPW= Arcsine square root percent soil moisture.

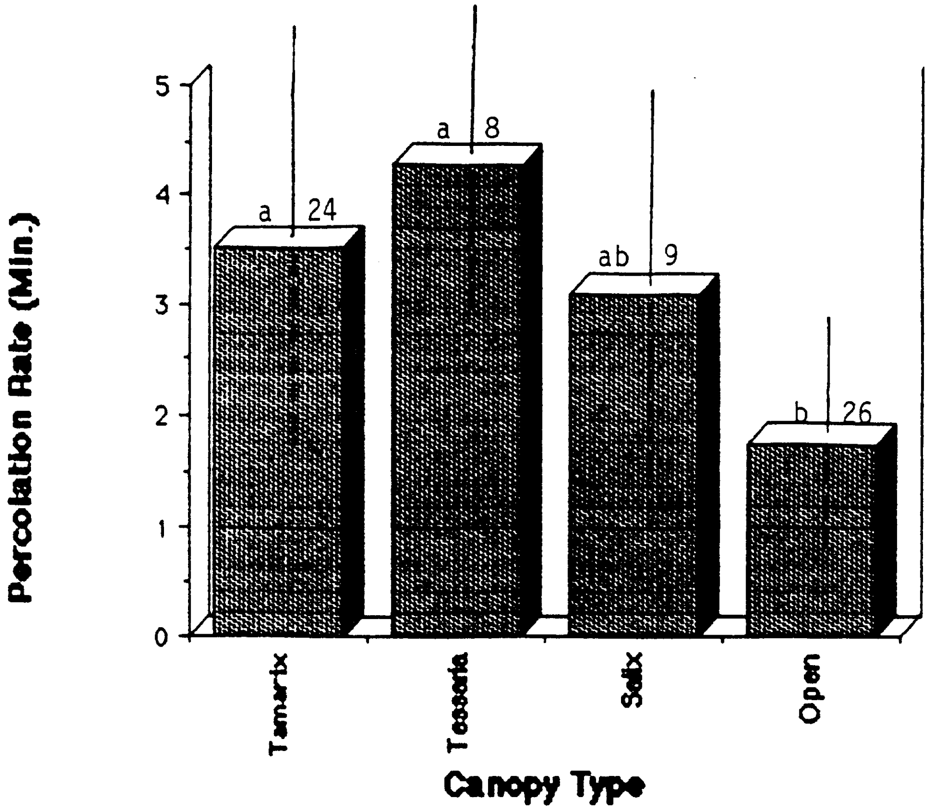
ROW	MILE	CANOPY	PERCRATE	PSLT	ASPSC	PWATER	ASPW
1	8.00	1	3.40000	0.71	0.084362	0.00	0.000000
2	8.00	4	2.46667	1.94	0.139738	0.00	0.000000
3	20.01	4	5.03333	1.62	0.127625	0.55	0.074230
4	20.01	1	2.50000	3.00	0.174083	0.00	0.000000
5	20.01	4	1.21667	0.78	0.088433	0.00	0.000000
6	20.21	4	1.38333	1.40	0.118599	0.67	0.081945
7	20.21	1	2.43333	1.51	0.123193	0.00	0.000000
8	34.91	4	4.70000	1.43	0.119869	0.89	0.094480
9	34.91	1	3.68333	1.57	0.125630	0.00	0.000000
10	41.00	4	2.60000	0.64	0.080086	0.88	0.093946
11	41.00	1	5.40000	1.68	0.129981	0.00	0.000000
12	41.00	2	4.50000	0.96	0.098137	0.00	0.000000
13	53.00	1	2.20000	0.68	0.082556	1.80	0.134570
14	53.00	1	3.11667	3.44	0.186553	0.00	0.000000
15	53.00	2	4.15000	0.88	0.093946	0.10	0.031628
16	53.00	2	3.56667	0.77	0.087863	2.80	0.168123
17	53.00	2	3.85000	0.59	0.076887	1.94	0.139738
18	53.00	4	1.50000	3.48	0.187647	2.56	0.160691
19	53.00	4	1.40000	0.60	0.077537	2.06	0.144024
20	58.10	3	4.11667	5.00	0.225513	1.77	0.133437
21	58.10	3	3.68333	2.09	0.145077	4.00	0.201358
22	58.10	4	1.81667	0.32	0.056599	0.87	0.093410
23	58.10	4	0.96667	2.22	0.149554	0.00	0.000000
24	58.10	1	2.56667	1.66	0.129200	0.00	0.000000
25	58.10	1	1.63333	1.26	0.112487	0.00	0.000000
26	61.01	3	5.76667	4.01	0.201613	0.85	0.092327
27	61.01	4	1.56667	1.00	0.100167	1.01	0.100669
28	61.01	1	2.45000	1.20	0.109765	0.00	0.000000
29	94.01	2	7.08333	2.17	0.147847	0.00	0.000000
30	94.01	1	3.50000	8.37	0.293505	0.00	0.000000
31	94.01	4	1.48333	0.12	0.034648	0.37	0.060865
32	119.91	1	2.80000	3.70	0.193560	0.70	0.083764
33	119.91	1	1.78333	2.66	0.163827	0.00	0.000000
34	119.91	4	1.03333	0.73	0.085544	0.47	0.068610
35	119.91	4	1.03333	0.83	0.091231	0.46	0.067875
36	120.00	1	2.58333	1.66	0.129200	0.00	0.000000
37	120.00	1	9.83333	25.52	0.529583	0.00	0.000000
38	120.00	3	2.93333	1.14	0.106975	0.65	0.080710

