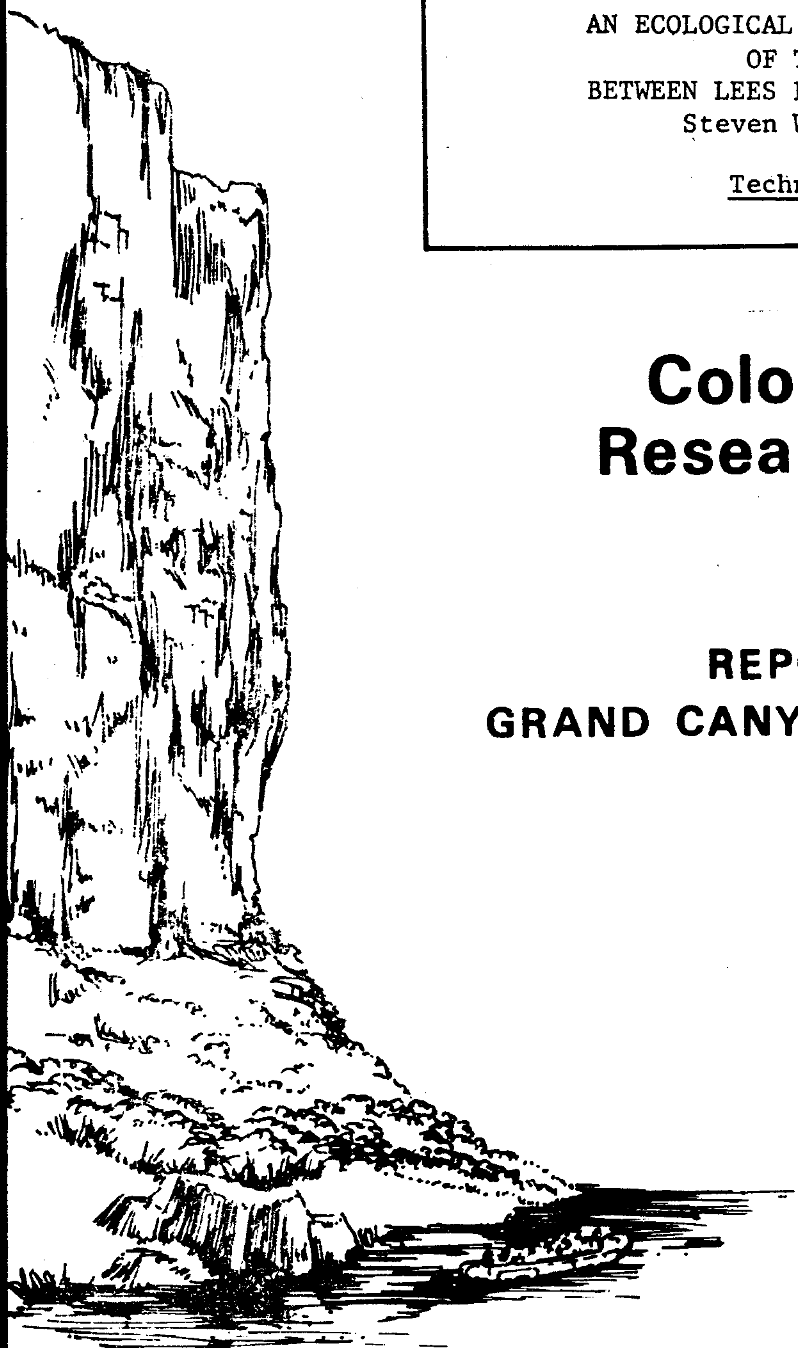
AN ECOLOGICAL SURVEY OF THE RIPARIAN ZONE
OF THE COLORADO RIVER
BETWEEN LEES FERRY AND GRAND WASH CLIFFS

Steven W. Carothers and Others

Technical Report No. 10



Colorado River Research Program

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Department of the Interior
National Park Service

AN ECOLOGICAL SURVEY OF THE RIPARIAN ZONE OF THE COLORADO RIVER BETWEEN LEES FERRY AND THE GRAND WASH CLIFFS, ARIZONA

FINAL RESEARCH REPORT

June 1976

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30 June 1976

DEDICATION

To future generations in the hope that "running the Grand" will be as exciting, fulfilling, wonderful, and mysterious for them as it has been for us.

ABSTRACT

An ecological survey of the riparian zone of the Colorado River from Lees Ferry to the Grand Wash Cliffs, Arizona, was initiated between 1 June 1974 and 30 June 1976. The purposes of this study were:

First, to describe vegetational changes as a result of the controlled water release from Glen Canyon Dam, second, preparation of a vegetation map from river level up to the 500 foot contour level, third, to describe population densities, home ranges, and demography of important vertebrates, fourth, to inventory insects of the riparian zone, fifth, to describe the distribution and impact caused by feral burros, and sixth, to describe the interrelationships of humans with the biota.

The major findings include the following: (1) The construction of Glen Canyon Dam has permitted the development of a new riparian community. This community is characterized by salt cedar, arrowweed, coyote willow, desert broom, and seep willow. (2) Botanical investigations in the riparian and adjacent habitats discerned the presence of 807 species of vascular plants representing 92 families. Also, two species, previously undescribed, Flaveria mcdougallii and Euphorbia rossii, are presented. (3) An accessment of important vertebrates and insects revealed: a) rodent communities on beaches tend to be less productive and less stable than those rodent communities of the terrace areas, b) Peromyscus eremicus appears to be the most successful small mammal in the riparian zone, c) rodent survivorship is very low and suggests a nearly annual population turnover, d) 178 species of birds utilize the riparian zone, of these 41 breed there, e) the most common bird species is the Lucy's Warbler, f) over 12,000 insect specimens in 20 orders and 247 families were collected and prepared, g) insect production on the exotic salt cedar fluctuate dramatically in comparison to insect production on dominant native plants. (4) Feral ass distribution was found to be greater than previously believed. It has been determined that the expanding feral ass populations are systematically destroying riparian and desert habitats within the study area and their immediate removal is suggested. (5) Human impact seems to be a function of visitor activities and the specific biotic sensitivity of the use area rather than a function of the total number of users. (6) In 1974, 395 different campsites were reported between Lees Ferry and Pierce's Ferry. In 1975, 350 different campsites were used. (7) Establishment and maintenance of an inner canyon trail system, the removal of all future human fecal waste material and education of river users may be the means to minimize habitat destruction rather than just setting a user-day limit.

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*These are computer print-outs and are under separate cover.

ACKNOWLEDGEMENTS

This project could never have been accoumplished without the assistance of a myriad of scientists, technicians, boatmen, cooks, universities, and research centers.

First and foremost, our thanks go to the National Park Service for the conception and financial and logistical support of this project; in particular, M. E. Stitt, R. R. Johnson, D. Ochsner, P. Bennett, and S. Stockton. Dr. R. R. Johnson, Director of the NPS River Research Project, was a constant source of aid and his interaction has greatly expedited this project.

In many cases help came from individuals from outside institutions; namely, Dr. H. S. Gentry, and J. H. Lehr, Desert Botanical Gardens; Dr. C. Mason and his staff, University of Arizona; Dr. G. Ownbey, University of Minnesota, Dr. D. J. Pinkava, E. Lehto, T. Keil and T. Reeves, Arizona State University; Dr. J. Rominger, Northern Arizona University; and Dr. M. Willson and R. Von Neuman, University of Illinois.

The acquirement of the rafts and all the accessories and training of scientists to become boatmen was a project of its own. We wish to thank the American River Touring Association and especially Lou and Bob Elliot for generously donating the frames and oars for the two snout-rig crafts. The expertise and incredible patience of boatmen Peter Winn and Scott Imsland made the dream of negotiating the rapids, whirlpools, and other hazards of the Colorado River a reality. Without them and many other boatmen this project could have never been done.

The people on our biology staff contributed much time and effort above and beyond the "call of duty." Thanks goes out to George Bain, James Bain, Debra Crisp, Jill Downs, Steve Kreigh, Dr. W. B. McDougall, Don Morehouse, Dr. O. J. Reichman, Kathy Shoemaker, Don Wertheimer, and Bill Williams. Special thanks to Pam Lunge, Museum of Northern Arizona Artist, for doing all the illustrations for this report. Photography was graciously done by John and Helen Running and Carroll Bennett. Ralph Heinz undertook the arduous task of locating and photographing the matching pictures found in Chapter I.

We are particularly grateful to the commercial and private river running outfitters that abided with our wishes and turned in their visitor usage forms.

The typing, proofing, and photocopying of this report was a colossal task. To this end we wish to thank Nancy Morgan and

Nancy Goldberg. Others who graciously helped include, Bonnie Haldeman, Melanie Neuman, and Sandy Martin.

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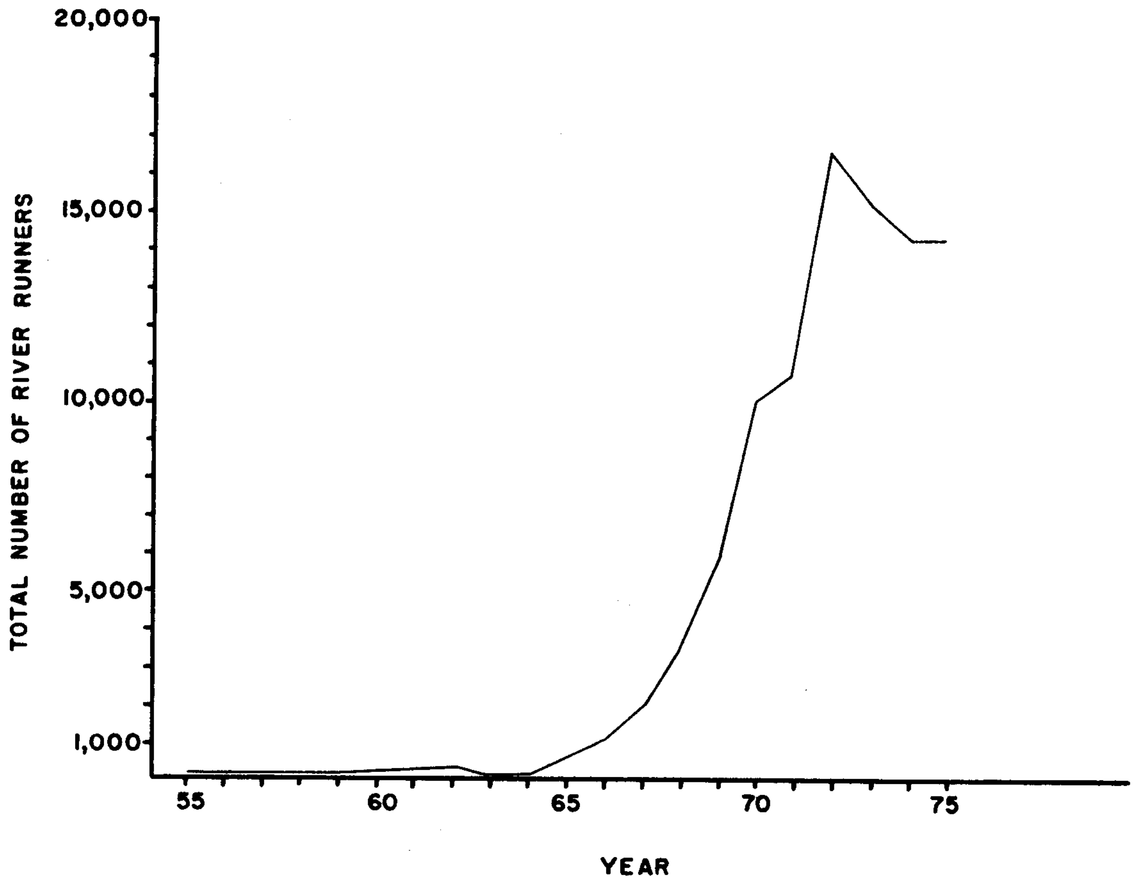

Figure 1.--Between 1967 and 1972, the total number of river runners increased 682 percent.

PREFACE

The Setting and The Problem

Until the early 1960's human usage of the Colorado River and its attendant riparian vegetation was so minimal that impact upon the biota was no doubt negligible. However, beginning in 1963, the gates of Glen Canyon Dam were closed and the riverine ecosystem was altered by the hand of man as never before. Instead of a river of mud and silt, "too thick to drink and too thin to plow," a clear, cold green flow was released from the dam. No longer would the annual spring run-off scour the canyon and deposit new beach sands and replenish driftwood.

For Colorado River rafters, the dam presents mixed blessings. On the one hand, daily river level fluctuations now occur in response to power demands in distant cities. Sometimes these fluctuations make certain rapids impossible to navigate. Commonly a boat moored at high water is left high and dry by next morning's low water. On the other hand, controlled release of water makes fall and winter trips possible during dry years when natural run-off would have been insufficient to float a boat.

However, today river running itself is one of the major problems confronting managers of our wilderness rivers. Between 1967 and 1972, river running in the Grand Canyon grew from 2099 users to 16,432, an increase of 682 percent (Figure 1). This alarming user-growth rate forced the National Park Service to initiate a ceiling on the number of boaters. The commercial allotment for 1972 was set at 105,000 passenger-days (pds). Of these only 88,135 pds were used, so for 1973 the allotment was adjusted downward to 89,000 pds. In 1973, 86,264 pds were used therefore the 89,000 figure was maintained to date. The public has been advised no final decision will be made until a carrying capacity figure is derived from the multi-disciplinary research underway at Grand Canyon.

The Harold S. Colton Research Center, Biology Department, was charged by the National Park Service with the investigation of the biotic resources of the riparian zone of the Colorado River.

The objectives were:[1]

1. To describe successional changes in vegetational patterns as a result of the controlled water release from Glen Canyon Dam. This was to be accomplished primarily through comparison of present day with pre-dam photographs.

2. Preparation of a vegetation map from river level up to the 500 foot contour level along the Colorado River from Lees Ferry to the Grand Wash Cliffs.

3. To describe population densities, home ranges, and demography of important vertebrates.

4. To inventory insect species of the riparian zone.

5. To describe impact of feral burros in the riparian zone.

6. To describe the interrelationships of visitors with the biota.

These objectives were pursued from 1 June 1974 through 30 June 1976. A total of 17 river trips and numerous backpacking trips representing a grand total of 2484 person-field days were expended.

Although work was done along the entire 300 river miles from Lees Ferry to the Grand Wash Cliffs, several study areas were set up for intensive investigation. These were:

1. Nankoweap Control, river mile 52.5R[2]. This area receives little human usage.

2. Nankoweap Impact, river mile 53.0R. This is a favorite camping and attraction area due to a large beach and a picturesque ancient Indian granary perched in a nearby cliff.

1/ These objectives do not appear in this combination in the contract but rather have been reorganized into a more logical sequence. The intended purposes of research have remained the same.

2/ All locations are given as river mile from Lees Ferry. The letters R and L are used to designate right or left side of river while looking downstream.

3. Cardenas Beach, river mile 71.0L. This area a heavily camped at site and was largely chosen because of relatively easy access (via Tanner Trail) and wide diversity of habitats.

4. Granite Park, river mile 208.6L. A heavily used area by river runners but without feral asses.

5. 209 Mile Canyon, river mile 208.6R. Little used by campers but devastated by burros.

The results of our research efforts are presented in a scientific symposium format. The overall conclusions are summarized in Chapter XIII.

As an introduction to previous biological investigations within the Grand Canyon the reader is referred to the following literature.

Aitchison, S. W., S. W. Carothers, M. M. Karpiscak, M. E. Theroux, and D. S. Tomko. 1974. An ecological survey of the Colorado River and its tributaries between Lees Ferry and the Grand Wash Cliffs. Phase I. Unpublished National Park Service Report.

Carothers, S. W., J. H. Overturf, D. S. Tomko, D. B. Wertheimer, W. W. Wilson, and R. R. Johnson. 1974. History and bibliography of biological research in the Grand Canyon region with emphasis on the riparian zone. Unpublished National Park Service Report.

Wertheimer, D. B. and J. H. Overturf. 1975. A history of biological research in the Grand Canyon region. Plateau 47(4):123-139. (Contribution No. 10 in Grand Canyon National Park Colorado River Research Series.

CHAPTER I

VEGETATIONAL CHANGES ALONG THE COLORADO RIVER

Martin M. Karpiscak

INTRODUCTION

Substantial photographic data have been collected on the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs. Comprehensive analysis and evaluation of this information indicate that man's activities on the river have considerably affected the vegetation of the area.

Prior to the construction of Hoover and Glen Canyon Dams there existed three distinctive vegetation belts which paralleled the river from Lees Ferry to the Grand Wash Cliffs. These collinear vegetational zones varied in composition; however, the species which existed within each of these belts were generally ecological equivalents. The zone closest to the river and thus subjected to flooding was composed of numerous short-lived species able to adapt to periodic disturbance. Above this ephemeral zone was a belt of vegetatation whose lower boundaries were delineated by the high water line of major floods which periodically sweep away the vegetation below this zone. This belt was typified by three species, mesquite (Prosopis juliflora), catclaw acacia (Acacia greggii), and Apache plume (Fallugia paradoxa) which is most common in the upper portion of the Canyon. On the talus above this zone were to be found species typical of the desert such as creosote bush (Larrea divaricata), ocotillo (Fouguieria splendens), beavertail cactus (Opuntia basilaris) and brittlebush (Encelia farinosa).

The construction of Hoover Dam flooded out the existing vegetational belts and established two distinctive zones below mile 240.0. The lower one is characterized by almost impenetrable thickets of salt cedar (Tamarix chinensis) and the upper one is composed of the typcial desert flora which existed there before Lake Mead.

The construction of Glen Canyon Dam in 1963 and thus the partial elimination of flooding from Lees Ferry downstream to mile 240.0 has permitted the development of a new riparian community. This vegetational community characterized by salt cedar, arrowweed (Pluchea sericea), coyote willow (Salix exigua), desert broom (Baccharis sarothroides) and seep willow (Baccharis glutinosa has become more firmly established in the zone once subjected to periodic flooding. Variations in water released from the power plant at Glen Canyon Dam determine the lower boundary of this new community. These variations in flooding of the area below this zone have prohibited the establishment of any extensive communities; however, cattail (Typha latifolia) and horse-tails (Equisetum spp.) have become established in some locations below the new salt cedar belt.

In many areas this new community occupies all the former ephemeral zone, while in other locations little or no discernable change has occurred in the vegetation. Between this vegetation belt and the pre-dam high water mark from Lees Ferry to approximately mile 240.0, we find another vegetational zone composed of numerous ephemeral species capable of completing their life cycle before the influx of river boat parties, such as red brome (Bromus rubens), tansy mustard (Descurainia pinnata), sixweek's fescue (Festuca octoflora) and Chaenactis fremontii. Many of these same species are also found on the numerous trails in and around camping areas and points of interest in the early spring and disappear with the coming of summer. Other speices, such as Russian thistle (Salsola kali) and bermuda grass (Cynodon dactylon) have also become well established in areas subjected to intensive use by man.

Today, therefore, we find four visually distinct vegetation belts from Lees Ferry to mile 240.0. The lowest is characterized by a salt cedar/seep willow/ willow zone; above this is the zone of ephemeral plants which is heavily utilized by man. We then find a mesquite/acacia/Apache plume belt and beyond this we have the communities of typical desert species on the talus slopes.

In order to fully comprehend the impact of man upon the vegetation of the Colorado River within the Grand Canyon, we must understand the tremendous influence of the construction of Glen Canyon and Hoover Dams. In addition, we have to acknowledge the invasion of numerous exotic species, such as salt cedar, camelthorn (Alhegi camelorum), red brome, bermuda grass and smotherweed (*Bassia hyssopifolia*) especially into areas disturbed by man's actual presence.

As noted above, man's activities are concentrated in the present dam-dependent communities below the mesquite/acacia zone. Photographic evidence appears to suggest that without the continued presence of man, the entire area below the mesquite/acacia belt would be exposed to possible accelerated invasion by the species of the new post-dam dependent community, especially salt cedar. This would likely produce a situation very similar to what presently exists around Lake Mead where salt cedar thickets have become all but impenetrable. Therefore, the disturbance caused by man may have partially substituted for the disturbance formally produced by periodic flooding and may be a factor in helping to maintain areas such as Red Wall Cavern and Granite Park. This is not in any way to suggest that man's presence in the Canyon does not have associated sociological, biological or geological problems, such as waste accumulation, deterioration of camping areas or erosion.

This apparent effect of man's presence on the river only applies to the areas below the mesquite/ acacia belt because the desert community above is very sensitive to disurbance by man. The surrounding territory of camping areas and points of interest such as the ruins at Nankoweap are subjected to heavy disturbance as numerous unnecessary trails are cut and recut. These trails in turn prevent the establishment of the typical vegetation of the area and instead are similar in species composition to the lower ephemeral zone. In addition, they are subjected to substantial erosion.

Man is not the only organism which has had great impact on the vegetaion. Burros have also influenced the vegetation of the mesquite/acacia belt and the desert community both by trail cutting and over browsing.

METHODS

Photographs of pre-dam beach conditions were obtained from the U. S. Geologic Survey and National Archives and were duplicated during 1974.

SUMMARY

The rematching of photos taken before the construction of Hoover and Glen Canyon Dams indicates that obvious vegetational changes have taken place in many areas of the Canyon while other areas appear to have changed very little. Exotics, such as salt cedar, camelthorn, red brome, Russian thistle and native species, such as coyote willow, desert broom, seep willow, cattails and arrowweed have flourished since the construction of the dams.

Vigorous new riparian communities have become established along the banks of the river from Lees Ferry to Lake Mead. The old high water vegetation belt of mesquite/acacia/Apache plume continues to endure and shows little observable change and may be moving down slope in some areas. However, only by continued monitoring of the changes that are occurring as a new equilibrium is slowly established will we know if it can survive in competition with salt cedar.

In conclusion, we can say that man has had tremendous impact on the flora and the riparian zone of the Colorado River region and continues to do so today. The exact nature of man's impact on the present flora will depend on the interactions of the plant species involved and the regulation of their exposure to man.

RESULTS AND DISCUSSION

The following comparisons will serve as examples of areas that have been photographically rematched and evaluated in regard to changes that have occurred in the vegetation. In all cases, there are paired photos--an old, pre-dam (a) and contemporary Museum of Northern Arizona (b) photo.

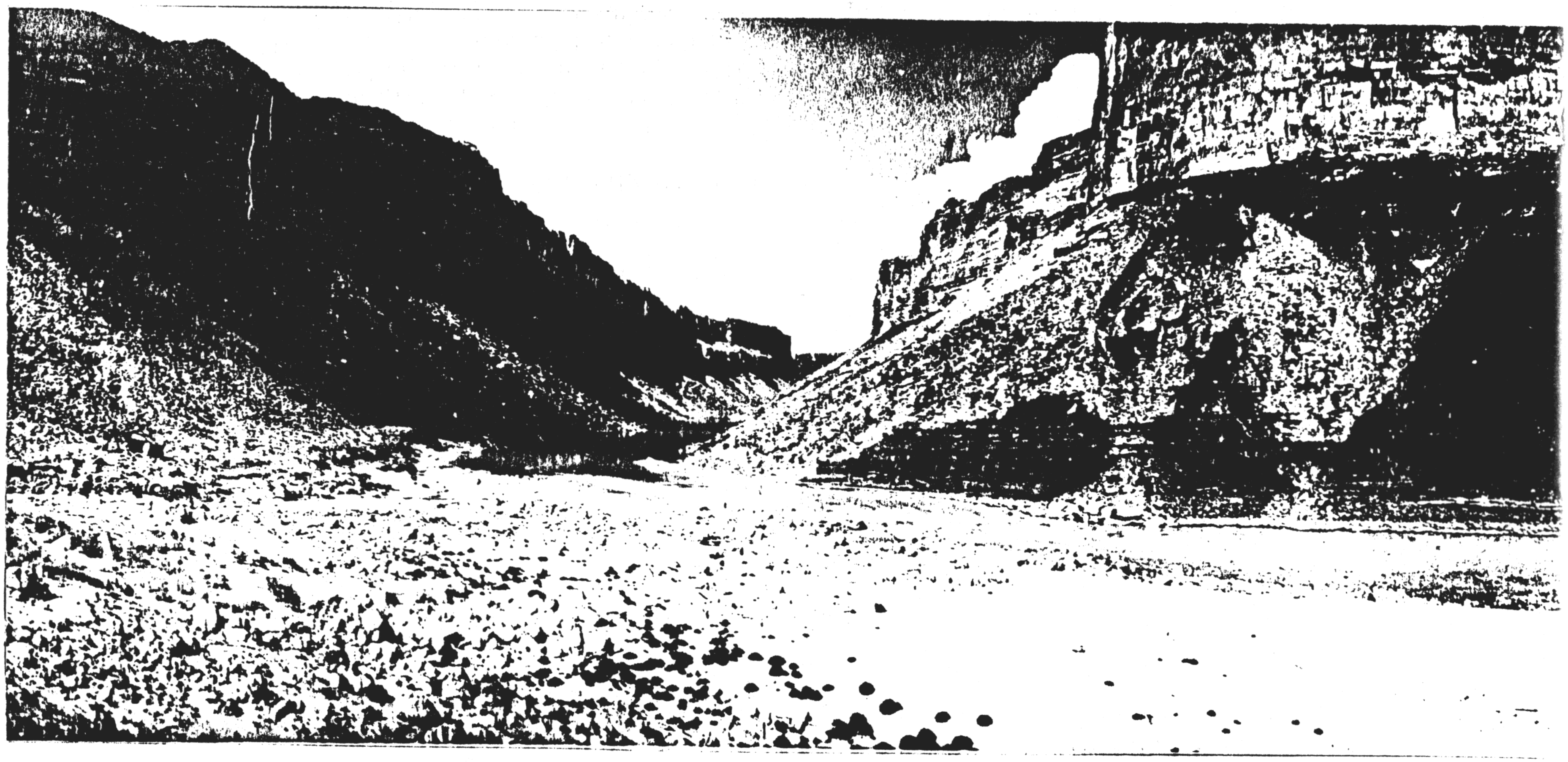

Figure I-1a.--Soap Creek Rapids, Mile 11.5, August 2, 1923.

Upstream view of Marble Canyon taken from the right side of the Colorado River (elevation 3100 feet) by E. C. LaRue. The location of the photo station is just below the mouth of Soap Creek Rapids, which can be seen right-center in the old photograph, 10.6 miles below the Paria River at mile 11.5. In the original photograph note the absence of any densely vegetated areas on either side of the river. Four-wing salt bush (Atriplex canescens) can be seen on the sand dune on the left.

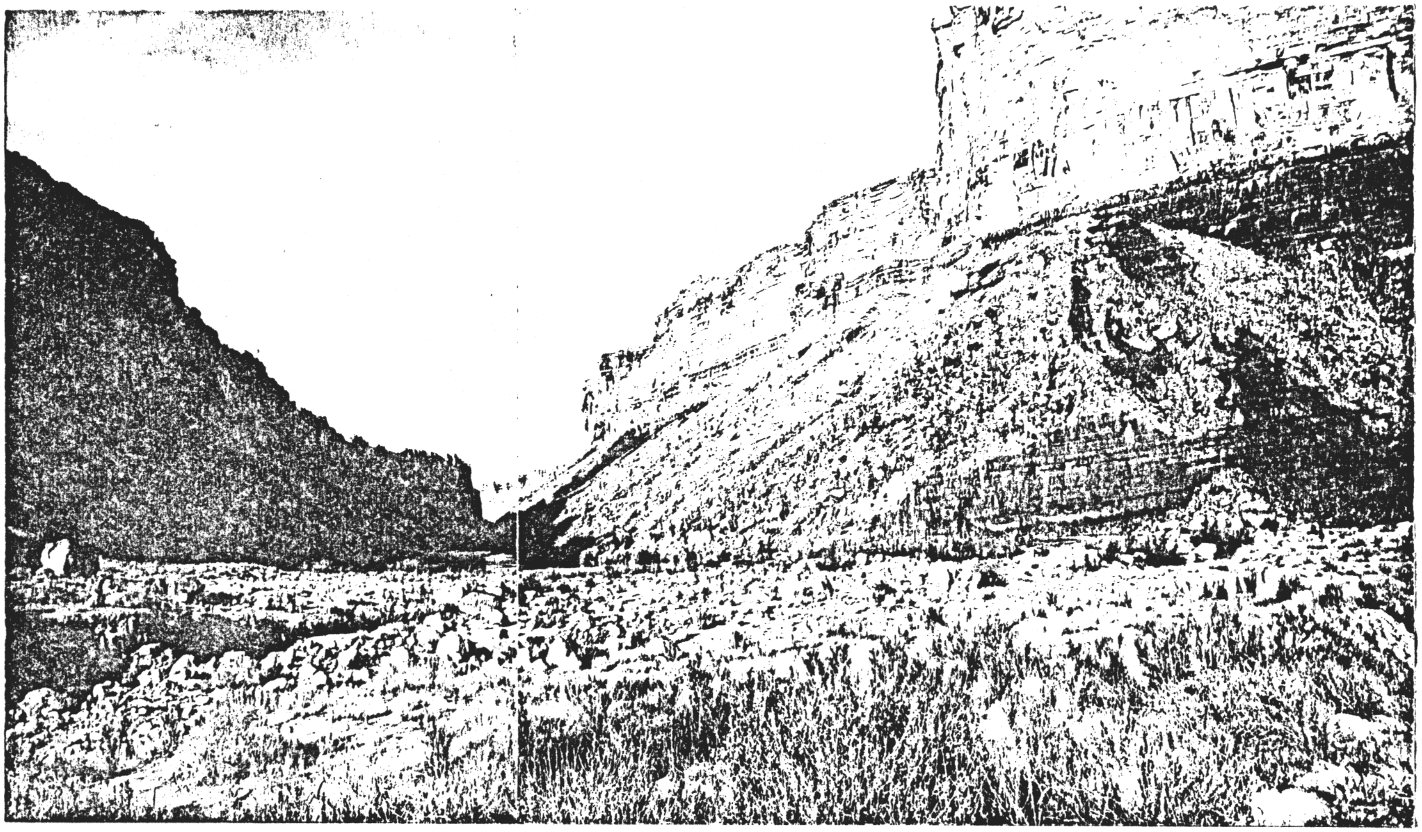

Figure I-1b.--Soap Creek Rapids, July 23, 1974.

This matched photograph shows salt cedar along both sides of the river. A dense stand can be seen growing on the north bank (on the right side of the photograph) below the rock slide which is on the opposite side of the river. Arrowweed and willow are found in the sandy areas of the beach near the river while four-wing salt bush, pepper grass (Lepidium spp.), Mormon tea (Ephedra spp.) and a Brickellia sp. are found in the foreground near the photo station. A large pile of driftwood can be seen which is not visible in the original photograph.

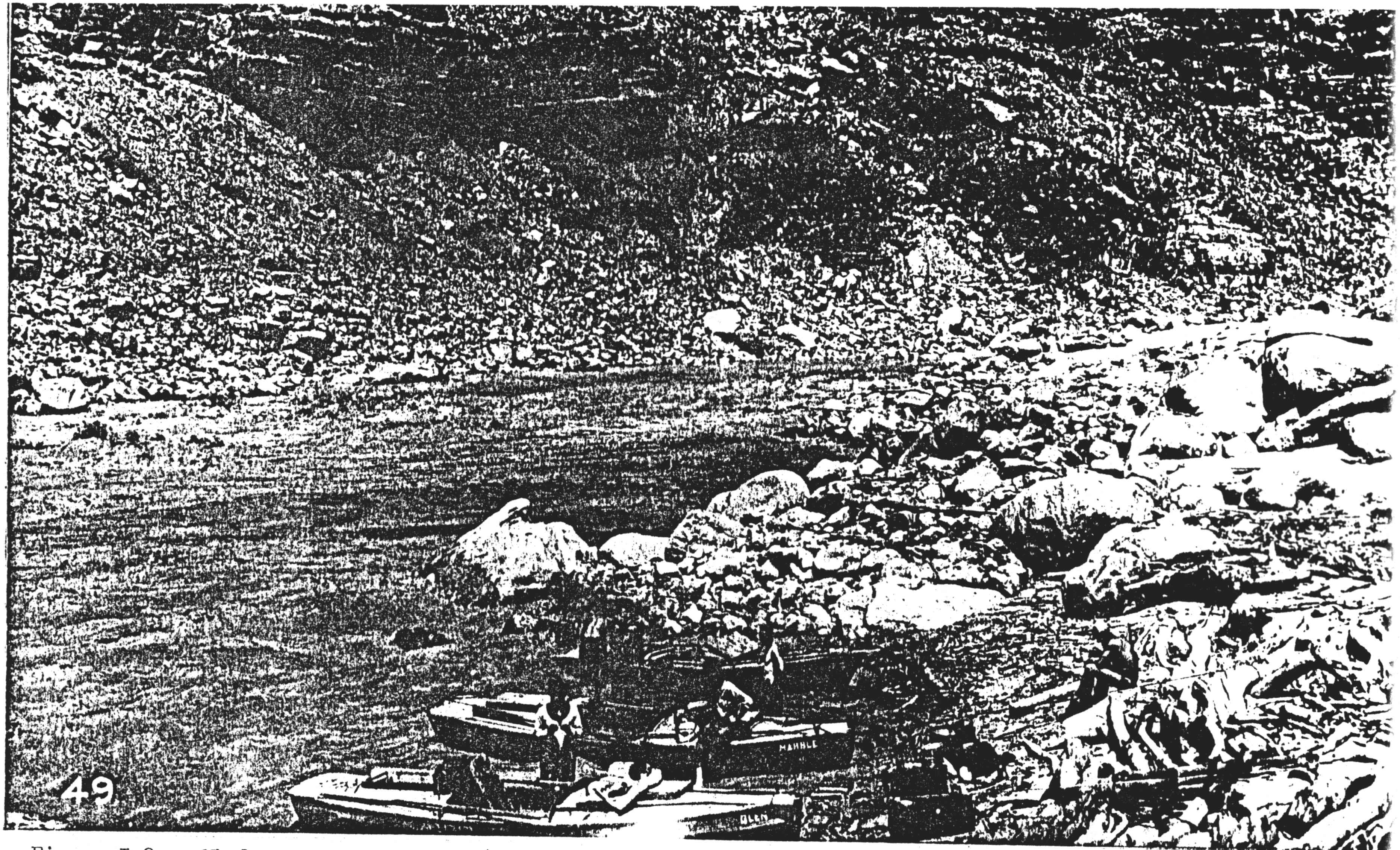

Figure I-2a.--Whale Head Rock, Mile 24.5, 1923.

E. C. LaRue photographed this view of mile 24.5 rapids from the left side of the river looking upstream, elevation 3000 feet. Note a complete absence of any visible vegetation on either side of the river. The most outstanding physical features to be seen are the large accumulation of driftwood in the small cove and the very distinctive boulders. The first of these boulders rests at the upper edge of the cover just behind and to the left of the men and boats. The other boulder, resembling an inverted whale head, is on the right.

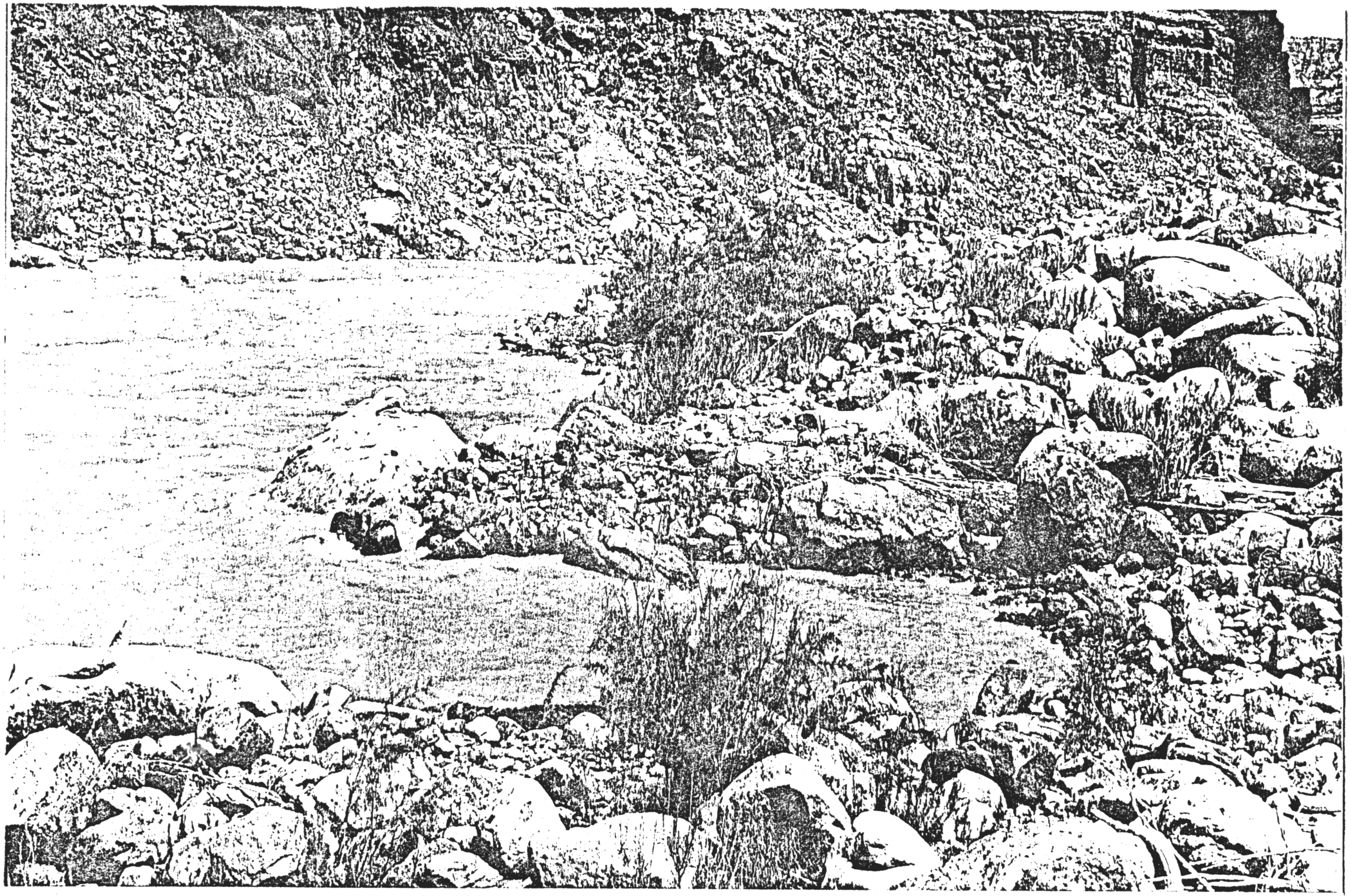

Figure I-2b.--Whale Head Rock, July 24, 1974. This photograph was taken slightly downstream from the original photo station. Nevertheless, as shown in the 1974 photograph the large boulders (Jonah and the Whale) are still there as is the large flat rock (center-left) on the opposite shore. The water level appears to be approximately the same in both photos; however, the river is substantially more muddy in the old photo. Portions of the large accumulation of driftwood observed in the old photo are still to be seen and many of the large boulders seen in the old photo can still be found in the same relative positions. Vegetation which was obviously absent in LaRue's photo is quite abundant today. Russian thistle, *Opuntia* spp. and dropseed are present on the right. Young salt cedar seedlings are developing along the edge of the river as well as in the foreground. *Brickellia longifolia* can be seen both in the foreground and extensively inland from the dense salt cedar stand in the center

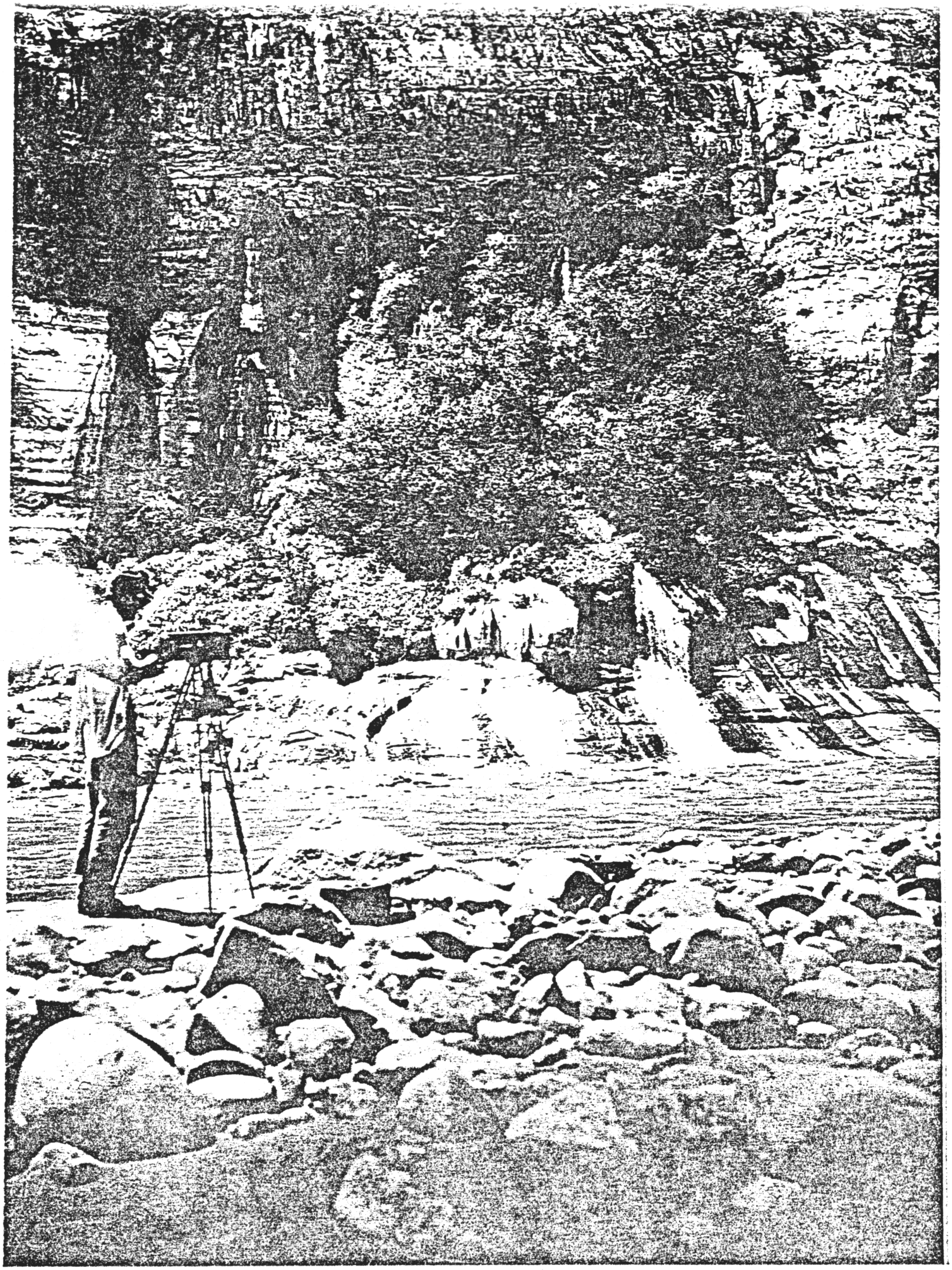

Figure I-3a.--E. C. LaRue at Vasey's Paradise, Mile 31.9, ca. 1923. Vasey's Paradise taken by L. R. Freeman from a sand bar in the center of the river, elevation 3000 feet.... Lush vegetation covers the base of the falls with redbud (Cercis occidentalis) covering the upper portion of the slope. Poison ivy (Rhus radicans) can be seen on the left below the small falls, just behind LaRue.

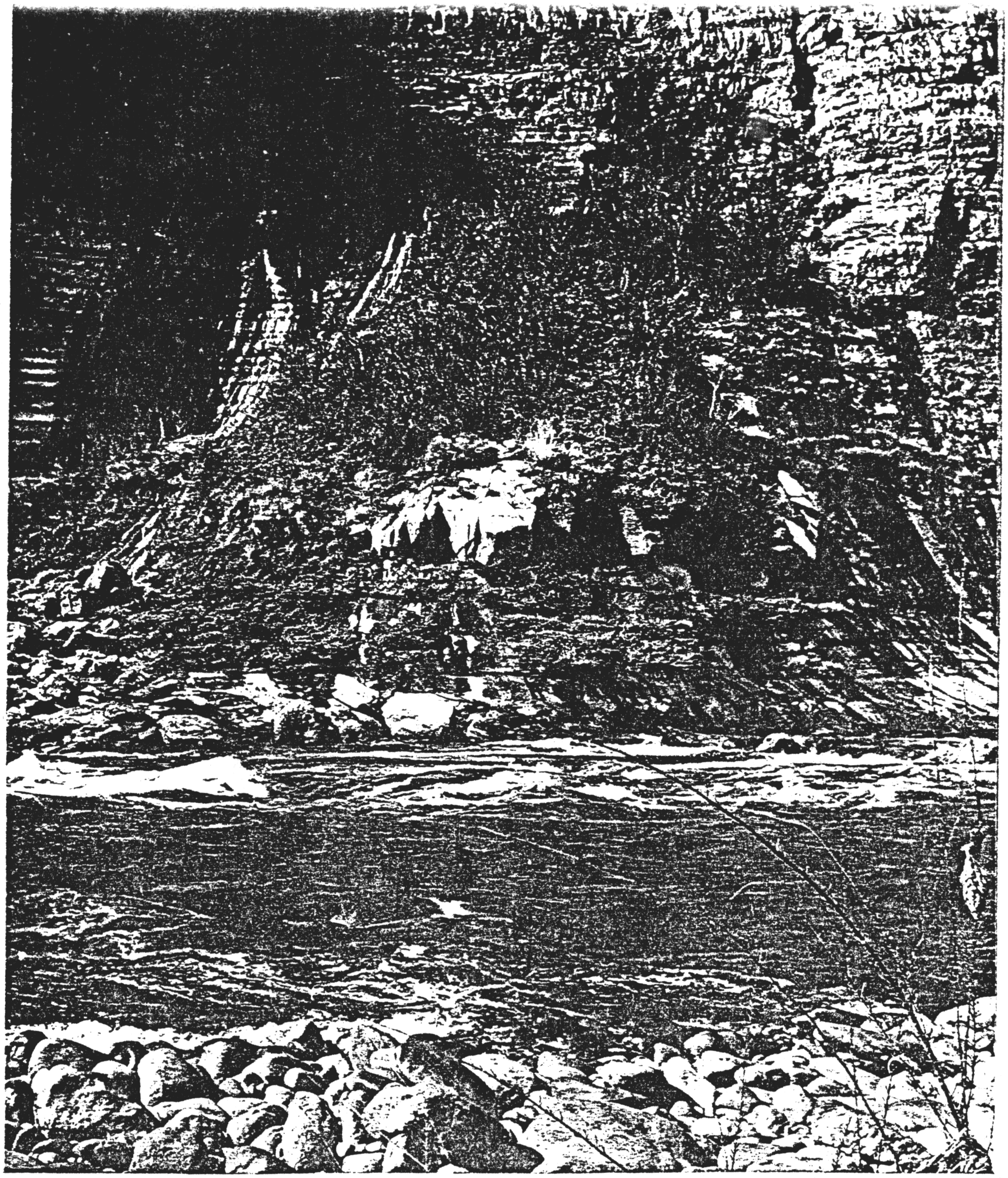

Figure I-3b.--Vasey's Paradise, March 17, 1974.
Dead branches of many of the redbud trees can be seen in this matching photo. The herbaceous layer directly beneath the redbuds is covered by shoulder high poison ivy which extends over to the left. Horsetails, watercress (Rorripa nasturtium-aquaticum) and monkey flower (Mimulus cardinalis) both red and yellow flowered cover the area below the poison ivy. These species are probably the same ones that were shown in the original photo; however, because of flood control by Glen Canyon Dam they have been able to extend their distribution down slope so that today they can be easily seen below the large projecting rock in the center of the photograph. Meanwhile, salt cedar as seen in the foreground has been able to establish a foothold on the sand bar from which the photo was taken.