39	120.00	4	2.28333	2.98	0.173496	0.68	0.082556
40	120.00	4	0.68333	0.51	0.071475	0.62	0.078822
41	120.00	3	5.18333	2.48	0.158138	0.59	0.076887
42	122.50	3	0.95000	0.64	0.080086	0.00	0.000000
43	122.50	3	2.35000	1.05	0.102650	0.32	0.056599
44	122.50	4	0.93333	0.55	0.074230	0.30	0.054800
45	122.50	4	0.71667	0.87	0.093410	0.00	0.000000
46	122.50	1	4.15000	0.62	0.078822	0.33	0.057477
47	122.50	1	3.28333	1.87	0.137178	0.00	0.000000
48	122.81	4	1.38333	0.11	0.033172	0.34	0.058343
49	122.81	1	6.31667	1.57	0.125630	0.00	0.000000
50	122.81	2	3.88333	8.89	0.302765	0.00	0.000000
51	122.81	3	1.45000	1.25	0.112038	0.50	0.070770
52	132.00	3	1.43333	0.99	0.099664	0.60	0.077537
53	132.00	4	2.26667	3.12	0.177567	0.00	0.000000
54	139.00	4	1.26667	0.54	0.073551	0.00	0.000000
55	139.00	4	1.25000	1.05	0.102650	0.70	0.083764
56	139.00	1	6.26667	6.49	0.257594	3.18	0.179284
57	139.00	1	1.56667	3.47	0.187374	0.69	0.083162
58	166.61	4	2.55000	2.43	0.156523	*	*
59	166.61	2	5.20000	1.71	0.131143	0.57	0.075570
60	166.61	1	5.40000	4.78	0.220412	1.95	0.140100
61	171.51	1	2.60000	1.11	0.105552	1.45	0.120709
62	171.51	4	1.85000	0.48	0.069338	0.00	0.000000
63	171.51	2	2.06667	1.79	0.134193	0.00	0.000000
64	[illegible]	4	1.01667	0.55	0.074230	0.34	0.058343
65	[illegible]	1	2.41667	1.33	0.115583	0.62	0.078822
66	220.00	4	1.10000	1.95	0.140100	0.00	0.000000
67	220.00	1	2.78333	0.96	0.098137	0.00	0.000000

Percolation rates were found to be significantly related to canopy type (F=8.33, p<0.001, df=3,63). Tessaria had the slowest percolation rate and open sand has the fastest percolation rate. Tamarix and Salix, had intermediate percolation rates showing no significant difference in the percolation rate (refer to Graph X-1 and Table X-2).

Percolation rate was multiply regressed against Arcsine transformed percent silt+clay and percent soil moisture (Table X-3). This analysis revealed a strong positive correlation between percolation rate and fine-particle content of soil, (Graph X-2) but a non-significant relationship between percolation rate and soil moisture.

Percent silt+clay was significantly beneath Tamarix canopies, intermediate beneath Tessaria and Salix and lowest in unvegetated soils (F = 2.90, p = 0.042, df = 3,63). The transformed mean percent silt + clay for Tamarix was 0.162 (n=24,s.d.=.0954); Tessaria was 0.134 (n=8,s.d.=.0727); Salix was 0.137 (n=9,s.d.=.0499); Unvegetated soil was 0.104 (n=26,s.d.=.0423). Percent soil moisture was not significantly different in the 4 canopy types, although Salix showed a non-significant trend of higher soil moisture.



Graph X-1: Mean percolation rates of 4 canopy types in post-1983 new high water zone soil in the Colorado River corridor of the Grand Canyon. Error bars are + 1 s.d., and lower case letters indicate significant t-test differences at p<.01. N indicated at top left of each bar.

Table X-2: Analysis of variance on percolation rates as a function of four canopy types post 1983 beach sands in the Grand Canyon.