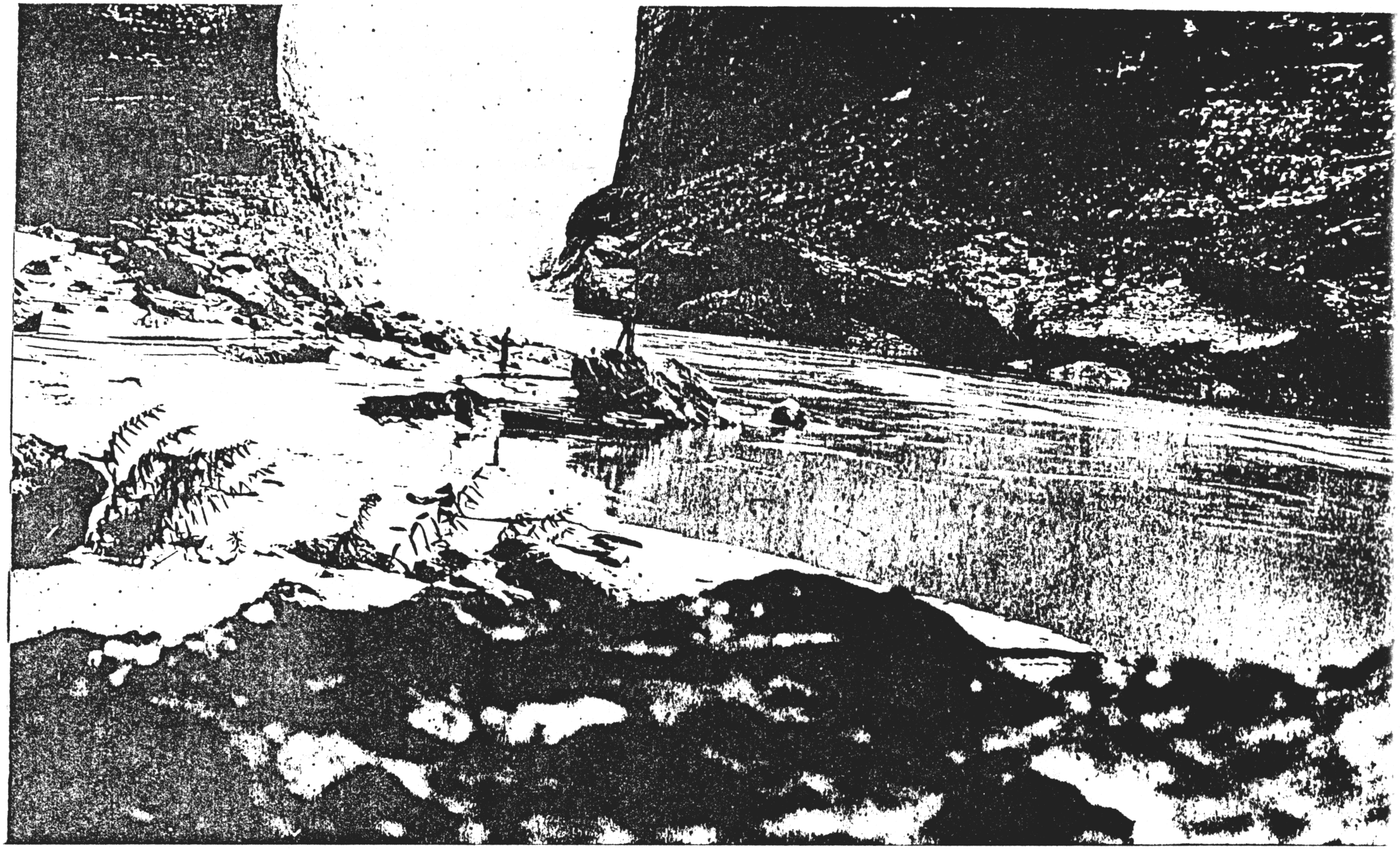

Figure I-4a.--Red Wall Cavern, Mile 33.0, ca. 1923.

The next area downstream is Red Wall Cavern on the left side of the river, elevation 2875 feet. In 1923, L. R. Freeman photographed this downstream view from inside the upstream end of the Cavern. Note that in this older photo there is a large amount of erosion visible along the river bank. The beach itself is almost completely void of vegetation except for the dogbane (_Apocynum_ _sibericum_ var. _salignum_) which is to be seen in the foreground.

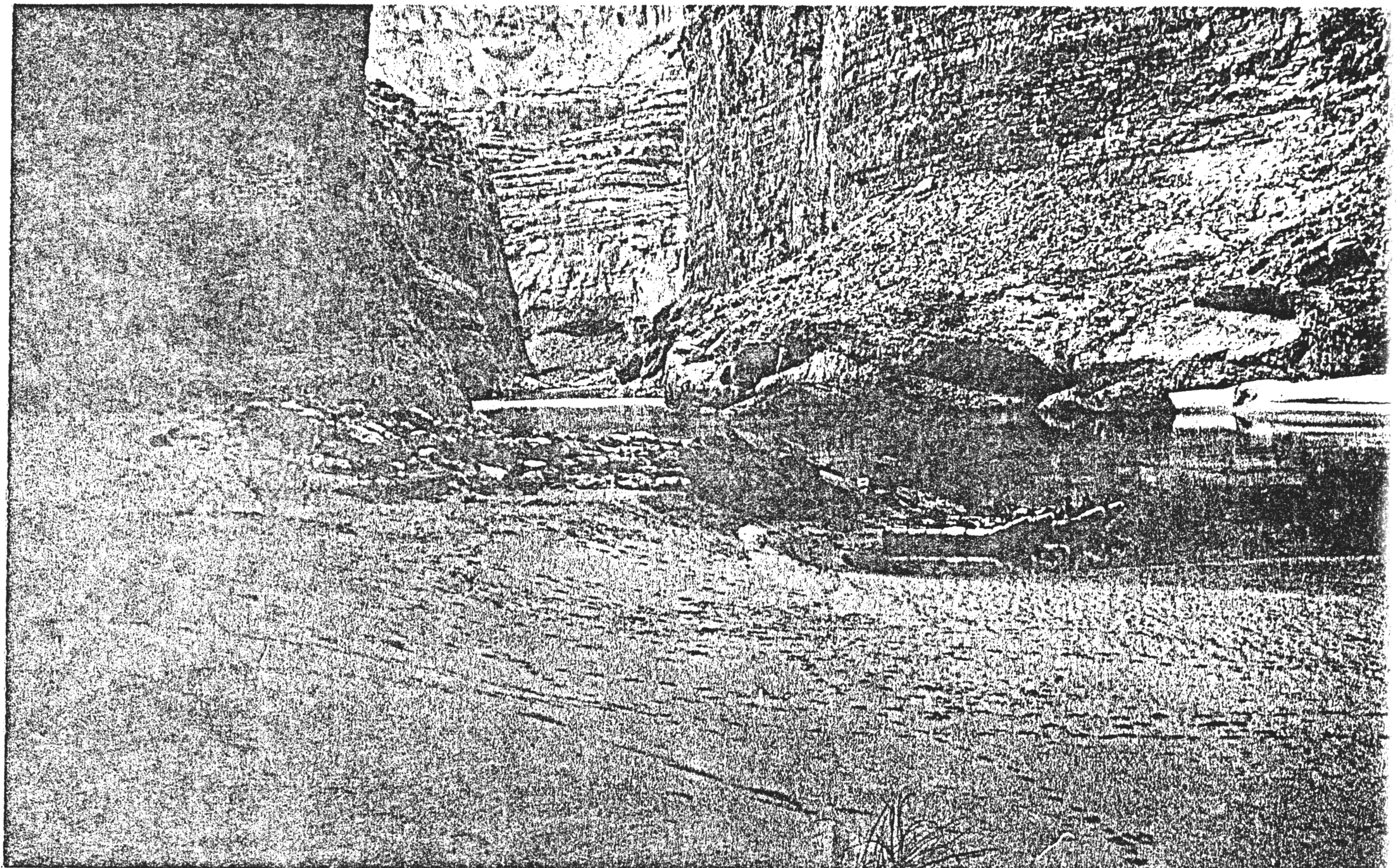

Figure I-4b.-- Red Wall Cavern, March 17, 1974.

Today, we still find the same large boulder on which one of the men was standing in the 1923 photo. The dogbane is gone and the only vegetation to be seen is salt cedar. Two individuals of salt cedar can be seen on the sand dune while more can be found just behind the large boulder where the rafts are moored. The sharp edge of erosion is no longer visible; and the topography of the beach itself has changed very little in the fifty-one years since the original photo was taken.

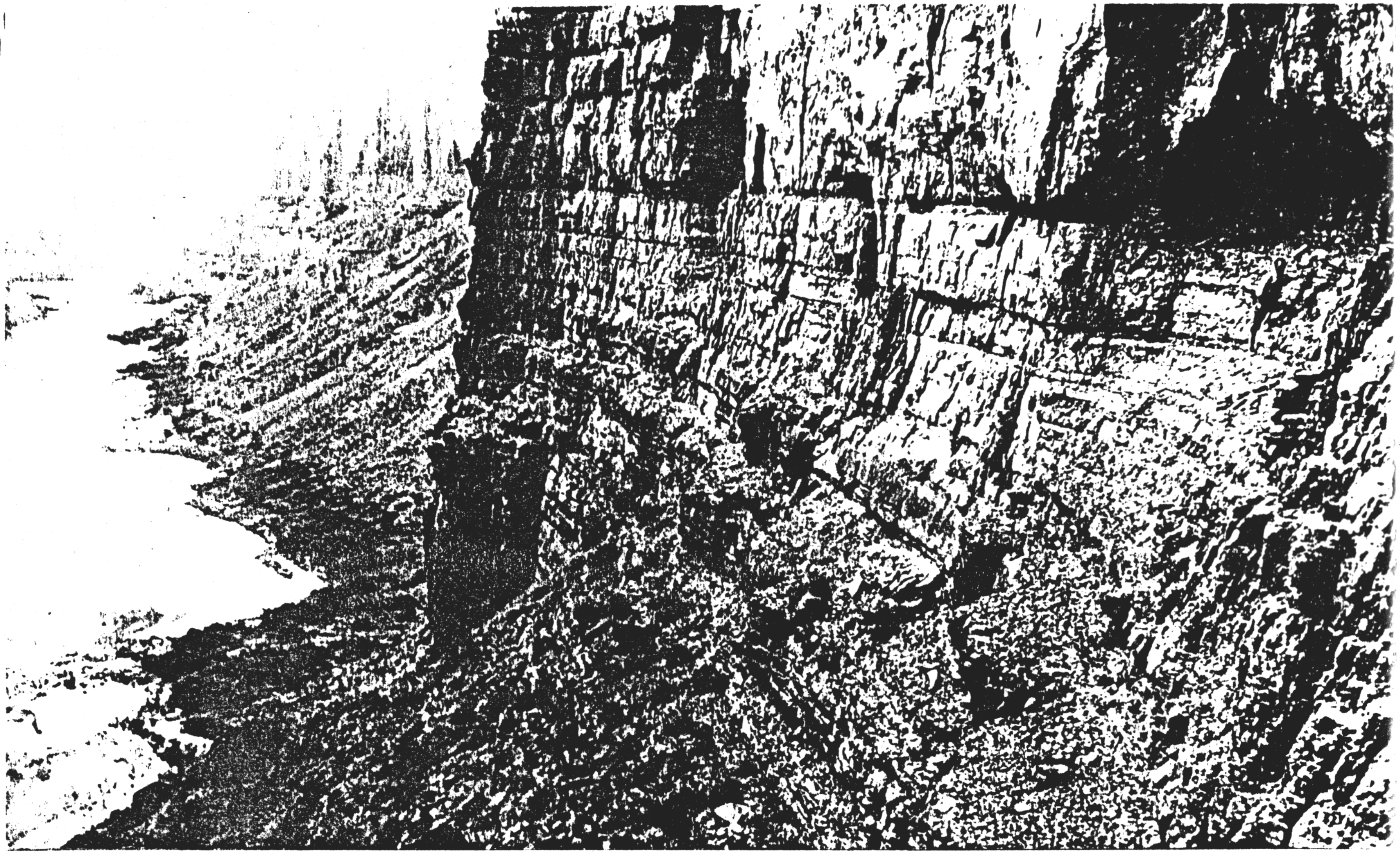

Figure I-5a.--View from Indian Ruins at Nankoweap, Mile 52.5, ca. 1923.

The United States Geological Survey took this picture of the Indian ruins at Nankoweap looking downstream from just above the ruins at an elevation of 3500 feet. Note the very distinct mesquite/acacia/Apache plume belt on both sides of the river downstream from the ruins. The vegetational belt on the south side of the river is dominated by Apache plume while on the right side of the river the dominant forms are mesquite and acacia, thus accounting for the apparent difference in the width of the zone.

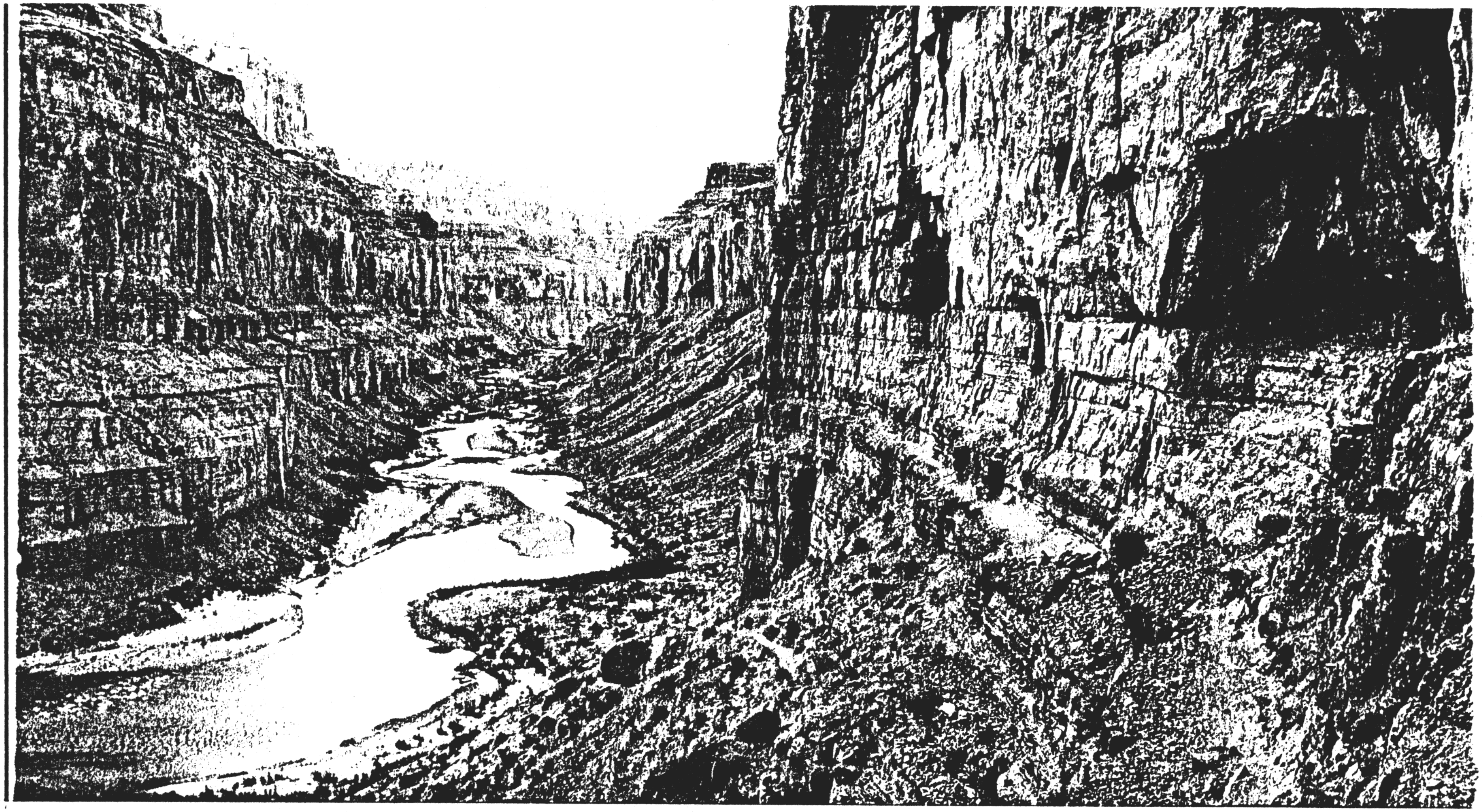

Figure I-5b.--Nankoweap Ruins, March 19, 1974.

In this recent photograph we can still see the old mesquite/acacia/Apache plume vegetation belts but we can also observe the development of the new salt cedar/willow/seep willow belt. The apparent decrease in the density of the old belt is probably due to the fact that at the time when the recent photograph was taken the mesquite and acacia had not fully leafed out. Moreover, the mesquite and acacia stand just above the boat and thus the camping area was damaged approximately seven years before by a man-caused fire. Many of the burnt trees are coming back from their roots; however, most of these plants have not fully recovered. Moreover, salt cedar has invaded some of the area once occupied by mesquite. Observe that the once barren beaches are dissected by the newly developed salt cedar vegetation belt on both sides of the river. Numerous trails on the slopes leading up to the ruins have been established since the original photo was taken. Above the new mesquite belt and below the burnt mesquite/acacia belt other species which may be found are Russian thistle, prince's plume (Stanleya pinnata), Baccharis emoryi, red brome, and pepper grass. Numerous ephemeral species covered the trail as well as the beach in March but were gone by April. The upstream edge of the small cove where the boats are moored is dominated by coyote willow (Salix exigua) with arrowweed having extensive stands on the sand dunes above the willow.

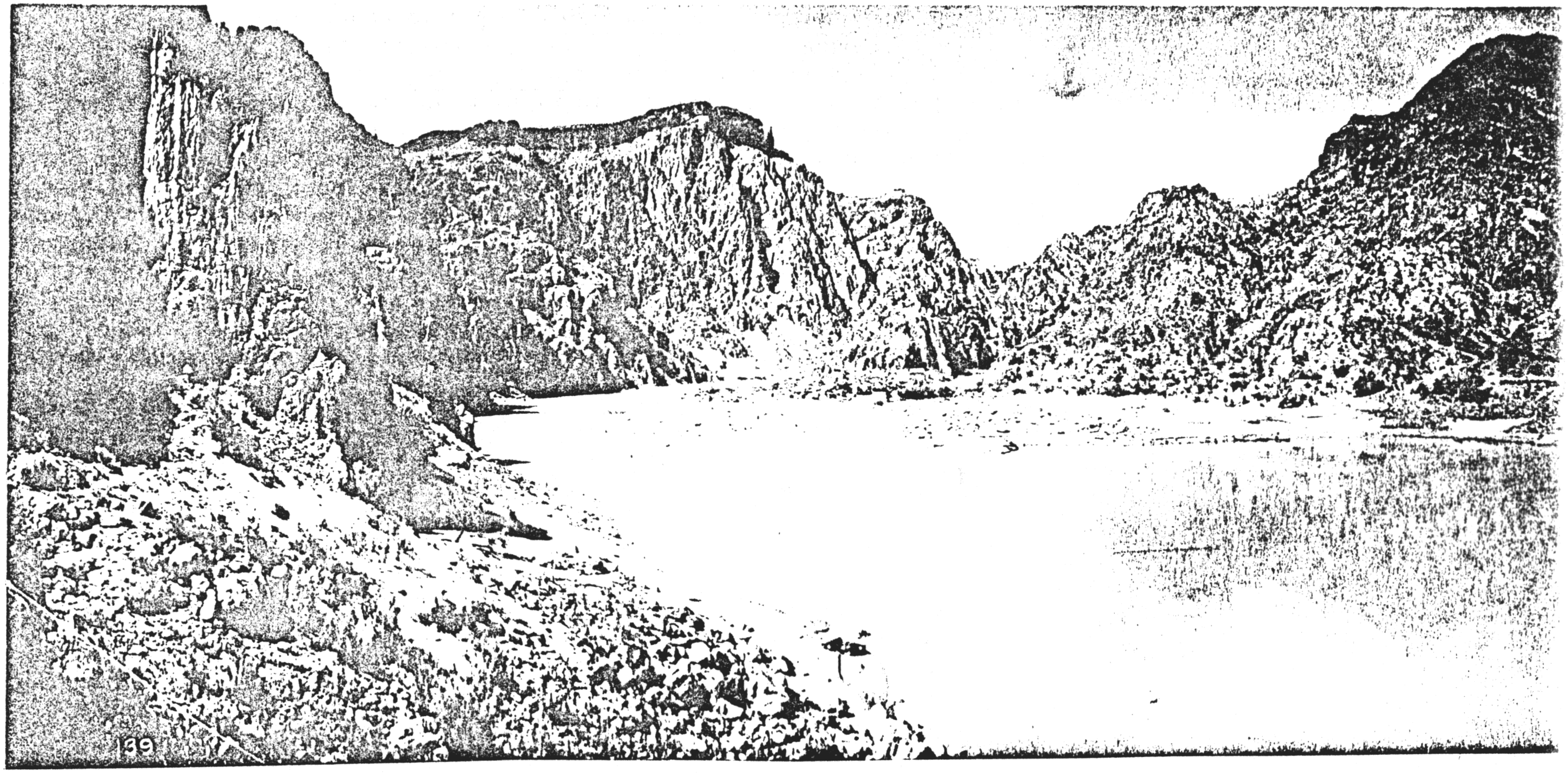

Figure I-6a.-- Bright Angel Creek, Mile 87.3, August 26, 1923.

Bright Angel Creek (mile 87.3), elevation 2425 feet, is shown in this 1923 photograph taken by E. C. LaRue from the south end of the Kaibab Suspension Bridge looking downstream. In the center of the photo the Park Service buildings are clearly visible because the cottonwood trees (Populus fremontii) have not yet hidden them. The beaches on both sides are devoid of extensive vegetational development while the remains of the mesquite/acacia belt which has been dissected by the Kaibab trail are visible.

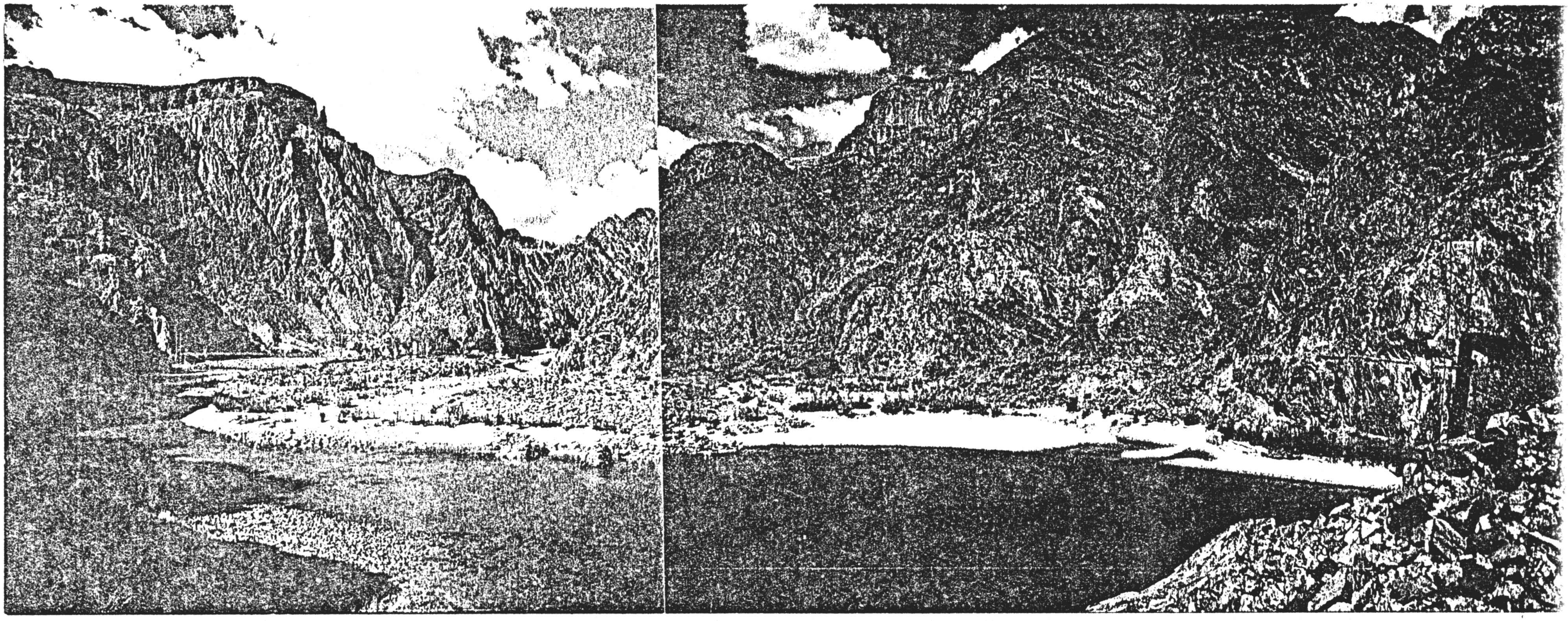

Figure I-6b.-- Bridges at Bright Angel Creek, March 21, 1974.

The matching photo shows the development, just below the northern end of the Kaibab Bridge, of salt cedar, while arrowweed is to be seen behind the large sandy beach downstream from the bridge. The large plant above the downstream end of the sandy beach is a mesquite with numerous acacias found downstream from it, near the trail. Large amounts of arrowweed are growing below the mesquite/acacia belt. Numerous Mormon tea are found near the trail and several well developed individuals of brittle bush (*Encelia farinosa*) are also found here.

On the left side of the photo proceeding toward the river from the large cottonwoods at the downstream end of the delta, we have mesquite, salt cedar and *Baccharis* spp. as well as other species typical of the post-dam high water vegetation belt. Some of the other species from behind the salt cedar belt in the creek bed include desert trumpet (*Eriogonum inflatum*), Mormon tea and sacred datura (*Datura meteloides*). At the upstream edge of the creek bed where it meets the river we find horsetails. The rocky beach behind the Museum of Northern Arizona boats is covered with *Brickellia* spp., *Dyssodia* spp., arrowweed, red brome and numerous other species. A large expanse of salt cedar and arrowweed is to be found on the once barren beach of the left side. Note that although the water level in the original photo was higher than in the matched photograph there appears to be very little change in the shoreline. However, one very obvious physical change has occurred since the original photo was taken and that is the construction of the downstream suspension bridge.

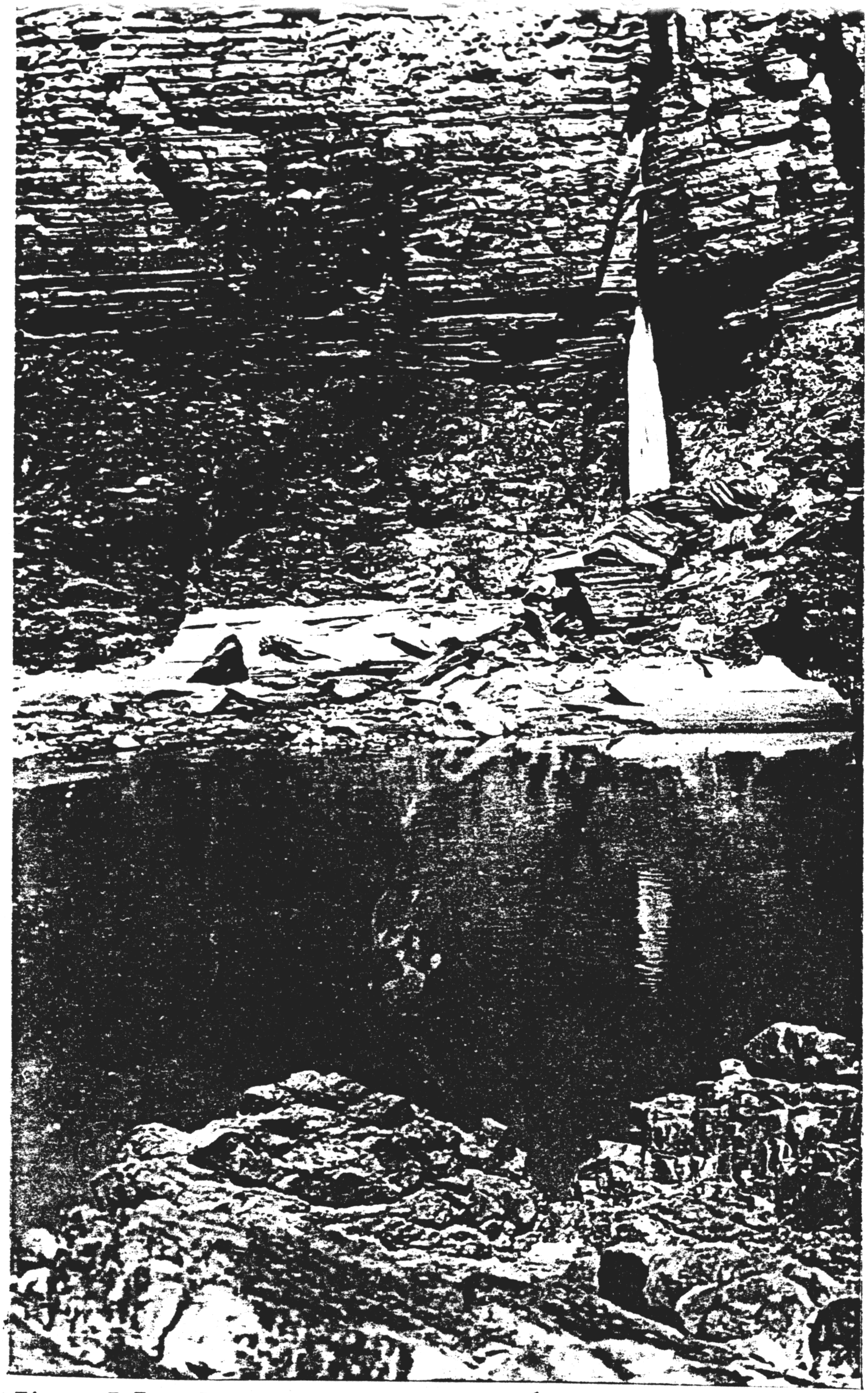

Figure I-7a.--Deer Creek Falls, Mile 136.2, ca. 1923.

L. R. Freeman took this photo of Deer Creek Falls at an elevation of 2000 feet from the south bank of the river. Note the complete absence of any visible vegetation in the photo.

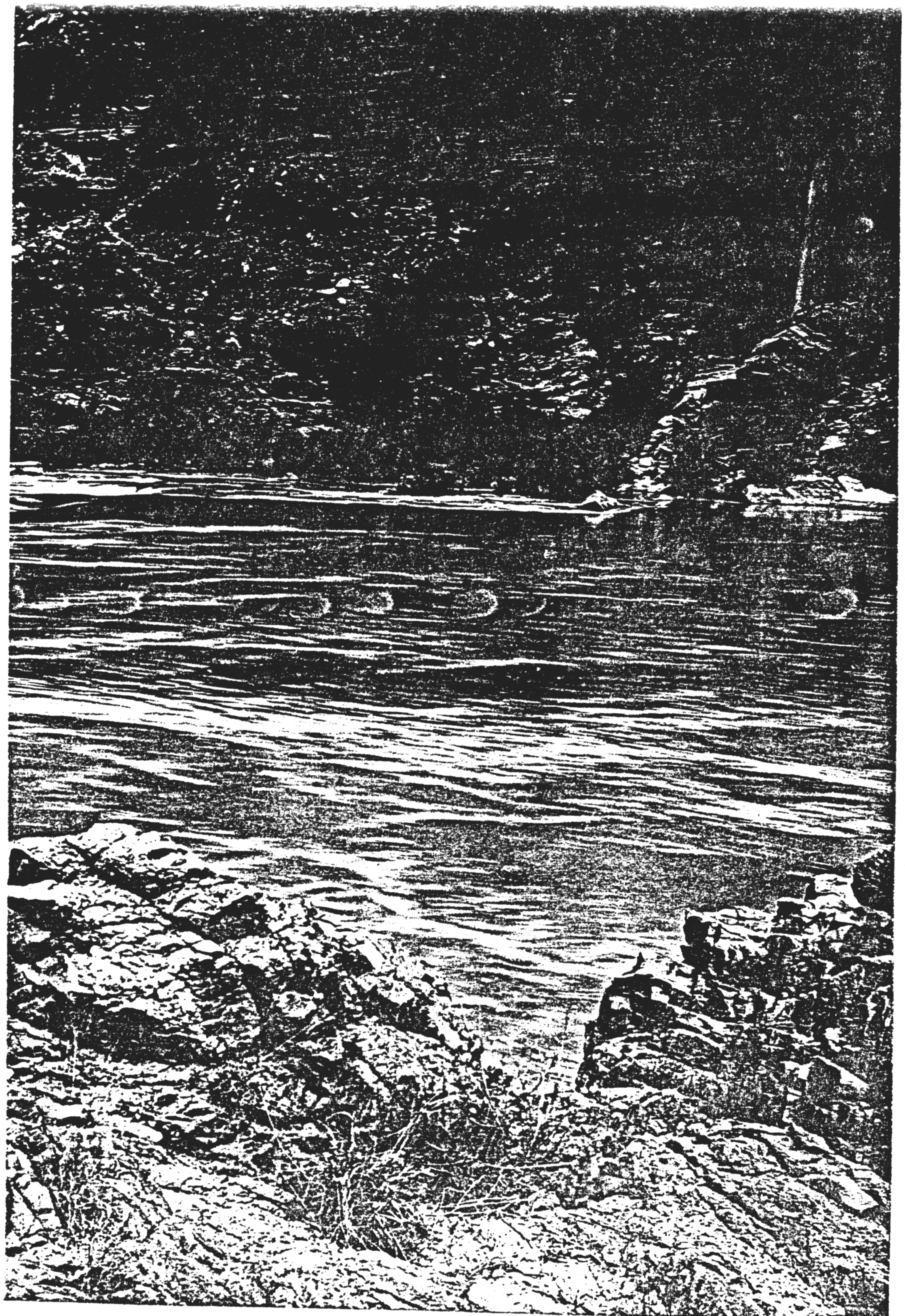

Figure I-7b.--Deer Creek, August 1, 1974.

This recent photo shows a completely different story. Monkey flower and maidenhair fern (Adiantum capillus-veneris) are found growing up the sides of the falls. On the upstream side of the falls we find Opuntia sp., Mormon tea and sacred datura, to mention just a few. The dense area of vegetation below the falls is dominated by seep willow and evening primrose (Oenothera hookeri) while some scattered salt cedar individuals are to be found near the river. Most of the plants at the foot of the falls were covered with red mud and were beaten down to the ground because of a recent flash flood.

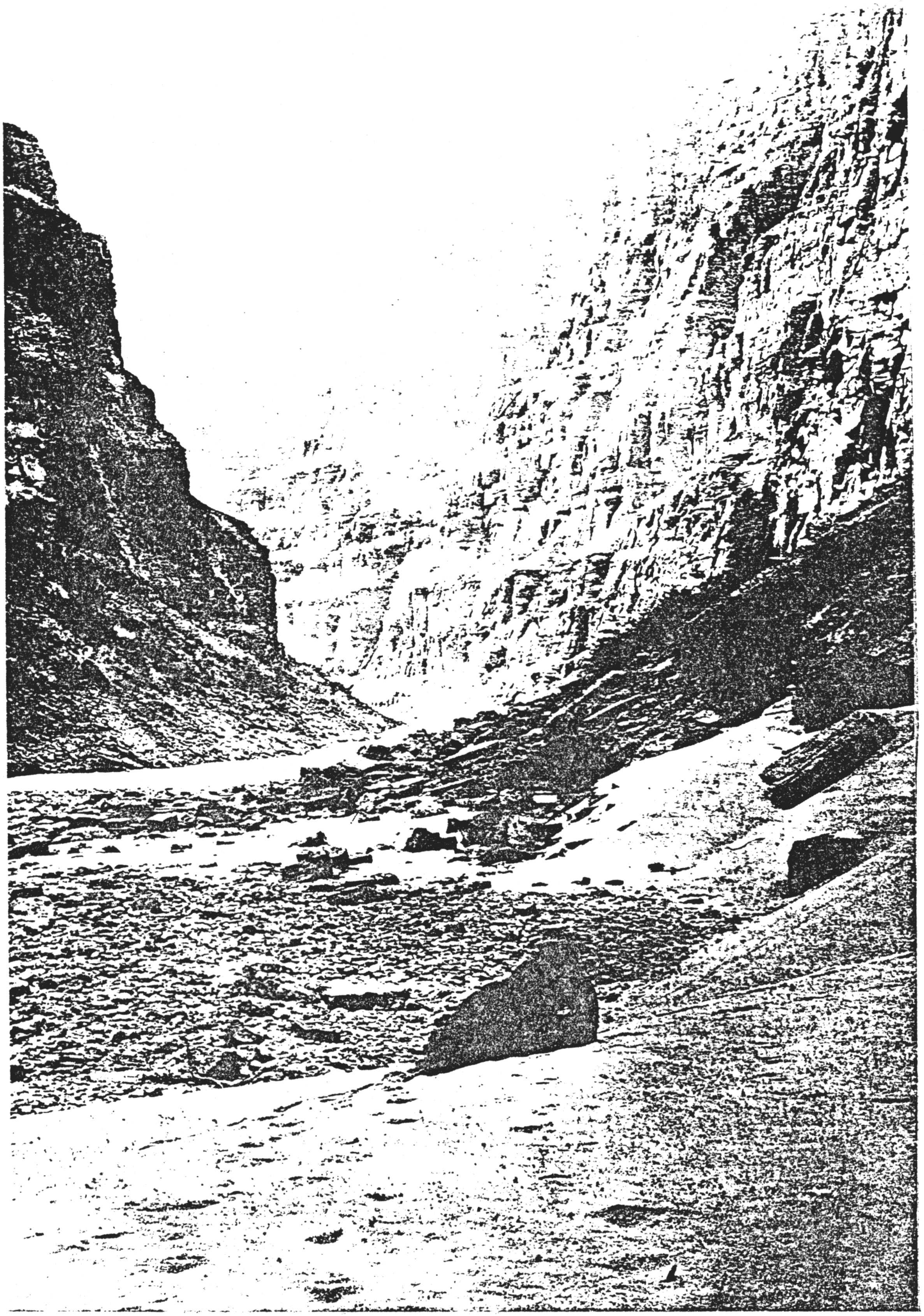

Figure I-8a.--Kanab Creek, Mile 143.5, ca. 1872.
W. Bell of the Wheeler Expedition of 1872 took this photograph of the mouth of Kanab Creek, at an elevation of 1900 feet from the upstream side of the canyon looking downstream.

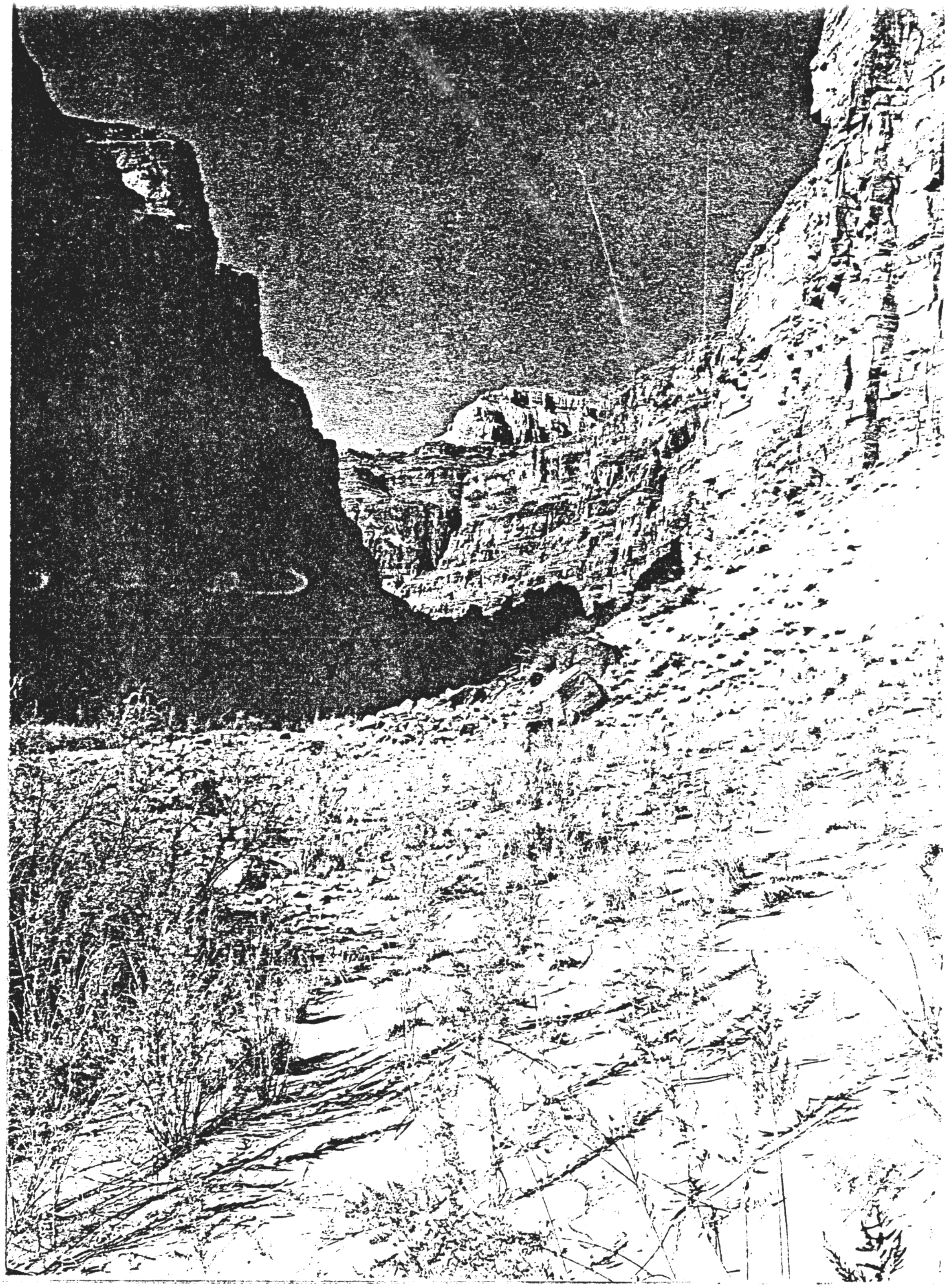

Figure I-8b.--Kanab Creek, March 25, 1974.

No visible vegetation is to be seen on the beach in Bell's picture; however, in the photo Figure I-8b, we find arrowweed in the foreground, as well as extensive development of salt cedar on the left towards the river. The plants just behind the large rock in the center of the photo are acacia, part of the mesquite/acacia belt also visible in the original Bell photo. Some reduction in the amount of sand around the large boulder in the center is also evident.

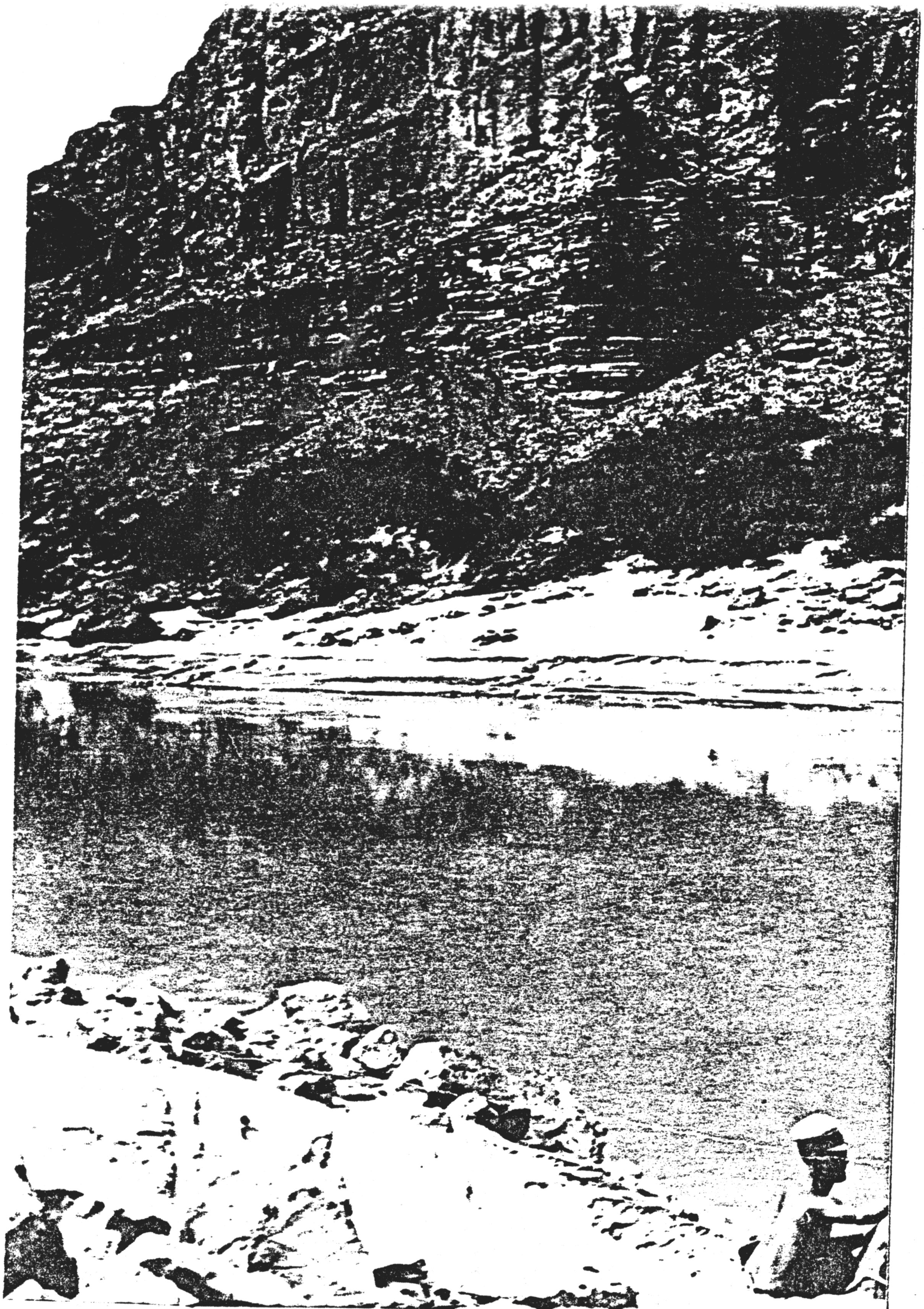

Figure I-9a.--Mile 178.6, ca. 1923.

L. R. Freeman took this downstream photo at mile 178.6, elevation 1700 feet, approximately one mile above Lava Falls Rapids from the south side. The mesquite/acacia belt is well developed; however, no vegetation is visible below this zone.

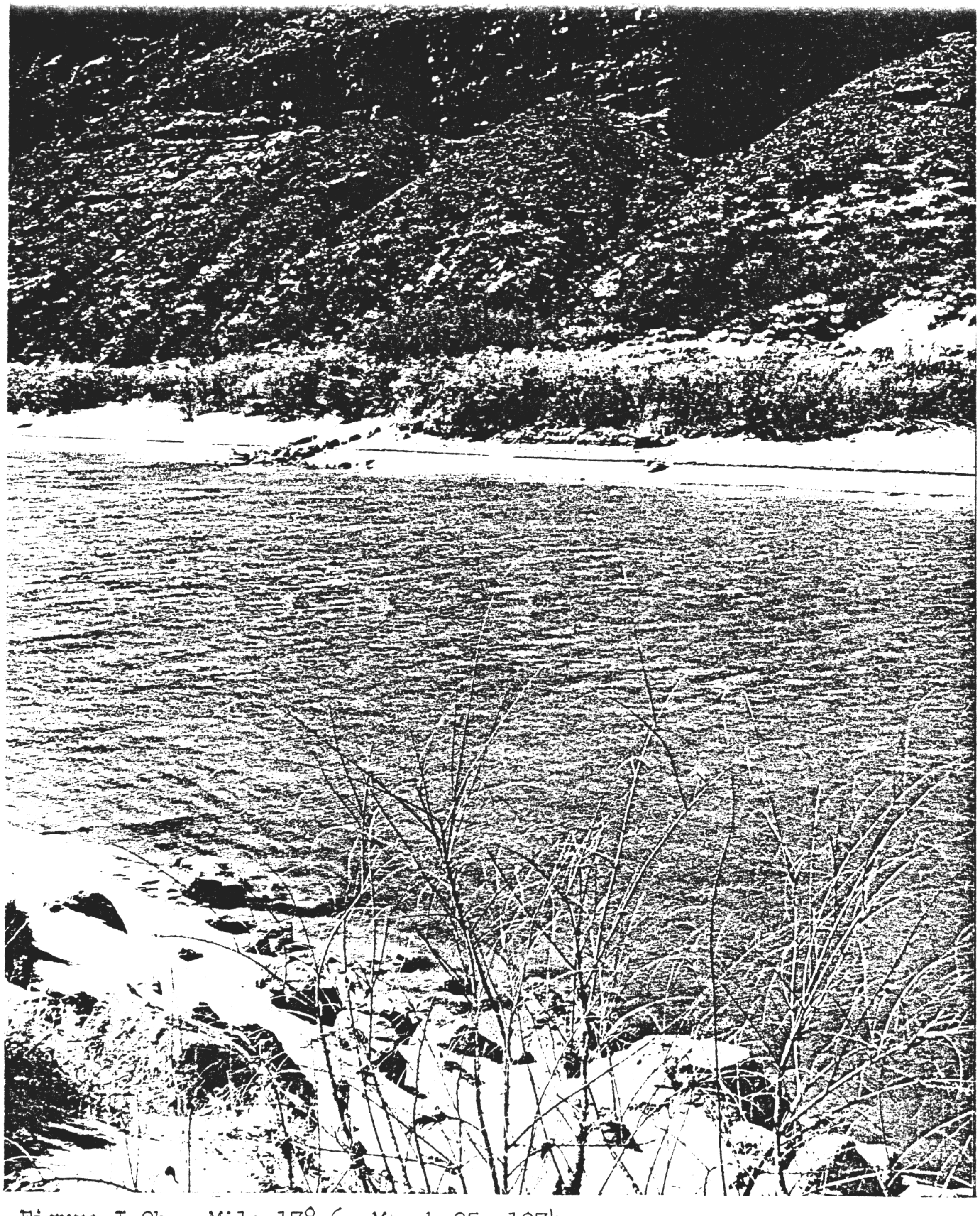

Figure I-9b.--Mile 178.6, March 25, 1974.

The matching photograph shows that the mesquite/acacia community is still present, although at the time of the photograph they had not fully leafed out. Salt cedar in the interim has established itself as indicated by the seedlings in the foreground. On the opposite shore a well developed salt cedar, seep willow, desert broom, arrowweed and willow belt is present. Behind this zone, Russian thistle, red brome and creosote bush are to be found. Above the old mesquite/acacia belt, creosote and barrel cactus (Ferrocactus sp.) are abundant. Several small mesquite were found to be mixed in with the salt cedar. Cattail is found below the willow.

Note the large boulders on the upper part of the talus slopes which are present in both photos. The large boulder on the beach in Freeman's photo is still in place although hidden within the new dam-dependent community.

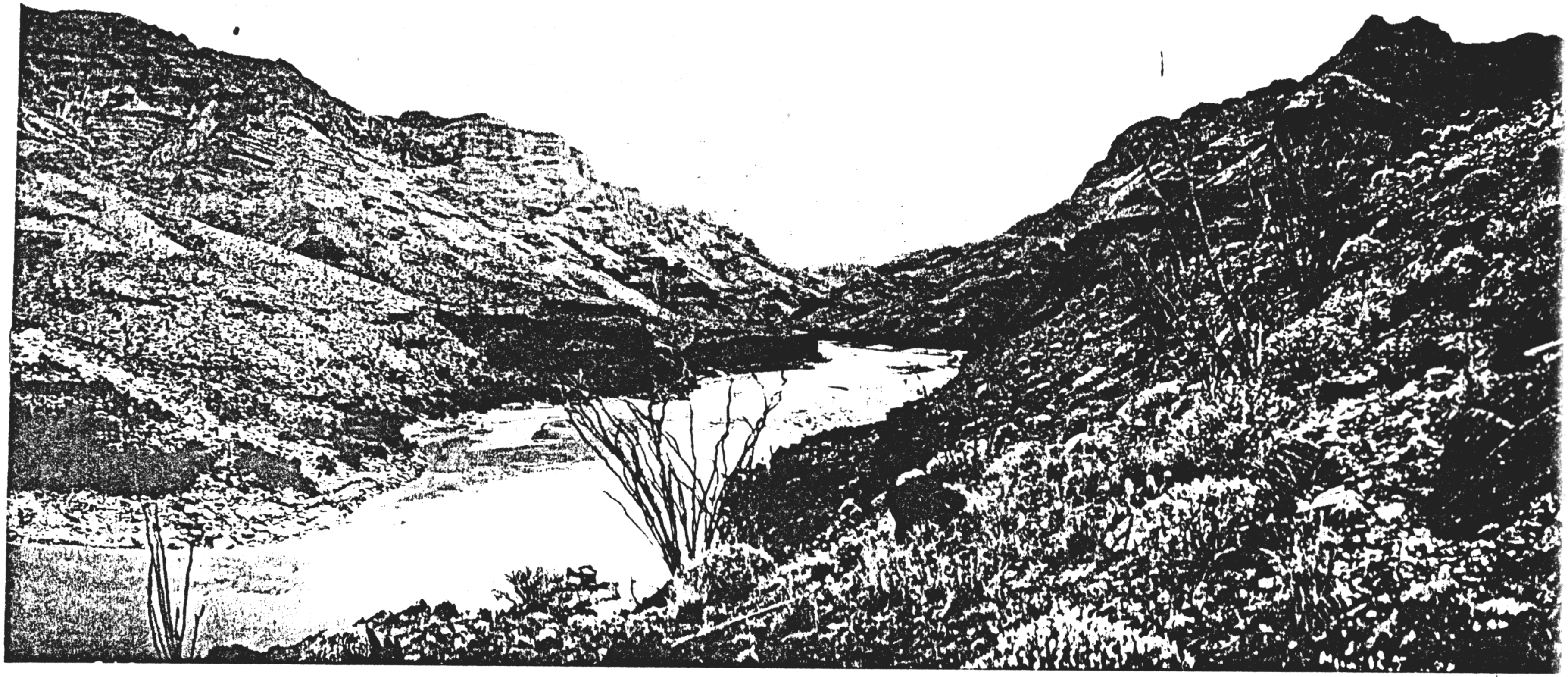

Figure I-10a.--Downstream View of Spring Canyon, Mile 204.4, Elevation 1500 Feet, September 27, 1923.

The typical mesquite/acacia belt is to be seen on the left side of the river in which acacia predominates. The hillside in the foreground is covered with brittle bush, ocotillo, barrel cactus and creosote. (Photo taken by E. C. LaRue.)

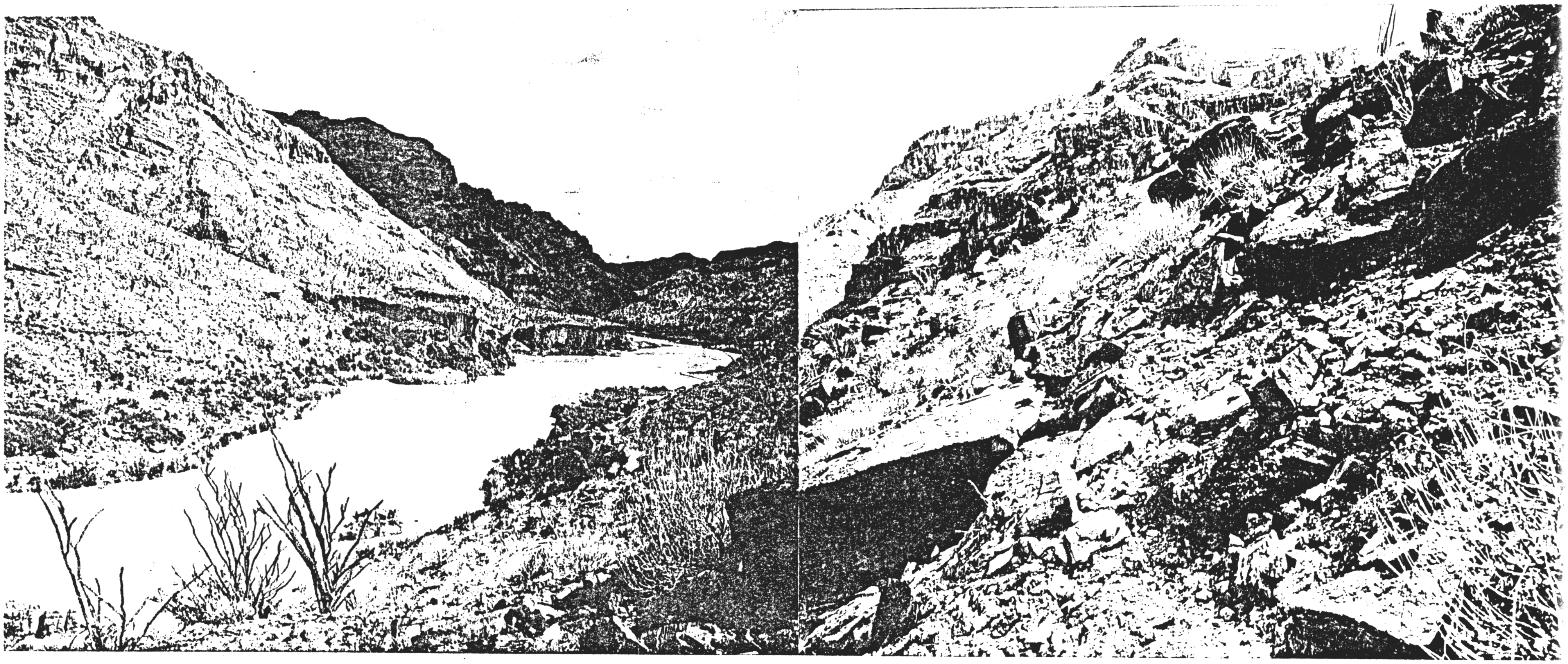

Figure I-10b.--Spring Canyon, August 3, 1974.

The matching photo shows the same small island just below the right bank as well as the same vegetation as the old photograph taken by LaRue. On the left side of the river we can see the now typical double belted system. The upper belt in this instance is mostly acacia and the lower one is mostly desert broom. The beach on the right side downstream from the small island which was barren in the original photo today is covered with salt cedar, seep willow, and arrowweed, and the higher area with mesquite and acacia.

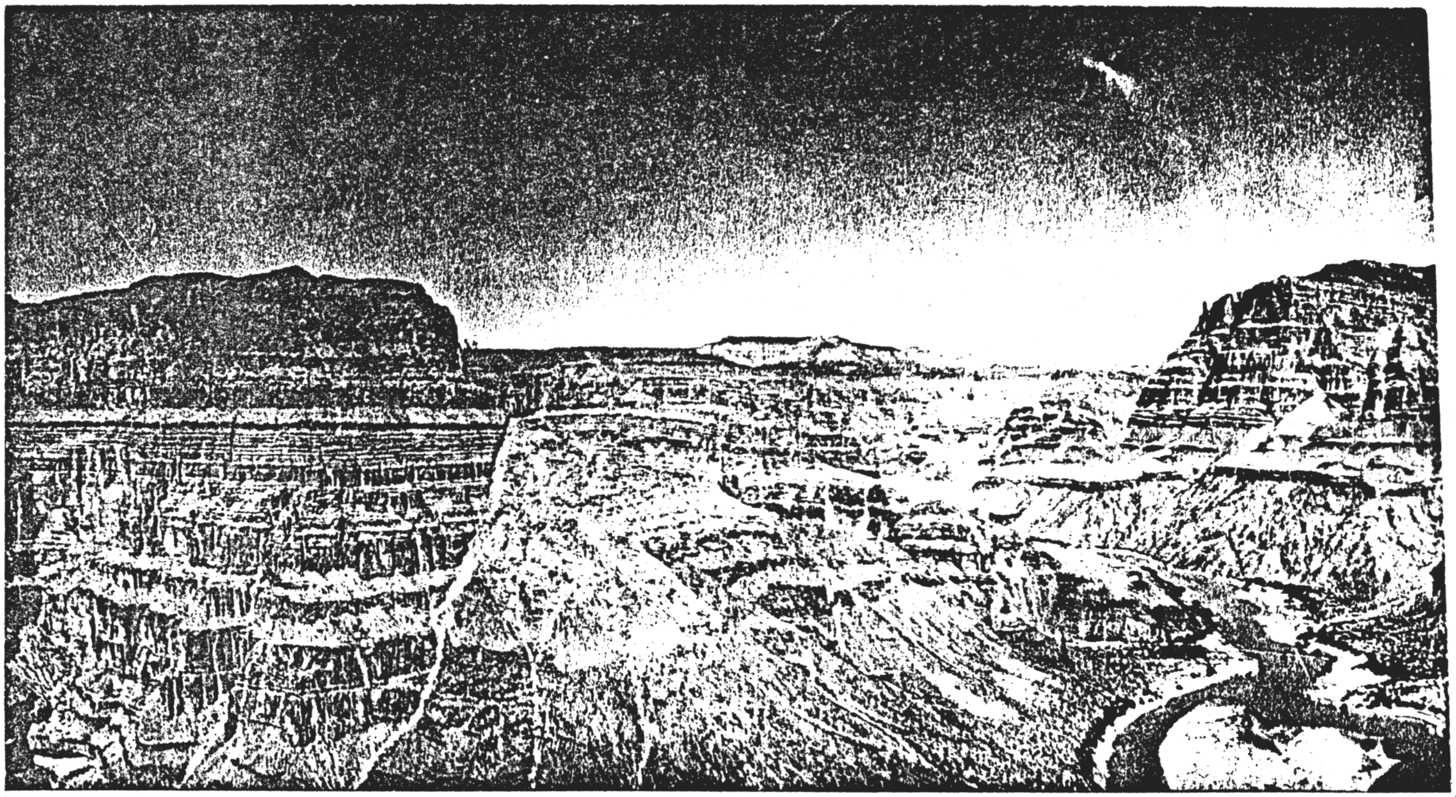

Figure I-11a.--Granite Park Overview, Mile 209.0, September 28, 1923.

E. C. LaRue took this upstream photo of Granite Park from a point on the left wall at an elevation of 2800 feet. On the right side of the photo we have Granite Park just upstream from the island and on the left side of the photograph we have 209 Mile Canyon. The mesquite/acacia zone is well developed on both sides of the river. On the beach at Granite Park at the water's edge we can see the willows pictured in the following set of matched photos.

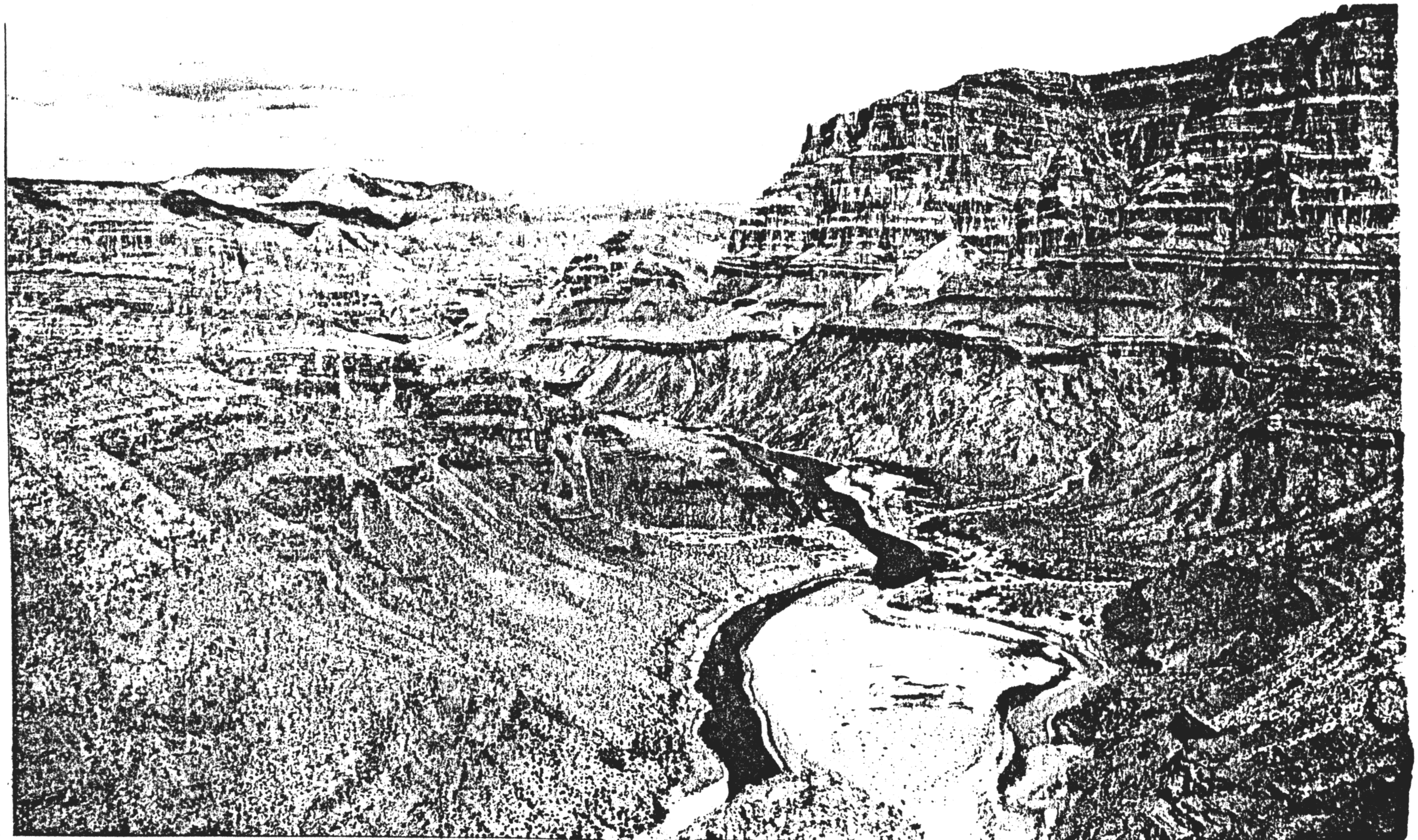

Figure I-11b.--Granite Park, March 27, 1974.

In this 1974 photograph there appears to be a decrease in the mesquite/acacia belt on both sides of the river but this is largely the result of the phenological status of the plants. However, 209 Mile Canyon on the river's right side has been subjected to heavy impact by burros. Also note that the once almost vacant beaches at Granite Park on the left side of the river now are covered with salt cedar, willow, camelthorn and arrowweed. The sand dune area above the beach is covered by evening primrose, sand verbena (Abronia elliptica), dropseed and red brome. Creosote comes in on the bajada and as the slope increases we find white bursage (Franseria dumosa), ocotillo, range ratany (Krameria parvifolia), pepper grass, Opuntia spp., barrel cactus, brittle bush and desert trumpet.

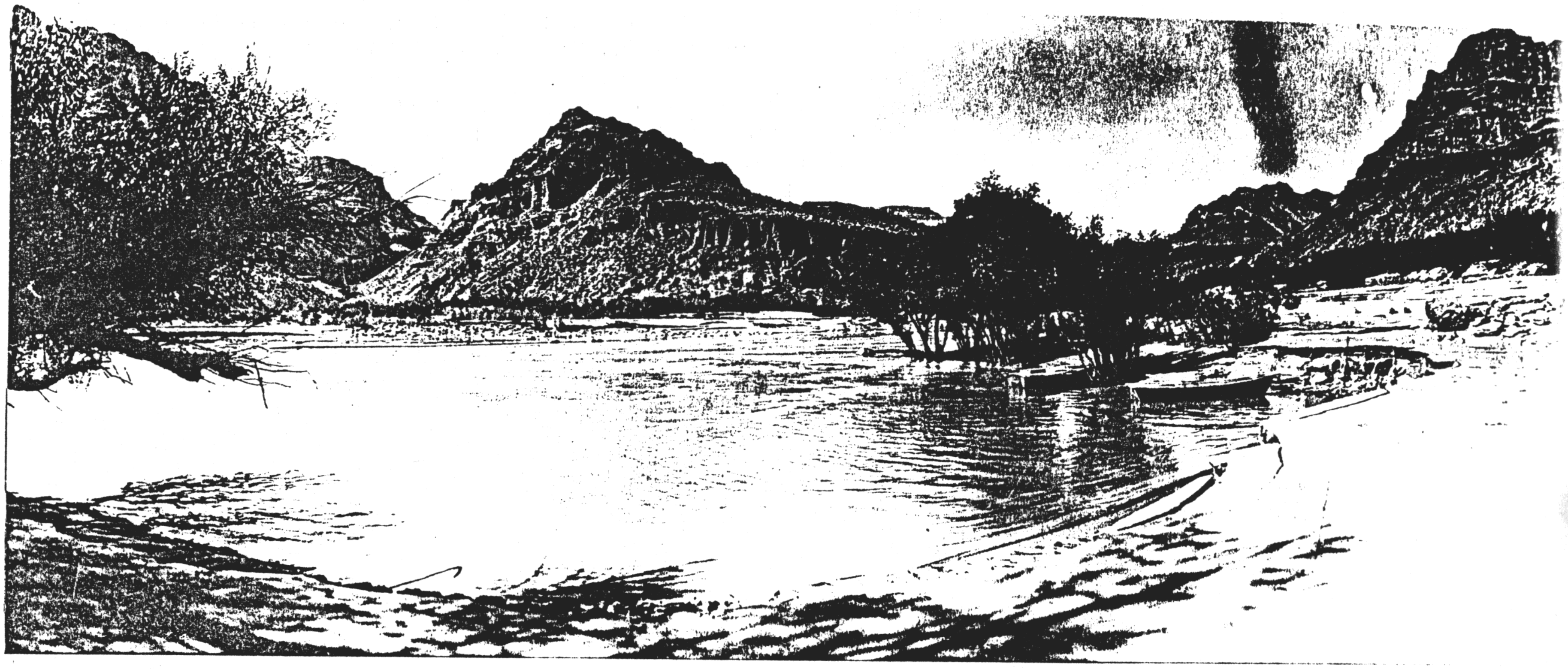

Figure I-12a.--Granite Park, Mile 209.0, ca. 1923.

E. C. LaRue photographed this site at an elevation of 1500 feet, across from 209 Mile Canyon. The mesquite/acacia belt is well developed below the lava palisades and extends across the mouth of the canyon.

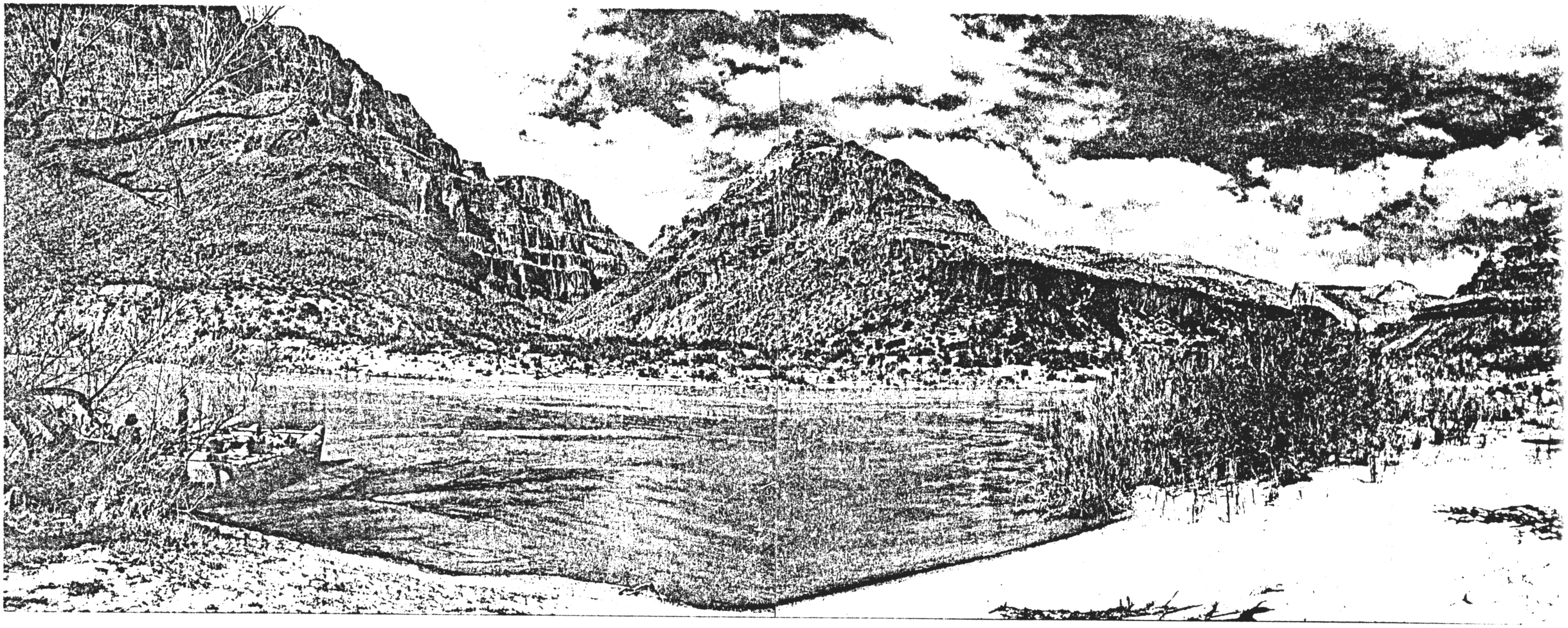

Figure I-12b.--Granite Park Beach, March 30, 1974.

The large boulder with desert broom growing on its left side, found on the right side of the old photo, can still be seen in this recent photograph. The large red willow (Salix laevigata) shown in the original picture is also present; however, all the small willows on the right side of the small cove in LaRue's photo appear to be gone. Nevertheless, young Goodding willow (Salix gooddingiii) can be seen today behind the old willow area. Just to the right of where the willows once were is an area of arrowweed and this stand continues to endure in the present photograph. The hillside on the right side is part of the mesquite/acacia belt. In the center of the present photo we find salt cedar and arrowweed. Evening primrose, sand verbena and dropseed dominate the upland sandy dune on the right. A well developed stand of camelthorn is to be found to the left of the present photo while under the large willow is an area of bermuda grass. In the spring, red brome covers the sandy beach. Looking across to 209 Mile Canyon some other species present are desert willow (Chilopsis linearis), datura, and pigmy cedar (Porophyllum gracile).

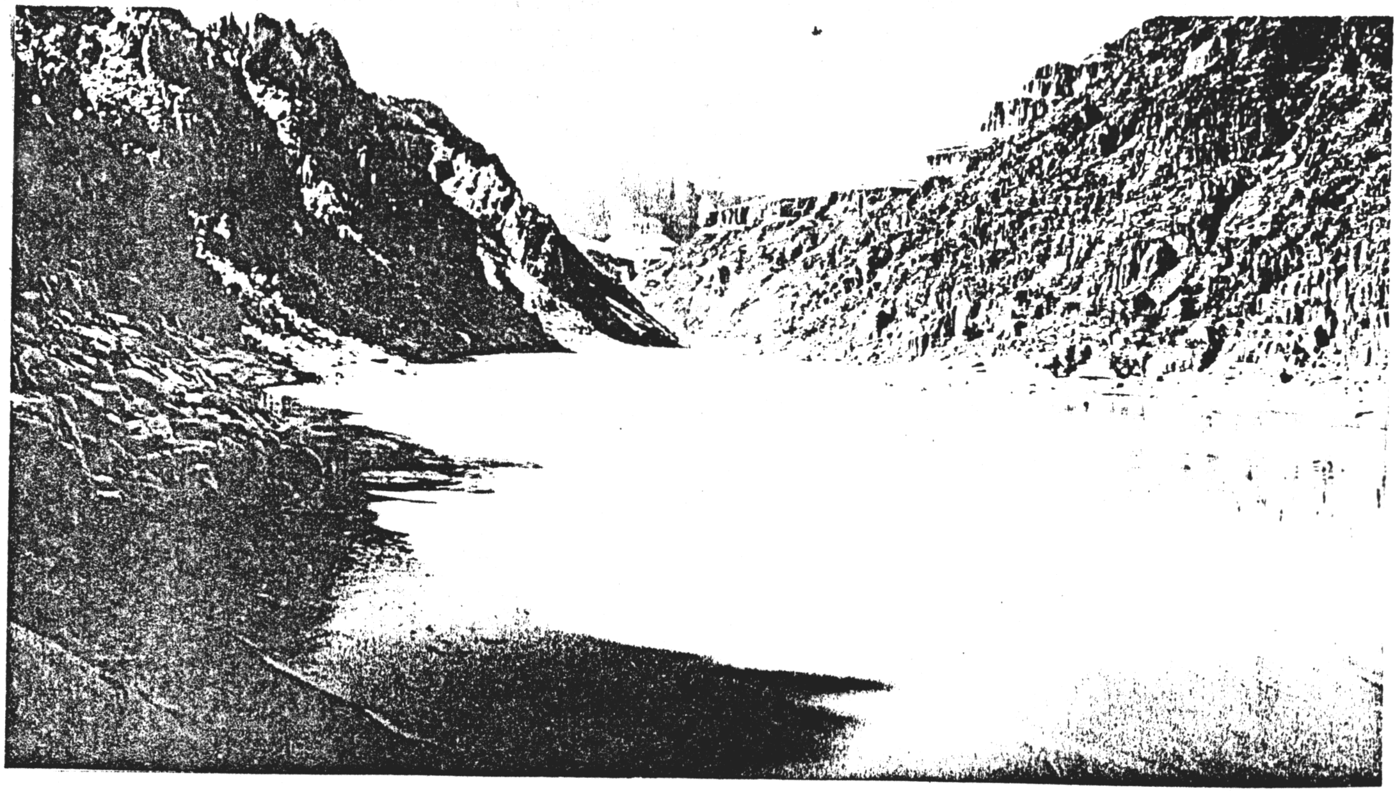

Figure I-13a.--A downstream view at Mile 225.2, above Diamond Creek, Elevation 1400 Feet, October 2, 1923.

No vegetation appears to be present in this old photo by E. C. LaRue except for the few trees on the north shore which are probably mesquite.

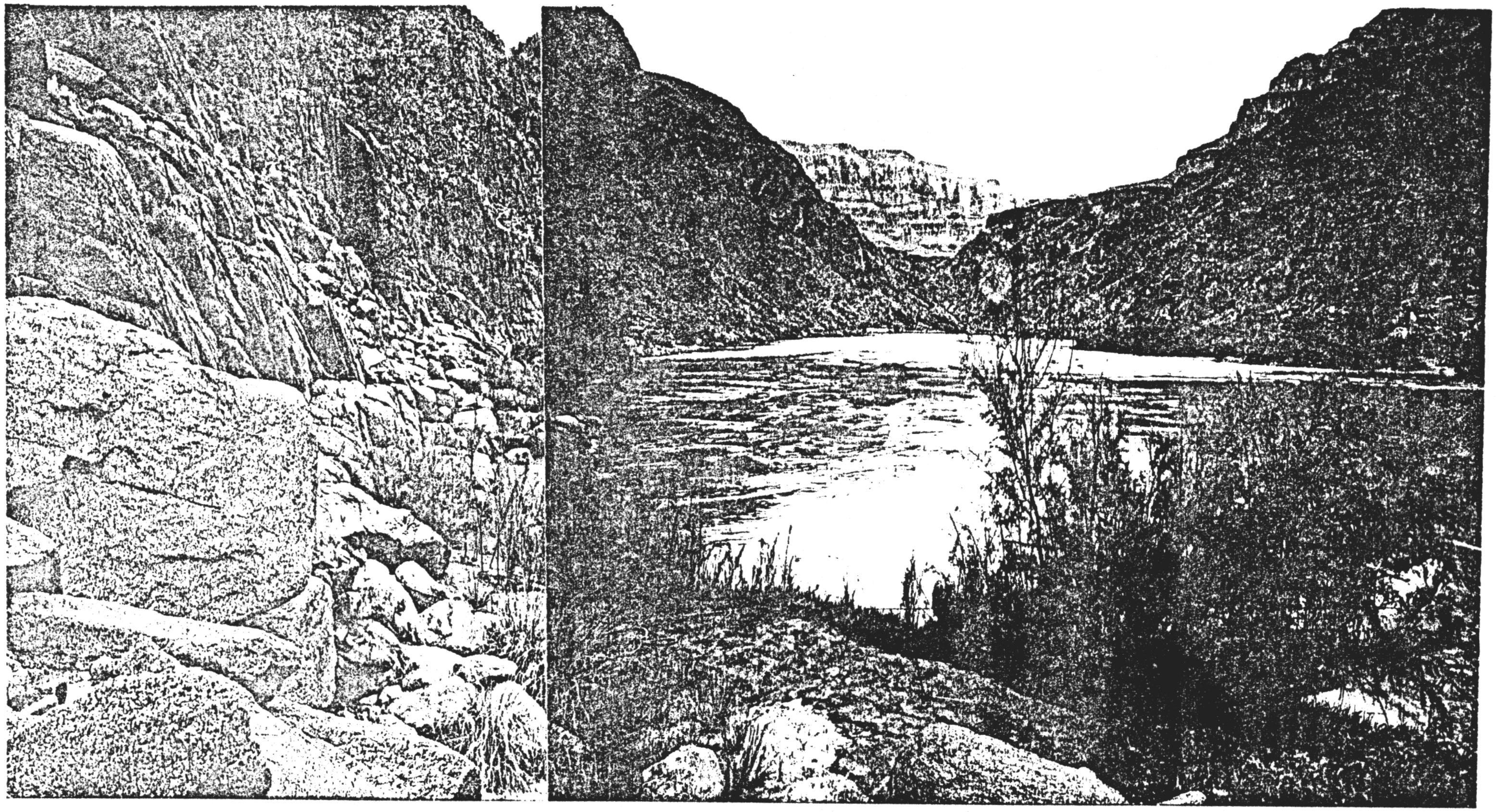

Figure I-13b.--Downstream view at Mile 225.2, August 4, 1974.

The matching photo shows that some seep willow, but predominately salt cedar with cattails at the river's edge make up the vegetation which covers the north beach. On the south side of the river we have many young salt cedar seedlings as well as a few Baccharis spp. individuals. A mesquite seedling can also be seen on the extreme right of the photo while bermuda grass is to be found at the river's edge around the base of the large clump of salt cedar on the right.

Note the rocks on the left side of the photo which indicate that the new photo site was slightly below and to the left of the original photo station. Moreover, the beach from which the photo was taken appears to have increased in size since the original photo and there has been a corresponding decrease in the amount of visible sand piled against the large boulders in the foreground.

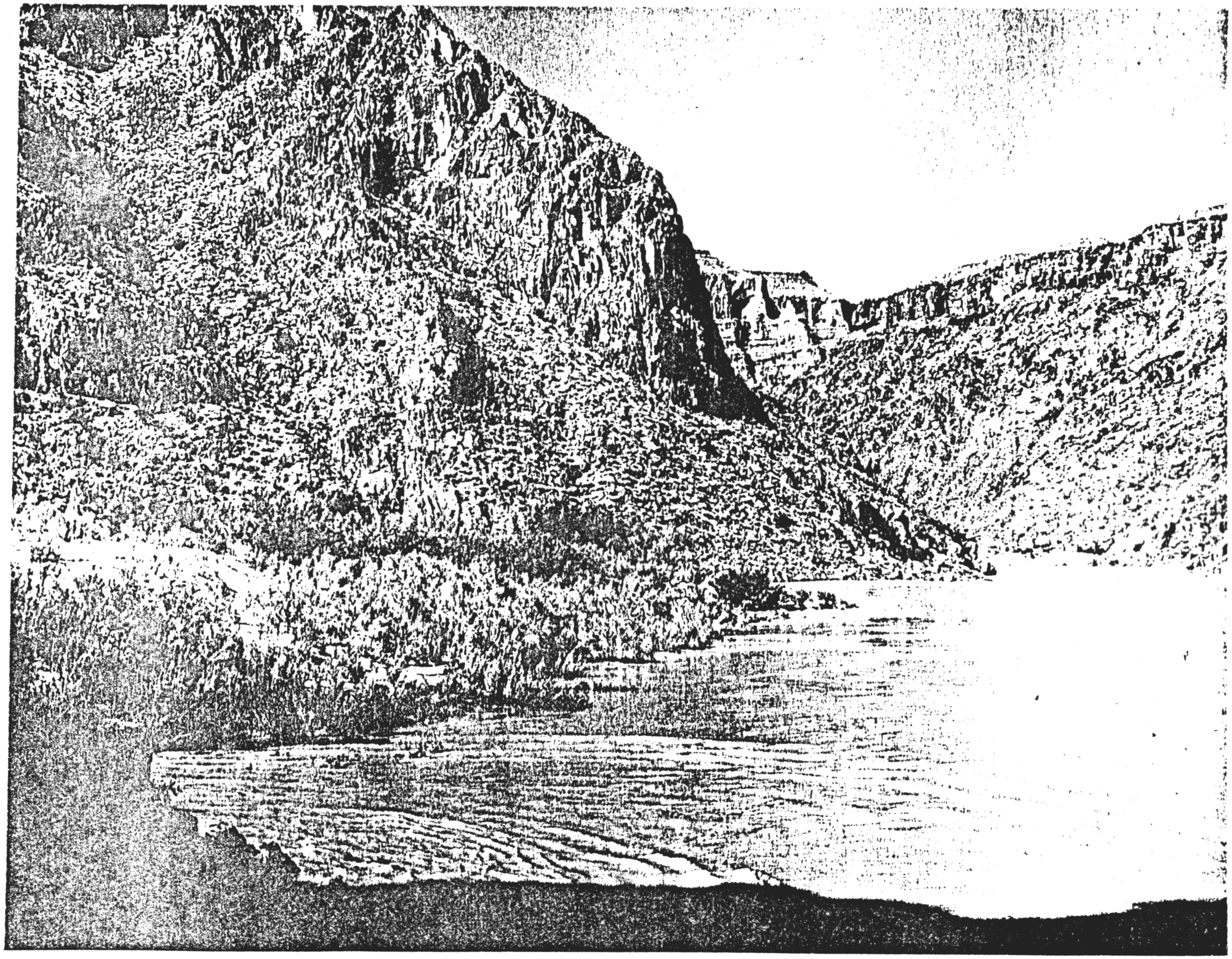

Figure I-14a.--Diamond Creek, Mile 225.7, Elevation 1350 feet, June 20, 1949.

Note the arrowweed near the river's edge and salt cedar in the background with a Baccharis sp. near the water's edge.

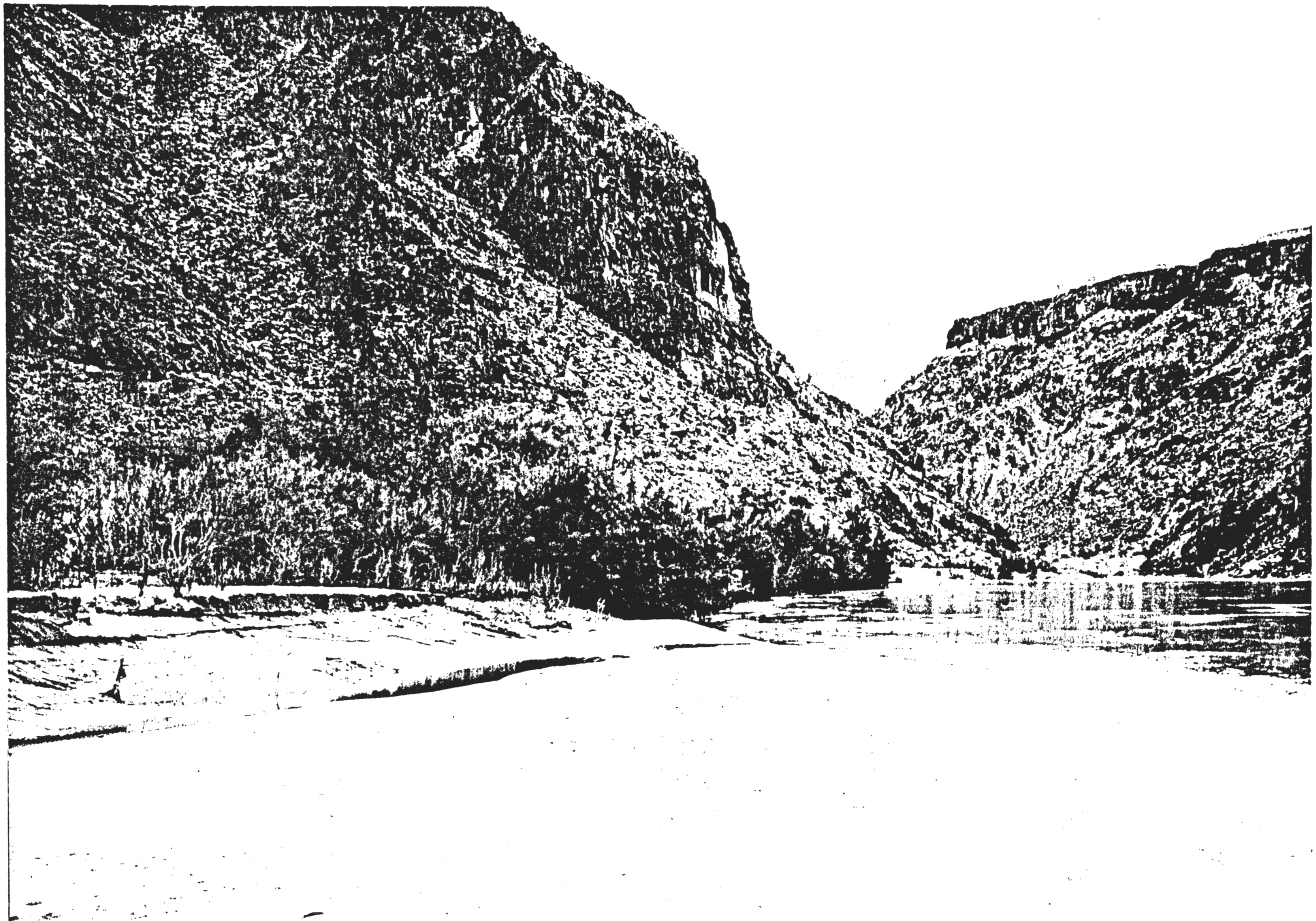

Figure I-14b.--Diamond Creek, August 4, 1974.

In the matched photo taken from the sand bar we can still see some Baccharis sp. at a new downstream location. The dominant species along the river is now mostly salt cedar with an occasional seep willow with a small area of arrowweed on the left side. The sand area visible downstream on the left side is the area presently used as a landing site for some boat parties leaving the river and going up to Peach Springs. Also note that the talus slope on the left is the location of the photo station for the following photo of the overview of Diamond Creek.