SOURCE	DF	MS	F	p
Canopy Type	3	19.84	8.33	0.000
Error	63	2.38		
Total	66			

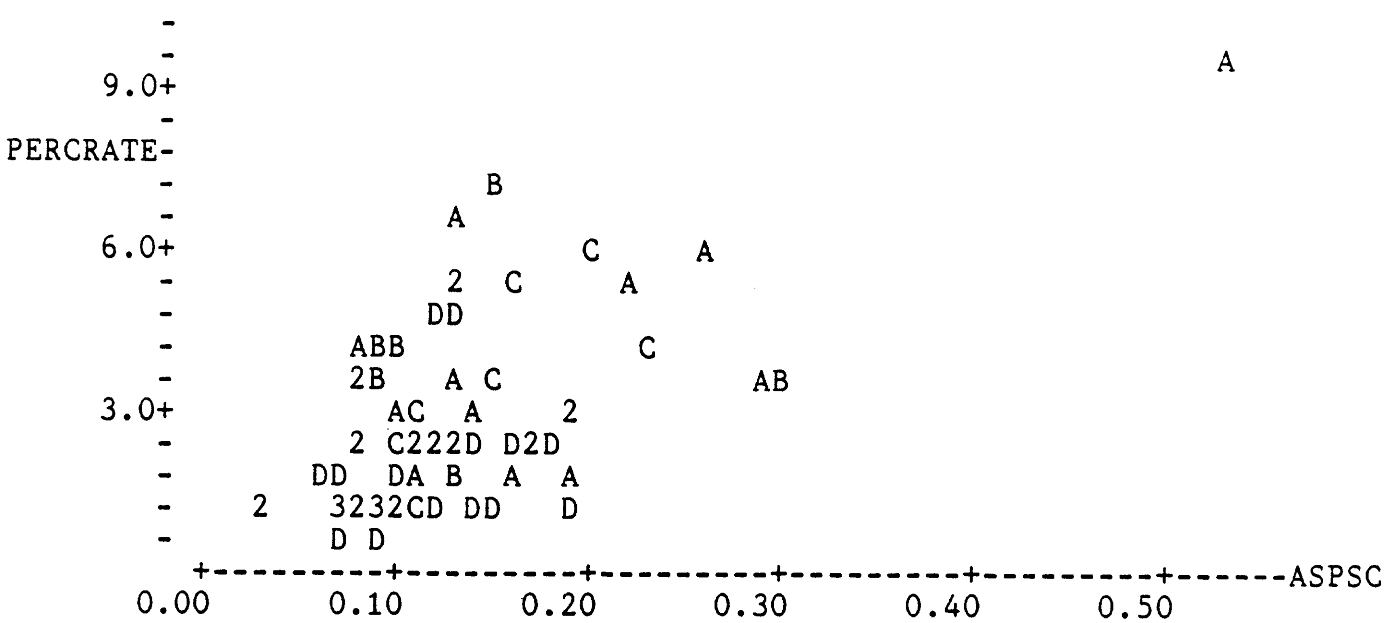
Table X-3: Multiple linear regression of percolation rate as a function of arcsine square root transformed percent silt+clay (AS%S+C) and percent soil moisture (AS%W). $F = 18.37$, $p = 0.000$, $df = 2,63$.

PREDICTOR	COEF.	ST.DEV.	t-RATIO	p
ASPSC	14.772	2.443	6.05	0.000
ASPW	2.560	3.212	0.80	0.428

REGRESSION EQUATION:

Percolation rate = 0.782 + 14.8(AS%S+C) + 2.56(AS%W)

$s = 1.450$ R-sq=36.8%



Graph X-2: Percolation rate in soils beneath 4 canopy types: A = _Tamarix_, B = _Tessaria_, C= _Salix_, D= Unvegetated soil.

DISCUSSION

We made several observations during the course of this study:

1. Accumulation of organic matter (resins, sugars and other plant byproducts) under the canopies of *Tamarix* and *Tessaria* are mechanisms responsible for hydrophobicity of soil.

2. Production of duff under *Salix* and *Tessaria* was not as abundant and visible as in Tamarix.

3. Sandy substrate supported large stands of *Salix* and *Tessaria.*

4. Seedling establishment was inhibited under *Tamarix* and *Salix* and *Tessaria* canopies as a function of soil hydrophobicity (supporting Stevens and Waring 1988).

5. *Salix* and *Tessaria* have the rhyzomal capability to overtake the hydrophobic soil of *Tamarix* and accomplish succession (supporting Stevens and Waring 1988).

CONCLUSIONS

Succession and successional inhibition are occuring simultaneously within the Grand Canyon. We found several riparian vegetation types to employ the successional mode of inhibition (Connell and Slatyer 1977) in hydrophobitizing the soil, thus preventing establishment of seedlings of all species. However, *Salix* and *Tessaria* have an advantage in ability to rhizomally colonize under *Tamarix* canopies, while *Tamarix* is only able to colonize by seedlings in a safe site.

This study determined that:

1. Change in surface substrate was found under canopy of *Tamarix* and *Tessaria* significantly reducing percolation rate as compared to unvegetated soil. *Salix* percolation rates were intermediate.

2. *Salix* soils contained non-significantly higher percentage of soil moisture due to the proximity to the river.

3. More silt + clay content was beneath *Tamarix* and less in unvegetated soil.

4. On the basis of these results we conclude that canopy-induced soil hydrophobicity serves as a mechanical, interference form of competition which influences riparian plant succession in this system by preventing seedling establishment.

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CHAPTER XI

PLANT SPECIES RICHNESS ALONG THE COLORADO RIVER IN GRAND CANYON NATIONAL PARK

Cyn-d Turner

INTRODUCTION

Perennial plant species were sampled on 19 beaches in the Colorado River corridor in Grand Canyon National Park to determine the species richness in four zones. This study was part of the reptile report (Chapter 4).

METHODS

Plants were identified using Kearney and Peebles (1973), McDougall (1973), Phillips et al. (1987), Warren et al. (1982). Specimen identifications were verified using the Northern Arizona University Deaver Herbarium.

Data from the desert zone (1), old high water zone (2), back beach zone (3) and riverbank zone (4; Carothers et al. 1979) were compiled. Raw data on species richness were analyzed and estimated species richness was calculated using the Heltshe and Forrester (1983) jackknifing formula. The formula used for estimating total number of species was:

$$\hat{S} = s_0 + \left(\frac{n-1}{n}\right)K$$

S_0 = observed # of species
n = # of samples
K = total # unique species

The variance formula used was:

$$s^2 = \frac{n-1}{n}\left(\sum_{0}^{s} j^2 f_j - K^2/n\right)$$

An analysis of variance on both raw and transformed data was conducted using Zar (1984).