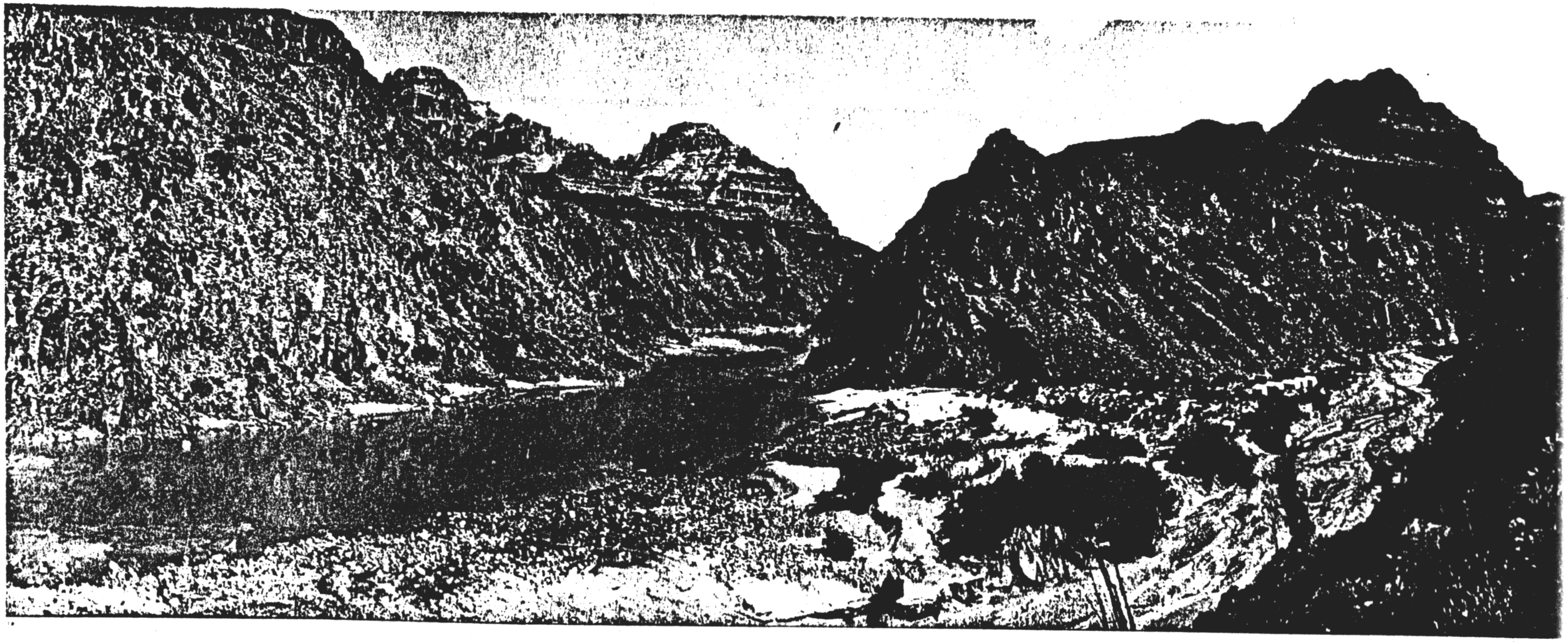

Figure I-15a.--Overview of Diamond Creek, by E. C. LaRue, September 22, 1922.

Diamond Creek looking upstream from the talus slope shown in preceding photo. Note the absence of any visible vegetation in the creek bed itself as well as on the beach. The dense area of vegetation on the lower right is predominately mesquite while creosote can be seen on the upper parts of the sand dune toward the upstream edge of the Canyon wall. The hillside from which the photo was taken was covered with white bursage, Mormon tea, ocotillo and some creosote.

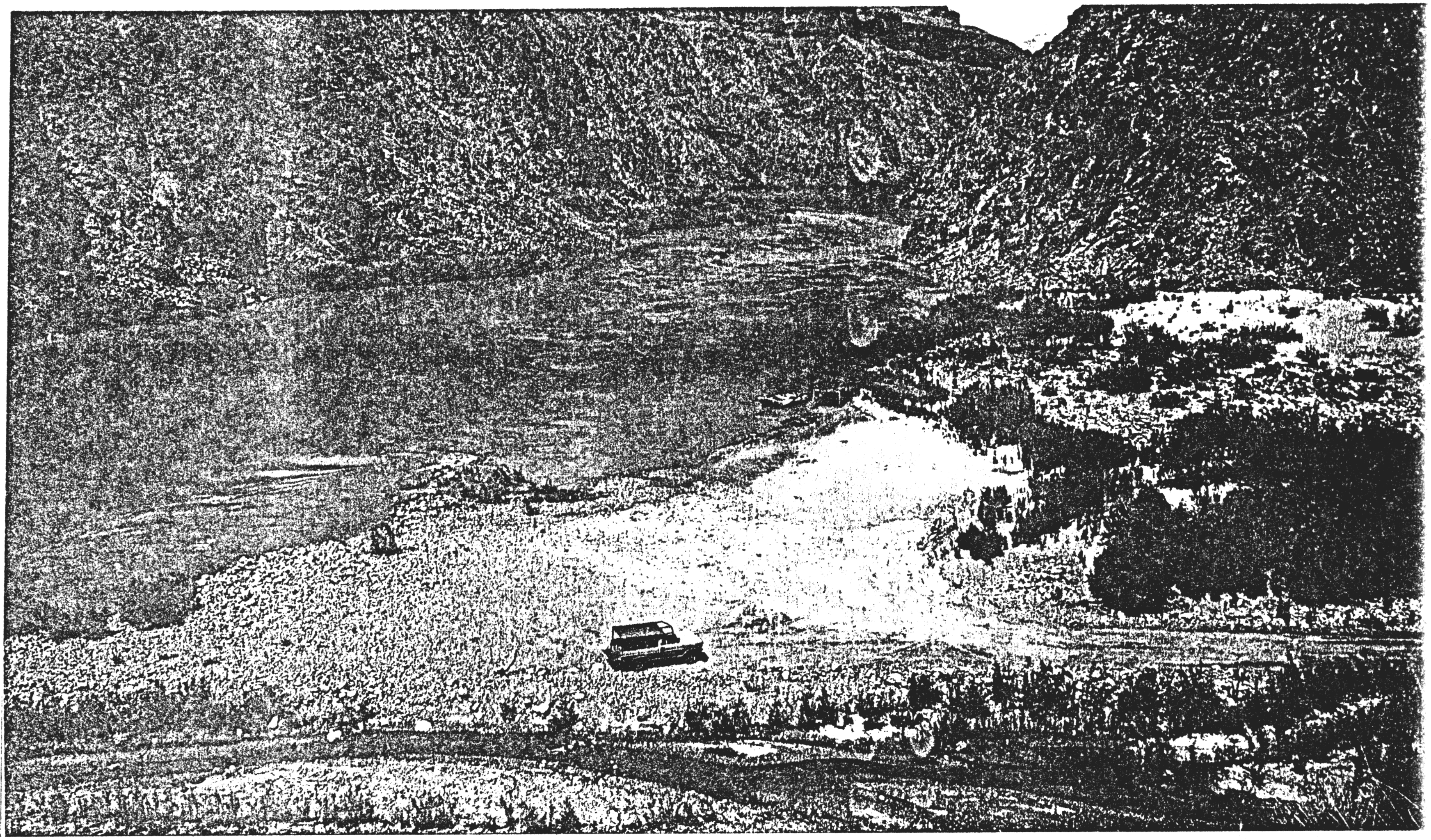

Figure I-15b.--Diamond Creek Overview, August 4, 1974.

In the recent matched photo we can find a ramada which has been built by the Haulapai Indians for campers. The dense area of mesquite seen in the old photo still remains. It is now the location of the rest facilities and a small willow can be found in with the mesquite. Just below and towards the river from the mesquite is a dense stand of arrowweed which extends back upstream towards the ramada. The dense vegetation behind the ramada consists of salt cedar, seep willow and arrowweed. Diamond Creek itself is densely covered with salt cedar seedlings (just out of view). Acacia is also to be found with mesquite in the vegetated area above the ramada. Also to be found on the dune are sand verbena, evening primrose, datura, brittle bush, salt bush and Brickellia spp. The upstream canyon wall is dominated by brittle bush.

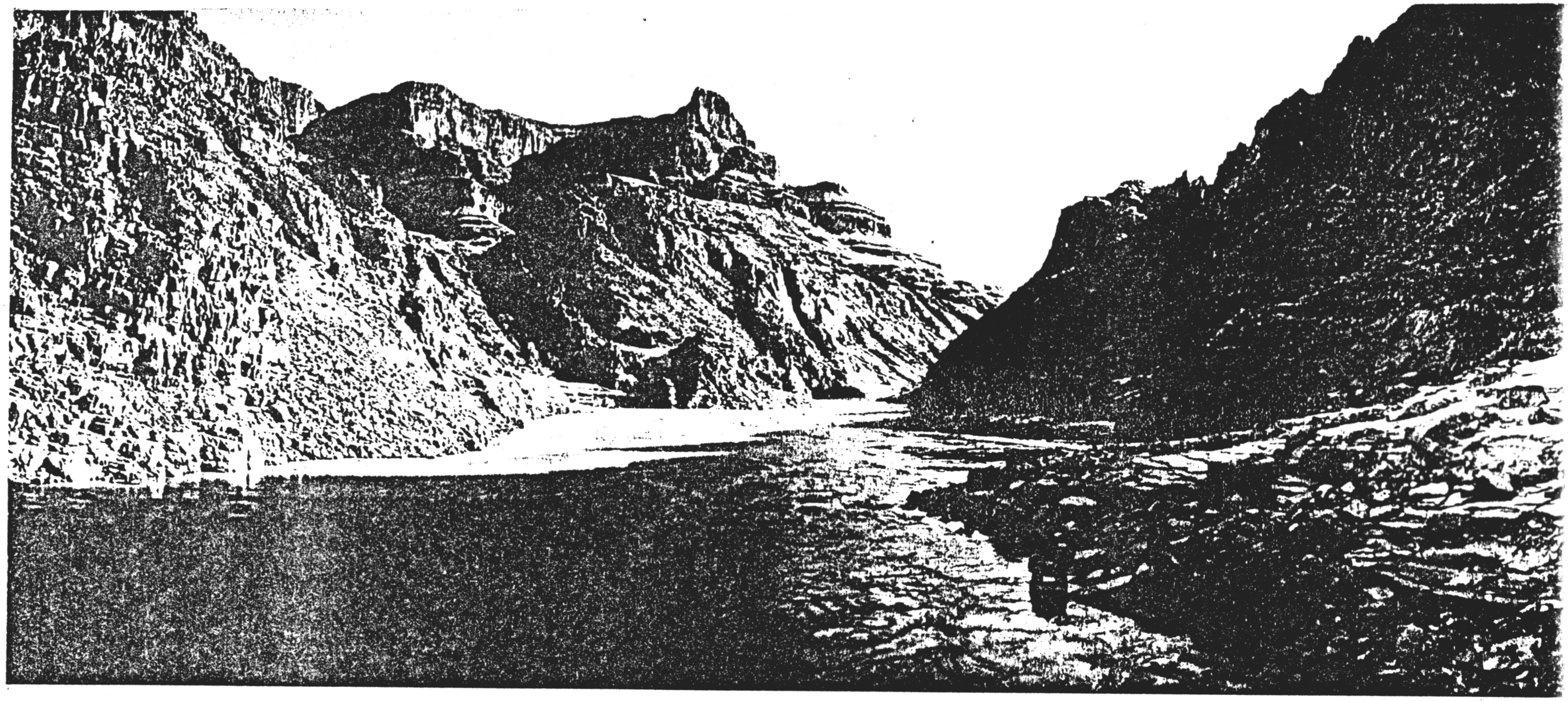

Figure I-16a.--Downstream view of Mile 243.0, Elevation 1250 feet, October 10, 1923.

Note the absence of vegetation on either shore. (Photo by E. C. LaRue.)

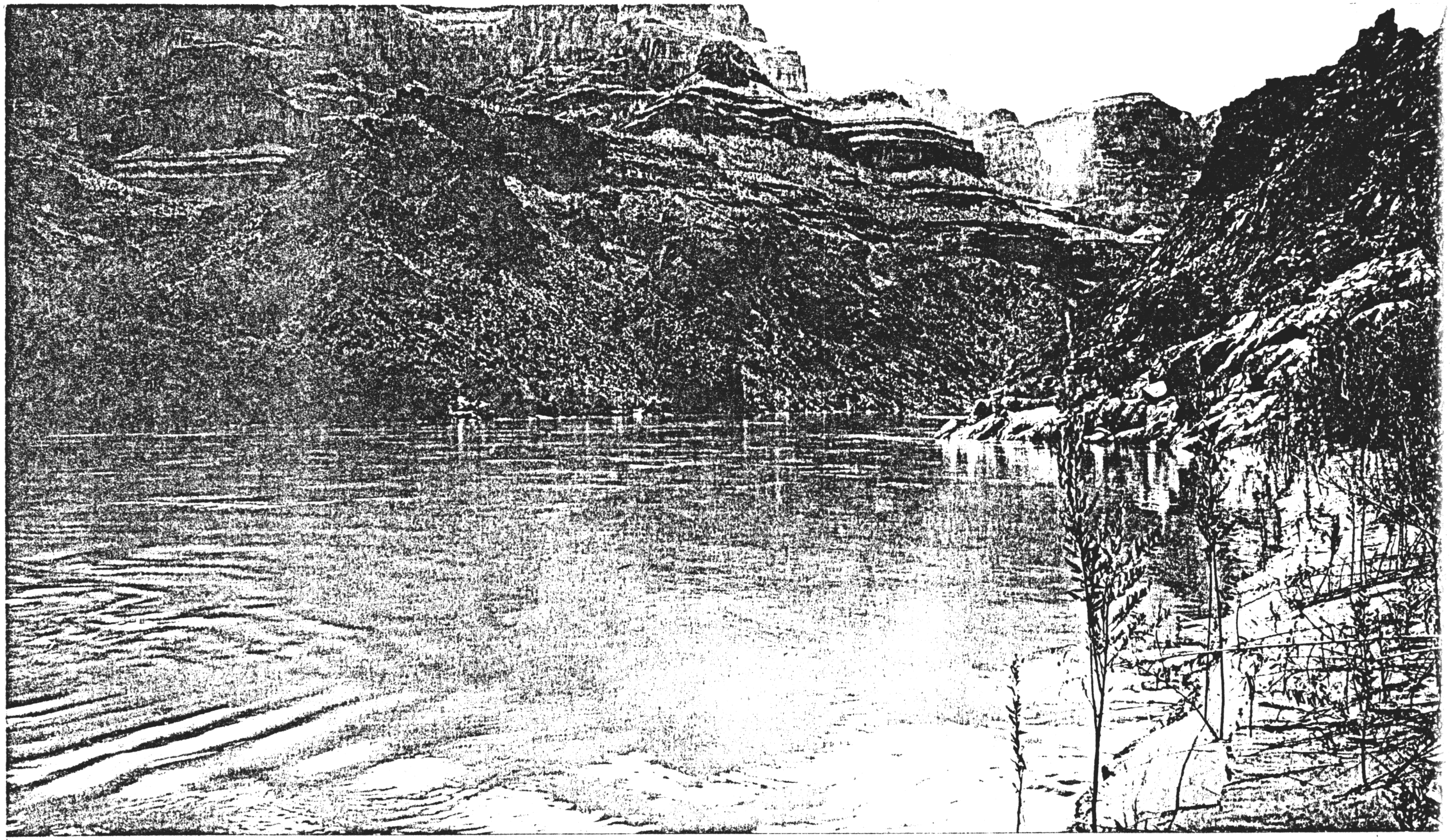

Figure I-16b.--Mile 243.0, August 5, 1974.
This matching photo shows a dense stand of salt cedar on the opposite (left) side of the river. Arrowweed is found in the foreground with salt cedar on the rocks downstream from the photo station. Also observe the rising water level of Lake Mead as seen from the comparison of photos.

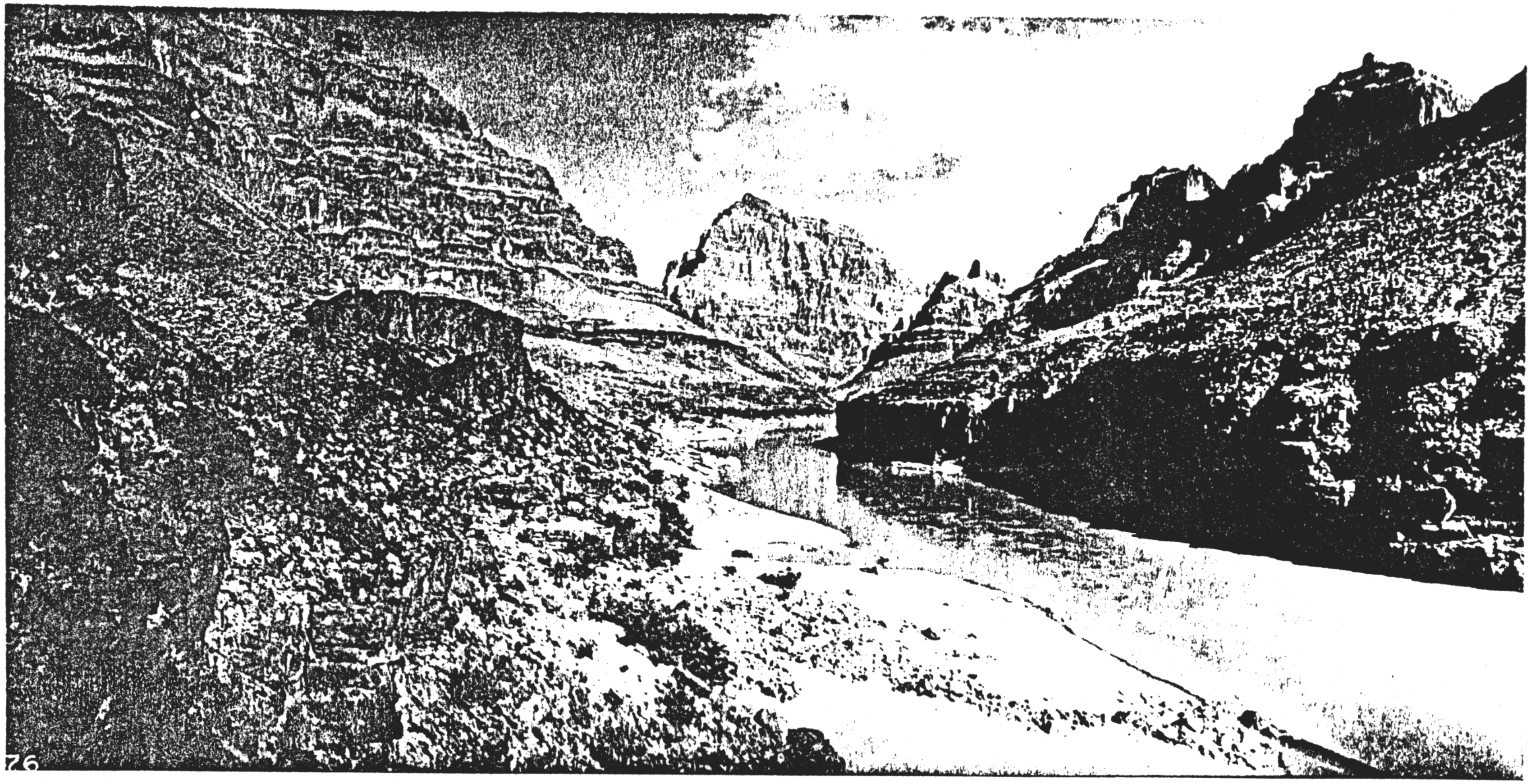

Figure I-17a.--E. C. LaRue's downstream photo of Mile 262.4, elevation 1000 feet, October 15, 1923.

Note the large sandy beach in the foreground and the mesquite/acacia belt on the left side of the river. Observe the lava palisades on the left and the steep canyon walls on the right. This site is now under water.

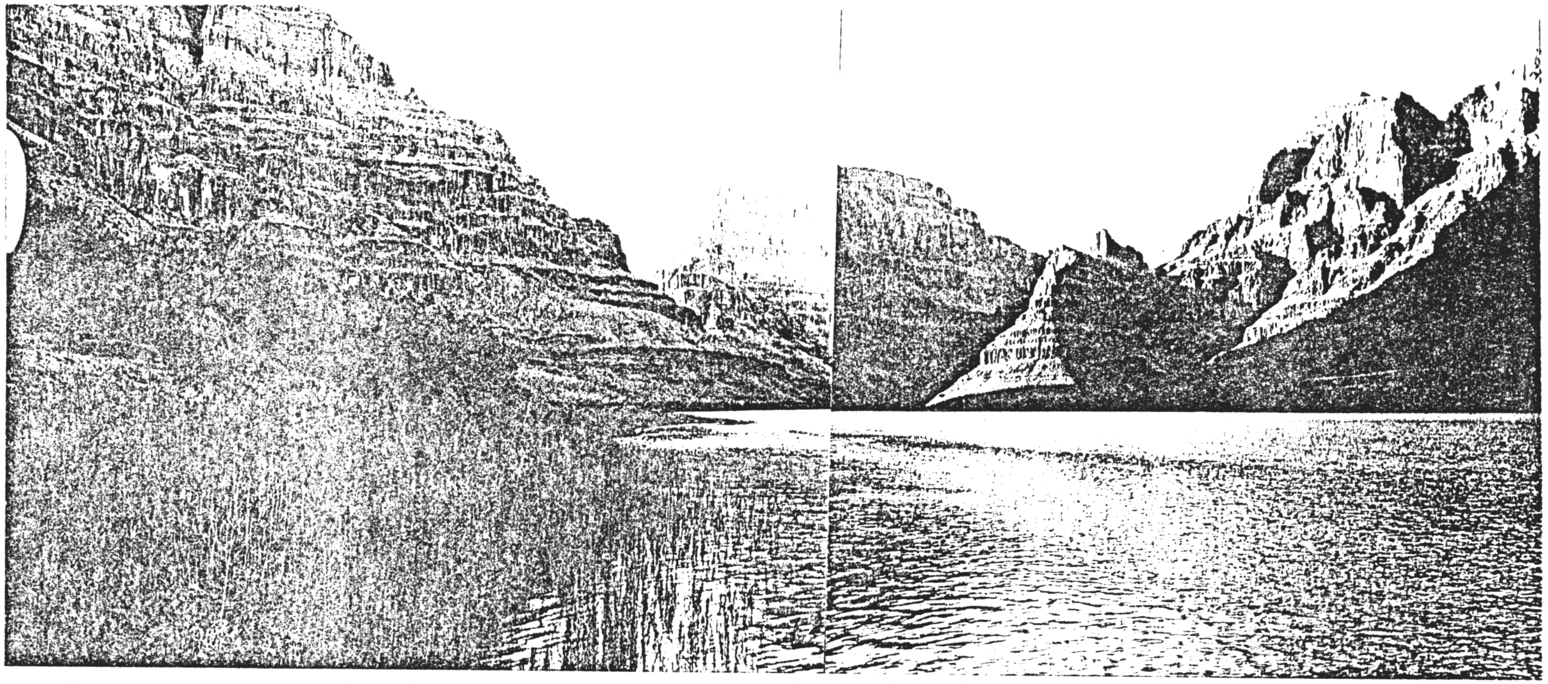

Figure I-17b.--Mile 262.4, August 5, 1974.

In this matching photo, note that the only obvious vegetation is salt cedar on the left, with numerous seedlings at the water's edge. The small rock palisades which were seen at the center of the old photograph are presently just above the water line.

CHAPTER II

VASCULAR FLORA OF THE GRAND CANYON

Michael E. Theroux

INTRODUCTION

The purpose of this study was to inventory and describe the vegetation of the vascular flora occurring along the Colorado River from Lees Ferry to the Grand Wash Cliffs. In an earlier report (see Aitchison et al., 1974)[1] we described the vascular flora of the canyon's riparian zone based on our first years work. This report is a continuation and update of that plant inventory, summarizing our findings during the entire project.

METHODS

Botanical research of the vascular plant species composition in the study area for the current contract has involved 17 field excursions by Museum of Northern Arizona staff and associates during all seasons totalling approximately 200 man-days. During this field time, approximately 1500 specimens have been taken within Grand Canyon National Park, with an additional 242 from the Supai Indian Reservation within Haulapai and Havasu Canyons. The staff has utilized river craft, aerial transport and backcountry hiking to faciliatate the work.

General collecting has been accomplished using a vasculum and standard plant press. Field data for each specimen included, (1) date, (2) river mile (measured from Lees Ferry) and side (designated "left" or "right" looking downstream), (3) collector's number and name, (4) field identification, if possible, (5) general habitat description, as "river-edge" or "upper talus," (6) soil texture/type, as "fine sand" or "granite rock face," (7) surrounding dominant vegetation, (8) slope exposure in cardinal direction and relative degree, and (9) any unusual site or plant characteristics, as "recent burn" or "heavily infested with mistletoe." Further data was then computer coordinated to include for each collection site, elevation and further site names, and for each species the taxonomic nomenclature and synonomy, structure (growth-form) etc.

1/ Aitchison, S. W., S. W. Carothers, M. M. Karpiscak, M. E. Theroux, D. S. Tomko. 1974. An ecological survey of the Colorado River and its tributaries between Lees Ferry and the Grand Wash Cliffs. Unpubl. ms.

The bulk of taxonomic identification was performed at the Museum of Northern Arizona. Many problem situations arose for the various families; in such cases specialists were contacted where possible.

A few noted exceptions, the systematic taxonomy follows the most recently recognized authorities. Synonomy is presented in the more confusing cases, especially where previously recognized species have been "lumped" into one species (example: Yucca whipplei Torr., LILIACEAE includes Y. newberryi McKelvey and Y. navajoa J. M. Webber), and where past collections were listed under now archaic nomenclature. Sub-specific information has been combined, and entered only at the species level, as conflicting data must be further studied before varietal and sub-species habitat differentiation may be depicted.

Each plant species entry in the computerized inventory is accompanied by extensive data. An exemplary entry is presented and described per data item in Appendix II-1.

Three local herbaria were searched in entirety for holdings from the study area. These were the Museum of Northern Arizona Herbarium (MNA), the Deaver Herbarium at Northern Arizona University and the Grand Canyon National Park Herbarium, located at the South Rim research facility. Additional extensive spot-checking for specific holdings have involved the herbaria of the Arizona State University, the University of Arizona at Tucson and the Desert Botanical Gardens at Papago Park, Tempe.

RESULTS AND DISCUSSION

The vascular flora inventory (Appendix II-1) represents all collection records known by the author to occur along the 280 miles of the Colorado River within the Grand Canyon. A total of 807 species representing 92 families is presented.

The inventory includes two species that may be considered new to science. These are Flaveria mcdougalli (Theroux et al., in press) and Euphorbia rossii (species nova proposed by Dr. A. Holmgren). Flaveria mcdougalli is a large shrubby member of the Compositae and has thus far been collected in two localities within the study area, Cove Canyon (mile 174.2R) and Matkatamiba Canyon (mile 148.8L). Euphorbia rossii is a low-growing member of the Euphorbiaceae and has thus far been collected from one area within the upper reaches of Marble Canyon (mile 19.0L).

The vascular plant inventory is presented in Appendices II-1 and II-2. Both of these appendices are computer print-outs, Appendix II-1, presenting the 807 species in phylogenetic order (after Kearney and Peebles, 1951), and Appendix II-2 presents the 807 species in a 10 mile sort, based on the distribution of the flora within the canyon (i.e., for a given 10 mile section of the canyon, all plants known to occur in that area are presented).

The inventory presents a total of 210 species that may be considered new to the flora of the localized flora of the riparian zone of the Grand Canyon. Many of these "new" additions to the flora were discovered during the extensive herbaria search, however, 74 new plants were collected during this project. The plant inventory of the riparian zone of the Colorado River is by no means complete nor will it ever be. Plant communities are dynamic, ever changing entities of the natural world, and there will always be new species or new records appearing. We are, however, much closer to being able to describe the vascular plant resources of this area than we were before this project began.

SUMMARY

1. Botanical investigations within the riparian and adjacent habitats of the Colorado River study area have discerned the presence of 807 species of vascular plants representing 92 families.

2. Two species, previously undescribed, *Flaveria mcdougallii* and *Euphorbia rossii*, are presented.

3. A total of 210 species are new to the local flora, 74 of which resulted from collections during this project. The remainder are from refined herbaria and literature searches that took place during the contract period.

REFERENCES CITED

Kearney, T. H. and R. H. Peebles. 1951. Arizona flora. Univ. of Calif. Press, Berkeley.

Table III-1.--A Collection Gazetteer of Specimens. Entries Read as : River Mile (Sample Size) Month.

<u>Uta</u> <u>stansburiana</u>

35(5)VII, 52(10)VI, 52(1)VII, 66(4)VII, 69(10)VIII, 70(10)VIII, 71(8)IV, 71(8)IV, 71(35)V, 71(20)VI, 71(10)VII, 71(10)VIII, 87(2)VII, 93(2)VII, 95(12)X, 109(5)VII, 117(1)VII, 125(11)VII, 134(6)VII.

<u>Urosaurus</u> <u>ornatus</u>

18(5)VII, 33(4)VII, 35(1)VII, 117(1)VII, 134(3)VII.

<u>Sceloporus</u> <u>magister</u>

0(1)VII, 32(L)VI, 32(1)VII, 39(1)VIII, 41(1)VIII, 52(1)VI, 52(1)VII, 66(6)VII, 71(1)VII, 71(1)VIII, 94(3)VII, 109(2)VII, 117(1)VII, 125(1)VII, 131(1)VII, 131(1)VIII, 157(1)IV, 166(1)V, 180(1)VII.

<u>Crotaphytus</u> <u>insularis</u>

125(1)VII, 131(1)VIII, L36(3)VII, 208(1)VIII.

<u>Cnemidophorus</u> <u>tigris</u>

52(10)VI, 66(3)VII, 71(1)V, 71(4)VI, 71(4)VII, 94(1)VII.

<u>Bufo</u> <u>woodhousei</u>

64(1)IX, 71(15)VII

<u>Bufo</u> <u>punctatus</u>

35(1)VII, 125(1)VII, 270(1)VII.

<u>Hyla</u> <u>arenicolor</u>

35(2)VIII, 41(2)VIII.

CHAPTER III

DIETARY CHARACTERISTICS OF SOME GRAND CANYON AMPHIBIANS AND REPTILES

Dennis S. Tomko

INTRODUCTION

The present study is a survey of the dietary characteristics and interrelationships of eight herptile; i.e., reptile and amphibian, species commonly found along the shores of the Colorado River from Lees Ferry to the Grand Wash Cliffs.

Some effort has been put forth to extend this study beyond a simple list of diet items. The common side-blotched lizard, Uta stansburiana, is used to demonstrate many of the principles which apply to all the Grand Canyon's diurnal lizards. Interspecific diet differences are discussed in terms of general ecological differences existing between species.

METHODS

The Study Area

Collection locations, months, and sample size data are presented in Table III-1. Most specimens were collected in the Tamarix/Salix/forb habitat existing between the Colorado River and the old, pre-dam high water line. The substrate here is essentially sandy with gravels and/or boulders scattered over it.

Field and Laboratory Methods

Specimens were collected either by noosing or shooting with a "BB" gun. Knowlton (1936) has shown that insects in the stomachs of Uta stansburiana loose their taxonomic integrity several hours after ingestion so the lizards and amphibians used in this study were all sacrificed within two hours after collection. It was also found that if the animals were not taken until 1 to 2 hours after the start of their daily activity period, the stomachs contained a large amount of prey matter.

Each stomach was excised and place in a vial of 70 percent isopropyl alcohol. The eviserated body was preserved in 57 percent formalin and stored for later autopsy.

In some cases, specimens already in the herpetology collection of the Museum of Northern Arizona were used to supplement the field data.

Insect material was identified to order using the keys in Borror and DeLong (1970) and Borror and White (1970). Absolute density and relative volume estimates of prey in each stomach were made visually. Bolus volume was measured by displacement to the nearest 0.1 ml. Prey categories may be found in Table III-2.

Analysis

Stomach content lists were used to formulate quantified composite diets for each species and to provide a basis of inter- and intraspecific comparisons. Various aspects of diets were calculated. Relative density of prey items reflects the impact of predators upon the prey resources. Relative volume reflects the potential value of items to the caloric needs of a predator. A composite of these two parameters is the importance value, a modified form of the statistic used by botanists in plant ecology (Curtis and McIntosh, 1951). An importance value is calculated for each prey category as follows:

$$I.V. = \frac{1}{200} (\%\ density + \%\ volume)$$

Thus, the sum of importance values for any species must equal 1.00.

Certain comparative ecological statements were made based upon diet information in the form of I.V. lists. These included comments on interspecific relationships (paired species comparisons), location characteristics (one species at different locations during the same month), and temporal changes in forage behavior (one species at the same location during many months). These comparisons were all based upon the statistic, percent similarity (Bray and Curtis, 1957) which totals the amount of shared importance value (w_i) within each prey category, i, in two species' diet lists:

$$PS = \frac{2\ w_i}{(a + b)}$$

where a + b is the sum of each species importance value total and must, by definition, be equal to 2.00. Thus, PS may be described as diet similarity, food niche overlap, or (in the case of two species) a measure of potential competition. PS values range from 0, complete separation, to 1, complete identity.

The Species

The following brief species accounts represent information gathered during field work in the Grand Canyon and from Stebbins (1966).

Uta stansburiana.--By far the most common lizard in the Grand Canyon, this small species (Snout-Vent Length = 46mm) reaches its highest density in the riparian zone along the Colorado River. Its wide geographical distribution and range of habitats identify it as the most generalized of the Canyon's riparian lizards. The high densities Uta attains are the reason it is chosen as the indicator species for this study. Primarily saxicolous and highly territorial, Uta employs a "sit and wait" type of foraging strategy. In the Canyon it can be seen foraging on any day of the year, weather permitting.

Urosaurus ornatus.--Because of its small size (SVL = 52mm) and similar foraging behavior, this species is a potential competitor with Uta. However, Urosaurus, though locally common, is most often found within 1 or 2 meters of a permanent water source where large rocks and an appreciable amount of overhead cover are available. Uta is usually not found within Urosaurus territories in the Grand Canyon so that these two similar species can coexist due to microhabitat separation.

Sceloporus magister.--This is a large species (SVL = 90mm) which reaches its highest densities in the riparian zone where the availability of Prosopis, Acacia, Tamarix and Salix trees provide a high quality habitat for this semi-arboreal lizard. Although it makes ample use of rocks occurring within its territories as basking sites, Sceloporus probably carries out most of its foraging activity on or around the bases of trees. Apparently, this species also employs a "sit and wait" type of foraging strategy.

Cnemidophorus tigris.--This medium sized (SVL = 73mm) lizard is second only to Uta in relative density of riparian lizard species. It is the most exclusively terrestrial of all the lizards included in this study as evidenced by the observation that it is never seen in trees and only very rarely on rocks. Unlike the previously described species, Cnemidophorus is a very active forager and is constantly in motion searching out prey items, most often within 50cm of the base of trees and shrubs. This seems to be the only common terrestrial lizard species whose foraging activity is evenly distributed from the lower edge of the desertscrub to the wet, sandy shores of the Colorado River.

Crotaphytus insularis.--A large (SVL = 89mm) uncommon species, this saxicolous lizard is actually characteristic of boulder-strewn desert scrub habitats but can be found on rocky, open beaches. It also employs a "sit and wait" foraging strategy.

Bufo punctatus, Bufo woodhousei.--These are the only two toads commonly found in the riparian zone. They are nocturnal and, judging from the tracks found in the sand, they spend their days under large rocks or among the roots of shrubs away from the river bank, emerging at night to forage along the shore.

Hyla arenicolor.--This tree frog may actually be the nocturnal counterpart of Urosaurus ornatus with respect to its microhabitat requirements.

RESULTS AND DISCUSSION

Diet Descriptions

The diet information for eight species of reptiles and amphibians is summarized in Table III-2. Although 18 taxonomic categories of animal prey are listed, three orders, Diptera, Hymenoptera, and Coleoptera account for 70 percent of the mean importance value totals for these 8 predatory species.

In some instances orders were broken down into smaller units. Within Hymenoptera the ratio of ants to bees and wasps was 1.6 to 1.0 in Uta, 7.6 to 1.0 in Sceloporus, and 0.3 to 1.0 in Cnemidophorus. Within Diptera the ratio of flies to other Dipterans was 0.1 to 1.0 in Uta and 0.1 to 1.0 in Cnemidophorus. The apparent similarity of the last pair of numbers is modified somewhat by the fact that flies are only about 1/3 as important to Uta as they are to Cnemidophorus.

Although all the predators are primarily insectivorous, several minor exceptions are found. Aquatic crustaceans, ie., amphipods, were consumed by Urosaurus and Cnemidophorus (which also ingested snails). These two species frequently forage close to the water's edge and it is quite likely that the aquatics were taken from very shallow ($<$ 5mm) pools created by the daily ebb of the Colorado River. In this sense, Glen Canyon Dam has had a direct, though minor, effect upon lizard diets since these water conditions did not exist prior to 1963.

Vertebrates appear in the diets of Sceloporus and Crotaphytus. These are Uta and are not taken by Sceloporus in large quantities although they are fairly important to Crotaphytus.

Table III-2.--Reptile and amphibian diets along the Colorado River, Grand Canyon, Arizona.

	Uta stansburiana			*Urosaurus ornatus*			*Sceloporus magister*			*Crotaphytus insularis*		
	%den	%vol	I.V.	%den	%vol	I.V.	%den	%vol	I.V.	%den	%vol	I.V.
INSECTA												
Thysanura	00.02	00.01	.001									
Collembola	01.36	00.02	.005									
Orthoptera	00.08	01.52	.008				00.72	14.33	.075	19.00	51.18	.351
Isoptera	02.85	04.25	.036				20.31	04.28	.123	06.00	00.39	.032
Thysaroptera	00.01	00.01	.001									
Hemiptera	01.81	03.19	.025				00.31	00.13	.002			
Homoptera	02.77	00.99	.018	02.78	00.75	.018	00172	08.11	.044			
Coleoptera	03.23	11.28	.073	00.73	07.81	.043	06.08	18.79	.124			
Neuroptera	00.28	01.36	.008				00.10	00.44	.003			
Tricoptera				00.22	03.72	.020						
Lepidoptera	00.22	02.12	.012									
Diptera	55.66	25.64	.407	94.88	70.39	.826	.4.54	07.84	.112	13.00	08.07	.105
Hymenoptera	24.93	34.35	.296	00.95	04.69	.028	55.58	31.98	.438	50.00	01.38	.258
Misc. Larvae	02.93	05.15	.040	00.07	02.98	.015	00.82	01.49	.012			
ARACHNIDA	03.85	10.17	.070	00.29	02.98	.016	00.72	00.90	.008			
CRUSTACEA				00.07	06.69	.034						
MOLLUSCA												
REPTILIA							00.10	04.05	.021	13.00	32.48	.227
VEGETATION								07.66	.038		06.50	.027
SAMPLE SIZE		162			14			29			6	

Table III-2.--continued.

	Cnemidophorus tigris			*Bufo woodhousei*			*Bufo punctatus*			*Hyla arenicolor*		
	%den	%vol	I.V.	%den	%vol	I.V.	%den	%vol	I.V.	%den	%vol	I.V.
INSECTA												
Thysanura												
Collembola	00.03	00.01	.001									
Orthoptera	00.06	01.60	.008	19.83	22.38	.211				05.56	25.67	.161
Isoptera							12.59	04.67	.086			
Thysaroptera												
Hemiptera	00.10	00.22	.002				01.40	03.33	.024			
Homoptera	01.13	02.86	.020									
Coleoptera	03.60	21.15	.124	54.31	56.51	.554	05.59	26.67	.161	50.00	54.67	.523
Neuroptera	00.52	06.05	.033				01.40	06.67	.040			
Tricoptera												
Lepidoptera	00.45	18.02	.092	05.17	03.60	.044				05.56	01.33	.034
Diptera	91.05	26.60	.588	01.72	.001	.009	00.70	00.33	.005			
Hymenoptera	00.81	04.34	.026	13.79	01.38	.076	76.92	56.67	.668	33.33	07.15	.202
Misc. Larvae	00.71	05.78	.032							05.56	08.00	.068
ARACHNIDA	00.88	06.47	.037	05.17	00.41	.028	01.40	00.03	.007			
CRUSTACEA	00.49	05.57	.030									
MOLLUSCA	00.16	01.33	.007									
REPTILIA												
VEGETATION					15.72	.079		01.67	.008			
SAMPLE SIZE	23			16			3			4		

Vegetation is occasionally encountered in stomachs. The importance value of plant matter is quite small and the ingestion of vegetation is probably accidental. When the data are examined closely it becomes apparent that the large-mouthed predators have the greatest amount of vegetation. Presumably, a large-mouthed predator is more likely to ingest the leaf an insect is resting on than a small-mouthed species.

Table III-3 reveals a great deal of variability in the dietary relationships between lizard species. PS values less than .500 can be interpreted as "more dissimilar than similar." Uta is a generalized lizard in the sense that it is commonly found in the habitats of the other 3 species; Cnemidophorus ranks second in this respect. Therefore, it is not surprising to find the highest and second highest mean PS values for these two species which indicate a relatively high amount of diet sharing between each of them and the other species. The least amount of overlap is found in Sceloporus, a large semi-arboreal lizard, and Urosaurus, a small terrestrial rocky shoreline forager. The greatest overlap is found between Urosaurus and Cnemidophorus, both of which are terrestrial shoreline foragers.

The precision of the PS values in Table III-3 is somewhat modified by the fact that they are based upon composite diet lists from many locations along the Colorado River during several months. The effect of different locations upon diet lists can be seen in the Uta data in Table III-4. When 5 different locations are compared a mean PS value of .458 results. Therefore, even when data are collected during the same month, a great deal of interlocational variability is introduced into the resulting composite diet list. This also points out the fallacy of basing a diet estimate for a Grand Canyon species based upon collections made at one or two sites.

Table III-5 presents data which emphasize the effect of seasonal change upon diet. When 5 months of data from the same location are compared a mean value of .539 results. Thus, a great deal of temporal variability as well as locational variability exists in lizard diets in the Grand Canyon. The locational and monthly comparisons suggest that variability through space may be slightly greater than through time.

An estimate of food niche overlap between Uta and Cnemidophorus which are sympatric in space and time is given in Table III-6. The estimated overlap value is fairly high

Table III-3.--PS values of diets of common diurnal lizards using June and July importance values.

SPECIES NAME	*Uta stansburiana*	*Urosaurus ornatus*	*Sceloporus magister*	*Cnemidophorus tigris*
Uta stansburiana		.448	.663	.527
Urosaurus ornatus	.448		.221	.736
Sceloporus magister	.663	.221		.315
Cnemidophorus tigris	.527	.736	.315	
mean ($\overline{PS}$)	.546	.468	.399	.526

Table III-4.--Importance value PS comparisons of *Uta stansburiana* diets of various locations in mid-summer. Mean value ($\overline{PS}$) = .458.

	Mi. 52	Mi. 71	Mi. 109	Mi. 125	Mi. 134
Mi. 52		.652	.287	.312	.476
Mi. 71			.265	.576	.724
Mi. 109				.237	.341
Mi. 125					.714
Mi. 134					

Table III-5.--Monthly importance value PS comparisons of Uta stansburiana diets at Cardenas (mi. 71). Mean value (PS) = .539.

	April	May	June	July	August
April		.723	.524	.715	.388
May			.580	.581	.480
June				.676	.378
July					.351
August					

Table III-6.--PS values of Uta stansburiana and Cnemidophorus tigris (sympatric in space and time) and PS contribution of Diptera in percent of total PS value.

	Nankoweap June	Cardenas June	Cardenas July
PS Overlap	00.728	00.511	00.607
Diptera Percent	57.000	48.700	58.000

and indicates more similarities than dissimilarities. When the PS values are analyzed in detail it is apparent that a great deal of the estimated overlap is accounted for by shared predation of Diptera. The two sites which were examined are heavily used by Canyon visitors and it is likely that the densities of Diptera at these sites have responded positively to this usage. Therefore, it is not unreasonable to postulate human interference into one competitive mechanism which regulates species diversity. This assumes, of course, that insect prey is a limiting factor in population dynamics.

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CHAPTER IV

DEMOGRAPHY OF THREE SPECIES OF GRAND CANYON LIZARDS

Dennis S. Tomko

INTRODUCTION

The study of reptile and amphibian demographic characteristics in the Grand Canyon was undertaken to help establish the position of these species in the ecology of the Canyon's fauna. It was decided to limit this work to a consideration of the lizards Uta stansburiana, Sceloporus magister, and Cnemidophorus tigris since these are common species. In this way a significant amount of information was obtained for a single faunal group rather than fragmentary data for a diverse herptile assemblage.

This study is largely descriptive in nature and it is hoped that future studies of a more theoretical nature will be undertaken. Certainly, the Canyon provides a compressed geographical area for testing concepts such as the recently postulated relationships of reproductive effect in lizards to latitudinal gradients (Tinkle and Hadley, 1975) and life history evaluations (Tinkle, 1969).

MATERIALS AND METHODS

Lizards were collected within the riparian zone of the Grand Canyon during 7 months of the year. In all instances lizards were field-fixed in 7 percent formalin and later changed to 50 percent isopropyl alcohol.

Male reproductive stages were characterized by the length of right testes to the nearest 0.1m. In so doing the reproductive cycles could be compared with similar data from other areas. Female reproductive stages were assessed by the presence of ovaductal eggs. This provided an approximation to the timing of egg deposition.

The intensity of predation upon lizards was estimated using tail-break frequencies. Since tail autonomy is a primary predator escape mechanism in lizards, the frequency of broken tails can be used as a relative indicator of encounters with predators (Pianka, 1967). A tail was considered broken regardless of the amount of regeneration which had taken place.

RESULTS AND DISCUSSION

The male reproductive data are shown in Figure IV-1. All three species undergo testicular regression during the summer. The morphological patterns shown in Figure IV-1 indicate a histological pattern of winter and spring spermatogenesis followed by a cessation of interstitial cell activity in late summer (Fox, 1958). The timing of events in the Grand Canyon is very similar to that found in other southwestern desert lizard studies (Parker and Pianka, 1975; Vitt and Ohmart, 1974; Parker, 1972).

Female *Uta stansburiana* reproductive cycle data is shown in Figure IV-2. Late spring to early summer is the period of greatest activity for these lizards. The occurrence of multiple clutches in *Uta* is well documented (Tinkle, 1961; Parker and Pianka, 1975). Tinkle (1961) has estimated 38 days as the time required to produce a clutch. Dividing 38 days into the reproductive season in Figure IV-2 an estimate of 4 clutches per adult female is reasonable. Females yielded a modal clutch size of 3 eggs. Therefore it is likely that a female *Uta* reproduces approximately 12 young per year.

Reproductive data from other studies have been gathered to supplement the information gained during the present work (Table IV-1). A survey of the literature for any single species reveals a great deal of variability in time and space. For example, the annual clutch frequency for *Uta* has been recorded from 1 (Parker and Pianka, 1945) to 12 (Medica, pers. comm.). Annual precipitation and the timing of the frost-free period probably account for the greatest amount of variability in the Table IV-1 data.

Tail break data is summarized in Table IV-2. If the lower Canyon data for *Sceloporus* and *Cnemidophorus* are dropped due to small sample size, the significant intraspecific differences in tail break frequencies (p less than .05) occur in comparisons of upper and middle *Cnemidophorus* and of middle and lower *Uta*. If all data is pooled, weighed mean lizard tail break frequencies are: upper, .48; middle, .60; lower, .26. A standard "Z test" reveals a significantly lower level of predator pressure in the lower canyon than in the upper and middle portions which are not significantly different from each other. Thus, it seems likely that predator pressure on lizards below Havasu is less than it is above mile 155.0.

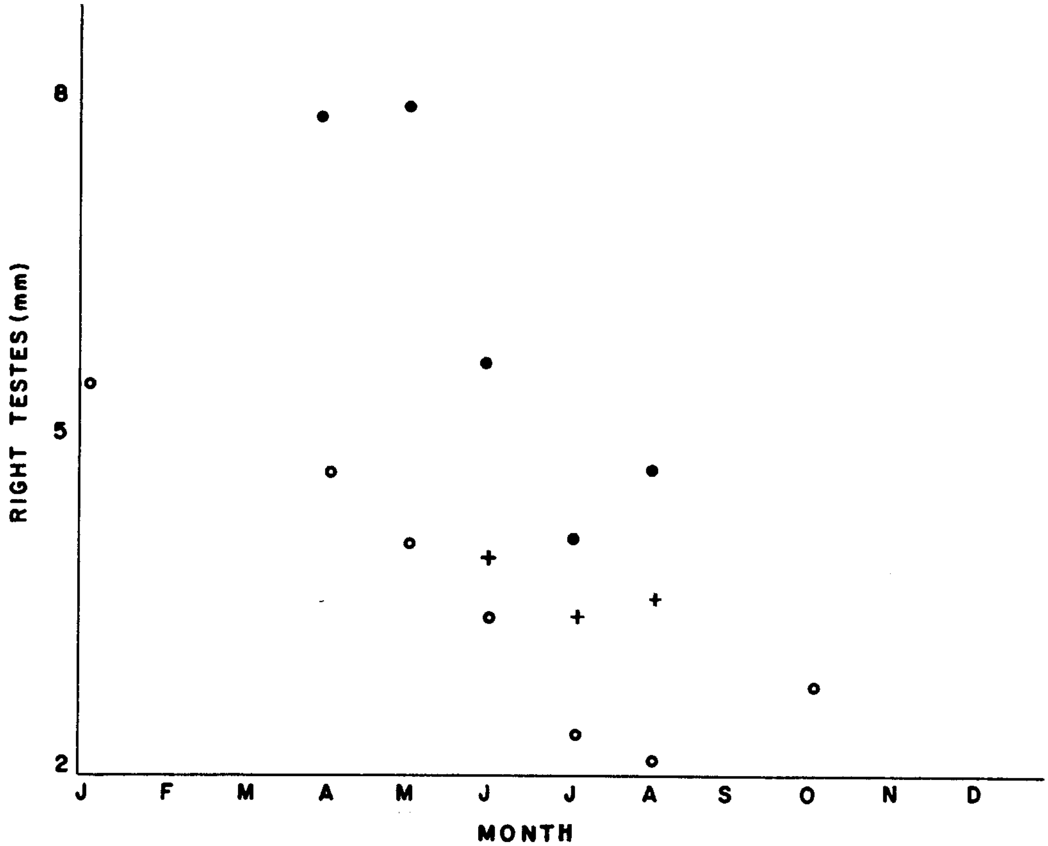

Figure IV-1.--Testicular cycles of Grand Canyon lizards. O = Uta stansburiana (n = 82), + = Cnemidophorus tigris (n = 31), ● = Sceloporus magister (n = 17).

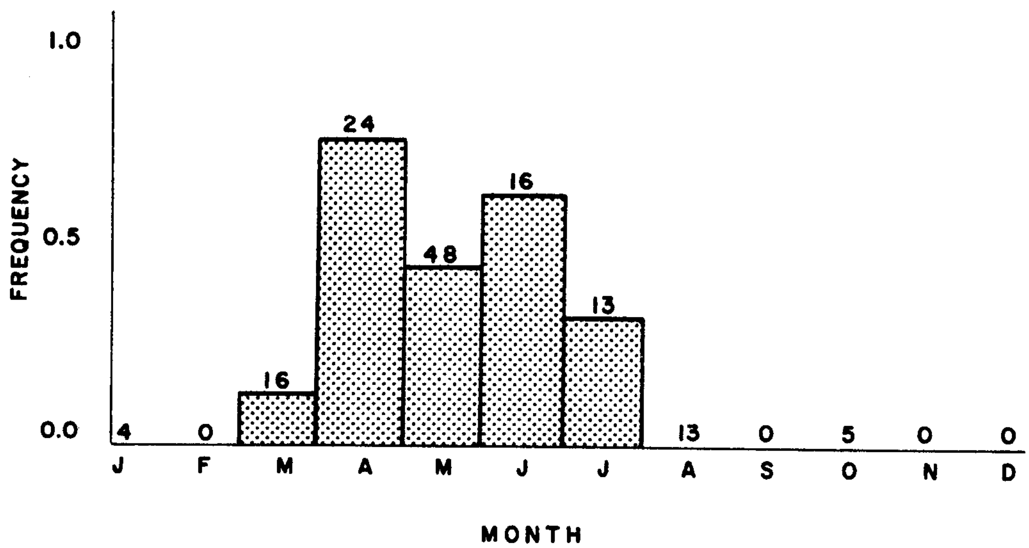

Figure IV-2.--Frequency of oviductal female Uta stansburiana. Numbers at column tops indicate sample size. Total n = 135.

Table IV-1.--Demographic parameters for the four common riparian lizard species. Sources: 1-Tinkle, 1969; 2-Parker and Pianka, 1975; 3-Parker, 1973; 5-Vitt and Ohmart, 1974; 6-Parker, 1972.

	TIME TO MATURITY	SVL (mm) MATURE	NO. CLUTCHES PER YEAR	MEAN CLUTCH SIZE
Uta stansburiana	4 mo.[1]	45[2]	multiple[2]	3-4[2]
Urosaurus ornatus	6 mo.[3]	45[3]	multiple[3]	4-6[3]
Sceloporus magister	2-3 yr.[4]	81[4]	multiple[5]	3-12[4]
Cnemidophorus tigris	1 yr.[6]	63[6]	multiple[6]	1-6[6]

Table IV-2.--Tail break data for Grand Canyon riparian lizards.

	Mi. 0-75		Mi. 76-155		Mi. 156-280	
	n	freq	n	freq	n	freq
Uta stansburiana	127	.53	40	.60	21	.33
Sceloporus magister	18	.55	9	.55	4	.00
Cnemidophorus tigris	29	.24	16	.62	2	.00

Table IV-3.--Male, female tailbreak data. (*) indicates departure from 1.00 significant at p = .05.

	n ♂	freq ♂	n ♀	freq ♀	freq/ freq ♂ / ♀
Uta stansburiana	99	.56	78	.45	1.24
Sceloporus magister	15	.33	16	.63	0.53
Cnemidophorus tigris	30	.47	17	.18	2.61*

Table IV-3 summarizes tail break data in terms of sexual categories. The only evidence of uneven sexual pressure is found in *Cnemidophorus* where males are attacked more frequently than females. This is puzzling since this species is the least territorial and dimorphic of the three and it is therefore impossible to see why males should be differentially exposed to predators.

A third aspect of demography, that of lizard population density, was scheduled for investigation according to standard mark/recapture methodology (Medica et al., 1971). A total of five attempts to do this were carried out at the Nankoweap and Granite Park mammal grid sites (see work plan for National Park Service contract No. CX821500007). None of these efforts yielded data in sufficient quantity to provide density estimates. The problems inherent in any grid site density investigation of Grand Canyon lizards are of such a magnitude as to make a density study a major project in itself. A team of 4 to 6 workers would be required to noose lizards because of the very dense riparian understory which provides excessive escape cover. Such a team would, ideally, need 5 to 10 consecutive days of undisturbed work in the spring or summer. This time requirement is complicated by the very few sites with sufficient area (at least 1 ha.) and the frequency of boat party landings. A major problem at Nankoweap was the appearance of visitors which cancelled several mornings work. If the above conditions could be met, then realistic density figures could be estimated for *Uta stansburiana*, *Cnemidophorus tigris* and *Sceloporus magister*.

Some general density trends can be described. Spring is the period of greatest overt (i.e., behavioral) reproductive activity since courtship and territorial defense take place during this time. By late summer the apparent density of lizards seems to have dropped but this is most likely an artifact of decreased activity making them less obvious visually. This type of early courtship and later reproduction is possible since female lizards can store viable sperm for at least 80 days after copulation (Cuellar, 1966).

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CHAPTER V

MAMMALS OF THE COLORADO RIVER

George A. Ruffner
Dennis S. Tomko

INTRODUCTION

Rodents are an amazingly successful group. They are the largest order of mammals, ubiquitously distributed and are an important part of all terrestrial mammalofauna (Golley et al., 1975). Ecological interactions of rodents in many areas have been studied, although voids do exist. One such void is the Grand Canyon.

Several important contributions resulting from the study of rodent distribution and taxonomy in and around the canyon are available (c.f., Goldman, 1937; Hoffmeister, 1972). However, investigations on rodent demography and feeding habits within the Canyon are sorely lacking.

We have initiated studies of rodent populations, diets, reproduction and habitat distribution in the riparian zone of the canyon. We hope that the data herein will stimulate further, more intensive studies of rodent communities in the riparian zone of the Grand Canyon.

We chose to study small rodents because of several reasons. There are at least thirteen species of rodents, representing seven genera, that we know to occur in the riparian zone. This great diversity provides the ideal conditions for studying interactions of co-existing species. However, we found that it was impractical to study all thirteen species of rodents occurring in the riparian zone and therefore limited ourselves to nine species of nocturnal rodents of the genera *Perognathus*, *Reithrodontomys*, *Peromyscus* and *Neotoma*. Rodents are relatively simple to study and are very common in the riparian zone. Literally volumes of literature dealing with the ecology of rodents are available and these data provide a valuable basis for the analysis and interpretation of the information we have gathered.

Several investigators have reported the results of long-term studies of rodent populations. Chew and Chew (1970) investigated energy relationships among Sonoran Desert rodents. MacMillen (1964) studied demographic characteristics

Table V-1.--Generalized descriptions of the grid sites and their habitat units.

Site	River Mile	Side	Elevation Ft. (m)	Habitat Unit	General Topography	Characteristic Veget. in Order of Importance
Nankoweap DR	53.5	R	2800'	Beach	Low, rolling dunes grading to packed sand flats	Tamarix, Salix, Pluchea, Festuca, Plantago
				Terrace	Flat, packed sand grading to lower talus	Prosopis, Lepidium, Festuca, Plantago, Acacia
Nankoweap UR	52.5	R	2800'	Beach	low, rolling dunes gravel edge near river	Equisetum, Tamarix, Echinochloa, Juncus, Salix
				Wash	Rock strewn and cut deeply where it contacts terrace	Gutierrezia, Stephanomeria, Mentzelia, Eriogonum
Granite Park	208.6	L	1480'	Beach	Low dunes to rock strewn sand	Tamarix, Salix, Pluchea Alhagi
				Terrace	Generally flat with some wash dissection	Acacia, Prosopis, Ehphedra, Larrea
209 Mile Canyon	208.6	R	1480'	Beach	Rock strewn low sand dunes	Tamarix, Pluchea, Baccharis, Encelia
				Terrace	Irregularly flat and dissected deeply by washes, packed sand to rock strewn	Prosopis, Acacia, Creosote

of a southern California rodent fauna. M'Closkey (1972) discussed temporal changes of populations and species diversity in coastal sage scrub habitats of California. More recently Whitford (1976) reported the results of a four year study of Chihuahuan Desert rodent density and diversity. In general there are data available for rodents in most major habitats of North America. However, Carothers et al. (1974) and Hubbard (1971) noted the paucity of information available on vertebrates in southwestern riparian habitats. Those authors presented data on avian inhabitants of riparian habitats. We are not aware of any studies dealing with small mammals of southwestern riparian habitats.

Description of the Study Sites

The major objectives in this study have been to monitor demographic characteristics and diets of small mammals in the riparian zone. To facilitate these studies we have established four major study sites in the canyon. At each study site habitats are usually defined by one of three topographic characteristics (beach, terrace or wash) and plant species typically associated with each (Table V-1). The riparian zone in the canyon is arranged in belts of vegetation with mesically adapted species on the beaches and xerically adapted species in the washes and on the terraces. In a few instances some mesically adapted species are present on the terraces, a relict of pre-Glen Canyon Dam high water lines Most of the present beach vegetation has been established since the gates of Glen Canyon Dam were closed in 1963.

Mile 52.5R, Nankoweap UR.--Low rolling sand dunes and sandy flats are prevalent along the beach. A wash, strewn with boulders, traverses the area and the adjoining terrace is cut along the wash/terrace interface. The terrace is characterized by large sand dunes with sandy flats interspersed throughout. The beach vegetation is characterized by dense stands of *Tamarix* and *Salix* with an understory of *Equisetum*, *Echinocholoa* and *Juncus*. The wash habitat is sparsely vegetated with *Gutierrezia*, *Stephanomeria*, *Mentzelia* and *Eriogonum*. Because of periodic flash flooding much of the vegetation in the wash habitat is temporary at best. The terrace is covered with dense clumps of *Acacia* and *Opuntia*. The understory is typified by *Festuca*, *Lepidium* and *Plantago*.

Mile 53.5R, Nankoweap DR.--The beach at this study site is typified by low rolling sand dunes interspersed with sandy flats. Terrace habitats represent the pre-dam high water line and are comprised of level packed sand and grading into the lower edges of an adjoining talus slope. Vegetation on the beach is characteristically dense with clumps of Tamarix, Salix and Pluchea Ground cover is typically Festuca and Plantago. Terraces have an overstory of Prosopis, some of which was burned in the summer of 1968. Lepidium, Festuca and Plantago are common members of the understory.

Mile 208.6L, Granite Park.--A sandy beach with low dunes and a terrace provide the principal topographic relief at this study site. Thickets of Tamarix, Salix and Pluchea are common. Dense clumps of Alhagi are also encountered. Understory vegetation includes Oenothera, Bromus and Sporobolus. Terrace vegetation is characterized by scattered Larrea or Acacia and dense clumps of Prosopis with an understory of Encelia, Bromus and Ephedra.

Mile 208.6R, 209 Mile Canyon.--Two habitats are apparent at this study sie, the beach and the terrace. Low rocky sand dunes characterize the beach while the terrace is irregularly flat and dissected by several small washes. Soil is sandy and became rocky near adjacent talus slopes. Tamarix, Pluchea Baccharis and Encelia are associated with the beach at this study site. On the terraces Prosopis, Acacia and Larrea are dominant. This site is inhabited by a small burro herd and consequently vegetation was drastically altered when compared with the mile 209.6L site.

Animals snap-trapped for analysis of diets were taken at mile 52.5R and mile 208.6L in areas with habitats similar to those found on the live-trapping grids.

METHODS AND MATERIALS

The overall objective of this study entailed a survey of the demographic characteristics of small mammal species and involved measurements distributed over space and time. To accomplish this four live-trap grids were established and operated at irregular intervals from November 1973 through June 1975.

The location of each grid, the size and distribution of major habitat units within it, and its orientation is shown in Figure V-1. Some of the information contained in this section is supplemented by non-grid snap-trapping carried out from March 1974 through August 1975.

Each grid was sampled with 120 Sherman live-traps placed at 15m intervals and distributed in a 10 x 12 array. An exception to this array was made at Nankoweap because of the narrowness of the riparian habitat there, requiring an 8 x 15 array. The 10 x 12 grids each covered 2.23 ha. (5.58 acres); the 8 x 15 grid covered 2.21 ha. (5.53 acres). These grids were run for four consecutive nights per trapping period and resulted in a total effort of 14,400 trap nights. Traps were opened and baited with oats and scratch grain each day at 1700 hours and were checked and closed the following morning at 0700 hours. New animals were marked by toe clipping. Each animal's number, species, sex, reproductive condition, weight, and trap location was recorded prior to its release at the point of capture.

All density data are drawn from the grid work and are based upon the number of individuals trapped per hectare of each habitat during each 4 night period. The area of each habitat was determined from grid maps using a polar planimeter. An individual was assigned to a particular habitat according to the location of his recapture center (Hayne, 1949) during a given trapping period. In actuality the parameter, density of species i in habitat z is the number of centers of species i per hectare of habitat z($N_{i,z}$). This is a simplistic approach to density similar to the parameter, no./100 trap nights, and probably lends itself to slight underestimations. However, the use of trappable population estimators such as the Lincoln Index (Bailey, 1952) necessitates a grid size correction factor and this would be extremely imprecise considering the irregularly shaped habitats within each grid. It was felt, then, that within the context of the present locally comparative study, the more conservative method was most informative. Finally, the initial practice of estimating the total numbers of mammals per whole grid area (which did satisfy the Lincoln Index/grid correction requirements) was abandoned because the rodent species responded so differently in each habitat (as will be shown) that it was often uninformative to speak of a grid site as a homogeneous unit.

Relative density is an expression of a species importance in its particular habitat and is calculated as:

$$r_{i,z} = N_{i,z} / N_{t,z}$$

where $N_{i,z}$ is the density of species i in habitat z and $N_{t,z}$ is the total rodent density in that habitat.

S% is used here as an expression of density stability through time and, as such, is a weighted variance function. This is calculated as:

$$S\% = S_{\overline{N}_{t,z}} / \overline{N}_{t,z}$$

where $S_{\overline{N}_{t,z}}$ is the standard deviation of the mean density, $\overline{N}_{t,z}$ for an area. S%, then, is an inverse measure of stability or predictability.

Habitat Distributions

The distribution of each species over z major habitats of each grid is expressed as:

$$D_{i,z} = \overline{N}_{i,z} / \sum_{z=1}^{9} (\overline{N}_{i,z})$$

where $\overline{N}_{i,z}$ is the mean density (no./ha.) of species i in habitat z. The value $D_{i,z}$ does not consider the relative size of each habitat, z, and is, therefore, a measure of frequency of occurrence.

Annual Survival

Annual survival is a probability function, modeled after Kreb's (1966) design and is applied to species i with respect to the entire grid which, for this purpose was considered as a single riparian unit. The capture records for species i were arrayed with respect to time in order to record the proportion of animals alive at time x and surviving to time x + 1. An individual was included among the survivors even if he was not caught at time x + 1 but was trapped at some future date. Since the intervals between trapping periods were irregular, this surviving proportion, p, was used to estimate a mean biweekly survival probability, $\hat{p}$ as:

$$\hat{p} = (p)^{\frac{1}{b}}$$

where b is number of two-week time units between trapping periods. Each grid yielded a number of $\hat{p}$'s equal to one less than the number of trapping periods. The estimated annual survival probability S was calculated from the mean $(\hat{p})$ as:

$$S = (\bar{\hat{p}})^{26}$$

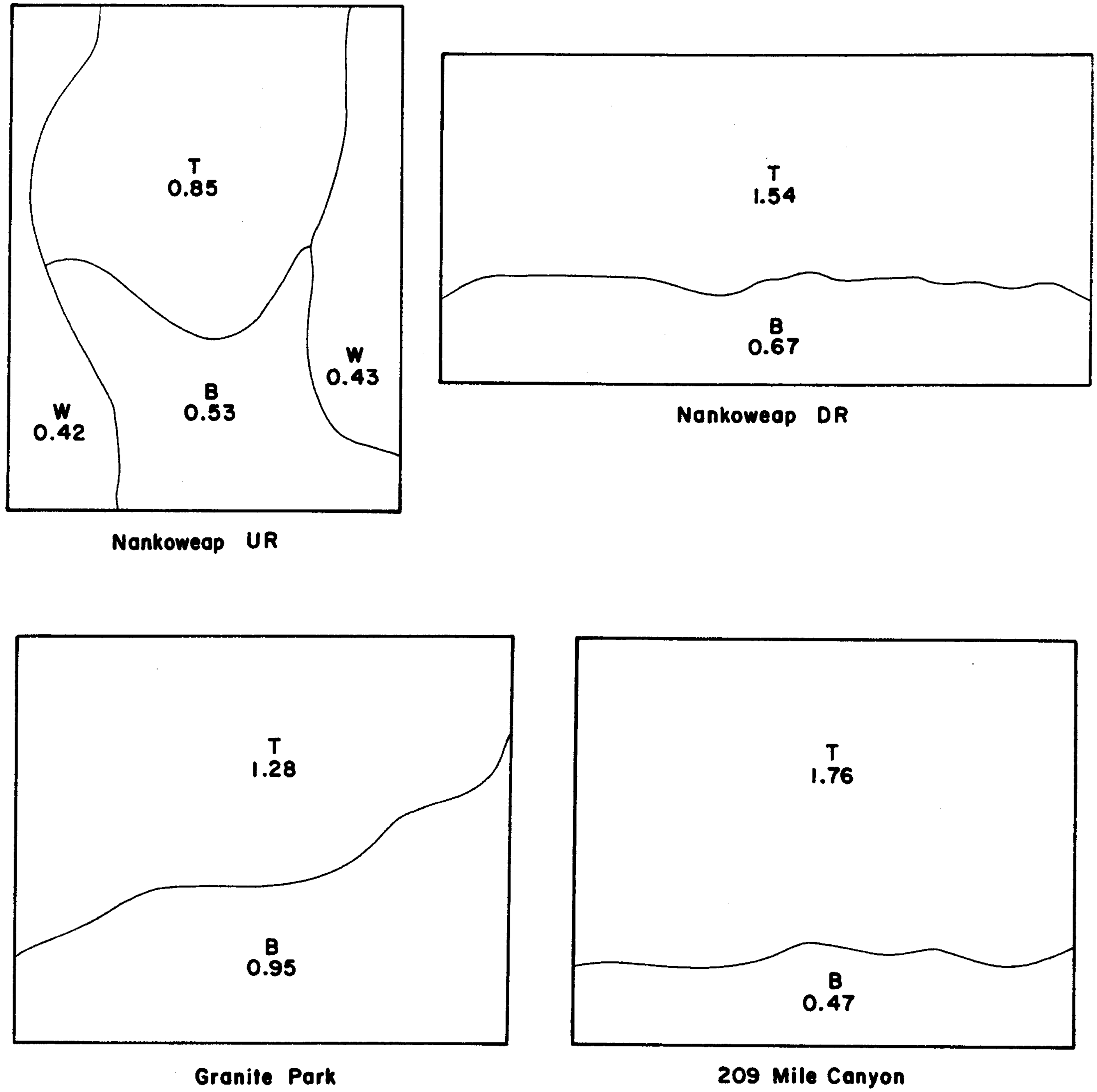

Figure V-1.--Habitat maps of the four grid sites. T = Terrace, B = Beach, W = Wash. Numbers indicate area of each in hectares. The bottom of each map is coincidental with the river's edge.

Of the nine species involved in this study, only five were used in survival calculations. It was felt that *Neotoma* spp. were often non-grid residents and that an estiamte of their grid survival was unrealistic. The other species yielded too small a sample to allow for practical use of their data.

Species Diversity

Species diversity, a community parameter, is a description of the complexity of the rodent community in habitat z at each grid site. This measure utilizes mean relative densities ($\bar{r}_{i,z}$) and treats each set of data as a sample of the rodent community found in habitat z. In the case of sampling, the use of H' (Shannon and Weaver, 1963) is appropriate (Pielou, 1975) as the basic unit of species diversity:

$$H'_z = \sum_{i=1}^{n} \bar{r}_{i,z} \ln \bar{r}_{i,z}$$

for n species, H' itself is difficult to use as a comparative between habitat parameter because of different values of n and thus it needs to be adjusted by n (Pielou, 1975).
A better value is J', which measures the evenness of community structure as:

$$J' = H'/H\ max, \text{where } H\ max = \ln n$$

Home Range

Home range, as used here, is an expression of minimal movement of species and is used as a population, rather than an individual, descriptive parameter. The values which this analysis yielded are somewhat relative since they are based on four-night periods and cannot possibly include all the trap locations which an animal might visit over an extended period of time.

The home range model used treats the animals' movements as an elliptical bivariate function based on an x,y grid coordinate system (Koeppl et al., 1975). Mathematically, it considers an individual's coordinate distances from its recapture center (Hayne, 1949) on a variance/covariance matrix. It is this x and y distance characteristic which facilitated the pooling of data from many individuals into a single matrix which represented data from a hypothetical composite rodent; thus, the sample size could be greatly increased beyond the four night limit. To be considered as a contributor to the matrix, an individual had to have been captured 3 or 4 times and recorded at 2 or more different locations. These restrictions eliminated all but P. eremicus and P. maniculatus from home range consideration.

The home range analysis yielded the following kinds of information: (a) size of range (herein referred to as capture range) in hectares, (b) slope of the major axis of the capture range ellipse; this considers the grid as an x,y system with the side paralleling the river's shore as the x-axis, (c) shape of the range; designated x/ y, this is a ratio of major axis to minor axis and increases as the shape becomes more non-circular.

Cluster Analysis

The relationship or affinity of one rodent species for another based on mean density in each of nine subsites; i.e., $\bar{N}_{i,z}$ was analyzed using a nine species by nine subsite matrix. The indices of similarity was that of Euclidian Distance (ED) and the cluster method was the weighted pair-group method (WPGM) as described by Sokal and Sneath (1963). ED is a negative measure of ecological similarity and WPGM groups pairs of species by ascending ED. In this manner groups, i.e., clusters, of rodent species with similar habitat distributions, were identified.

Reproduction

During 14,400 live-trap nights on the grids used to study rodent populations each captured animal was assigned to one of seven reproductive categories (non-reproductive male, non-reproductive female, scrotal male, vagina perforate and not lactating female, vagina perforate and lactating female, estrous female and pregnant female). The data were summarized for the females of each species so that pregnant females, estrous females, lactating females and females with perforate vaginas were treated as reproductively active.

Information on mean litter size was gathered from specimen catalog cards of 695 specimens collected during the last four years throughout the riparian zone of the canyon.

Diet Studies

Small rodents were snap-trapped at mile 52.0R and mile 209.0L using museum special traps baited with oatmeal.

Seventy individuals (5 species) were taken during three trap periods of one night in duration in April, June and July of 1974 at mile 52.0. Twenty-five individuals (2 species) were taken during a three trap period of one night in duration in May 1974. Trap-lines were selected at the discretion of the biologist, however, traps were placed in all accessible habitats from the water's edge to the talus slopes.

Mammals were picked up in the morning, identified weighed and assessed for age and reproductive characteristics. Each individual was injected with an stored in 10 percent formalin during the remainder of the stay in the field. Upon return to the laboratory specimens were rinsed in cold tap water and placed in 70 percent 2-propanol.

Stomachs were removed from each specimen, dried at 60°C for 24 hours, and weighed before and after the contents were removed. Microscope slides were prepared as described by Reichman (1975).

Four major food classes were established to classify stomach contents (i.e., green vegetation, seed, arthropod and miscellaneous). The miscellaneous category included hair, pollen or unidentified material. Percent volume of each food class was estimated to the nearest 5 percent in 20 random fields examined at 100 X magnification on each slide. From these data relative volume (relative volume = volume of a food class in all stomachs/total volume of all food classes in all stomachs (x 100) and frequency of occurrence (number of fields in which a food class occurred/total number of field examined x 100) were calculated.

The data reflect dietary composition during the spring and early summer of one year. Several authors (Franz et al., 1973; Vaughan, 1974; Reichman, 1975) have shown the degree of seasonal and annual variation in rodent diets. Due to insufficient sample sizes it was not possible to document diets of all the species found on the study areas. We chose to document the diets of sympatric species of cricetid rodents at mile 52.5R and 2 sympatric species at mile 208.6L.

RESULTS AND DISCUSSION

Density

Density and relative density data are summarized in

Tables V-2 through V-9. The volume of data contained on these tables is considerable and this information has been summarized in Figures V-2 and V-3 which trace total rodent density changes through time on the terraces and beaches. The communities at both Nankoweap sites show a sharp decline in density going into the winter of 1974-1975 but both terrace communities appear to recover faster than those of the beach. The most consistent and precipitous population crashs occurred at Granite Park and 209 Mile Canyon, particularly on the terraces where the total rodent density decreased by factors of 10 and 13 respectively (beach densities dropped by factors of 9 and 11 at these locations). Thus, although the Nankoweap communities may be characterized as being in a state of dynamic equilibrium, the same cannot be said at Granite Park and 209 Mile Canyon which were apparently in a stage of population decline.

The data on Figures V-2 and V-3 demonstrate the difficulty of assigning density values for any single area or habitat. This low predictability is probably a function of high temporal variability which has been expressed in terms of S% (Table V-10). Using variance as a relative rather than absolute value, the two upper canyon (Nankoweap) areas appear more stable than those in the lower canyon. However, this statement must be qualified by the evidence of population crashes at Granite Park and 209 Mile Canyon. It should also be noted that, at a given location, the beach communities are less stable, i.e., show a higher S%, than the terrace communties.

Paired linear correlation analysis was run with the species densities from Nankoweap DR and Granite Park to test for the presence of synchronous relationships between species (Table V-11). Only major species, those with $\overline{r}_{i,z}$ more than 2, were considered since the others were often absent from the data. Twenty percent of the pairs at Nankoweap DR and 67 percent at Granite Park showed significant correlations through time. All these relationships were positive so that instances of interspecies inhibition could be identified. M'Closkey (1972), in a 16 month study of sagebrush mammal densities, found that only 6 of 15 possible species pairs showed evidence of significant correlations. Of these, 4 were positive. Thus, it appears that when conditions are favorable (at least at Nankoweap) no species benefits to the measurable detriment of another.

Table V-2.--Density of small mammals at Nankoweap DR as no./ha.
T = Terrace (1.54 ha.) B= Beach (0.67 ha.)

Species		Dec 73	Apr 74	June 74	July 74	Oct 74	Jan 75	Mar 75	June 75	Mean
P. eremicus	T	51.95	46.75	33.77	24.03	49.35	11.04	4.55	14.29	29.46
	B	8.96	20.90	29.85	13.43	52.24	4.48	0.00	23.88	19.34
P. maniculatus	T	5.19	0.00	0.00	0.00	0.00	1.30	0.00	0.00	0.81
	B	8.96	16.42	14.93	17.91	14.93	4.48	2.99	19.40	12.50
P. crinitus	T	0.00	1.95	1.30	7.14	7.14	2.60	3.90	5.84	3.73
	B	0.00	5.97	0.00	8.96	19.40	0.00	0.00	4.48	4.85
P. boylii	T	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	B	0.00	1.50	1.50	0.00	0.00	0.00	0.00	3.00	0.75
N. lepida	T	0.00	1.30	2.60	5.19	2.60	1.30	1.30	8.44	2.84
	B	0.00	0.00	2.99	4.48	0.00	0.00	1.49	7.46	2.05
R. megalotis	T	0.00	0.00	0.70	0.00	0.70	0.00	0.00	0.00	0.18
	B	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.19
P. formosus	T	0.00	11.69	12.99	14.94	5.84	0.65	14.29	19.48	9.99
	B	0.00	0.00	10.45	8.96	5.97	0.00	4.48	10.45	5.04
TOTAL	T	57.14	61.69	51.36	51.30	65.63	16.89	24.04	48.05	47.01
	B	17.92	46.29	59.72	53.74	92.54	8.96	8.96	68.67	44.72

Table V-3.--Relative density of small mammals at Nankoweap DR ((density sp_i divided by total density) x 100).

Species		Dec 73	Apr 74	June 74	July 74	Oct 74	Jan 75	Mar 75	June 75	Mean
P. eremicus	T	90.90	75.80	65.80	46.80	75.20	65.40	18.90	29.70	58.60
	B	50.00	45.20	50.00	25.00	56.50	50.00	00.00	34.80	38.90
P. maniculatus	T	9.10	00.00	00.00	00.00	00.00	00.00	00.00	00.00	2.10
	B	50.00	35.50	25.00	33.30	16.10	50.00	33.40	28.30	34.00
P. crinitus	T	00.00	3.20	2.50	14.90	10.90	15.40	16.20	12.20	9.30
	B	00.00	12.90	00.00	16.70	21.00	00.00	00.00	6.50	7.10
P. boylii	T	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
	B	00.00	3.20	2.50	00.00	00.00	00.00	00.00	4.40	1.30
N. lepida	T	00.00	2.10	5.10	10.10	4.00	7.70	5.40	17.60	6.50
	B	00.00	00.00	5.00	8.30	00.00	00.00	16.60	10.90	5.10
R. megalotis	T	00.00	00.00	1.40	00.00	1.10	00.00	00.00	00.00	0.30
	B	00.00	3.20	00.00	00.00	00.00	00.00	00.00	00.00	0.40
P formosus	T	00.00	18.90	25.30	29.10	8.90	3.80	59.40	40.50	23.20
	B	00.00	00.00	17.50	16.70	6.50	00.00	50.00	15.20	13.20

Table V-4.--Density of small mammals at Nankoweap UR as no./ha.
T = Terrace (0.85 ha.); W = Wash (0.85 ha.); B = Beach (0.53 ha.).

Species		Nov 73	Apr 74	June 74	July 74	Oct 74	Jan 75	Mar 75	June 75	Mean
P. eremicus	T	29.41	15.29	10.59	11.76	18.82	9.41	8.24	4.71	13.53
	W	36.47	22.35	17.65	15.29	29.41	11.76	7.06	8.34	18.53
	B	20.75	16.98	11.32	18.87	26.42	5.66	5.66	11.32	14.62
P. maniculatus	T	00.00	00.00	00.00	00.00	2.35	1.10	00.00	00.00	0.44
	W	2.35	4.71	5.88	1.18	10.59	5.88	3.53	00.00	4.26
	B	7.55	5.66	5.66	7.55	9.43	3.77	3.77	3.77	5.90
P. crinitus	T	2.35	5.88	1.18	00.00	1.18	00.00	1.18	1.18	1.62
	W	3.53	2.35	4.71	3.53	10.59	00.00	9.41	5.88	5.00
	B	00.00	5.66	00.00	00.00	00.00	00.00	00.00	1.89	0.94
P. boylii	T	00.00	00.00	1.18	1.18	1.18	00.00	00.00	00.00	0.44
	W	1.18	2.35	1.18	1.18	00.00	00.00	00.00	00.00	0.74
	B	1.89	3.77	00.00	3.77	00.00	00.00	00.00	00.00	1.18
N. lepida	T	00.00	4.71	10.59	15.29	12.94	1.18	7.06	18.82	8.82
	W	2.35	00.00	3.53	3.53	3.53	1.18	1.18	15.29	3.82
	B	00.00	5.66	3.77	1.89	00.00	00.00	00.00	11.32	2.83
R. megalotis	T	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
	W	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
	B	00.00	5.66	00.00	1.89	00.00	00.00	00.00	00.00	0.94
P. formosus	T	00.00	7.06	12.94	7.06	8.24	00.00	12.94	11.76	7.50
	W	1.18	3.53	8.24	3.53	4.71	00.00	2.35	7.06	3.82
	B	1.89	3.77	7.55	3.77	1.89	00.00	00.00	5.66	3.07
TOTAL	T	31.76	32.94	36.48	35.29	44.71	11.77	29.42	36.47	32.36
	W	47.06	35.29	41.19	28.24	58.83	18.82	23.53	36.47	36.18
	B	32.08	47.16	28.30	37.74	37.74	9.43	9.43	33.96	29.48

Table V-5.--Relative density of small mammals at Nankoweap UR ((density species $_i$ divided by total density) x 100).

Species		Nov 73	Apr 74	June 74	July 74	oct 74	Jan 75	Mar 75	June 75	Mean
P. eremicus	T	92.60	46.40	29.00	33.30	42.10	79.90	28.00	12.90	45.50
	W	77.50	63.30	42.90	54.10	50.00	62.50	30.00	22.60	50.40
	B	64.70	36.00	40.00	50.00	70.00	60.00	60.00	33.30	51.80
P. maniculatus	T	00.00	00.00	00.00	00.00	5.30	10.00	00.00	00.00	12.60
	W	5.00	13.30	14.30	4.20	18.00	31.20	15.00	00.00	12.60
	B	23.50	12.00	20.00	20.00	25.00	40.00	00.00	11.10	24.00
P. crinitus	T	7.40	17.90	3.20	00.00	2.60	00.00	4.00	3.20	4.80
	W	7.50	6.70	11.40	12.50	18.00	00.00	40.00	16.10	14.00
	B	00.00	12.00	00.00	00.00	00.00	00.00	00.00	5.60	2.20
P. boylii	T	00.00	00.00	3.20	3.30	2.60	00.00	00.00	00.00	1.10
	W	2.50	6.70	2.90	4.20	00.00	00.00	00.00	00.00	2.00
	B	5.90	8.00	00.00	10.00	00.00	00.00	00.00	00.00	3.00
N. lepida	T	00.00	14.30	29.00	43.30	28.90	10.00	24.00	51.60	25.10
	W	5.00	00.00	8.60	12.50	6.00	6.30	5.00	41.90	10.70
	B	00.00	12.00	13.30	5.00	00.00	00.00	00.00	33.30	8.00
R. megalotis	T	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
	W	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
	B	00.00	12.00	00.00	5.00	00.00	00.00	00.00	00.00	2.10
P. formosus	T	00.00	21.40	35.50	20.00	18.40	00.00	44.00	32.20	21.40
	W	2.50	10.00	20.00	12.50	8.00	00.00	10.00	19.40	10.30
	B	5.90	8.00	26.70	10.00	5.00	00.00	00.00	16.70	9.00

Table V-6.--Density of small mammals at Granite Park as no./ha. T = Terrace (1.27 ha.); B = Beach (0.96) ha.).

Species		Mar 74	May 74	June 74	Aug 74	Nov 74	Jan 75	Apr 75	Mean
P. eremicus	T	66.14	55.91	41.73	42.52	21.26	13.39	6.30	35.32
	B	60.42	25.00	29.17	18.75	13.54	3.13	8.33	22.62
P. boylii	T	00.00	00.00	00.00	1.57	00.00	00.00	00.00	0.22
	B	1.04	00.00	00.00	00.00	00.00	00.00	00.00	0.15
N. albigula	T	1.54	1.57	2.36	3.15	0.79	00.00	00.00	1.35
	B	2.08	00.00	00.00	3.13	00.00	1.04	00.00	0.89
P. intermedius	T	37.80	21.26	21.26	22.83	13.39	8.66	3.94	18.45
	B	19.79	13.54	13.54	16.67	7.29	1.04	1.04	10.42
TOTAL	T	105.51	78.74	65.35	70.07	35.44	22.05	10.24	55.34
	B	83.33	38.54	42.71	38.55	20.83	5.21	9.37	34.08

Table V-7.--Relative density of small mammals at Granite Park.
((density species $_i$ divided by total density) x 100)

Species		Mar 74	May 74	June 74	Aug 74	Nov 74	Jan 75	Apr 75	Mean
P. eremicus	T	62.71	71.00	63.90	60.70	60.00	60.70	61.50	62.90
	B	72.50	64.90	68.30	48.60	65.00	60.10	88.90	66.90
P. boylii	T	00.00	00.00	00.00	2.20	00.00	00.00	00.00	0.30
	B	1.20	00.00	00.00	00.00	00.00	00.00	00.00	0.20
N. albigula	T	1.50	2.00	3.60	4.50	2.20	00.00	00.00	2.00
	B	2.50	00.00	00.00	8.10	00.00	20.00	00.00	4.40
P. intermedius	T	35.80	27.00	32.50	32.60	37.80	39.30	38.50	34.80
	B	23.70	35.10	31.70	43.20	35.00	19.90	11.90	28.60

Table V-8.--Density of small mammals at 209 Mile Canyon as no./ha.
T = Terrace (1.76 ha.); B = Beach (0.47 ha.).

Species		Mar 74	May 74	June 74	Aug 74	Nov 74	Jan 74	Apr 74	Mean
P. eremicus	T	27.27	9.66	5.68	13.64	7.95	3.98	1.14	9.90
	B	44.68	14.89	19.15	10.64	10.64	2.13	2.13	14.89
P. crinitus	T	00.00	0.57	1.14	3.98	1.14	1.70	1.14	1.38
	B	00.00	2.13	12.77	6.38	4.26	2.13	2.13	4.26
P. boylii	T	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
	B	2.13	00.00	00.00	00.00	00.00	00.00	00.00	0.30
N. lepida	T	0.57	00.00	00.00	00.00	00.00	00.00	00.00	0.08
	B	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
P. formosus	T	0.57	1.14	0.57	0.57	00.00	00.00	00.00	0.41
	B	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
TOTAL	T	28.41	11.37	7.39	18.18	9.09	5.68	2.27	11.77
	B	46.81	17.02	31.91	17.02	14.89	4.26	4.26	19.75

Table V-9.--Relative density of small mammals at 209 Mile Canyon ((density $species_i$ divided by total density) x 100).

Species		Mar 74	May 74	June 74	Aug 74	Nov 74	Jan 74	Apr 74	Mean
P. eremicus	T	96.00	85.00	76.90	75.00	87.50	70.10	50.00	77.20
	B	95.40	87.50	60.00	62.50	71.50	50.00	50.00	68.10
P. crinitus	T	00.00	5.00	15.40	21.90	12.50	29.90	50.00	19.20
	B	00.00	12.50	40.00	37.50	28.60	50.00	5.00	31.20
P. boylii	T	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
	B	4.60	00.00	00.00	00.00	00.00	00.00	00.00	0.70
N. lepida	T	2.00	00.00	00.00	00.00	00.00	00.00	00.00	0.30
	B	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00
P. formosus	T	2.00	10.00	7.70	3.10	00.00	00.00	00.00	3.30
	B	00.00	00.00	00.00	00.00	00.00	00.00	00.00	00.00

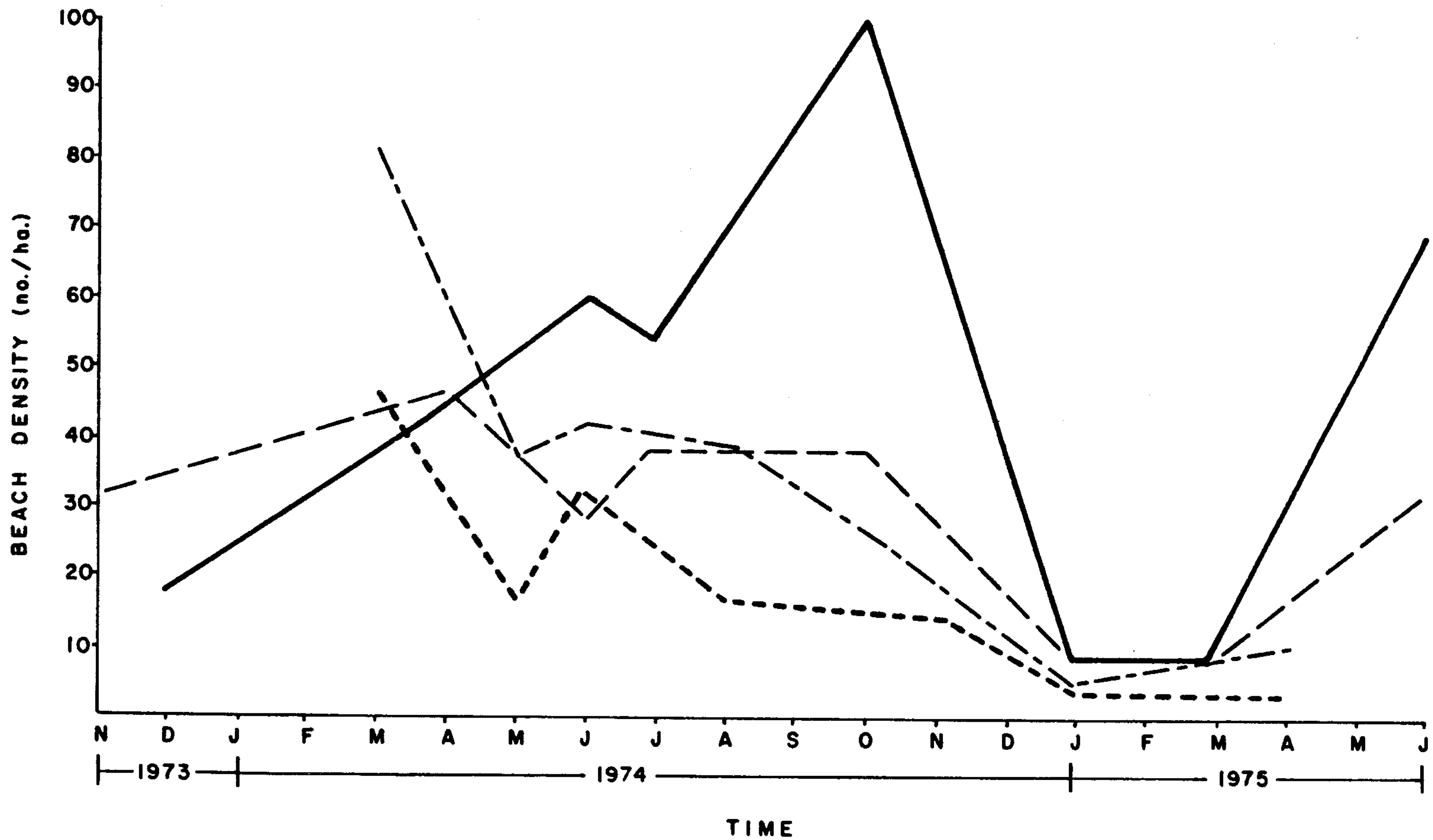

Figure V-2.--Density fluctuations on the beaches.
—— = Nankoweap DR, — — = Nankoweap UR,
—·- = Granite Park, ---- = 209 Mile Canyon.

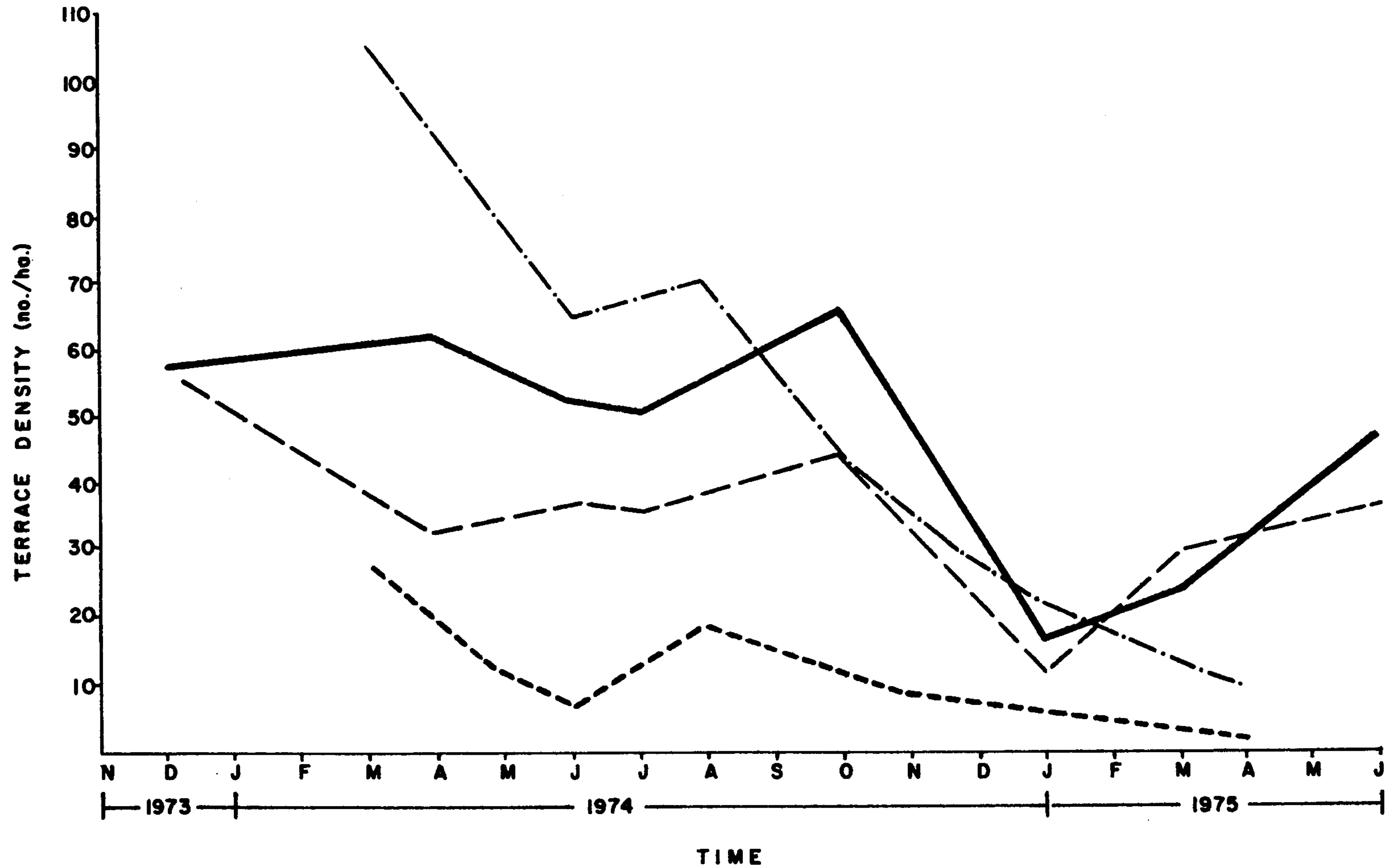

Figure V-3.--Density fluctuations on the terraces.
—— = Nankoweap DR, — — — = Nankoweap UR,
—·— = Granite Park, - - - - = 209 Mile Canyon.