For sampling methodology see the Methods section in the Reptile report.

Method Errors

1. The data was initially collected as a variable in the reptile study. At that point plant species identifications were not considered critical. Thus species numbers were lower for the first few beaches.

2. Plant identification by a novice was initially guess work which steadily improved with time, but provided untrustworthy data for the first 5-7 beaches.

3. Data were lost. In all, 9 zones were missing from the data set analyzed here.

RESULTS

Table IVa.1 shows the raw data on species richness in each zone at 19 sites. Species richness was negatively correlated with proximity to the river (Graph IVa.1 indicates mean and standard deviation of species richness for each zone). Despite this trend, analysis of variance of raw data failed to show any significant difference in species richness between zones ($F = 0.67$, $p > 0.573$, $df = 3,63$).

Graph IVa.2 indicates the total estimated species richness generated by jackknifing and the corresponding standard deviations. Significant difference was observed in species richness between all 4 zones ($F=300, p=.011$, df 3,63).

DISCUSSIONS AND CONCLUSIONS

In the analysis of the data I found the opposite pattern of what I expected. I expected a greater number of species along the riverside (zone 4). Raw data analysis showed no significant difference between zones where as the estimated species analysis proved a negative correlation between proximity to the riverside and expected species richness. The negative correlation may be due to;

1) daily disturbance by human use
2) daily floods
3) beach erosion

I present this report with a healthy scepticism as to its validity. It is a "spin off" report from data acquired for a reptile study and is not accurate enough to deduce any conclusion. However, the experience has given this researcher information to pass on to future researchers as to how to better perform this project. I don't think any accurate conclusions should be drawn from the table or graphs. They are merely exercises in compiling data.

Suggestions:

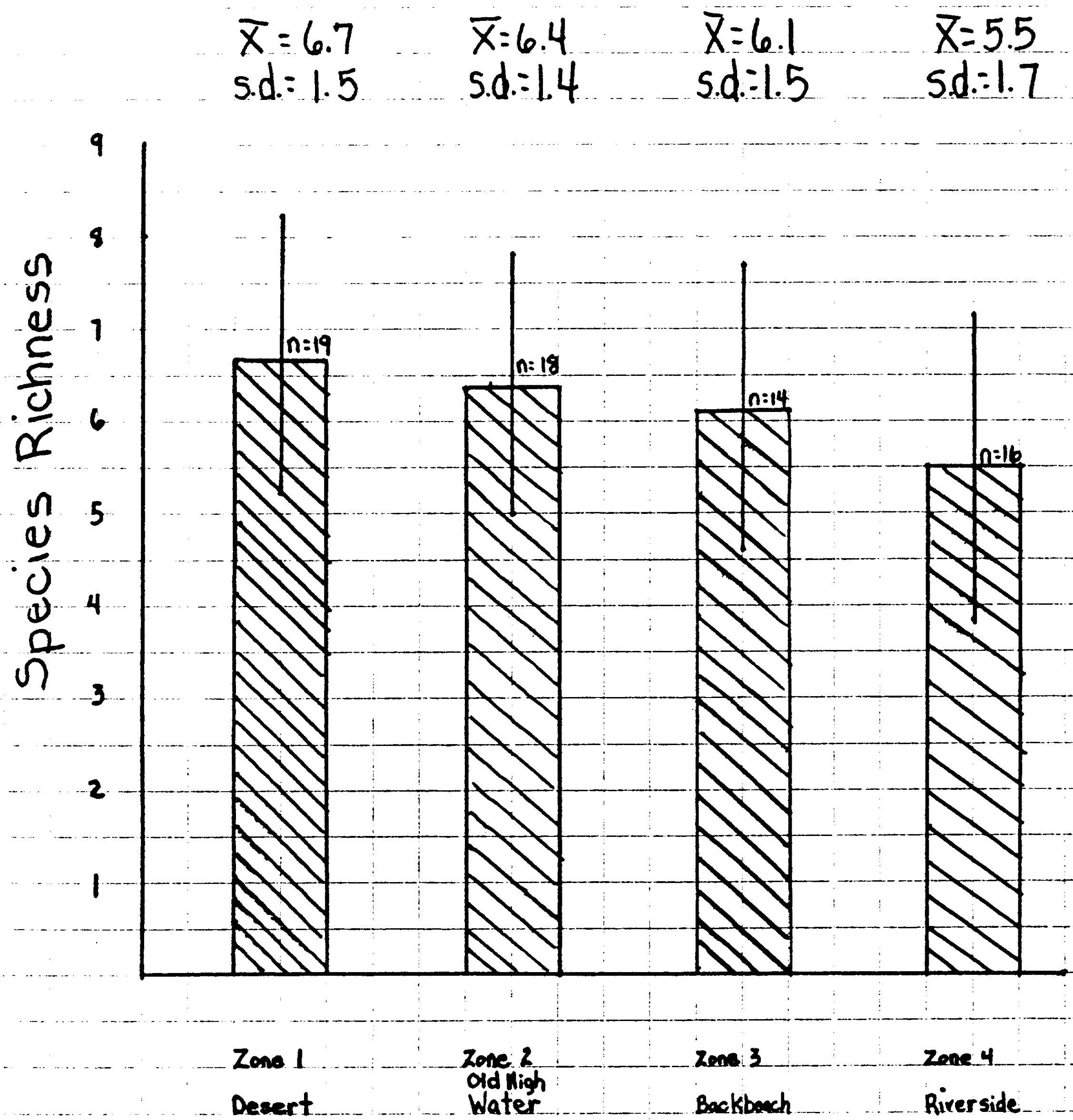
1. Plant species richness is an important topic for research in the Grand Canyon. It should be conducted in isolation to first establish accurate data.

2. The four zones at each beach site should be randomly selected irregardless of the difficulty of accessability.

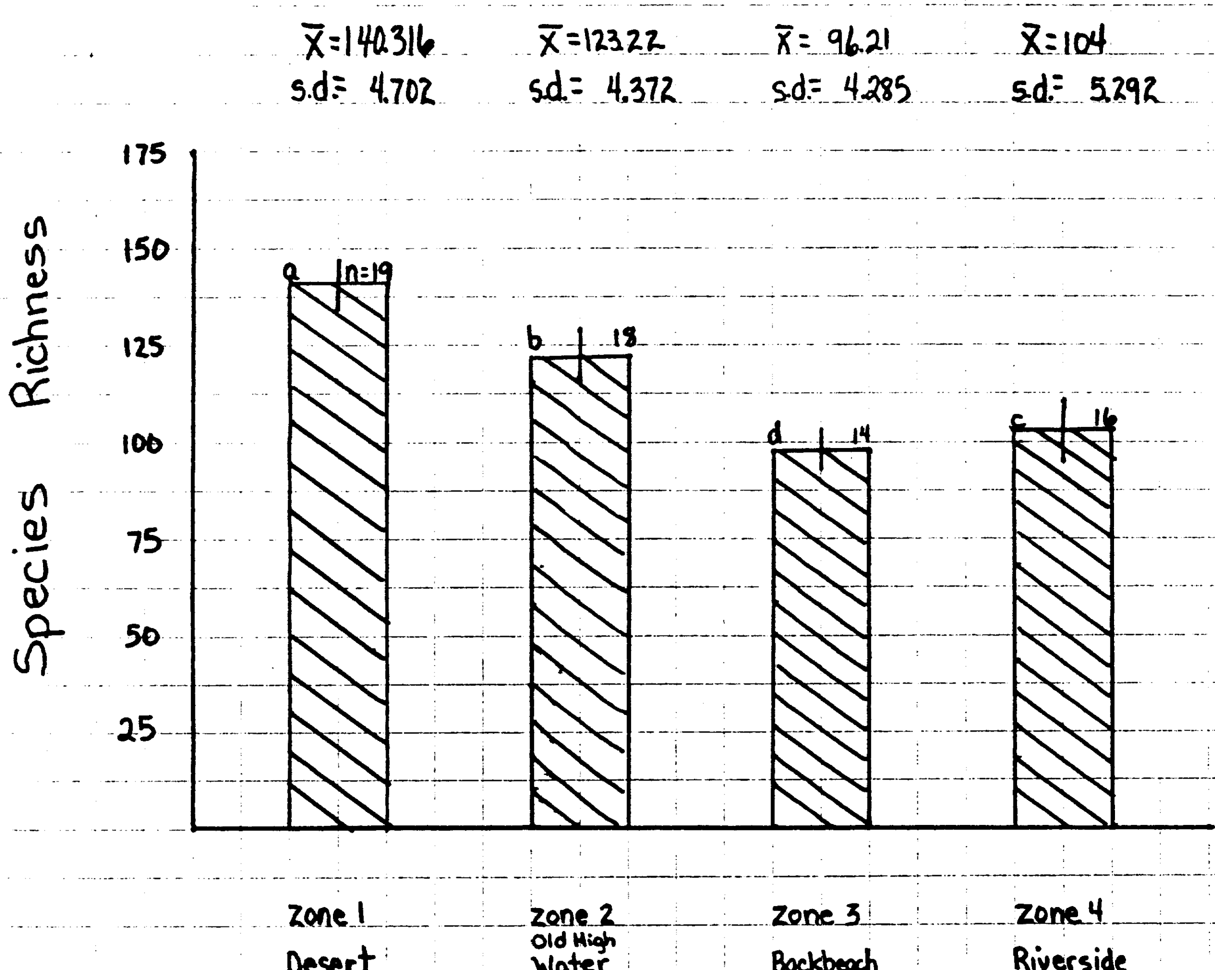
Table 1 SPECIES RICHNESS

Mile	Zone	# Of Species
29	1	7
	2	—
	3	--
	4	3
34.7	1	2
	2	6
	3	
	4	2
52	1	3
	2	4
	3	4
	4	3
64.6	1	7
	2	5
	3	3
	4	3
75.5	1	5
	2	4
	3	
	4	2
81.1	1	4
	2	4
	3	
	4	
93.2	1	4
	2	4
	3	
	4	
119	1	6
	2	5
	3	6
	4	5
120.1	1	7
	2	7
	3	8
	4	9
122	1	7
	2	8
	3	6
	4	6
123	1	8
	2	6
	3	3
	4	6
131	1	11
	2	7
	3	9
	4	3
136.6	1	8
	2	8
	3	5
	4	7
164	1	7
	2	9
	3	3
	4	3

Mile	Zone	# Of Species
166.5	1	11
	2	10
	3	6
	4	6
190.2	1	8
	2	
	3	7
	4	11
194	1	7
	2	6
	3	11
	4	
208.2	1	5
	2	6
	3	8
	4	10
220	1	11
	2	11
	3	7
	4	10



Graph IVa.1 Mean number of species and standard deviation from raw data. Sample size indicated by n at top of bar.