Table V-10.--Rodent community demographic parameters.

	Nankoweap DR			Nankoweap UR			Granite Park			209 Mile Canyon		
	$S\%\bar{N}_t$	$\bar{N}_t$	J'	$S\%\bar{N}_t$	$\bar{N}_t$	J'	$S\%\bar{N}_t$	$\bar{N}_t$	J'	$S\%\bar{N}_t$	$\bar{N}_t$	J'
Beach	00.68	44.72	00.73	00.46	29.48	00.70	00.77	34.08	00.56	00.78	19.45	00.41
Wash	---	---	---	00.36	36.18	00.74	---	---	---	---	---	---
Terrace	00.37	47.01	00.59	00.29	32.36	00.67	00.61	55.34	00.54	00.75	11.77	00.40

Table V-11.--Density through time correlation tests for major species. Terrace is above each major matrix axis; beach data is below. (*) indicates significance at $p = 0.05$.

Nankoweap DR

	P. eremicus	*P. maniculatus*	*P. crinitus*	*N. lepida*	*P. formosus*
P. eremicus		0.39	-0.26	-0.36	-0.40
P. maniculatus	0.62		-0.60	-0.48	-0.71
P. crinitus	0.78*	0.51		0.66*	0.20
N. lepida	0.57	0.57	-0.05		0.66*
P. formosus	0.40	0.58	0.21	0.82*	

Granite Park

	P. eremicus	*N. albigula*	*P. intermedius*
P. eremicus		0.68*	0.95*
N. albigula	0.16		0.65*
P. intermedius	0.83	0.52	

The relative density data indicate that *P. eremicus* is numerically dominant throughout the riparian zone, showing mean $\bar{r}_{i,z}$ values of 61.1 and 56.4 on the terraces and beaches respectively. This role is maintained rather consistently through time and space. With the exception of the 209 Mile Canyon communities, *Perognathus* spp. assumes a generally secondary importance role.

The hierarchial stability of a species was estimated by $S\%\ \bar{r}_{i,z}$. Mean values for all species on all beaches and terraces were 1.23 ± .85 and 1.12 ± .77 respectively and demonstrated no significant difference with respect to this, a community stability parameter. Thus, the average magnitude of positional shifts by species in beach and terrace communities is nearly the same.

Rank correlation values were computed to test the relationship between a species' mean rank ($\bar{r}_{i,z}$) and the amount of temporal shifting of its rank within its community ($S\%\ \bar{r}_{i,z}$). The linear coefficients were: Nankoweap DR, -.73; Nankoweap UR, -.86; Granite Park, -.80; 209 Mile Canyon, -.83. All these values are significant at $p < .05$. Thus, it appears that, as relative density increases, the stability of a species' hierarchial position also increases.

Two population stability statistics, $S\%\ \bar{r}_{i,z}$ and $S\%\bar{N}_{i,z}$ show a powerful relationship of $r = .93$ which is significant at p less than .01. A species which is best able to maintain a steady equilibrium population level is also best able to maintain its position within the importance sequence of its community. Conversely, those species which occur at the bottom of a community's (numerical) importance list are those species which are least able to maintain a constant population size. This last statement arises from the relationship between mean relative density ($\bar{r}_{i,z}$) and density instability ($S\%N_{i,z}$) where $r = .63$ and is significant at p less than .01. Thus, a small mammal species occuring at high density at a riparian location in the Grand Canyon has the additional advantages of stability with respect to population density and community hierarchial position.

Species Diversity

The comparative diversity parameter, J' is contained in Table V-10. Beach rodent communities tend to be slightly more

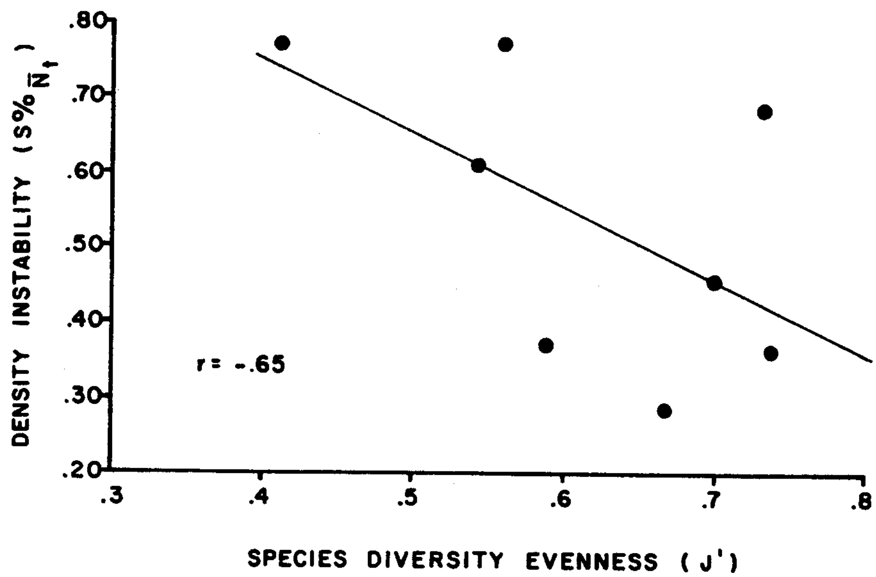

Figure V-4.--The relationship of total rodent density stability to community complexity. The linear correlation value is significant at the .05 level.

complex than those on the terrace. Also, a given community in the upper canyon may be expected to be more diversified than its counterpart in the lower canyon. No correlation between mean density ($\bar{N}_{t,z}$) and J' was established (r = .43). However, an inverse relationship between density instability ($S\%\bar{N}_{t,z}$) and J' does exist at the p .05 level (Figure V-4). Therefore, a highly complex community can be expected to be a fairly stable community. It should be noted that this is a case of complexity within a single trophic level whereas most of the arguments concerning complexity and stability deal with several trophic levels (see MacArthur, 1955; Pimentel, 1961; May, 1973). However, if the formulations of May (1973) are accepted and applied here, a stable rodent community tends to predict a stable total food web. Now, since rodent community complexity, i.e., J', predicts rodent community instability, i.e., $S\%\bar{N}_{t,z}$, the rodent J' value (which can be estimated at a single point in time) may be developed as an indirect measure of total food web stability for a given riparian site. At the present stage, J' seems to have value as a qualitative predictor.

Habitat Distribution

Habitat distributions, in terms of percent of density, are presented in Table V-12. A pronounced avoidance of the terrace is obvious with *P. maniculatus*; snap-trap data support these figures. The species of *Neotoma* and *Perognathus* tend to concentrate their distributions on the terraces. The only species with a heavy emphasis on wash distribution is *P. crinitus*. It is difficult to recognize a clear pattern for the numerically dominant *P. eremicus*.

J' values for density distributions of each species on all nine habitats were calculated with the assumption that all species had an equal opportunity to disperse to each of these sites (Table V-13). This assumption was known to be invalid in the case of the two *Perognathus* which are restricted by the side of the River so both species were lumped into a single taxonomic generic unit. *P. eremicus* displays a very evenly distributed diversity which qualitatively correlates well with snap-trap data for the rest of the Canyon. *Perognathus*, *Peromyscus crinitus*, *P. boylii* and *N. lepida* comprise a moderately diversified group. An unevenly distributed group includes *P. maniculatus*, *N. albigula*, and *R. megalotis*.

A positive relationship, significant at $p < .05$ exists between a species distribution J' (Table V-13) and its unweighed mean relative density ($\bar{r}_i$) giving a rank correlation value of r = .66. A high habitat J' value is equivalent to a broad habitat niche. That is, a species with a high J' (*P.*

Table V-12.--Habitat distribution of noctural small mammals. Species' distributions are expressed for each grid as density in habitat divided by density in all habitats.

	Nankoweap DR		Nankoweap UR			Granite Park		209 Mile Canyon	
	Beach	Terrace	Beach	Terrace	Wash	Beach	Terrace	Beach	Terrace
P. eremicus	0.40	0.60	0.31	0.29	0.40	0.39	0.61	0.60	0.40
P. maniculatus	0.94	0.06	0.56	0.04	0.40	---	---	---	---
P. crinitus	0.54	0.43	0.12	0.21	0.66	---	---	0.76	0.24
P. boylii	1.00	0.00	0.50	0.19	0.31	0.41	0.59	1.00	0.00
N. lepida	0.42	0.58	0.18	0.57	0.25	---	---	0.00	1.00
N. albigula	---	---	---	---	---	0.40	0.60	---	---
R. megalotis	0.51	0.49	1.00	0.00	0.00	---	---	---	---
P. formosus	0.34	0.66	0.27	0.52	0.21	---	---	0.00	1.00
P. intermedius	---	---	---	---	---	0.36	0.62	---	---

Table V-13.--Habitat distribution diversity as J' assuming equal opportunity to disperse to all nine habitats.

P. eremicus	.97
P. maniculatus	.54
P. crinitus	.82
P. boylii	.79
N. lepida	.67
N. albigula	.31
P. megalotis	.36
Perognatus spp.	.82

eremicus) may be considered very successful in colonizing the variety of habitats with which it is presented. Such a species is an ecological generalist with respect to habitat selection within the spatial limitations of the Grand Canyon's riparian system. The J' to $\bar{r}_i$ relationship predicts that the most common species within a given rodent community may be also the most generalized. This applies not only to habitat distributions but to a species' adaptability to environmental change as demonstrated in the previous $\bar{r}_i$ to $S\%\bar{N}_i$ relationship. Thus, wide habitat niche breadth, stable hierarchial positions, stable density, and high hierarchial positions are all positively interrelated..

Home Range

The movement data for 2 species at Nankoweap DR and one at Granite Park are summarized in Table V-14. Although a considerable amount of temporal variation exists, all three mean values are quite similar. The range size variation for P. eremicus and P. maniculatus can be partially explained at Nankoweap DR by variation in minimum nightly temperature. A significant negative correlation exists between nightly temperature and range size at $p<.05$ (Figure V-5). The data from December, 1973, were deleted from this calculation since P. eremicus and P. maniculatus were the only species apparently active at that period, a condition never recorded since. It was felt that, due to possible lack of movement interference by other species, the December, 1973, figures could not be used validly in a temperature-to-range relationship. It is interesting to note that the slopes of the regression lines in Figure V-5 are identical (-.02). At Granite Park no such temperature-to-range relationship was established though this may be an artifact of a small sample of only 5 points.

At Nankoweap DR P. eremicus and P. maniculatus are species which are evenly distributed between the two habitats and very unevenly distributed respectively (Table V-12). The slope data in Table V-14 indicate no strong River orientation in the movements of the evenly distributed P. eremicus. However, during 7 of the 8 periods, the beach restricted P. maniculatus demonstrated movement vectors that were nearly parallel to the River; the map in Figure V-1 illustrates this. P. eremicus at Granite Park also lacked a river-to-range orientation as was the case at Nankoweap DR.

The shapes of home ranges for the three sets of data summarized in Table V-14 are very strongly linear. Although

Table V-14.--Home range approximations. Size of range given in ha. Slope refers to alignment of major axis with the River (a value less than 1 indicates nearly parallel association). $\lambda x/\lambda y$ is a coefficent of shape (as values approach 1 the range approaches a circular shape).

Nankoweap DR

		Dec 73	Apr 74	June 74	July 74	Oct 74	Jan 75	Mar 75	June 75	Mean
P. eremicus	ha.	0.17	.29	.12	.09	.25	.44	.40	.14	.24 ± .13
	slope	0.07	-.59	100.00	-.77	.20	-1.25	-.67	-3.33	13.36
	$\lambda x/\lambda y$	11.00	1.60	3.60	2.10	1.50	3.60	8.00	9.30	5.10
P. maniculatus	ha.	0.06	.23	.06	.07	.05	.46	.09	.16	.15 ± .14
	slope	-.05	0.37	-.07	0.11	2.50	-.71	-.43	.07	.54
	$\lambda x/\lambda y$	2.60	5.90	3.20	4.80	1.60	1.40	7.50	25.10	6.50

Granite Park

		Mar 74	May 74	June 74	Aug 74	Nov 74	Mean
P. eremicus	ha.	0.07	0.13	0.29	0.07	0.23	0.16 ± .10
	slope	0.04	-0.52	-11.11	-2.00	-0.92	2.92
	$\lambda x/\lambda y$	36.30	3.00	2.60	4.30	2.80	9.80

Table V-15.--Annual survival probabilities of major grid-resident rodent species.

	Nankoweap DR	Nankoweap UR	Granite Park	209 Mile Canyon
P. eremicus	.029	.076	.009	.001
P. maniculatus	.007	.001	---	---
P. crinitus	.014	.296	---	
P. formosus	.058	.062	---	

circular distribution is a popular assumption in many studies, it cannot be used here.

Survivorship

Non-age specific survival data are summarized in Table V-15. Only those species which were encountered in fairly high densities were used due to sample size considerations. The survival probabilities at the two lower canyon sites are lower than those from the upper canyon sites. In general, a nearly annual population turnover can be predicted from these data.

A relationship exists at the upper canyon sites between the relative amount of productivity a species invests in the new (beach) habitat and the old (terrace and wash) habitat versus that species' survival probability. This relationship is shown in Figure V-6 where the new habitat investment is used in its inverse form and called α . Thus, an investment in the new habitat seems to be made at the cost of decreased survivorship. This explains the extremely high survivorship of P. crinitus at Nankoweap UR (0.296) where 87 percent of the density occurs in old habitats which make up 76 percent of the grid area.

A partial explanation of the negative effect of beach colonization upon riparian species survivorship deals with the effect of temperature upon density. The beach habitats are, by virtue of their proximity to the Colorado River and their low elevation, colder than the adjacent terraces (V. Shaeffer, pers. comm.). Thus, it is reasonable to expect the total rodent densities on the beaches to respond more sharply to temperature change than densities on the terraces. The data from Nankoweap DR support this hypothesis. Both beach and terrace densities are correlated with minimum nightly temperature ($r = .78$ and $.67$ respectively, significant at $p<.05$) but the slopes of the regression equations are 3.18 and 1.03 respectively. Thus, the response of the beach community is approximately 3 times greater than that of the terrace (Figure V-7).

Although the beach habitat has become a relatively stable surface since 1963, species have still not fully adapted to it as well as they have the terrace habitats as is demonstrated by the survival data (Table V-15), the density stability data (Table V-10) and the species diversity data (Table V-10). The temperature-to-density data

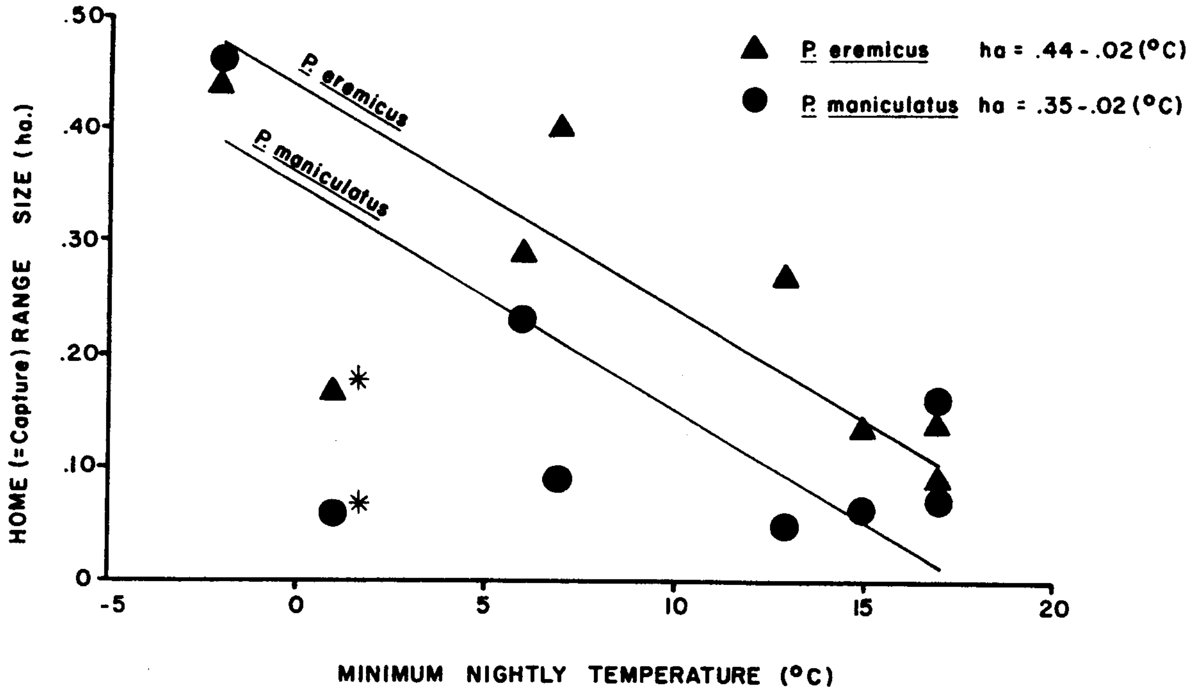

Figure V-5.--The regression of movement on temperature. (*) indicates the December 1973 data which were not used in the regression analysis.

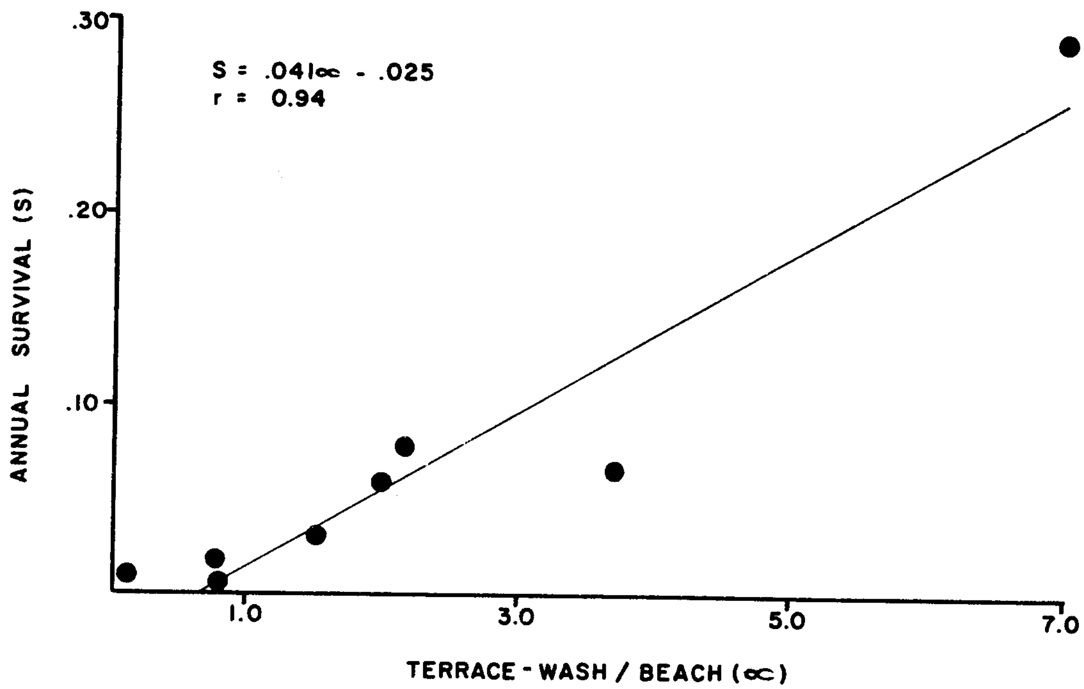

Figure V-6.--Annual survival probability as influenced by a species' investment in colonizing the new (beach) habitat. α = old habitat density $\div$ Beach Density Each point represents data for a single species at either Nankoweap DR or Nankoweap UR.

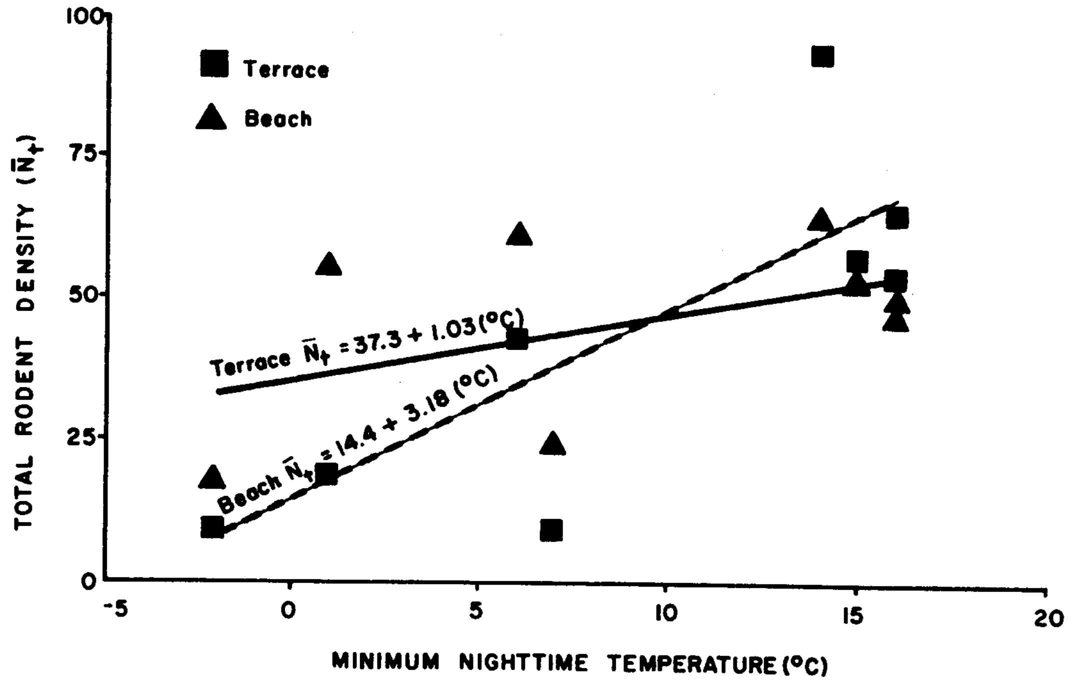

Figure V-7.--The influence of temperature on beach and terrace densities at Nankoweap DR.

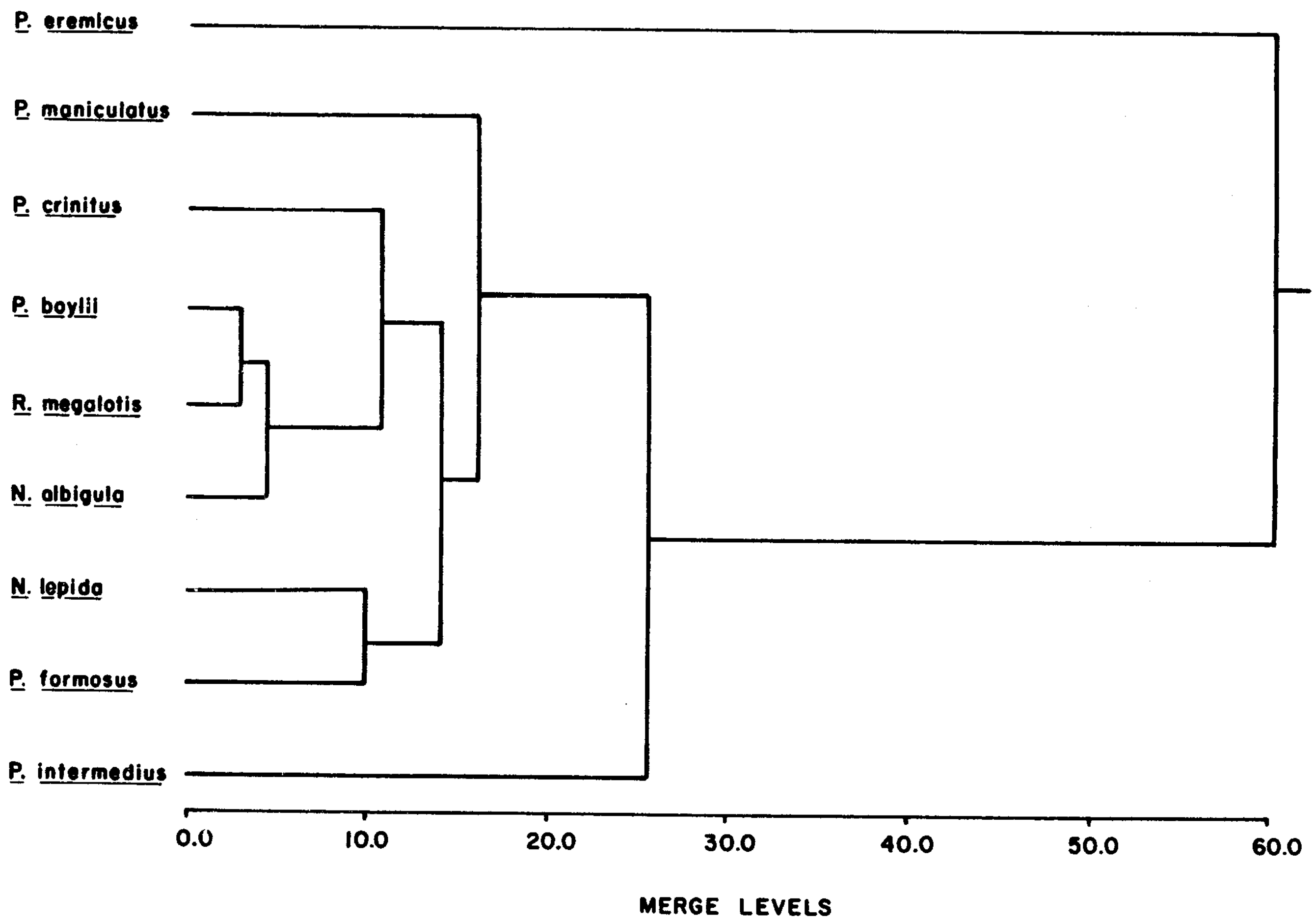

Figure V-8.--Cluster analysis (WPGM) of rodent species according to their densities on each of nine subsites shown in Figure V-1. Merge levels are in Euclidean Distance Units.

from Nankoweap DR suggest that newness alone may not be solely (if at all) responsible for this; the beach presents a thermally harsh environment and this may be endured only at the expense of increased mortality.

Cluster Analysis

The cluster dendrogram (Figure V-8) emphasizes the ubiquitous distribution of P. eremicus. It can be argued that there are two major "groups": a habitat generalist "group" comprised of P. eremicus, and a group of mammals showing degrees of habitat preference comprised of the rest of the riparian system's small mammals. If the analysis is to have any value at all, this second group must be examined by subgroups.

Two species are eliminated at relatively high levels within the non-generalist group. P. maniculatus is quite restricted to beach habitats and Perognathus intermedius is limited in its distribution to the south side of the river. This last species has been eliminated from the non-generalist cluster at a misleading level since only 2 of the 9 habitat subunits are on the south side of the River.

Two groups of non-generalists remain, these are: a 4 species group (I) of P. crinitus, P. boylii, R. megalotis, and N. albigula; and a 2 species group (II) of N. lepida and Perognathus formosus. Habitat distribution alone does not explain the integrity of group I but group II is obviously a non-beach assemblege as indicated by averaging the beach distribution values in Table V-12 where $\bar{D}$ = .20.

Food Habits

The diets of five sympatric species of cricetid rodents at mile 52.5R are summarized in Figure V-9 and Table V-16. Two species were preferentially herbivores and a third exploited insects. The final two species were generalists, one relied heavily on greenery while the other favored insects. No species displayed a heavy reliance upon seeds.

It is most fruitful to consider the dietary preferences in relation to the habitat preferences of the species examined at mile 52.5R. We have summarized these data in Figure V-8 and Table V-12.

Table V-16.--Diets of five sympatric species of small mammals at mile 52.5R during the spring and early summer of 1974. Numbers of parentheses represent the number of stomachs sampled.

	Relative Volume (%)				% Frequency of Occurrence			
	Green	Seed	Arthropods	Misc.	Green	Seed	Arthropods	Misc.
R. megalotis (5)	54	13	32	1	92	31	84	8
P. crinitus (8)	41	13	45	1	66	32	84	6
P. eremicus (33)	54	12	34	1	89	34	86	5
P. maniculatus (13)	42	7	50	1	68	20	92	5
P. boylii (6)	67	4	28	1	97	10	88	5

Table V-17.--Diets of two sympatric species of small mammals at mile 208.6 during the spring and early summer of 1974.

	Relative Volume (%)				% Frequency of Occurrence			
	Green	Seed	Arthropods	Misc.	Green	Seed	Arthropods	Misc.
P. crinitus (3)	60	7	37	1	93	5	97	8
P. eremicus (22)	66	1	31	2	88	4	75	12

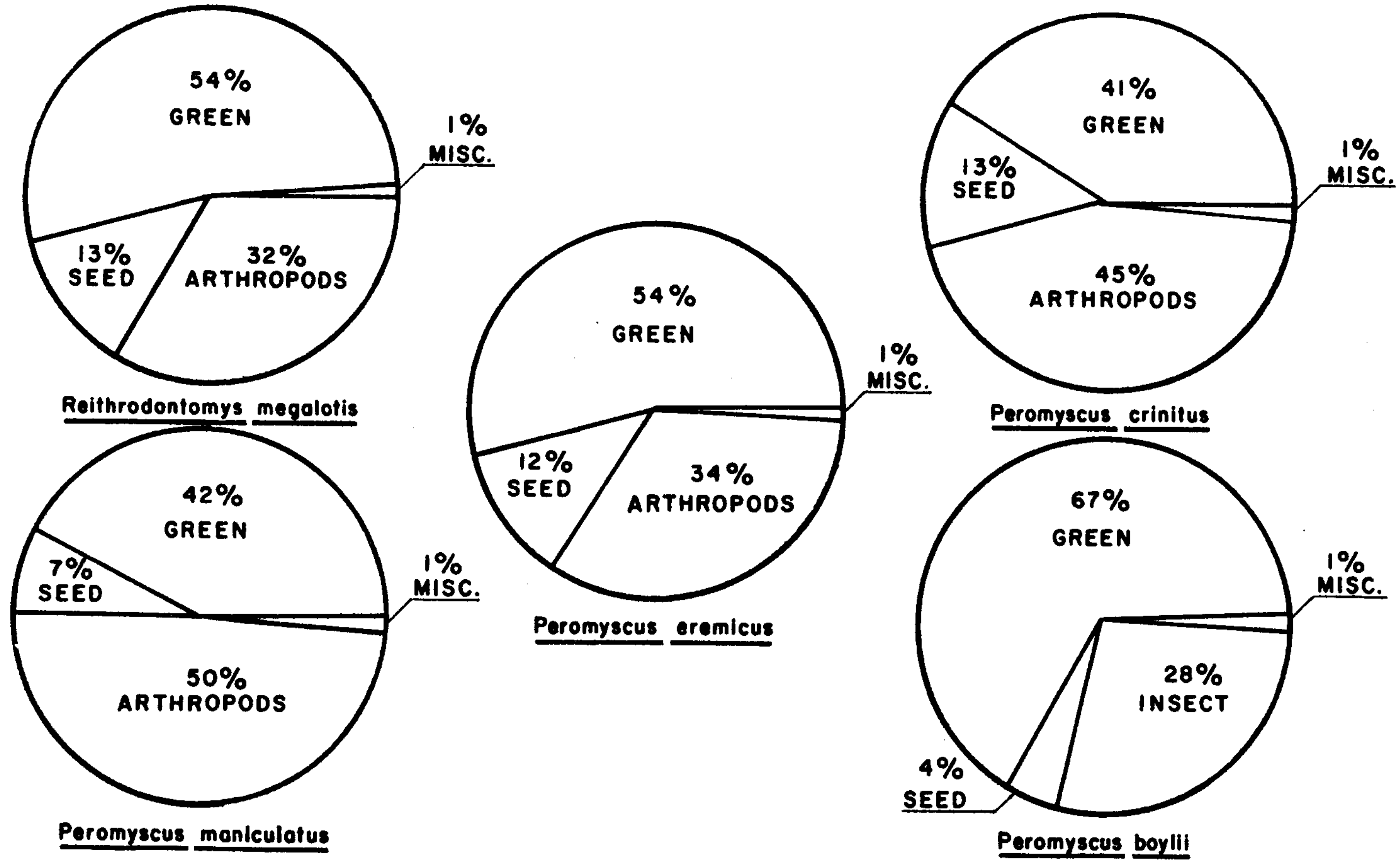

Figure V-9.--Relative volume of four major food categories in the diets of five sympatric cricetid rodents at mile 52.5R.

R. megalotis populations at mile 52.5R were most commonly associated with beach habitats. Relative volume and frequency of occurrence are shown in Figure V-9 and Table V-16. Greenery was the most important food source in the diet of this species, both in terms of relative volume and frequency of occurrence. Although insects were often encountered, they represented only 32 percent of the relative volume in the diet.

P. boylii populations at mile 52.5R also favored the beach habitat. This species preferred greenery to other food categories. Relative volume and frequency of occurrence of greenery was greater in brush mice than in any other species studied. Insects were less important in the diet of *P. boylii* than they were in *R. megalotis* diets, although they were encountered more frequently in *P. boylii* stomachs.

These two species showed closer similarities with respect to their habitat prefereneces than did any other pair of rodent species present on the study area (Figure V-8). Likewise, a similarity is evident in dietary preferences of the two species. Although it is possible that these species exploit different plants or plant parts (i.e., stems versus foliage) within the beach habitat, it is remarkable that, overall, diets are so similar. *Reithrodontomys* exploits seeds in a greater volume and they are more commonly encountered in *Reithrodontomys* stomachs than they are in *P. boylii*.

P. maniculatus were confined to the beach habitat for the most part. We have shown that deer mice are not closely related to any other species in terms of habitat preferences. Insects were the major item in the diet of this species, both in terms of relative volume and percent frequency.

Stevens (see Chapters VII and VIII) found that insect density and diversity were greatest in the beach habitat of the riparian zone within the canyon. The importance of insects in the diets of *P. maniculatus* may, in part, be due to the abundance of this prey within their habitat.

The habitat preferences of *P. crinitus* were typified by washes, cliff faces and talus slopes. Habitat preferences of this species elsewhere were previously discussed by Egoscue (1964). Diets of canyon mice at mile 52.5R were extremely diverse. No single food category comprised more than 45 percent of the relative volume. Insects were the most prevalent item both in terms of relative volume and percent frequency. Greenery was of secondary importance while seeds were only used occasionally.

P. eremicus was the most commonly encountered species during the study and occurred in all major habitats in the riparian zone (Table V-12). At mile 52.5R greenery was the most important item in the diet of this species. Insects and seeds were of lesser significance but the former was more important than the latter.

Two species were sampled in sufficient numbers to analyze diets at mile 208.6L. The data for P. crinitus and P. eremicus are summarized in Figure V-10 and Table V-17. R. megalotis and P. maniculatus were not taken at this study site. P. boylii was uncommonly encountered and a sufficient number of stomachs were not available to analyze the diet of this species at mile 208.6L.

Greenery was far more important in the diet of P. crinitus at mile 208.0L than at the mile 52.5R site. Utilization of arthropods and seeds was reduced in P. crinitus diets at mile 208.6L although arthropods were more frequently encountered. This species was not present on the live trapping grid at this site (Table V-12).

P. eremicus at mile 208.6L was found in both the beach and terrace habitat but favored the latter (Table V-12). Greenery was the major item in the diet of this species. Insects were frequently encountered but made up less than one-third of the relative volume. Seeds were almost absent from P. eremicus stomachs at this site.

Comparisons of P. crinitus and P. eremicus diets from mile 52.5R and mile 208.6L are striking. Greenery was much more important in the diets of both species at mile 208.6L, being encountered at higher relative volumes and more frequently. Insects and seeds were generally taken less commonly by the two species at mile 208.6L than at mile 52.5R.

Seeds were the least important item in R. megalotis and Peromyscus spp. diets at both study sites. Flake (1973) and Vaughan (1974) found seeds to be the most important item in P. maniculatus diets from two different habitats in Colorado. Seed production is probably highest on the terrace habitats of the riparian zone (M. Theroux, pers. comm.). This is the preferred habitat of both heteromyid rodents in the riparian zone. As a group, heteromyids are better suited to explcit seeds than are cricetids. This may account for the paucity of seeds in cricetid rodent diets in the riparian zone.

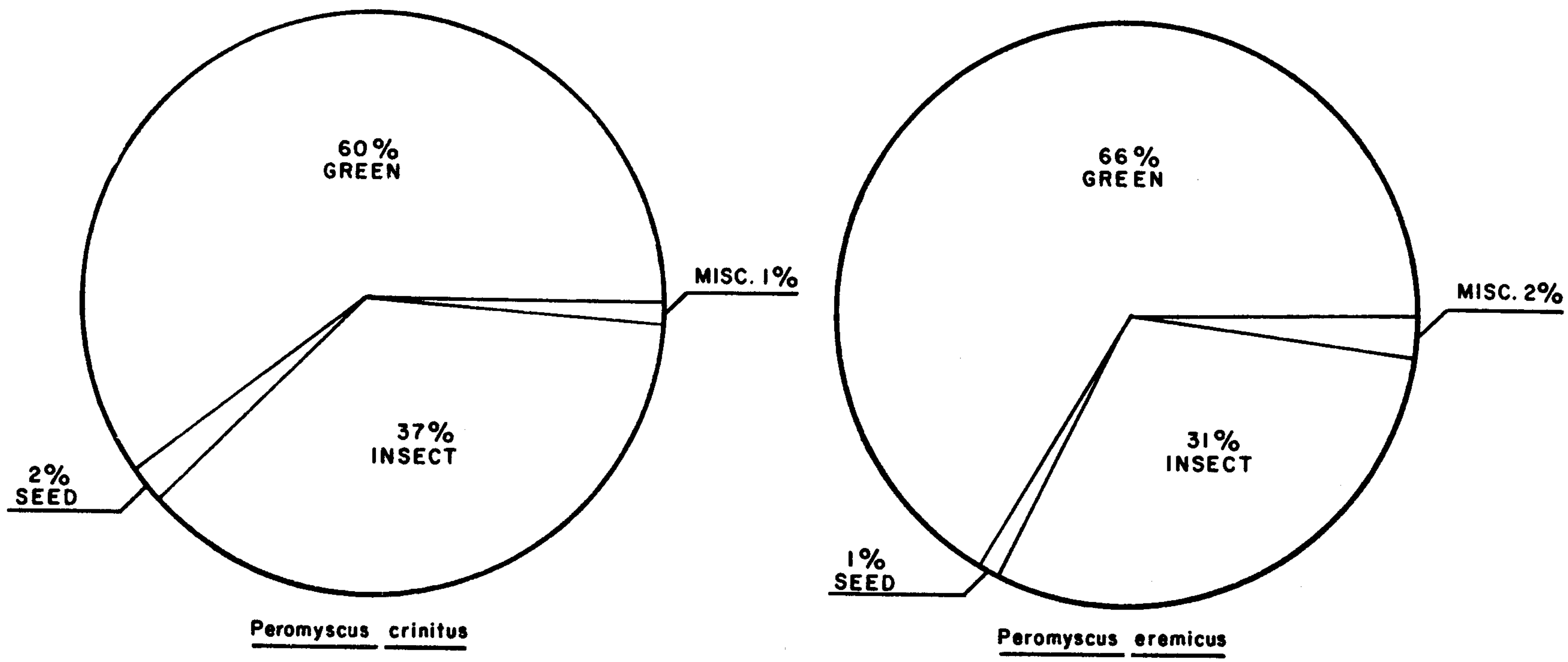

Figure V-10.--Relative volume of four major food categories in the diets of two sympatric cricetid rodents at mile 208.6L.

Insects provide a fairly stable and important food source for *R. megalotis* and *Peromyscus* spp. in the riparian zone. They are preyed upon to different degrees by the cricetids examined in this study. This may account, in part, for the diversity of several closely related species. We are currently investigating rodent diets at a number of localities in the canyon to more precisely define the mechanism(s) which permit co-existence of a number of closely related species.

REPRODUCTION

Perognathus formosus had a mean litter size of 6.25 (n = 4) as determined from embryo counts. Corpora lutea counts revealed a mean litter size of 4.43 (n = 7). Mean number of embryos reported here is greater than reported by French et al. (1974), while placental scar counts were less than reported by those authors. During live trapping, carried out in all seasons of the year during 18 months, reproductively active females were observed in April (58 percent, N = 12; 33 percent, N = 3), June (10.5 percent, N = 19; 70 percent, N = 23; 8 percent, N = 12) and July (14 percent, N = 7). We have no data to suggest reproductive activity in this species outside of the spring and early summer months. These data are supported by the findings of Chew and Turner (1974), who found that in Nevada reproductive activity was limited to the period between March and August.

Perognathus intermedius had a mean litter size of 5.00 (n = 4). No data on mean numbers of corpora lutea were available for this species. During a 4 month study in southern Arizona, Franz et al. (1973) found mean litter sizes at 3.3 and 3.4 as indicated by embryo and corpora lutea counts respectively. Larger sample sizes may bring our estimates of litter size closer to those of previous studies. Live-trapping data gather during all seasons over a period of 14 months at mile 208.6L revealed reproductively active females in March (12 percent, N = 24), April (20 percent, N = 5), May (15 percent, N = 20), and June (15 percent, N = 13). Reichman and Van De Graaff (1973) found that reproductive activity in *P. intermedius* was characteristically limited to the spring months. Elsewhere, these authors (Reichman and Van De Graaff, 1975) suggest that the ingestion of green vegetation and heteromyid reproduction are related. If such a relation does exist it is not surprising that reproductive activity is characteristic of the spring and early summer months when ample resources are available for female parents, and later, the offspring.

We have no data on litter sizes of Reithrodontomys megalotis in the canyon. Indeed, there is a paucity of data available in the literature dealing with reproduction of this species. Limited information on reproductive cycles is available for this species in the canyon. Individuals were observed in reproductive conditon in April, May and June; however, small sample sizes prohibit conclusions. This species is relatively rare and has been taken from only a few localities in the canyon. Further work on all aspects of the ecology of this species is needed in the riparian zone.

Embryo counts of Peromyscus crinitus revealed a mean litter size of 4.75 (n = 4) while corpora lutea counts showed a litter size of 2.50 (n = 2). Other authors have reported mean litter (n = 2). Other sizes of 4.10 in Nevada (Moor and Bradley, 1974) and 3.00 in Utah (Egoscue, 1964) as revealed by embryo counts. However, Egoscue's study was on a laboratory population. Reproductive activity was observed in May (100 percent, n = 5; 50 percent, n = 4) and June (50 percent, n = 4; 88 percent, n = 8) on the study sites at miles 52.5R and 53.0R. At mile 208.6R reproductive activity was limited to June (75 percent, n = 4). Moor and Bradley (1974) recorded bimodal reproductive activity (May-August and November-February) for this species in southern Nevada. Young were produced in every month of the year in Egoscue's (1964) study in the laboratory, however, the majority (109 to 135 litters) were born between January and August. We found no evidence of reproduction outside of the spring and early summer months in this species.

Mean litter size of the Peromyscus eremicus was 3.25 (n = 8), as determined by embryo counts. Franz et al. (1973) recorded a mean litter size of 2.60 for this species in southern Arizona using embryo counts and corpora lutea counts. MacMillen (1964), using embryo counts, found that cactus mouse populations in southern California had a mean litter size of 2.90. Cactus mouse reproductive cycles during the study are summarized in Table V-18. Reproductive activity is most intense in the spring and early summer months. Late fall reproduction did not occur during our study. Franz et al. (1973) and MacMillen (1964) have discussed year around reproductive activity in females of this species. Our live-trapped animals showed no evidence of reproduction during trap periods in October, November or December; however, reproductive activity was noted on one study site (mile 53.0R) in January, 1975.

Table V-18.--Percent of reproductive females *P. eremicus* captured on the four live trapping grids during the study. Numbers in parentheses are sample sizes.

	Miles 52.5R	Mile 53.0R	Mile 208.6L	Mile 208.6R
November, 1973	0(31)	--	--	--
December, 1973	--	0(39)	--	--
March, 1974	--	--	19(83)	0(28)
April, 1974	48(25)	74(49)	--	--
May, 1974	--	--	30(47)	9(11)
June, 1974	62(16)	46(33)	30(37)	75(4)
July, 1974	70(17)	0(22)	--	--
August, 1974	--	--	26(35)	0(12)
October, 1974	0(36)	0(51)	--	--
November, 1974	--	--	0(20)	0(10)
January, 1975	0(15)	46(11)	0(8)	0(7)
March, 1975	100(8)	75(4)	--	--
April, 1975	--	--	100(10)	0(0)
June, 1975	67(9)	42(26)	--	--

Mean litter size of Peromyscus maniculatus as determined by embryo counts, for this was 4.67 (n = 3). Flake (1974) found mean litter size of this species to be 4.70, as indicated by embryo counts. MacMillen (1964) found that southern California populations of deer mice had a mean litter size of 4.30. Unfortunately, the small sample sizes prohibit us from reaching any conclusions concerning litter sizes of this species in the canyon. We found that female reproductive activity was limited to the months of March (100 percent, n= 5), April (75 percent, n = 4; 25 percent, n = 5) and June (60 percent, n = 5; 40 percent, n = 5; 62 percent, n = 8). MacMillen (1964) captured pregnant females every month from December to May in southern California.

From embryo counts we established a mean litter size for Peromyscus boylii of 3.17 (n = 6). This compares favorably with the data of Jameson (1953). During our live-trapping studies we did not find any reproductively active female P. boylii. Jameson's (1953) data indicate two breeding periods per year in the Sierra Nevada, one during May and a second in September. Reproductive biology of this species deserves further study in the canyon.