Graph IVa.2 Estimated species richness, standard deviation and sample size(n) along the Colorado River. $\hat{S}$ was derived using Heltshe and Forester's (1983) Estimation of species richness using the JackKnife Procedure. Lower case letters indicate significant differences between means at $p < 0.001$.

3. The slough environment should be surveyed as a seperate or sub-zone.

4. Time restraints are sometimes necessary in research but I found it an invalidator for the project. In order to acquire accurate data the researcher needs adequate time to travel the necessary distance to identify or collect species.

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CHAPTER XII

TAMARISK (TAMARICACEAE: TAMARIX RAMOSISSIMA) SEEDLING ESTABLISHMENT IN THE COLORADO RIVER CORRIDOR, GRAND CANYON NATIONAL PARK, 1989

by

L.E. STEVENS, P.L. BENENATI, G.RENDON-COKE AND J.E. KINNAMON

INTRODUCTION

Tamarisk (*Tamarix ramosissima*) is an exotic riparian phreatophyte which invaded the Colorado River riparian corridor in Grand Canyon National Park between 1922 and 1938 (Stevens in press). It presently dominates the riverside environment where it persists because of its tolerance of flooding disturbances (burial, scouring, inundation and defoliation) and desiccation, and its impressively large reproduction capacity (Waring and Stevens 1988; Stevens 1989a,b). Tamarisk is also a subdominant in tributaries, particularly along perennial drainages where tightly packed native phreatophytes apparently limit colonization space.

As a widespread weed and a dominant exotic species in a national park, tamarisk is of considerable concern. Regulated discharge of the Colorado River by Glen Canyon Dam has permitted establishment of native plant species in the new high water zone, and these native species are beginning to colonize tamarisk stands, a pattern of riparian succession not noted elsewhere in the drainage (Turner and Karpiscak 1980; Brian 1982; Phillips et al. 1987; Stevens 1985, 1989). Investigation of seedling establishment is necessary to understand how and why riparian succession takes place, and such research may be used to improve habitat management in this system.

The status of tamarisk seedling densities in the Colorado River riparian corridor has been monitored since 1984 at several sites (Stevens 1985; Stevens and Waring 1985, 1988; Waring and Stevens 1988), and this report is a continuation of those monitoring efforts. We tested Stevens and Waring's (1985, 1988) contention that tamarisk seedling establishment along the Colorado River in the Grand Canyon was flood-related, and we predicted that seedling densities should be high following flood events or years, and low in non-flooding years. As 1989 was a non-flooding year in the Grand Canyon reach of the Colorado River, we predicted that little tamarisk establishment would be observed during our river trip.

BACKGROUND

The previously-mentioned studies by Stevens and Waring have revealed much about tamarisk natural history. Tamarisk produces tiny, wind and water-dispersed seeds with a peak in May in the Grand Canyon. Water-stressed individuals produce seed only during the spring, while plants growing at the water's edge remain in reproductive condition throughout the growing season. A large, mature tamarisk is capable of producing an estimated 250,000,000 seeds/yr. Because tamarisk are long-lived (perhaps more than a century) and reproductive behavior varies little between years, a large plant growing in favorable conditions may potentially produce 25 billion propagules over the course of its life. Tamarisk seedling densities in strandlines may reach 17,000/m2 (Warren and Turner 1975), and tend to occur as even-aged cohorts on riverside sediment deposits. Self-thinning occurs rather rapidly, with densities decreasing to less than 100 plants/m2 in 5 year-old stands. Mature stands in the system typically have densities of less than 1.0 plants/m2.

METHODS

To test the above hypothesis, we censused 13 quadrats along the river in 1989, and compared tamarisk seedling densities with data from 1984-1988 (Table 1). These quadrats were 30m in length and included two flood zones/quadrat: the water's edge to the approximate 40,000cfs stage (stage had been determined during previous studies, Stevens and Waring 1988); and the 40,000-60,000cfs zone. The lower zone has been flooded up to ca. 28,000cfs on an annual basis, while the higher zone was last flooded in 1986. All seedlings were counted in each zone, and, where time permitted, older age-class plants were also counted. Results were tabulated and compared with previous year's census data.

RESULTS

In support of our hypothesis, this census showed that tamarisk seedling density was low in 1989, a non-flooding year (Table 1). Mean tamarisk seedling density was 0.004 seedlings/m2 in the new high water zone (<40,000cfs) in 1989, and no tamarisk seedlings established in the 40,000 to 60,000cfs flood zone. Figure 1 shows that mean tamarisk seedling density was: 1) lower in the upper (40,000 to 60,000cfs) flood zone than in the lower flood zone; and 2) lower in 1989 than in flooding years (e.g. 1984-1986). Exceptionally high densities in 1988 in the low zone were attributed to tributary flooding events, not mainstream flooding. This peak in seedling density was produced by the Kanab Creek site, a unique event that produced a high variance for the 1988 mean seedling density value (Figure 2).

DISCUSSION

Tamarisk seedling establishment is dependent on availability of moist, silty substrates during the summer months as the short-lived seeds are produced. Post-dam flooding in the Colorado River corridor in Grand Canyon has occurred during May and June when tamarisk seeds are abundant, thus it is no surprise that tamarisk is such a strong dominant in the new high water zone. During the past 5 years of censusing, tamarisk seedling densities have increased immediately following flooding events, and have been consistently lower in non-flooding years, except on sites where tributary flooding has provided suitable germination conditions. Thus the high density of tamarisk seedlings at Kanab Creek in 1988 was attributed to deposition of a new deposit of silt at the tributary mouth, rather than from mainstream flooding. Continued disturbance by fluctuating discharge therefore favors tamarisk establishment over native phreatophytes in the new high water zone; however, decreased disturbance favors native species establishment and successional replacement of tamarisk on higher terraces.

Many questions remain unclear regarding the future of tamarisk in this system. We recommend that future studies: 1) continue to monitor tamarisk seedling densities along the river corridor; and 2) establish long-term study quadrats in tributaries that can be monitored through time to determine if tamarisk is continuing its invasion of this system. Study plots should be established in at least 10 ephemeral and 10 perennial tributaries; plots should be at least 100m2 to be representative; and at least 3 replicate quadrats/tributary should be established at different distances from the mainstream to assure adequate representation.

Table 1: Quadrat location (Colorado River mile downstream from Lees Ferry, Arizona), and tamarisk seedling density information along the Colorado River in the Grand Canyon, in 1989. Actual number of seedlings on a quadrat floodzone, where greater than zero, are in parentheses.

LOCATION (CR MILE)	AREA (M2) LOW	HIGH	TAMARISK SEEDLING DENSITY/M2 <40,000CFS ZONE	40,000-60,000CFS ZONE
31.0R	900	900	0.000	0.000
41.0R	746	717	0.000	0.000
52.0R	600	600	0.000	0.000
52.5R	150	180	0.000	0.000
118.5L	375	240	0.000	0.000
122.1R	370	680	0.000	0.000
131.0R	240	210	0.000	0.000
131.6R	600	300	0.035 (21)	0.000
139.0R	150	210	0.000	0.000
144.0R	1048	627	0.000	0.000
171.5L	1531	1634	0.000	0.000
180.0R	240	120	0.017 (4)	0.000
198.5R	2223	1987	0.000	0.000
208.5L	674	529	0.000	0.000
		MEAN	0.004 (25)	0.000