Reproductive biology of Neotoma albigula is poorly known in the canyon. We have no data on litter sizes or reproductive cycles of this species in the canyon. Finley's (1958) data from embryo counts show a mean litter size of 2.19 for N. albigula in Colorado and that reproduction was usually limited to Aprl, May and June.

Mean litter size, of Neotoma lepida was 2.67 (n = 3) as determined by embryro counts. Burt (1934) reported that N. lepida bore 4.00 young per litter while MacMillen's (1964) study indicated a mean litter size of 2.7, as determined by embryo counts. On the live trap grids at mile 52.5R reproductively active females were captured in March (89 percent, n = 9), April (60 percent, n = 5) and June (44 percent, n = 9; 44 percent, n = 18). At mile 53.0 reproductively active females were captured only in June (33 percent, n = 9). In Colorado young N. lepida are born in early spring and early summer (Finley 1958). While in southern California MacMillen (1964) found pregnant and lactating females between November and May.

Although our sample sizes for most species are small, two general trends are reflected by the data. First, mean litter sizes reported herein are generally larger than those reported elsewhere. Secondly, reproduction is generally confined to the spring and summer months. Our data for R. megalotis, P. boylii and N. albigula are inconclusive. However, five other species or rodents (Perognathus intermedius, P. formosus, P. crinitus, P. maniculatus and N. lepida) limited reproductive efforts to the spring and early summer months. The P. eremicus showed evidence, at one study site, of reproductive activity in January, otherwise reprodution was limited to the spring and early summer months. The available information suggests that a reproductive period confined to one season of the year. This is contrary to the findings of MacMillen (1964) for P. eremicus and Moor and Bradley's (1974) data for P. crinitus. It is plausible perhaps that by increasing litter sizes, the riparian zone rodents are able to concentrate reproductive activity into the most favorable time of the year (i.e.; spring) when sufficient resources for parents and young are available.

SUMMARY

The demographic data yield several generalizations regarding the small mammals of the riparian zone.

1. The beach and terrace rodent communities should be considered as separate entities in spite of the opportunities for exchange of individuals across ecological borders. Beach communities tend to be less stable, less productive, and very slightly more complex with respect to species diversity.

2. Intracommunity structural analysis indicates a positive series of relationships between single species' population stability, mean rank (i.e., importance), rank positional stability, and ecological distributional evenness. If all these are interpreted as indicators of ecological success, then P. eremicus is the most successful small mammal in the riparian zone of the Grand Canyon.

3. Home range data indicate an inhibitory effect of high temperature upon movement in at least two species. Home ranges are apparently linear in horizontal distribution and, in the special case of a beach restricted species, they tend to be oriented

parallel to the Colorado River.

4. Survivorship is very low and suggests a nearly annual population turnover rate. Low survival in the riparian system tends to be associated with a heavy investment in the colonization of the new (12 year-old) beach habitat.

5. Diets of sympatric cricetids were studied at mile 52.5R and 208.6L during the spring and early summer of 1974. Five species of cricetids were studied at mile 52.5R. Two beach dwelling species (R. megalotis and P. boylii) were most dependent upon greenery. The precise mechanism that permits the coexistance of the two species is currently unknown. We are now examining diets and habitat characteristics with more precise methodology in hopes of determining how resources in the beach habitat are allocated.

6. P. maniculatus also preferred the beach habitat of the riparian zone at mile 52.5R. Those mice utilized insects to a greater degree than did any other species. Insects were more abundant on beach habitats than on terrace habitats in the canyon. Insects were also the most important item of P. crinitus, a species that typically is found in association with washes, cliff faces and talus slopes.

7. P. eremicus were most reliant upon green vegetation. Insects and seeds were of less importance. P. crinitus were ubiquitous in all habitats within the riparian zone.

The diets of two species of cricetids were analyzed at mile 208.6. In contrast to mile 52.5R, P. crinitus at mile 208.6 were more dependent upon green vegetation. However, these mice were not captured in habitat similar to that found on the live trapping grid. P. eremicus were captured in all habitats at mile 208.6L. Green vegetation was the most important food category in the diet of this species.

8. The low representation of seeds in cricetids diets in the riparian zone of the Canyon is puzzling. Seed production is probably greatest on the terraces yet the only cricetid studied that regularly occurs on

the terrace, P. eremicus, does not rely heavily upon seeds. Terrace dwelling Perognathus spp. might be better suited to exploit this resource. Insects were an important resource in the diets of all the cricetids we examined during the study, although different degrees of exploitation were apparent.

9. Analysis of reproduction in nine species of rodents found in the riparian zone of the canyon revealed two interesting trends. Mean litter sizes reported herein are generally larger than those reported elsewhere. In addition, reproduction is generally confined to the spring and summer months. Our data for two species (P. crinitus and P. eremicus) are contrary to the findings of other authors who have studied reproduction of these species. Productivity within the riparian zone might be such that all reproductive activity is concentrated into the more favorable spring and early summer months. Our future efforts will be directed toward examining seasonal productivity and its role in reproduction of riparian zone rodents.

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CHAPTER VI

BIRDS OF THE COLORADO RIVER

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N. Joseph Sharber

INTRODUCTION

Studies on the avifauna of the Grand Canyon region, particularly within the inner gorge of the Canyon or along the Colorado River have not been extensive. Ornithological investigations began in the late 1920's and early 1930's with the earliest publication treating the birds of Havasu Canyon (McKee, 1927), soon followed by a second paper (Jenks, 1931) also on the birds of the Havasu Canyon area. The first checklist of the birds of the Grand Canyon area was published by Grater (1937) and Bailey (1939) followed with an anecdotal account of all that was known about the birds in the Grand Canyon up to that time.

From 1939 to the late 1950's, the bird checklists were periodically revised and updated by various naturalists, most of whom were employees of the National Park Service (see Bryant, 1945a, 1945b, 1952; Huey, 1939 and McKee, 1939).

The Park wildlife observation files are replete with bird observations for the intervening years, but little recent information has been published with the exception of the annual Christmas bird counts (see Hill, 1969, 1970, 1971; Leishman, 1973 and Ochsner, 1972) and more recently, our investigations have resulted in two publications (Carothers and Johnson, 1975a and Johnson et al., 1976) dealing with the distribution and status of the birds of the Grand Canyon area, with particular emphasis on the Colorado River.

Unfortunately, the majority of the published works on the avifanua within the Grand Canyon area are not quantitative. This is especially distressing since many habitat changes have taken place, particularly along the Colorado River. Without any substantial information on the birds of the Colorado River through the Grand Canyon prior to the construction of Glen Canyon Dam, we have no positive way of knowing how the avifauna found in this area now compare with the pre-dam days when the Colorado River was wild. As a direct influence of the dam, the riparian (streamside) habitat of the

Colorado River is still changing. Gone forever are the vegetation scouring floods of pre-dam days and each year we witness an increased growth and proliferation of this "new" riparian habitat. (See Chapters I and II of this report for full description of these changes.)

This report deals with the birds that are found throughout the year along the Colorado River from Lees Ferry to the Grand Wash Cliffs. Breeding bird density information is presented for only the area from Lees Ferry to Diamond Creek, a distance of 225 miles. As there is no previous account of the birds along the river, this information must serve as our "baseline" level, a yardstick or indicator of future changes in the distribution and abundance of birds within the inner gorge of the Grand Canyon.

METHODS

Although the time span of this project covers the period 1 June 1974 to 30 June 1976, the field work on the birds of the Colorado River and the inner gorge of the Grand Canyon has been underway since 1968. For the most part, the field work has consisted of recording breeding and migrating birds as they were encountered during our forays into the little known areas of the Grand Canyon region. In an attempt to quantify the relative densities of the breeding birds along the 225 mile river corridor from Lees Ferry to Diamond Creek, we recorded the number of individuals of each species per mile of river that were encountered as we floated the river in oar-powered boats. During the breeding season (April-August) the activities of the birds were also recorded (e.g., singing, nest construction, feeding young etc.) and most of the relative density and absolute density data have been based on singing males encountered along the river. The absolute density data cannot be considered in a literal sense as the absolute numbers of birds within the study area, but only as the absolute numbers we encountered. The censusing method employed, and the speed with which our craft were moving, have undoubtedly resulted in many individuals being overlooked. The censusing usually began early in the morning, as soon as the boats departed from the previous night's camp. Normally, we moved at a relatively constant speed (2-5 mph), and censusing was discontinued if we stopped during the day, or if the weather was such that the bird activities would be obviously affected (e.g., wind or rain). Migrating birds were censused in the same manner throughout the year. An attempt to duplicate this data gathering process on a motor-powered craft was undertaken with poor results. The noise of the motor and the faster rate of speed resulted in a substantial number of birds being overlooked, that would otherwise have been recorded on an oar-powered craft.

Over 20 separate river expeditions, covering every month of the year with the exceptions of February and December, are represented by the data presented herein. In addition, at least 25 separate backpacking or land based (helicopter support) forays into the tributaries of the Colorado River and/or high interest areas along the river (e.g., Nankoweap mile 52.0; Cardenas Creek, mile 71.0; Granite Park, mile 209.0) were also a source of data on the status and distribution of birds within the study area.

Bird species diversity was determined by using the diversity index, H', as developed for biological parameters by MacArthur and MacArthur (1961). The formula used to compute this value is $H' = -\sum p_i \log_e p_i$, where p_i equals the relative density of each species. The evenness of distribution of the species, J', is determined by dividing H' by the maximum possible $H' (\log_e N)$.

RESULTS AND DICUSSION

Birds Recorded in the Study Area
(Lees Ferry, mile 0.0 to the Grand Wash Cliffs, mile 279.0)

Approximately 240 species of birds have been recorded in the Grand Canyon region (see Johnson, et al. 1976), an area encompassing not only the Colorado River and its riparian habitat, but also the wide variety of habitat types found throughout the Grand Canyon area. These additional habitats include the spruce-fir-aspen, ponderosa pine, pinyon-juniper, oak woodland, chaparral, and desert scrub associations. Each of these vegetative associations contains an assemblage of breeding birds typical to that particular habitat, assemblages which are generally distinct between habitat types. The riparian habitat of the inner gorge also contains its distinct assemblage of breeding birds, yet during the non-breeding season, or migratory season, the riparian areas are frequented by birds that breed in all Grand Canyon habitats and some that breed elsewhere throughout the United States and Canada. The riparian habitat of the inner gorge provides a natural corridor for migratory movements of birds on their way to or from breeding grounds. Whether or not a species is on its way to the spruce-fir-aspen forests of the north rim (e.g., Ruby-crowned Kinglet) or the pinyon-juniper forest of the south rim (e.g., Common Bushtit) or the wetlands of the far north (e.g., Canada Goose) it will use portions of the Grand Canyon riparian corridor as it makes its way to the breeding grounds. The reasons for this are as varied as they are simple. The very depth and size of the entire Grand Canyon system provide for striking climatic differences between canyon bottom and canyon rim. Generally, the spring and fall weather along the Colorado River is much more hospitable than that of either rim. The deciduous riparian vegetation enjoys a longer growing season within the Canyon, providing insects with a longer period of food, which in turn provides a predictable food source for some migrating birds. The water of the Colorado River is an important resource for migrating birds that should not be overlooked, particularly in the arid Southwest where the presence or absence of running water in some cases is the single most important factor in determining the wildlife resources of an area (see Carothers and Johnson, 1975b).

Although we know that only 41 species (high compared to non-riparian areas in Arizona; e.g., transition zone or spruce-fir) of birds utilize the Grand Canyon riparian habitat for breeding (Table VI-1), we have recorded 178 species (see Appendix VI-1) representing 15 orders and 42 families, within the area. Thus, almost 80 percent of the bird species that are found along the Colorado River are on their way to breeding grounds elsewhere.

In addition to recently published revisions of bird checklists and new distributional information concerning Grand Canyon birds (see Carothers and Johnson, 1975a and Johnson et al. 1976), we include here, eight additonal species that have not been previously recorded in the Grand Canyon region. They are as follows: White Pelican, Common Goldeneye, Bonapart's Gull, Herring Gull, Forster's Tern, Lesser Nighthawk, Wied's Crested Flycatcher, and Blackburnian Warbler (hypothetical).

Seasonal Distribution of Birds in Study Area

Figure VI-1 illustrates the monthly distribution of the numbers of species that may be found within the study area throughout the year, and Figure VI-2 illustrates the relative differences in actual densities that occur throughout

Table VI-1.--The breeding birds of the Colorado River from Lees Ferry (mile 0) to Diamond Creek (mile 225).

Species	Preferred Habitat[1/]	Status[2/]	Relative Density	Average Absolute Density Pairs/225 mi.[3/]
Turkey Vulture	B	SR	0.76	6.8
Cooper's Hawk	A	SR	0.11	1.0
Red-tailed Hawk	B	PR	0.50	4.5
Golden Eagle	B	PR	0.25	2.3
Prairie Falcon	B	PR	0.15	1.4
Peregrine Falcon	B	PR	0.15	1.4
Sparrow Hawk	A	PR	0.84	7.5
Spotted Sandpiper	A	SR	6.44	57.0
Mourning Dove	A	SR	9.92	87.8
Roadrunner	B	PR	0.11	1.0
Great-horned Owl	B	PR	0.11	1.0
Black-chinned Hummingbird	A	SR	1.32	11.7
Ladder-backed Woodpecker	A	SR	0.11	1.0
Ash-throated Flycatcher	A	SR	1.09	9.7
Black Phoebe	A	SR	0.92	8.2
Say's Phoebe	A	SR	2.71	24.0
Willow Flycatcher	A	SR	0.11	1.0
Raven	B	PR	3.31	29.3
Dipper	A	PR	(not on river, in flowing tributaries)	
Canyon Wren	B	PR	11.45	101.3
Rock Wren	B	PR	8.98	79.5
Blue-gray Gnatcatcher	A	SR	1.27	11.3
Phainopepla	A	SR	0.22	2.0
Starling	A	SR	(only in heavily populated areas)	
Lucy's Warbler	A	SR	19.67	172.5
Yellow Warbler	A	SR	1.86	16.5
Yellowthroat	A	SR	0.92	8.2

(cont. on next page)

1/ A = riparian vegetation
B = desert scrub, talus slopes and vertical cliffs

2/ SR = Summer resident; PR = Permanent resident

3/ Average Absolute Density determined from field data gathered in April, May and June.

Table VI-1.--cont.

Yellow-breasted Chat	A	SR	2.03	18.0
House Sparrow	A	PR	0.11	1.0
Northern Oriole	A	SR	0.22	2.0
Brown-headed Cowbird	A	SR	1.01	9.0
Blue Grosbeak	A	SR	2.88	25.5
Indigo Bunting	A	SR	(only in Tapeats, Deer and Havasu Creeks)	
Lazuli Bunting	A	SR	(only in Tapeats, Deer and Havasu Creeks)	
House Finch	A	SR	15.25	135.0
Lesser Goldfinch	A	SR	0.41	3.7
Black-throated Sparrow	B	PR	0.11	1.0
Total			100.00	884.7

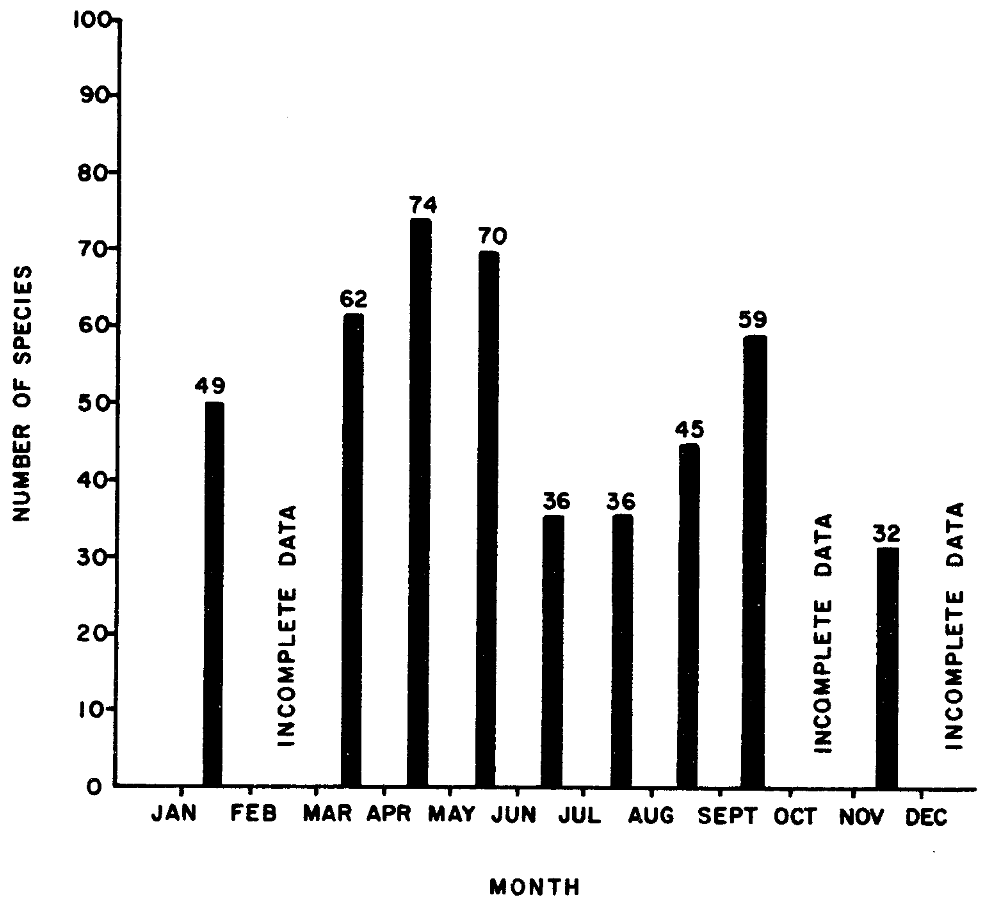

Figure VI-1.--Monthly distribution of the number of bird species to be found within the study area.

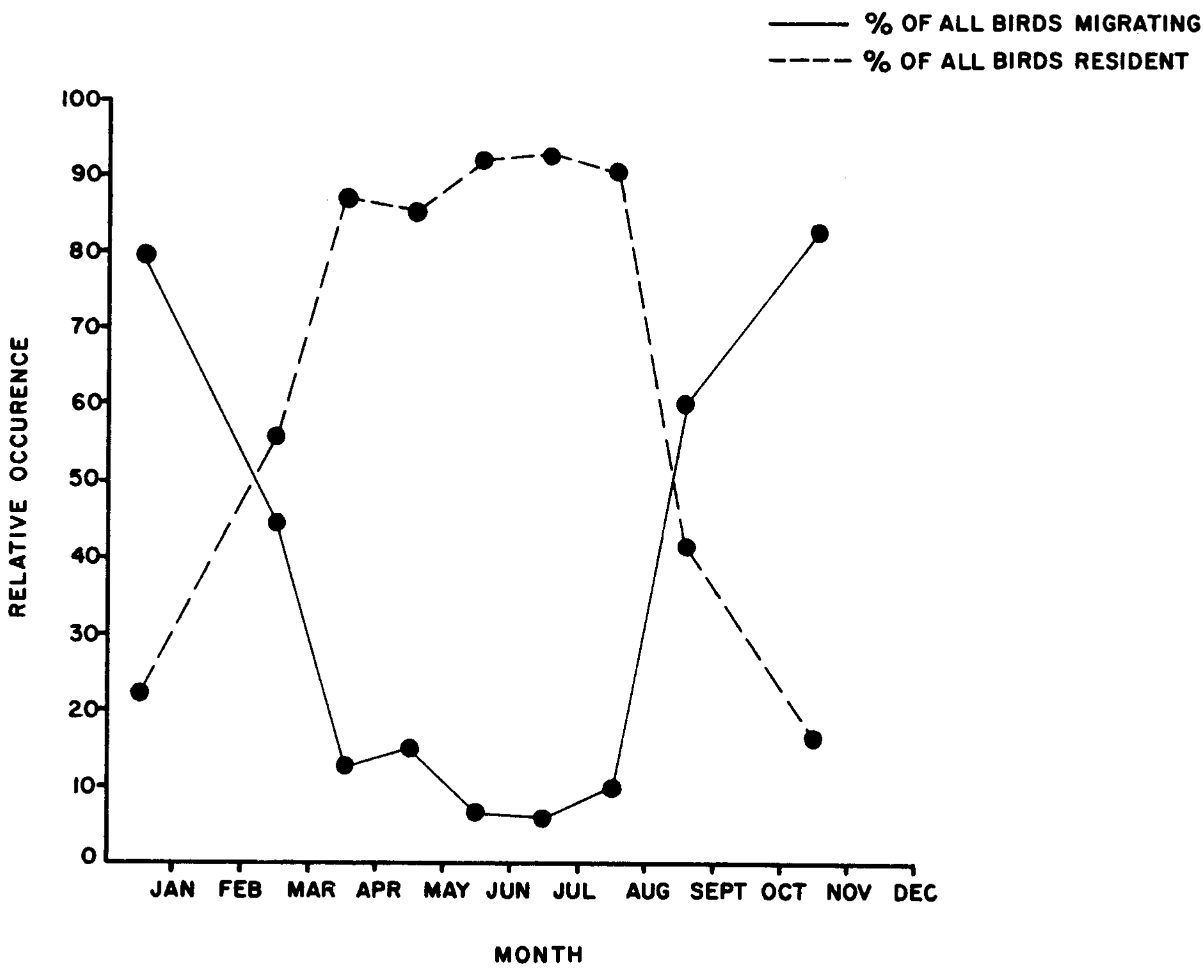

Figure VI-2.--The relative occurrence of resident vs. migrant birds by month on the Colorado River from Lees Ferry (mile 0) to Diamond Creek (mile 225).

the year between resident and migratory species. The months of April and May show the greatest diversity in numbers of species occurring within the study area, with 77 and 70 respectively. These high numbers reflect an overlapping of summer residents, some of which have already begun breeding by early April, and migrants, still on their way to northern breeding grounds. By June, most if not all of the migrants are gone, leaving only the breeding species on the study area. Most breeding activity is over by late June; however, the fall migration does not begin until mid-August, when we observe the number of species increasing again, building up through September and early October (pers. observations, quantitative October data lacking). By November, the migration is essentially over and the diversity of birds remains relatively constant through November and December (pers. observations, quantitative data lacking for December). During both the years 1974-1975 there was an influx of many species of migratory waterfowl during late December and early January, causing the increase in numbers of species observed in January. By mid to late March, most of the waterfowl species, with the exception of the teal species, had left.

Figure VI-2 dramatically illustrates the periods of migration and breeding within the study area. During the months April through August, at least 85 percent of the birds observed were resident species. By September, however, this drops to about 40 percent resident species, 60 percent migratory. Although good quantitative data are lacking for October, November shows that 17 percent of the birds are resident species. This low level of resident species is maintained through January and presumably February (data lacking), and then begins to increase in early March (56 percent resident).

Breeding Birds within the Study Area

A total of 41 species are known to breed within the study area. Of these, 27 species utilize the riparian vegetation as nesting habitat, while the remaining 14 nest in association with the surrounding desert scrub, the vertical cliffs or the loose talus slopes of the inner canyon. Three of the species which prefer the vertical cliff areas for nesting habitat, the White-throated Swift, the Violet-green Swallow and the Cliff Swallow are not considered in this section of the report, but are treated separately below. Although these species form a part of the breeding bird community of the inner canyon, they are typically colonial or partially (locally) colonial and as such, are impossible to report as number of birds per mile. In addition, the three above mentioned species belong to a feeding or foraging guild (aerial insect feeding) that naturally separates them from the ground and vegetation foraging birds that represented the remaining 38 species of breeding birds of the inner canyon. The flycatchers, Willow Flycatcher and Ash-throated Flycatcher are included in the ground and vegetation foraging category here, as the majority of the aerial insects they capture, originate from the vegetation along the banks of the river.

Table VI-1 presents the general habitat preference (riparian vegetation or cliff, talus or scrub), status (permanent or summer residents), relative density and average number of breeding pairs encountered within the study area. The average density of the breeding birds for the entire 225 mile study area was 884.7 pairs, or 3.93 pairs per mile. The bird species diversity (BSD) was 2.69, with an evenness of distribution (J') of 0.76. The 12 permanent resident species made up 26 percent of the total population density, while the 23 summer resident species accounted for the remainder. It is interesting to note, that the riparian vegetation, habitat type A (see Table VI-1) was preferred by 74 percent of the total population of breeding birds in the inner canyon. Of these 74 percent, only two species were permanent residents. Thus, it may be generalized, that the summer resident species of the inner gorge are almost exlusively restricted to the narrow belt of riparian vegetation along the river, while the permanent residents are restricted to, or prefer, the desert scrub, talus or vertical steep cliffs adjacent to the riparian habitat. Some of the species have a clear preference for the band of green vegetation immediately adjacent to the river and below the old high water line (see Dolan et al., 1974). These species are clearly increasing in density from year to year and probably have been ever since the flood gates of Glen Canyon Dam were closed in 1963. Since that time, the vegetaion scouring floods that would periodically denude the beaches below the high water line have been curtailed. The species most dramatically affected by this new stabilized vegetative community are as follows: Willow Flycatcher, Bell's Vireo, Yellow Warbler, Yellowthroat, Yellow-breasted Chat, Northern Oriole, Brown-headed Cowbird and Blue Grosbeak. These species account for about 14 percent of the total breeding bird population along the Colorado River. These are the animals that will continue to increase in density as long as the vegetation below the old high water line continues to proliferate. Also these are probably species that did not occur with significant frequencies along the river during the pre-dam era. Other species that are equally dependent upon this green vegetation such as Lazuli and Indigo Buntings might be expected to begin utilizing this vegetation along the banks of the river as well as the heavily vegetated tributaries they are now in. Although birds such as the Lucy's Warbler and the House Finch primarily utilize the high water line vegetation (*Acacia*, *Prosopis*, *Celtis*, *Fallugia*, etc.) we feel that their densities are also influenced by the proliferating green vegetation along the river as they frequently utilize this zone for foraging.

The most common breeding bird of the study area was the Lucy's Warbler, accounting for almost 20 percent of the total population of breeding birds. The House Finch was the second most common species (15 percent) followed by the Canyon Wren (11 percent).

Four species, the Starling, the Dipper, the Lazuli Bunting and the Indigo Bunting did not breed along the Colorado River, but were found commonly breeding up side canyons. The two buntings were only found in the Tapeats and Deer Creek drainages, but the Dipper was found in every tributary that contained permanent running water. The Starling and House Sparrow, exotic "weed" species, prefer only areas that are heavily inhabitated by humans. They were found as a common breeding species at Indian Gardens, Phantom Ranch, and Havasu campground and village.
Each of the breeding species is discussed separately in Appendix VI-2.

SUMMARY

During this investigation, we determined that 178 species of birds utilize the Colorado River and its riparian habitat in the 279 mile area from Lees Ferry to Lake Mead. Of these, only 41 species remain to breed. The majority (74 percent) of breeding species are primarily restricted to or prefer the narrow band of vegetation existing from the high water line to the banks of the river, while the remainder are restricted to the desert scrub, the talus slopes or the vertical cliffs of the canyon walls. Approximately 14 percent of the total breeding bird community is restricted to the "green" vegetation of the river bank, the vegetation that has proliferated since the construction of Glen Canyon Dam.

The breeding season within the area is April through August, with most activity occurring from April through June.

The most common breeding birds of the area are the Lucy's Warbler, accounting for almost 20 percent of the total popualtion, followed by the House Finch (15 percent) and the Canyon Wren (11 percent).

The total population density of the 225 mile breeding bird study area was determined to be 3.93 pairs/mile, bird species diveristy (H') was 2.69 and the evenness of distribution of the species (J') was .76.

Exotic bird species, the House Sparrow and Starling were only found in areas of heavy human concentration.

Discussion on eight species new to the list of Grand Canyon birds are included in this paper.

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CHAPTER VII

AN INSECT INVENTORY OF GRAND CANYON

Lawrence E. Stevens

INTRODUCTION

An inventory of riparian insect life in Grand Canyon was made over the twenty-five month interval of the project. Specimens were prepared and identified to the Family level and catalogued in the Museum of Northern Arizona insect museum. Small collections of Arachnida and other Arthropoda were also made however, most of this material is, as yet, unidentified.

This represents the first comprehensive general collection of insects from Grand Canyon over an extended period of time. Previous researchers, such as Garth (1950) and Polhemus and Polhemus (in press) were concerned only with individual taxa and not with Grand Canyon insect fauna as a whole. The amount of collecting time spent in the Canyon by these and other workers was usually of limited duration as the difficulties of travel there generally prohibited more than a single collecting expedition. The larger, more attractive species have been collected (e.g., Schellbach's collections in the National Park Service museum at the South Rim) while smaller, less distinctive groups have been largely ignored. Also, specimens have been deposited in various museums around the United States but nowhere has an extensive collection of Grand Canyon insects been brought together as a single body of material. This collection, now organized to facilitate further taxonomic determination, is an initial step in the ecological investigation of riparian insect life in Grand Canyon.

METHODS AND MATERIALS

Approximately two hundred man-days were spent in Grand Canyon sampling insects during the period of study. Collection sites ranged from Lees Ferry to Pierce Ferry along the Colorado River and collections were made in all major tributaries, in many minor side-canyons and in all major places of interest along the river in Grand Canyon. Extensive collections were made at the following sites: Lees Ferry (mile 0.0, R), the 19 mile area (L), Vasey's Paradise (mile 31.9, R), Nankowcap (mile 52.5-53.0, R), Cardenas Creek (mile 71.0, L), Unkar (mile 72.5, R), 75 mile area (L), Phantom Ranch (mile 87.7, R), Phantom Creek, Hermit Creek (mile 94.9, L), Elves Chasm (116.4, L), Forster Camp (122.9, L), Tapeats Creek (133.8, R), Thunder River, Mohawk Canyon (171.4, L), 182 mile area (R), Granite Park (mile 208.6, L), Diamond Creek (mile 225.8, L), Spencer Canyon (mile 246.0, L), and Emery Falls area (mile 274.3, L). Insect life in Grand Canyon was sampled during every month of the year except December.

A variety of sampling methods were employed. General collection of specimens was performed with fine-mesh, canvas and dip nets, water-color paint brushes, forceps, aspirators, beating sheets and eye-droppers, as well as by hand (Peterson 1959). A number of attracting techniques were employed including the use of 15 watt ultra-violet light, white light (approximately 50 hours of black and white light trapping was performed), carrion traps and sweet-bait traps.

Parasites were removed from birds, bats, rodents, and other mammals. Gall-forming and driftwood-inhabiting species, and species attacking dead, standing trees were collected, as were dung-inhabiting species. Both lentic and lotic aquatic habitats were sampled. Stomach contents from collected fish, amphibians, reptiles and birds were also examined for insect specimens.

Because of the harshness and difficulty of travel in Grand Canyon preparation of insect material at the collection sites was impossible. Specimens were transported in acetate envelopes or in vials of 80 percent iso-propyl alcohol to the laboratory and prepared and identified there using a variety of taxonomic keys (Appendix VII-3).

RESULTS AND DISCUSSION

More than twelve thousand insect specimens in 20 orders and 247 families have been prepared and identified thus far. Appendix VII-1 lists the families of insects collected in Grand Canyon. Locations between which specimens have been collected, general distribution along the Colorado River, relative abundance (estimated from field observations as well as from collected specimens), habitat preferences, vegetation associations (if any were noted) and methods of collections are also indicated.

Generalizations concerning insect life in Grand Canyon are not easily made with the amount of data available. As expected, species compostion gradually changes as one moves from the Great Basin and Upper Sonoran habitat zones to the Lower Sonoran and Mojave Desert zones. While this alteration is most evident in Diptera (probably the dominant order in the riparian ecosystem) and in Coleoptera, more data are needed before ecological boundaries along the Colorado River can be clearly delineated.

Grand Canyon may act as a barrier to some (particularly aquatic) species. The Belostomatids should be represented in the Canyon as the ranges of several species overlap the area. Abedus in this study was collected only in Spencer Canyon (mile 246.0, L) at the end of Grand Canyon. Great distances between suitable aquatic habitas (warm, lentic situations in general) probably prevent this group from moving into the Canyon.

A comparison of riparian insect diversity in Grand Canyon with riparian habitats at similar elevations in southern Arizona indicates that, at least in the case of aquatic Heteroptera (Hemiptera), the Canyon is relatively depauperate (Polhemus and Polhemus, in press). This is a further indication of the "barrier effect" the Canyon exerts on some populations.

It is likely that localized populations of insects occur in many instances, relatively isolated from external genetic influx. Notonecta lobata (Notonectidae), common in Grand Canyon, is considered isolated from the rest of its range which is centered in southern Arizona (Polhemus and Polhemus, in press). So too, certain sheltered habitats within the Canyon permit the survival of some species which could not otherwise exist at those low elevations. For example, Plecoptera and some Trichoptera occur only in the coolest side-streams (Royal Arch Creek, Thunder River and Tapeats Creek). In these cases Grand Canyon serves to protect some niche-specific populations.

There are, therefore, at least three ways in which Grand Canyon affects insect population movements. It may act, in a broad sense, as a channel between two major habitat zones (Great Basin and Mojave Desert). It may prevent the immigration of some forms, thus acting as a barrier to population movement. Lastly, it may protect and preserve relatively isolated populations by providing unique and specific habitats. A species' mobility and niche requirements will largely determine its population movements within Grand Canyon.

The only insect family recorded actually using the Colorado River was Chironomidae. The several Hydrophilid beetles taken from the River (apparently having entered inadvertantly) were unable to cope with the cold, swift water. No dredging was performed in the River during this investigation and more groups may be recorded with further study; however, as an aquatic habitat the Colorado River is generally non-productive.

Presumably the great turbulence and sediment load, dramatic water fluctuations and cold temperatures serve to limit aquatic insect life in the Colorado River. Before Glen Canyon Dam was constructed concentrations of insects in the Colorado were probably higher due to warmer water and more gradual fluctuations in water level. Pre-dam terrestrial riparian insect densities may have been somewhat lower because of the scouring effect of floods and limited amount of beach vegetation. Little data exist, however, to confirm these hypotheses.

SUMMARY

This inventory can only be seen as an initial, basic effort in the tremendously large task of the study of insect ecology in Grand Canyon. If the National Park Service is sincere in its quest into the study of entomological resources in Grand Canyon, a study period of twenty to forty man/years should provide a solid base of entomological data. In this amount of time species determinations, further collecting and mapping of species ranges and overall insect communities could be accomplished.

Several specific problems with regard to man's inadvertant affect on insect populations are arising along the Colorado River. Harvester Ant (Pogonomyrex californicus) usually occur in low densities along the beach-terrace interface near the river in Grand Canyon. On many heavily used beaches, however, Pogonomyrex densities are enormous and are probably directly related to human activity (camping and food disposal) there. Because of their great numbers and painful sting this species represents a minor health hazard and a source of discomfort for the many River users affected. With a modicum of research into control methods this problem species could be significantly reduced in an environmentally non-disruptive manner.

Flesh Fly (Sarcophagidae) and Blow Fly (Calliphoridae) populations, common in Grand Canyon, are frequently linked with sanitation problems. If a comprehensive program of general sanitation in beach areas is effected, particularly with regard to fecal and organic waste disposal, fly densities will diminish. If no program is initiated some fly-vectored health problems may arise.

Appendix VII-2 lists some Arachnida found in Grand Canyon. The only potentially dangerous groups of arachnids found along the River were scorpions (at least five species in two Families) and Black Widow Spiders (*Latrodectus* spp., Family Theridiidae). The most common scorpion in Grand Canyon along the upper section of the Colorado River is the occasionally deadly *Centruroides s. sculpturatus* Ewing (Family Buthidae). Though quite common, because of their secretive habits neither scorpions nor Theridiids pose significant threats to visitor use of the Colorado River.

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CHAPTER VIII

INSECT PRODUCTION ON NATIVE AND INTRODUCED DOMINANT PLANT SPECIES

Lawrence E. Stevens

INTRODUCTION

In addition to general collecting, determination of insect production on the dominant riparian plant species was attempted on a small scale. Introduced plant species have invaded much of the riparian habitat and in some cases exist in dominant and predominant capacities. An effort was made to determine insect population densities, diversities and biomass on several introduced and native dominant plant species. These data should indicate the degree to which invading plant species have been incorporated into the riparian ecosystem.

METHODS AND MATERIALS

Determination of relative insect densities and diversities among dominant plant species along the Colorado River was attempted during the spring and summer of 1975. The plant species sampled included *Salix gooddingii*, *Prosopis juliflora*, *Acacia greggii* and *Tamarix chinensis* as well as several others. Fifty uniform sweeps with a canvas and mesh collecting net were made in full sunlight in pure stands ($25m^3$ or more) of a dominant plant species. Insects were killed with sodium cyanide gas and transported to the laboratory for identification and counting. Using this technique general shifts in insect populations throughout the season were demonstrated for the various dominant plant species.

Absolute densities, diversities and biomass of insects on each dominant plant species were determined at the Unkar area (mile 72.5R) during a four-day period in May, 1975. This was accomplished by "bagging" entire branches or plants of the dominant species in 3 mil plastic garbage bags. Ethyl acetate was used to kill the insects which were then removed from the plant and transported to the laboratory. There the specimens were dried, weighed, counted and identified to family level. All green material was removed from the collected branch or plant, dried and weighed. Collections were made during mid-day in an attempt to standardize the

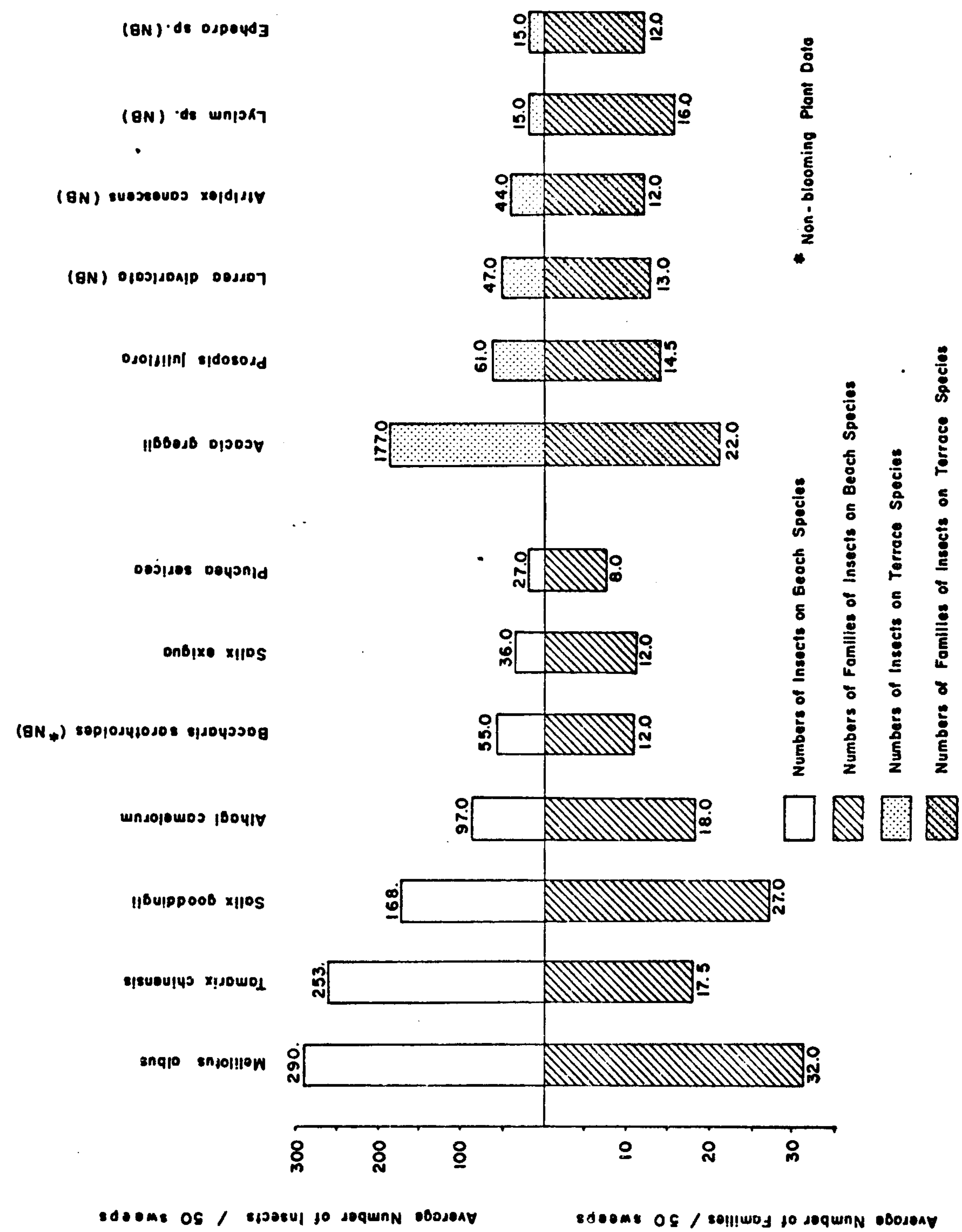

Figure VIII-1.--Average relative numbers of insects and average relative numbers of families of insects on beach and terrace blooming plant species. Beach plant species are shown on the left and terrace plant species are shown on the right. Note (1) the high relative insect production on blooming non-native plant species, and (2) the higher densities and diversities of insects on beach species in general.

activity level. This technique provided a comparison of absolute insect densities, diversities and biomass per unit of plant material between the dominant plant species at Unkar in early May, 1975. The labor involved with this technique for a single worker proved prohibitive for more than one collection site.

RESULTS AND DISCUSSION

Average relative insect densities and diversities on some plant species along the Colorado River are shown in Figure VIII-1. This figure indicates the degree to which introduced species (Melilotus albus, Tamarix chinensis and Alhagi camelorum) are utilized by insects during the blooming phase. It is obvious from these data that some non-native plant species are highly successful in attracting insects. This figure also indicates a marked drop in insect densities as one moves away from the more richly vegetated riparian zone and onto the terrace and talus slope areas.

Insect density and diversity during the blooming phase were shown to contrast sharply with that of the non-blooming phase on Tamarix chinensis. Tamarix chinensis in Arizona blooms bi-seasonally, usually with peak seed production in late June and late August (Warren and Turner, 1975). Figures VIII-2 and VIII-3 illustrate fluctuations in insect densities and familial diversities between the non-blooming and blooming dominant species (Salix gooddingii, Prosopis juliflora and Tamarix chinensis). In these figures the average numbers of insects per fifty sweeps and average number of families of insects per fifty sweeps (respectively) are compared in non-blooming dominant plant species. Insect densities (Figure VIII-2) nearly doubled on the two native dominant species when blooming occurred; on Tamarix a 655 percent average rise in density was noted. Average insect familial diversities (Figure VIII-3 rose by approximately 15 percent on the native dominants and by nearly 60 percent on Tamarix. Insect densities and familial diversities on non-blooming Tamarix were generally lower than those recorded on non-blooming native dominants.

Results of insect production analyses on dominant plant species occuring at Unkar (mile 72.5R) in May, 1975, are shown in Table VIII-1 and VIII-4. Tamarix chinensis in bloom at that time supported a lower

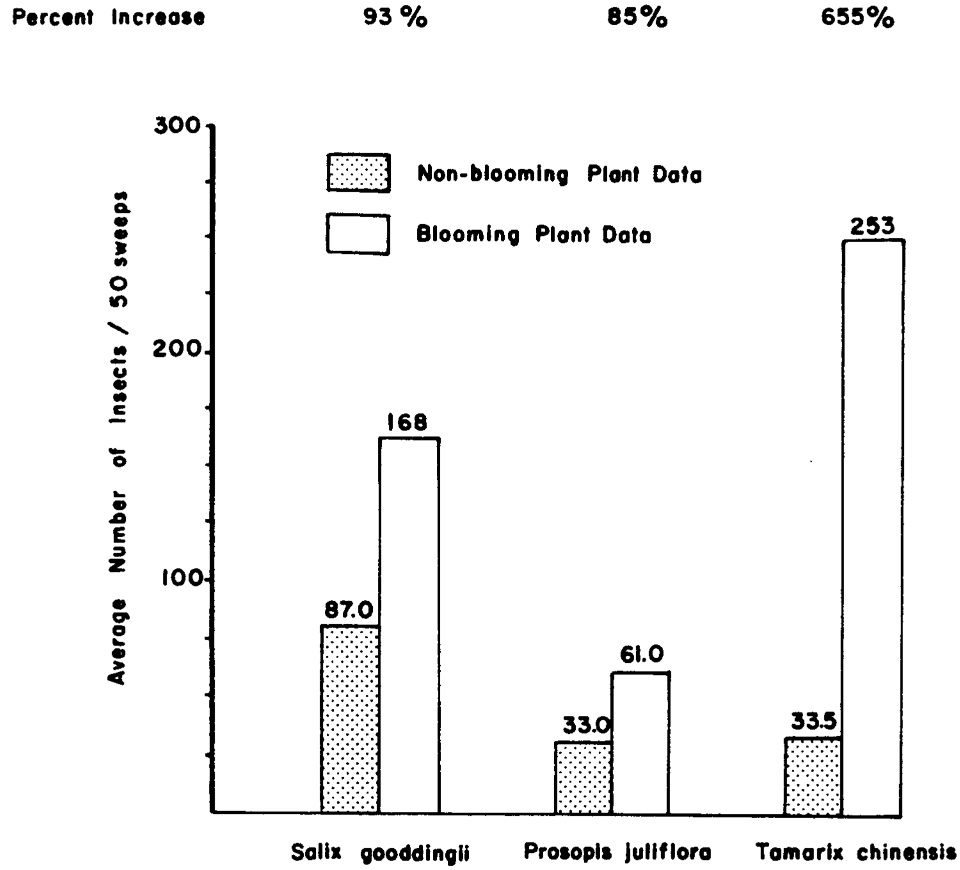

Figure VIII-2.--Average relative numbers of insects on three non-blooming and blooming dominant plant species. Note the extreme increase in insect density on Tamarix chinensis in comparison with the lesser rise in insect utilization on the two native dominant species.