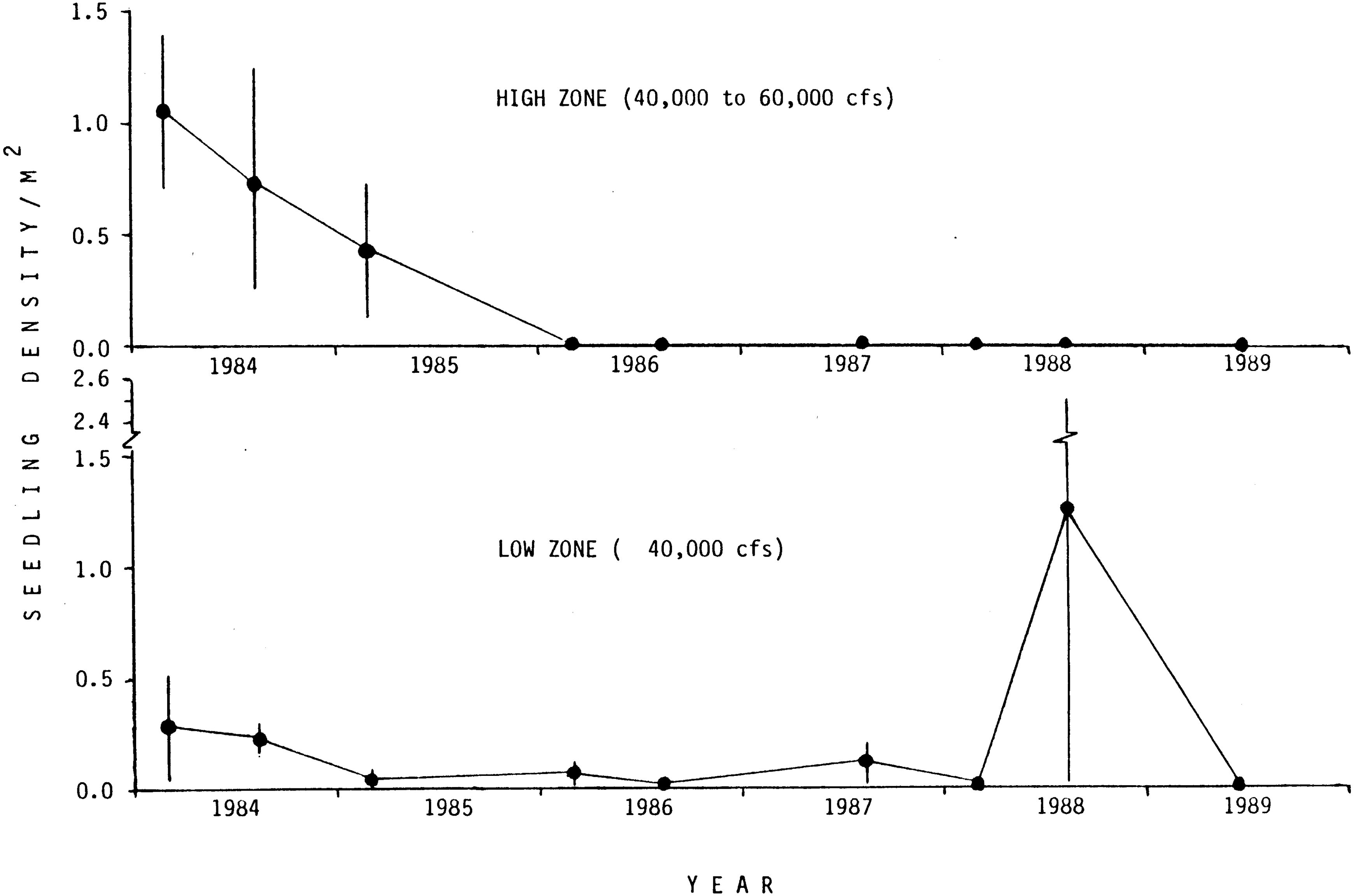

Figure 1: <u>Tamarix ramosissima</u> seedling density between flood zones and years in the Grand Canyon.

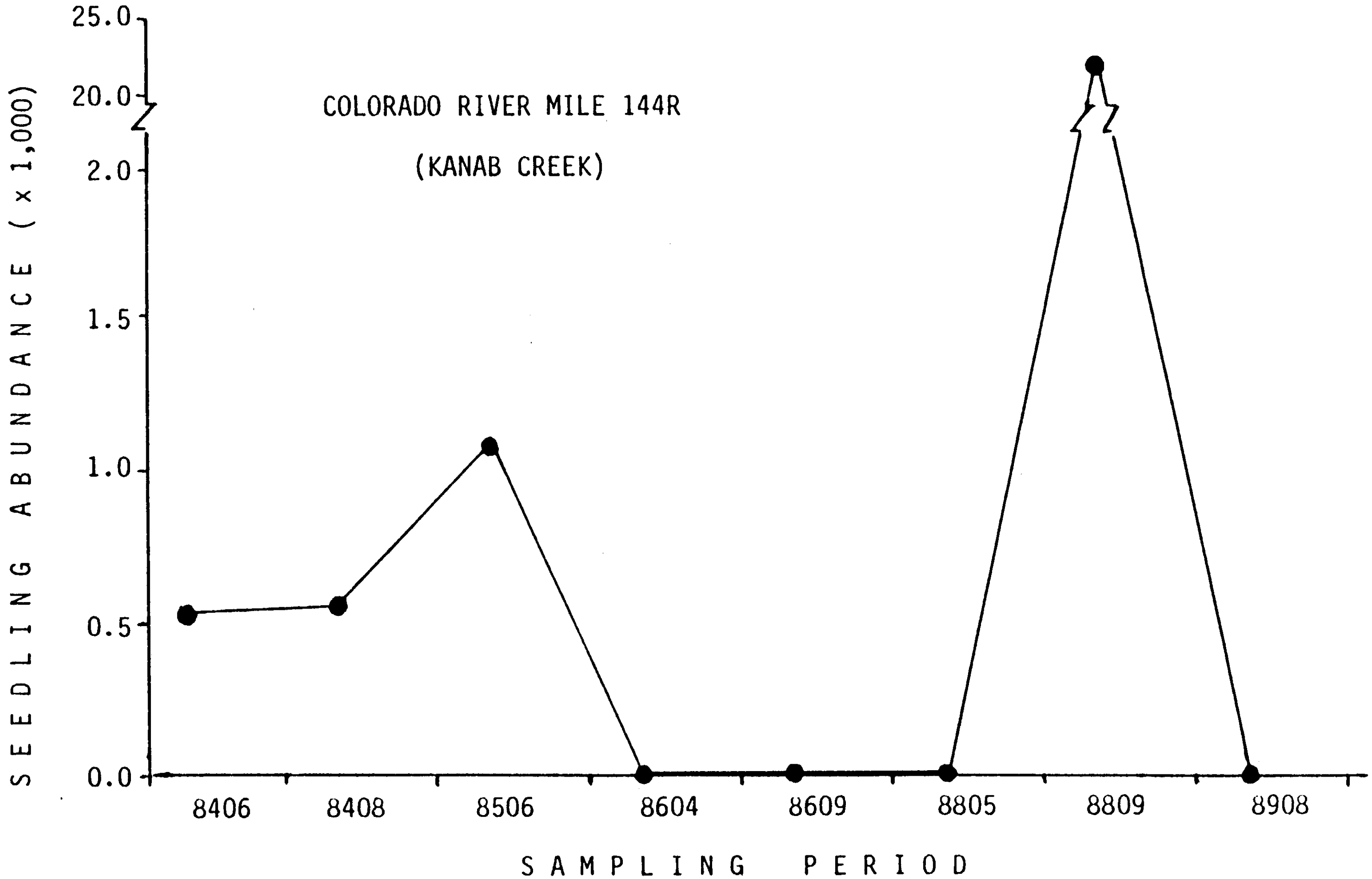

Figure 2: Total _Tamarix ramosissima_ seedling abundance at the Kanab Creek (CR 144R) quadrat, 1984 - 1989.

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