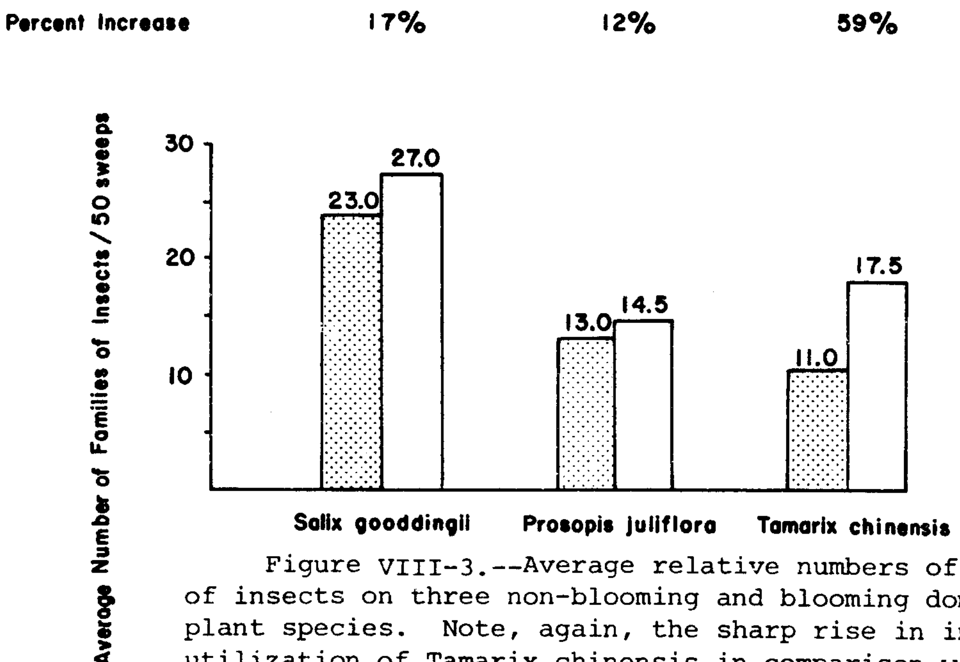

Figure VIII-3.--Average relative numbers of families of insects on three non-blooming and blooming dominant plant species. Note, again, the sharp rise in insect utilization of Tamarix chinensis in comparison with the native dominant plant species' insect utilization patterns.

Table VIII-1.--Insect Production on Blooming Dominant Riparian Plant Species at Unkar (Colorado River Mile 72.5R), May 8-11, 1975.

PLANT SPECIES	NUMBER OF INSECTS / g PLANT	AVERAGE WT. INSECTS (mg)	g OF INSECTS / kg PLANT
Salix gooddingii	1.06	0.512	0.543
Prosopis juliflora	2.34	0.132	0.308
Tamarix chinensis	3.85	0.053	0.205
Tamarix chinensis (NB*)	0.225	0.226	0.047
Pluchea sericea	0.120	0.610	0.073

*NB-Non-blooming

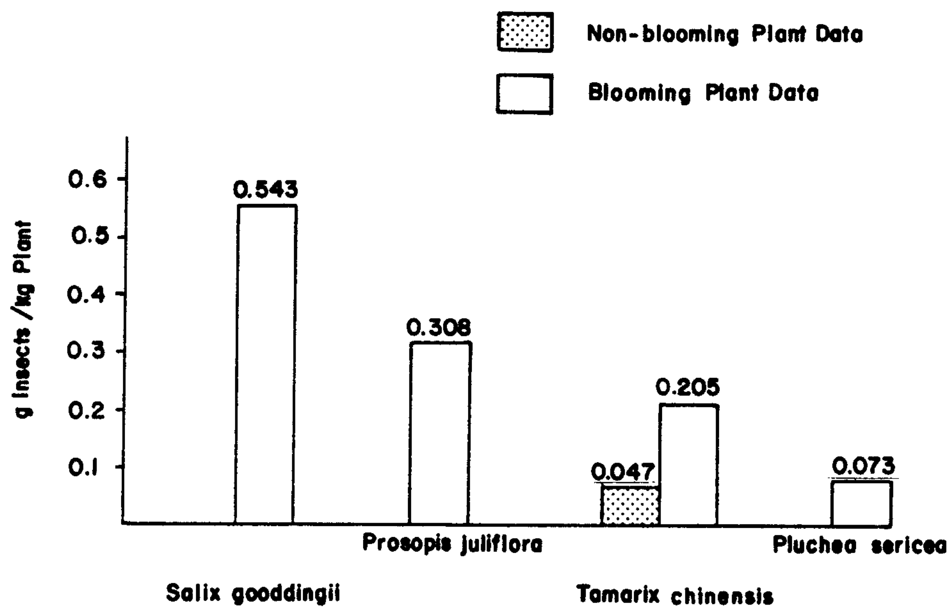

Figure VIII-4.--An illustration from Table VIII-1 of the biomass of insects supported on various blooming dominant plant species at Unkar (mile 72.5R). These data were gathered in early May, 1975. At that time in the season blooming *Tamarix chinensis* supported less absolute biomass of insects than did the native dominants. Non-blooming *Tamarix chinensis* displayed only approximately 10 percent the insect production capacity of the native dominant species. Blooming *Pluchea sericea*, a sub-dominant, is also shown to be unproductive in terms of the insect biomass supported.

biomass of insect life (g insects, kg plant) than was in evidence on either Salix gooddingii or Prosopis juliflora Furthermore, Tamarix chinensis supported a proportionally larger number of smaller insects (primarily Thripidae) at that time. Non-blooming Tamarix chinensis supported only ten percent of the insect biomass supported on those two native dominants. While relative insect density and diversity data (above) indicate that utilization of blooming-phase Tamarix chinensis by insects increases as the summer progresses, this pattern of early bloom insect depauperacy may be important in terms of the amount of available food for nesting birds.

Other trends noted in insect utilization of Tamarix chinensis were observed. Use of green Tamarix chinensis vegetation as a food source was noted only in Acrididae (Schistocera sp.), Cicadellidae and Buprestidae (Hippomelas sp.). Before the main blooming phase (late April through June) one species of Cicadellidae fed on Tamarix chinensis, in turn attracting some predators (primarily Salticidae). In early July Tamarix chinensis produced a new growth of green vegetation which was apparently an attractive food source to Schistocera, Hippomelas, and perhaps other herbivorous insect species.

A stand of Tamarix chinensis and Prosopis juliflora was accidentally burned in 1974 at mile 49.9R. In 1975 this site was visited and the standing dead wood was examined. The Tamarix chinensis wood at that time was completely free from wood-boring insect damage. In contrast, the Prosopis juliflora wood was riddled with holes and damage from wood-boring beetles (primarily Buprestidae).

The data and observations above indicate that Tamarix chinensis is not evenly incorporated into the riparian ecosystem. Within its cycles Tamarix chinensis insect production fluctuates dramatically in comparison to the more harmonious shifts noted on native dominant species. Tamarix chinensis attracts large numbers of pollinators when blooming but supports only a very limited insect comunity when not blooming.

This may also prove to be the case with some of the other non-native species, though data are lacking. Alhagi camelorum was found to be free from seed-boring bean weevils (Bruchidae) (C. D. Johnson, pers. comm.), yet it was heavily utilized by major orders (particularly Coleoptera, Diptera and Hymenoptera; see Chapter VII and

Appendix VII-1) when blooming. *Melilotus albus*, another non-native, was the most productive plant species sampled when blooming (Figure VIII-1). In terms of insect use *Salsola kali* and *Elaeagnus angustifolia* remain, as yet, unstudied in Grand Canyon.

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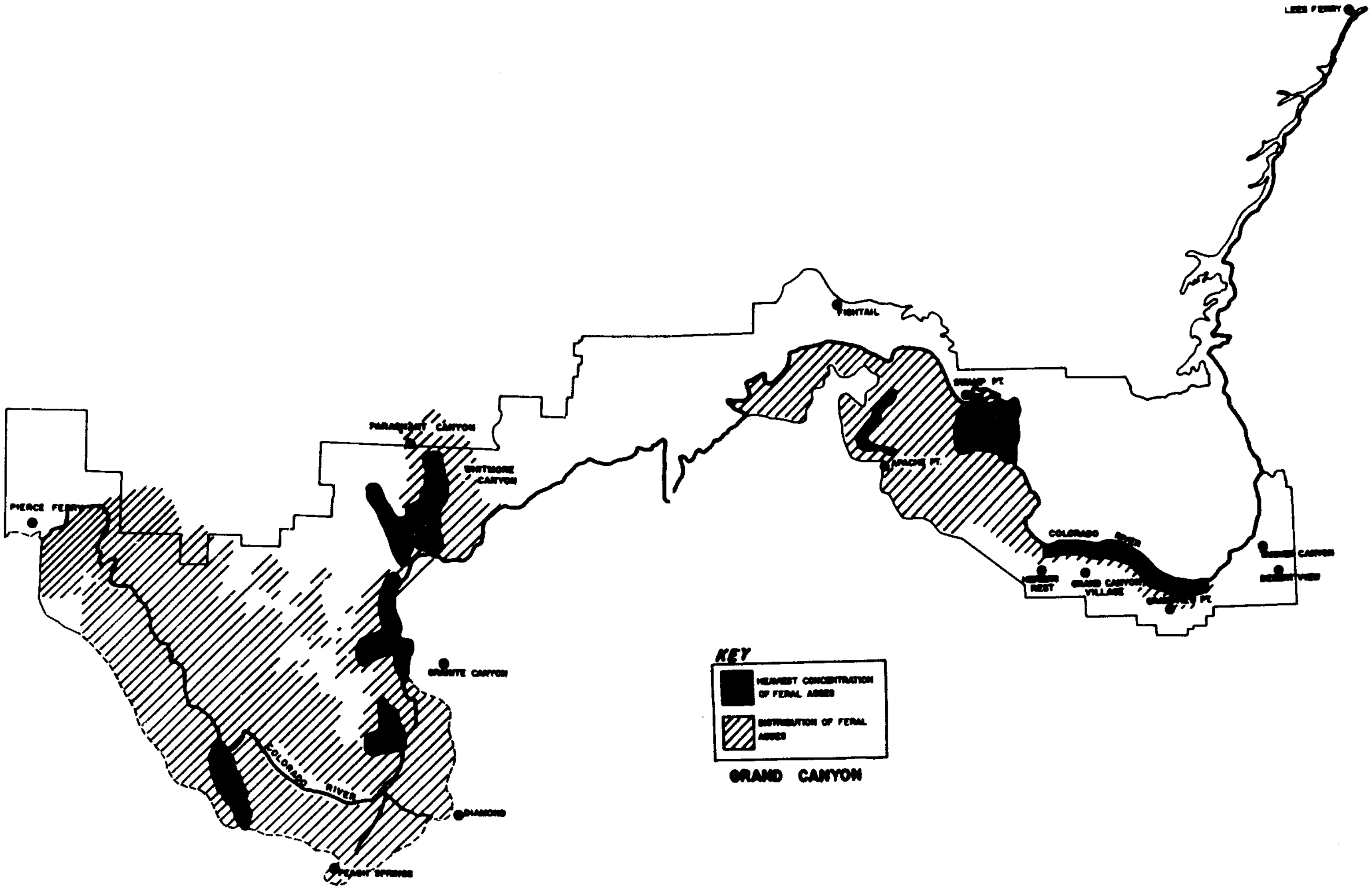

Figure IX-1.--Distribution of feral asses in Grand Canyon.

CHAPTER IX

DISTRIBUTION OF FERAL ASSES

Philip L. Shoemaker

INTRODUCTION

Because of the limited work done on populations and distributions of feral asses in the Grand Canyon, the effectiveness of past control measures are not known. The objectives of this survey were to delineate areas occupied by feral asses and to locate areas of highest concentration.

STUDY AREA

Grand Canyon National Park encompasses approximately 1 million acres of Coconino and Mohave Counties in northern Arizona. Elevation ranges from 9,125 feet on the Kaibab Plateau, on the north side of the river to 960 feet at the head of Lake Mead.

Vegetation ranges from spruce, fir, and ponderosa pine forests on the Kaibab Plateau to the desert scrub on the floor of the canyon (Lowe and Brown, 1973).

Precipitation ranges from 25 inches on the Kaibab Plateau to 10 inches in the bottom of the canyon (Green and Sellers, 1964).

The park has very few roads, all of which are on the rims, and a trail system which encompasses less than one-quarter of the park. The rest of the canyon is accessible only by aircraft or by boat (along the river).

METHODS AND PROCEDURES

During the initial stages of the survey, Park Service records, consisting of years of feral ass observation cards, were sorted and the sightings plotted on maps. Since most of the observations were made on inner canyon trails, the survey was begun by hiking the trails. Clear Creek, Tanner, Red Canyon, Grand View, Kaibab, Bright Angel, Hermit, Bass, and Tonto trails were hiked. All accessible side canyons along these trails were explored and feral ass sitings plotted on maps.

Because of the size and inaccessibility of the rest of the canyon, aircraft were the most feasible means of surveying. The high cost of helicopters excluded them from the project and fixed-wing aircraft were used instead. Cessna 150 and 172 type aircraft were used because of their low operating costs, slow airspeeds and because their high wing design allowed excellent air to ground visibility.

Nine flights were made from April through August 1975. All flights were made during the mornings because of the extremely hazardous flying conditions prevailing during the afternoons. Flight elevations varied from 200 feet to 800 feet above the river and 100 feet to 500 feet above the plateaus, depending upon terrain. Side canyons were examined as far up as terrain permitted.

Two flights were made from Kingman, Arizona, and included only the canyon from mile 190.0 to Lake Mead. Four flights were made from Grand Canyon, Arizona, and included only miles 70.0 through 209.0. Three flights were taken from Lees Ferry to Lake Mead encompassing the entire National Park.

RESULTS AND DISCUSSION

After the first flight, it became apparent that the rugged terrain would preclude an accurate aerial survey of feral ass numbers by fixed-wing aircraft. During the first flight, covering a 90 mile area reported to be heavily infested with feral asses, only 24 asses were counted. However, even from the air, extensive trail networks, dust baths, defecatoria and vegetation damage were readily seen and indicated much higher populations of asses.

In 209 Mile Canyon, an area of extensive feral ass damage, no asses were seen. However, a boating party had reported 15 asses there a few days before (MNA boat trip 1975).

In seven flights over a 12 mile section of the Tonto trail, no asses were noted. However, a survey on foot in the interim counted 34 feral asses inhabiting the same area.

The aerial surveys did, however, accurately indicate areas of feral ass habitation. In canyons with known resident ass populations of only 2 or 3, trails and dust baths were visible from the air. The areas where asses were consistently seen were covered with networks of trails and dust baths visible from over a thousand feet in elevation. Defecatoria and extensive vegetation damage were observed at lower flights over these same areas.

The areas occupied by feral asses in the Grand Canyon are from Tanner Canyon to Crystal Creek on the south side of the river. From Crystal Creek to Tapeats Creek, asses inhabit both sides of the river. This area between Crystal Creek and Tapeats Creek is the only area where feral asses appear above the Redwall of the Canyon in any numbers. Havasupai Point and Pasture Wash on the South Rim have resident ass populations. On the north side of the river, asses occasionally go above the Redwall on Point Sublime and Swamp Point.

From Tapeats Creek to Havasupai Creek, asses inhabit only the south side of the river. From Whitmore Canyon to 220 Mile Canyon, asses occur on the north side of the river. From 215.0 mile to Lake Mead, asses inhabit the south side of the river.

Areas of highest feral ass densities appear to be from Red Canyon to Hermit Canyon on the south side of the river, The Shinumo Amphitheater, Parashant Canyon to 220 Mile Canyon on the north side of the river, and mile 215.0 to Bridge Canyon on the south side of the river.

The area from mile 215.0 to Lake Mead is part of the Hualapai Indian Reservation and is not included in Grand Canyon National Park. However, this area appears to contain extremely large populations of feral asses.

SUMMARY

Feral asses have existed in the Grand Canyon since the early 1900's. Because of the immensity of the canyon and the inaccessibility of the asses' habitat, their distribution in the canyon has not been known.

By low level fixed wing aircraft flights and extensive cross-country hiking in the canyon, the distribution of feral asses has been surveyed and mapped (see Figure IX-1).

These data can be used to set up study areas and gather quantitative data on feral ass populations, home range, and if and what damage is being done to native vegetation and to native populations of animals.

Studies of this type will give National Park Service Resource Managers much needed data on which to base management policies.

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CHAPTER X

FERAL ASSES ON PUBLIC LANDS: AN ANALYSIS OF BIOTIC IMPACT

Steven W. Carothers

INTRODUCTION

The feral ass, or "wild burro," (*Equus asinus*), a native of northeastern Africa, was introduced into North America in the sixteenth century by Spanish explorers. Their value as "beasts of burden" had been recognized as early as 3400 B.C. in Egypt and Mesopotamia (Peake, 1933 and Antonius, 1937; fide McKnight, 1958) and they are still used as such in many portions of the world. Although the feral ass has been in North America since the sixteenth century, it has been reasoned (McKnight, 1958) that the species did not become feral in the southwestern United States until sometime during the nineteenth century. Prior to this, the animal was much too valuable to both Indians and Anglos as a work animal, and possibly food, to be allowed to become feral. It was only after the great impetus of mineral exploration subsided and the settlement of the region ensued that some animals were released, or escaped, and feralization began. By the end of the nineteenth century, the feral ass had become established in many isolated areas of the Southwest. Since their feralization, they have been credited with a considerable amount of habitat destruction resulting in alledgedly depriving native animals of essential food and water. In many areas where the feral ass has become established, it has done so at the expense of the native desert bighorn sheep (*Ovis canadensis*), an animal whose numbers have been severely reduced in the Southwest (Russo, 1956; Dixon and Sumner, 1939; Ferry, 1955; Laycock, 1974). Also, in a recent analysis of the problem in New Mexico, Koehler (1974) has found evidence that the feral ass directly competes with the native mule deer on certain ranges.

1/ This paper was presented at the North American Wildlife and Natural Resource Conference, Washington, D. C. With Merle E. Stitt and R. Roy Johnson, both of Grand Canyon National Park.

In a recently completed study on feral ass behavior and ecology in Death Valley, California, an area well known for very high population densities of feral asses, Moehlman (1972) denies noticeable habitat damage by the feral ass by stating... "Contrary to a widely held belief, the burros I observed did not strip the land, foul water holes or endanger other animals." She adds..."Although heavy browsing occurred within a mile of water, my first appraisal of vegetation data indicates [sic] that plants on which burros feed do not suffer severely." Our photographic evidence from Death Valley and the data presented in this paper from our investigations in other areas show that these conclusions are not valid. Blong and Pollard (1968) found that ewes, lambs, and yearling bighorn were concentrated within .75 miles (.46 km) of water during the summer of 1965. Denniston (1965) working in the River Mountains of southern Nevada found that desert bighorn concentrated within .5 miles (.30 km) of their only water source during the hot, dry months of summer. In a brief review of alleged vegetation destruction by the feral ass, Laycock (1974) writes..."The destruction of vegetation may cut sharply into rodent populations, reducing food for birds of prey, while habitat for such small birds as quail vanishes." Moehlman (1974) further attempted to evaluate the impact of feral asses on small rodents by counting the number of supposedly active rodent burros along transects ranging from high to low ass densities. By using this method, no difference was found in the number of apparently active burrows along these transects. Thus, Moehlman concluded on the basis of this questionable sampling technique that the asses were having little or no effect on the rodent populations.

The objective of our study was to quantitatively and qualitatively evaluate the influence of feral asses on desert riparian habitats in the Grand Canyon, Arizona. Absolute densities of small mammal populations and vegetative composition and structure were investigated. We selected two similar study plots, separated by the Colorado River, with feral asses present on one plot, but not on the other, thereby providing a "control plot" and an "impact plot."

History of the Feral Ass in Grand Canyon

The history of the feral ass' success in the Grand

Canyon may be considered typical of the problem throughout the Southwest. By the early 1920's, many rangers in Grand Canyon National Park were reporting to the Superintendent that for the sake of the native wildlife, drastic control measures were needed to restrict the destructive and rapidly expanding feral ass population. Burros were credited with much of the overgrazed range condition within the Inner Canyon. This is illustrated by the following quote found in an unpublished report written by Chief Ranger J. P. Brooks in 1932: "Overgrazed conditions existed on all areas ranged over by burros. In many places herbage growth was cropped to the roots and some species of shrubbery were totally destroyed. Soil erosion was greater in burro infested areas..."

From 1924 to 1931, a "burro hunt" was conducted in Grand Canyon National Park. The animals were shot with high powered rifles and left to decompose. During this 7 year period, 1,467 feral asses were killed. It was believed that the burro population in Grand Canyon National Park had been reduced to possibly 50 to 75 head, thus, Park Biologists were confident that no more "burro hunts" would be necessary. Yet, between 1932 and 1956, an additional 370 animals were removed. Between 1956 and 1968, 771 more were destroyed with an additional 252 having been captured and taken out of the park. This represents a total removal of 2,860 feral asses from the park in the 45 year period from 1924 to 1969. No control has been attempted since 1969. One of the main reasons for the lack of control efforts has been the negative public sentiment engendered by the "burro hunts" of the mid and late 1969's. This public sentiment, largely initiated by articles written by assinophiles (burro lovers) was quite effective in pushing through protective legislation for wild horses and burros. An example of the severity of public hysteria with which land managers must deal may be found in the text of an article by Weight and Weight (1953): "From time beyond memory, the humble, gentle burro has been man's uncomplaining servant and the playmate of his children. There is a legend that because he carried Mary to Bethlehem and Jesus along the desert trails of Palestine, he was given the mark of the Cross--which you can see upon his back and shoulders." An accompanying photo of a dead burro bears the caption, "Sportsmen, satisfied with the thrill of shooting a friendly burro at point-blank range, often do not even carry out the pretense of hunting for meat, but leave the body as it fell.

This burro was shot and left in Great Falls Canyon, not far from where the little colts, above, were found."

In the past, little quantitative data has existed to be used by those who suspected or knew of the environmental havoc that would be wrought by these "starlings" of the mammalian world. Logic and other examples of great ecological damage caused by introduced species, such as rabbits in Australia and red deer in New Zealand, fell way to anthropomorphized sentiments for "man's faithful friend." The result was Public Law 92-195 in 1972, which made killing a feral ass on most lands a felony. Killing bighorn illegally is merely a misdemeanor. We wish here to present quantitative and qualitative data on the environmental hazards wrought by wild burros and other information which raises questions concerning the wisdom of this law if not indeed its legality. It may very likely be that Public Law 92-195 is in conflict with the National Environmental Protection Act of 1969 (Public Law 91-190) and the Endangered Species Act of 1973 (Public Law 93-205).

METHODS

The duration of our field studies was from 1 March 1974 through 31 January 1975. Both study plots receives identical quantitative and qualitative vegetational and mammalian analyses. Vegetation was sampled by means of the line-intercept transects and 50 point-quarters stations were censused per study area. Percentage infestation of mistletoe (Phoradendron californicus) was measured by absolute counts of parasitized trees and shrubs on each study area. The vegetation data presented herein are a condensation of our field data collected during May, June, and August 1974.

For mammal censusing, each plot was sampled with a 10 by 12, 5.3 acres (2.2 ha.) grid of Sherman live traps placed at 50 feet (ca. 15 m) intervals. These traps were baited with a rolled oat/scratch grain mixture. Traps were set for four consecutive nights at 4:00 p.m. during March, May, June, November, 1974, and January 1975. They were checked once each day at 7:00 a.m. The following data were recorded: species and individual identification, trap number, sex, reproductive condition, weight (0.1 gram), and age class. Females were classed according to obvious signs of pregnancy, lactation, or vulvar condition. Age classes were determined on the basis of adult or immature pelage. All animals were toe clipped for individual identification.

The density of each species was estimated separately by a modification of the Lincoln Index (Bailey, 1952). The mammal and plant species diversity of each study area was determined by using the diversity index, H' (MacArthur and MacArthur, 1961).

DESCRIPTION OF STUDY AREAS

The sites selected for this investigation are located within the lower reaches of the Grand Canyon in the Mohave desertscrub vegetative community (Lowe and Brown, 1973). The impact plot, 209 Mile Canyon, is on the west side (right) of the Colorado River and is inhabited by a small herd (8 to 15 individuals) of feral asses. The control plot, Granite Park, is directly opposite 209 Mile Canyon and shows no evidence of occupation by feral asses. Both study plots are 5.3 acres (2.2 ha.) in size and include both desertscrub and riparian habitats on the alluvial fans of the respective drainages.

The riparian zone of the Colorado River in this section of the Grand Canyon is typified by co-linearly arranged belts of mesic to xeric vegetation. In addition, both study plots are fronted by sand and gravel beaches of river deposit origin. Elevations range from approximately 1,503 feet (458 m) at the river's edge to 1,601 (488 m) on the upper terraces above the historic high water line (Dolan et al., 1974).

Both plots show more similarities in gross vegetational composition and structure than differences. An east-west orientation, equal proximity to water and the relatively flat topography of the sites, tends to equalize the abiotic factors of irradiation, moisture gradients and protection from local weather for both sites.

RESULTS AND DISCUSSION

Vegetation

An analysis of the vegetation on the control plot and impact plot is presented in Table X-1. The control plot supported greater vegetative diversity including an understory of sub-shrubs and a dense carpeting of grasses and forbs (especially plantain). The ground cover and sub-shrub component was virtually absent on the impact area. The control plot contained vegetation

Table X-1. The line-intercept vegetation data summary for the control and impact study areas.

SPECIES		CONTROL				IMPACT			
		Relative Density	Relative Frequency	Relative Dominance	Importance Value	Relative Density	Relative Frequency	Relative Dominance	Importance Value
SHRUBS									
Acacia	1 a.	01.40	8.24	22.02	31.66	14.98	22.31	23.92	61.21
greggii	2 b.	15.69	16.28	26.73	58.70	35.22	32.93	26.00	94.15
Baccharis	a.	---	---	---	---	00.96	01.65	03.00	05.61
sergilloides	b.	---	---	---	---	02.27	02.44	03.26	07.97
Brickellia	a.	---	---	---	---	02.90	04.96	01.68	09.54
longifolia	b.	---	---	---	---	06.81	07.32	01.83	15.97
Larrea	a.	01.40	09.41	13.[illegible]4	23.95	03.69	05.30	02.47	09.66
tridentata	b.	15.69	18.61	15.94	50.24	04.54	04.87	02.68	12.09
Lycium	a.	---	---	---	---	00.48	00.83	00.24	01.55
pallidum	b.	---	---	---	---	01.14	01.22	00.26	02.62
Prosopis	a.	05.43	32.94	44.15	82.51	21.26	34.70	60.65	116.62
juliflora	b.	60.78	61.63	53.59	176.00	50.50	51.22	65.95	167.17
Sueda	a.	00.70	01.76	03.07	05.53	---	---	---	---
torreyana	b.	07.84	03.49	03.73	15.06	---	---	---	---
SUB-SHRUBS									
Chaenactis	a.	00.52	02.35	00.18	03.05	---	---	---	---
fremontii	b.	26.09	26.65	08.28	61.02	---	---	---	---
Cryptantha	a.	00.79	02.35	00.18	03.32	---	---	---	---
spp.	b.	39.13	26.50	08.28	74.06	---	---	---	---
Dyssodia	a.	---	---	---	---	00.96	01.65	00.15	02.86
pentachaeta	b.	---	---	---	---	11.76	13.32	03.47	28.55
Encelia	a.	00.09	00.59	00.25	00.93	03.86	04.96	03.33	12.15
farinosa	b.	04.35	06.68	11.59	22.62	47.06	40.03	78.87	165.96

Table X-1.--cont.

Ephedra	a.	---	---	---	---	00.96	01.65	00.12	02.73
spp.	b.	---	---	---	---	11.76	13.32	02.84	27.92
Lepidium	a.	00.44	02.35	00.48	03.27	---	---	---	---
montana	b.	21.74	26.65	21.85	70.24	---	---	---	---
Opuntia	a.	---	---	---	---	00.48	00.83	00.29	01.60
spp.	b.	---	---	---	---	05.88	06.69	06.94	19.51
Porphyllum	a.	00.09	00.59	01.07	01.75	01.93	00.33	03.30	05.56
gracile	b.	04.35	06.68	49.34	60.37	23.53	07.89	26.63	58.05
Sphaeralcea	a.	00.09	00.59	00.01	00.69	---	---	---	---
fendleri	b.	04.35	06.68	00.66	11.69	---	---	---	---
GRASSES									
Bromus [3]	a.	43.13	28.24	07.85	79.22	45.41	20.35	00.85	66.61
rubens	b.	48.22	72.73	52.89	173.84	95.92	85.00	90.14	271.06
Festuca	a.	00.87	00.59	00.09	01.55	01.93	[illegible].48	00.09	04.50
spp.	b.	00.99	01.52	00.58	03.09	04.08	15.00	09.86	28.94
Plantago	a.	20.56	04.71	04.01	29.28	---	---	---	---
spp.	b.	23.18	12.12	22.95	58.25	---	---	---	---
Sporobolus	a.	24.50	05.29	03.50	33.29	---	---	---	---
contractus	b.	27.61	13.63	23.58	64.82	---	---	---	---

1 Data summary comparing density, frequency and dominance of all species in cat-claw/mesquite area.

2 Data summary comparing density, frequency and dominance only between species of similar strata, i.e., shrubs, sub-shrubs and graminoids.

3 Exotic weed species.

cover on approximately 80 percent of the total transect area surveyed compared to 20 percent vegetation cover on the impact plot. The number of species found on the control area was 30 percent higher than that on the impact area.

The mean area (m^2) occupied by each individual cat-claw or mesquite on the control plot was $27.9m^2$ per plant, while the same species on the opposite side of the river at the impact plot was not as large, occupying only $20.7m^2$ per plant. Also, there was a higher infestation of mistletoe (*Phoradendron californicus*) on the impact plot, with 16.5 percent of all cat-claw/mesquite (*Acacia gregii/Prosopis juliflora*) being infested with this parasite as compared to only 5.4 percent of the same species parasitized on the control plot. Cat-claw and mesquite shrubs on the impact study area had been heavily browsed by asses. The mistletoe infestation may be correlated with over-browsing, but a definite conclusion cannot be drawn without further study.

There was no significant difference in total species diversity from one plot to the next, however, the control plot showed a richer subshurb and grass component (H' = 1.60042 and .821670) than the impact plot (H' = 1.28478 and .422710).

Small Mammals

The results of the small mammal population censuses are presented in Table X-2. The most striking difference between the populations on the two study areas is dramatically demonstrated by comparing the average absolute mammal density of both plots for the entire sampling period. The control plot has an average density of 128 mammals/acre (51.8/ha.), whereas the impact plot contains only 32.6 mammals/acre (13.2/ha.). It is also important to note that the species composition is different between the two study areas. The mammalian species diversity indices (H') on the control plot and the impact plot are .78652 and .69022 respectively. The greater species diversity on the control plot is also complemented by a greater evenness of species distribution (J') (.56736) than that found on the impact plot (.42886).

The total absolute densities of the small mammal populations on both plots were higher at the onset of

Table X-2. Small mammal population densities on the two study areas.

CONTROL

Species	Absolute Density (per hectare)						Relative Density (percent)						
	Mar	May	Jun	Aug	Nov	Jan	Mar	May	Jun	Aug	Nov	Jan	$\overline{X}$
Peromyscus eremicus	53.5	35.3	43.2	27.7	11.4	11.4	60.0	65.0	64.0	45.0	56.0	65.0	59.2
Peromyscus boylii	00.3	00.0	00.3	00.3	00.0	00.0	00.3	00.0	00.3	----	00.0	00.0	00.1
Perognathus intermedius	34.3	18.7	23.5	31.3	08.6	06.0	39.0	34.0	35.0	51.0	42.0	34.0	39.2
Neotoma albigula	00.8	00.5	00.8	02.5	00.3	00.2	00.7	01.0	00.7	04.0	02.0	01.0	01.5
TOTAL	88.9	54.5	67.8	61.8	20.3	17.6	100.0	100.0	100.0		100.0	100.0	100.0

Average total Absolute Density March 1974 to January 1975 = 51.8 mammals per hectare.

IMPACT

Species	Mar	May	Jun	Aug	Nov	Jan	Mar	May	Jun	Aug	Nov	Jan	$\overline{X}$
Peromyscus eremicus	30.4	09.4	08.2	09.1	08.7	02.9	97.0	94.0	76.0	66.0	85.0	67.0	80.0
Peromyscus crinitus	00.0	00.3	02.3	04.4	01.4	01.4	00.0	03.0	23.0	32.0	15.0	33.0	17.5
Peromyscus boyleii	00.3	00.0	00.0	00.0	00.0	00.0	01.0	00.0	00.0	00.0	00.0	00.0	00.2
Perognathus formosus	00.3	00.3	00.3	00.3	00.0	00.0	01.0	03.0	02.0	02.0	00.0	00.0	01.3
Neotoma lepida	00.3	00.0	00.0	00.0	00.0	00.0	01.0	00.0	00.0	00.0	00.0	00.0	00.2
TOTAL	31.3	10.0	10.8	13.8	09.1	04.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Average total Absoluate Density, March 1974 to January 1975 = 13.2 mammals per hectare.

this study (March 1974) than they were at its termination (January 1975). The fluctuations found in these densities (a decline of 77.3/acre (31.3/ha.) to 10.6/acre (4.3/ha.) on the impact plot and 219.7/acre (98.9/ha.) to 43.5/acre (17.6/ha.) on the control plot) are consistent for both plots and may be reflecting "normal" population fluctuations. Nevertheless, in all trapping periods, the density and diversity of the small mammal populations on the control plot were substantially higher than those across the river at the impact plot.

In addition to the total population densities, another striking difference in the rodent communities of the two study areas is in the relative species composition (Table X-2). On the impact area, the density of the cactus mouse (Peromyscus eremicus) accounted for an average of 80.8 percent of the entire rodent community, whereas on the control plot, this species accounted for an average of 59.2 percent of the population. The only other species which contributed significantly to the impact plot population was the canyon mouse (Peromyscus crinitus), averaging 17.5 percent of the total population. The canyon mouse was never encountered on the control plot. Reasons for this are a direct reflection of the habitat requirements of this species and the state of the habitat on each study area. The canyon mouse prefers rocky, near barren areas that are usually devoid of vegetation and may be found commonly throughout the Grand Canyon on upper talus slopes and rocky outcrops. Clearly, the alteration of the impact by feral asses has permitted a population of canyon mice to become established in an area not normally inhabited by this species.

The distribution and abundance of heteromyid rodents on the two study areas also further demonstrates the detrimental effects of feral asses. On the impact plot, only a few heteromyids, the long-tailed pocket mouse (Perognathus formosus), were captured, while the control contained a relatively large and stable population of the rock pocket mouse (Perognathus intermedius) (Table X-2). The rock pocket mouse made up an average of 39.2 percent of the rodent community on the control plot while the long-tailed pocket mouse constitued an average of only 1.3 percent of the population density on the impact plot. In the Grand Canyon, we have found that the long-tailed pocket mouse is exclusively restricted to the north and west banks of the Colorado River and the rock pocket mouse is restricted to the south and east banks. However, where suitable habitat exists, there is no measurable difference in the population densities of these two species. On the two study areas, differences in the population densities of these heteromyid rodents were directly related to their dietary requirements and the availability of food. The primary food of both species of Perognathus probably consists of seeds, especially the seeds of forbs (Reichman, 1975). As mentioned above (see Table X-1) the forb strata of the impacted area has been thoroughly decimated through grazing and trampling by feral asses, thus rendering the habitat of this study area inhospitable to a population of Perognathus.

SUMMARY

The results of this investigation demonstrate conclusively that the feral ass (Equus asinus) has a negative effect on the natural ecosystem of the lower reaches of the Grand Canyon. The principal impact of the feral ass is habitat destruction through grazing and trampling.

On the study area where feral asses occur the vegetation cover and rodent populations were significantly reduced when compared to the study area where feral asses were absent. On the control plot, 28 species of vascular plants were found compared to 19 on the impact plot. The total vegetation cover on the control plot was 80 percent, compared to 20 percent on the impact plot. The mean area (m^2) occupied by each individual cat-claw or mesquite shrub was $27.9m^2$ on the control plot and $20.7m^2$ on the impact plot.

The mammal species diversity (H') was higher on the control plot (.78652) than it was on the impact plot (.69022). In addition, the average absolute density of small mammals from March 1974 to January 1975 on the control plot was 128 mammals/ acre (51.8/ha.), approximately four times the 32.6/acre (13.2/ ha.) found on the impact plot. Thus, differences between the two areas in mammalian species composition and diversity were attributed to the depauperate flora, particularly the forbs and grasses, on the 209 Mile Canyon impact area.

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Table XI-I.--Boating use between Lees Ferry and Diamond Creek.

Year	Total Users
1955	70
1956	55
1957	135
1958	80
1959	120
1960	205
1961	255
1962	372
1963*	6
1964*	38
1965	547
1966	1067
1967	2099
1968	3609
1969	6019
1970	9935
1971	10885
1972+	16432
1973	15219
1974	14253
1975	14305

*Lake Powel Filling
+User-day limit set by NPS

CHAPTER XI

CAMPSITE USAGE AND IMPACT

Stewart W. Aitchison

INTRODUCTION

To determine the possible interrelationships between the river runners and the riparian biota certain data concerning total use, types of impact, and biological uniqueness or sensitivity of campsites (termed Biotic Resource Rating) had to be collected.

METHODS

The National Park Service keeps records of the total number of people boating from Lees Ferry to Diamond Creek (Table XI-1). However, these data do not afford pertinent information as to how many people were utilizing specific campsites or the location of these campsites. A visitor usage form (Figure XI-1) was devised and made available to the various commercial river running outfitters and to private trips for the 1974 and 1975 seasons (1976 data currently being collected). These forms were printed as postpaid postcards to facilitate return of them to the investigators. They asked for the number of passengers and crew, beginning date of the trip, camp locations, whether or not a campfire was made, and whether or not the manditorially carried portable toilet or equivalent (see NPS River Regulations, 1974) was dumped (i.e., sewage buried).

Campsite evaluation forms were constructed (Figure XI-2) and distributed to the various biology investigators. The forms helped in delineating the various observable types of human impact and in subjectively quantifying overall human impact for a specific location. Additionally, the biotic uniqueness or sensitivity of each campsite was rated subjectively (see Appendix XI-1 for instructions to this form).

All the above information was computerized for easy retrival and tabulation.

RESULTS AND DISCUSSION

Although initial return of visitor usage forms was

BUSINESS REPLY MAIL

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Department of Biology
Museum of Northern Arizona
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Flagstaff, Arizona 86001

VISITOR USAGE FORM 1

Beginning date Month ...., 197

Total Number of Passengers and Crew

FORM No. GRCA-NS 2 (10/73)
OMB No. 42 R1689
APPROVAL EXPIRES 12 31 76

DAY OF TRIP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
RIVER MILE OF CAMP																								
SIDE OF RIVER CAMPED ON N(North) S (South)																								
Wood or Charcoal Campfire Y (Yes) or N (No)																								
Porta Potty: Dumped at camp Y (Yes) or N (No)																								
Porta Potty: Depth of Burial (in feet)																								
Porta Potty: A (above) or B (below) high water mark																								

COMMENTS

Your replies and any additional comments will be strictly confidential. Your cooperation is of great value and is greatly appreciated.

THE BIOLOGY DEPARTMENT OF THE MUSEUM OF NORTHERN ARIZONA

Figure XI-1.--Visitor Usage Form

GRAND CANYON ECOLOGICAL SURVEY 1974
CAMPSITE EVALUATION SHEET - 2

Observer: ______________________________

Day	Month	Year	River mile	Side	Profession*

*Profession code:

Biologist	1
Boatman	2
Student	3
Other Scientist	4
Tourist	5

PARAMETER:	RATING:	COMMENTS:
MAN'S IMPACT		
litter		
trampling		
rock moving		
campfire		
wildlife		
human waste		
TOTAL:		
WILDLIFE AND HABITAT		
habitats		
special areas		
unique combinations		
modifications		
values and needs		
TOTAL:		

Figure XI-2.--Campsite Evaluation Form

poor, additional cards were received in the fall of 1974. A total of 183 cards (representing, of course, 183 trips) were completed and returned for 1974. This accounted for 21.1 percent of the total user-days.

In 1975, 196 cards were completed and returned, a representation of 22.6 percent of the total 1975 user-days.

In 1974, 395 different campsites were reported between Lees Ferry, river mile 0.0, and Pierce Ferry, river mile 280.0. Although some of these campsites are no doubt duplicates due to inaccuracies when filling out the forms, this number does indicate considerably more campsites than generally believed. For example, less than 200 have been noted by investigators using aerial photo-interpretation techniques (Yates Borden, pers. comm.).

In 1975, about 350 campsites were used. The visitor usage data is summarized in Tables XI-2, XI-3, XI-4. Copies of the complete computer print-out are on file with the National Park Service at Grand Canyon National Park and with Museum of Northern Arizona at Flagstaff.

Four hundred and twenty-five campsite evaluation forms were completed. Thirty-three campsites were evaluated in 1974 and 8 additional ones in 1975. These 41 sites along with their ratings are summarized in Table XI-5. Through the campsite evaluations forms, comments from river users and observations by the Museum of Northern Arizona investigators, the following types of human impact were revealed:

1. Fire
2. Litter
3. Trampling of vegetation
4. Porta-potty sewage disposal
5. Noise
6. River level fluctuations
7. Moving of naturally occurring objects
8. People presence

All of these types overlap to some extent and also produce direct and indirect effects of either long or short-term duration. Further discussion of the

Table XI-2.--Twenty campsite with the most usage.

1974				1975			
River Mile	Reported # of People	Projected # of People	% of Total of People	River Mile	Reported # of People	Projected # of People	% of Total of People
19.0 L	380	1799	1.62	19.0 L	318	1407	1.24
41.0 R	274	1297	1.17	19.5 L	276	1221	1.08
72.0 R	399	1889	1.70	20.0 L	383	1695	1.50
81.0 L	343	1624	1.46	22.0 L	314	1390	1.23
93.0 L	259	1226	1.10	29.0 L	329	1456	1.29
110.0 R	276	1307	1.18	31.0 R	277	1226	1.08
114.0 R	376	1780	1.60	50.0 R	330	1460	1.29
120.0 L	305	1444	1.30	66.0 L	277	1226	1.08
132.0 R	279	1321	1.19	72.0 R	610	2699	2.38
133.0 R	417	1974	1.78	75.0 L	358	1584	1.40
136.0 L	360	1704	1.53	81.0 L	355	1571	1.39
137.0 L	585	2769	2.49	109.0 R	310	1372	1.21
148.0 L	287	1359	1.22	114.0 R	354	1567	1.38
166.0 L	364	1723	1.55	136.0 L	888	3930	3.47
168.0 R	326	1543	1.39	137.0 L	764	3381	2.99
212.0 L	259	1266	1.10	168.0 R	428	1894	1.67
219.0 R	260	1231	1.11	178.0 L	273	1208	1.07
222.0 L	321	1519	1.37	179.0 L	426	1885	1.66
279.0 L	382	1808	1.63	209.0 L	371	1642	1.45
TOTAL	23,463	111,068	28.65		25,586	113,228	30.95

Table XI-3.--Twenty Campsites with the Most Campfires

1974		1975	
River Mile	Reported Number	River Mile	Reported Number
18.0 L	11	19.0 L	11
19.0 L	17	22.0 L	12
20.0 L	14	29.0 L	14
41.0 R	13	50.0 R	13
72.0 R	17	66.0 L	11
81.0 L	12	71.0 L	9
93.0 L	11	72.0 R	18
110.0 R	12	75.0 L	11
114.0 R	17	81.0 L	14
120.0 L	11	108.0 R	14
132.0 R	12	114.0 R	10
133.0 R	14	136.0 L	29
136.0 L	19	137.0 L	23
137.0 L	27	148.0 L	10
152.0 R	13	168.0 R	17
166.0 L	14	178.0 L	10
168.0 R	14	186.0 L	10
212.0 L	13	209.0 L	14
219.0 R	12	219.0 R	10
279.0 L	13	220.0 R	12

Table XI-4.--Campsites with the most porta-potty dumps

1974 River Mile	1974 Dumps	1975 River Mile	1975 Dumps
19.0 L	11	19.0 L	15
20.0 L	13	20.0 L	14
23.0 L	9	22.0 L	11
29.0 L	13	29.0 L	19
41.0 R	13	31.0 R	13
43.0 L	11	50.0 R	17
50.0 R	9	52.0 R	11
53.0 R	11	53.0 R	12
72.0 R	14	71.0 L	11
81.0 L	15	72.0 R	24
108.0 R	12	75.0 L	15
114.0 R	19	81.0 L	14
132.0 R	17	93.0 L	11
136.0 L	27	108.0 R	18
137.0 L	30	109.0 R	13
164.0 R	11	110.0 R	12
166.0 L	11	114.0 R	18
168.0 R	19	132.0 R	11
209.0 L	10	136.0 L	42
		137.0 L	34
		168.0 R	18
		178.0 L	11
		179.0 L	12
		209.0 L	20
		220.0 R	11

Table XI-5.--Summary of campsite evaluations.

River Mile	Side	Human Impact* 1974	Human Impact* 1975	Biotic Resource Rating** 1974	Biotic Resource Rating** 1975	# of Campers+ 1974	# of Campers+ 1975
17.0	R	11.2		11.5		232	
17.5	L	16.0		27.0			
18.0	L	15.6	16.0	15.9		994	1407
29.0	L		14.0				1456
31.5	R	15.3		19.7		147	
33.0	L	13.6		13.4		66	
35.0	L	20.0		19.0		213	
39.0	R	10.0		10.0			
43.0	L	20.6		22.6		473	
47.0	R		10.0				239
53.0	R	22.7		34.6		1013	
61.0	L	22.6		21.7		133	
64.0	R		9.7				876
65.5	L	18.2		25.7		275	
68.5	L	19.0		34.0		175	
71.0	L	19.8		30.2		951	
72.0	R		10.7				2699
76.5	L	20.0		26.0		232	
84.0	R		8.0				217
87.0	L	15.1		19.4		450	
87.5	R	21.8		27.3			
103.0	R		7.0				
104.0	R	15.4		20.1		658	
114.0	R	14.3		15.2		1780	
120.0	R		9.2				84
122.0	R	17.7		25.8		1046	
123.0	L	12.0		20.3		601	
133.5	R	12.8		17.9			
134.0	R	20.2		35.3		601	
137.0	L	16.4	11.0	15.2		2769	3381

*The numerical rating scale ranged from 10.0 (no impact) to 22.6 (greater impact) and represents a relative and subjective evaluation. (See Work Plan, Contract #CX821040079 for elaboration of the campsite evaluation form instructions. Also, see Appendix XI-1.

**The numerical rating scale ranged from 10.0 (no biotic resources) to 40.2 (greater biotic resources) and represents a relative and subjective evaluation.

+These data from Visitor Usage Forms - 1974 and 1975.

Table XI-5.--cont.

145.5	L		12.0			
164.5	R	15.1		18.0	497	1412
166.0	L	18.7		30.0	1723	
166.5	L	18.3	8.0	17.7	232	752
185.5	R	12.7		22.4		
188.0	R	16.2		23.3	260	
209.0	R	17.0		26.5	57	
209.0	L	20.0		32.8	715	
242.0	L	17.1		21.1	66	

interrelationships of recreationists and the biota will be found in Chapter XII.

Quantification of each type becomes the overriding problem.

Fire

This category includes campfires and also those man-caused fires that burn uncontrolled. Impact ranges from small charcoal piles to entire stands of beach vegetation being consumed in a holocaust. Short-term biological effects may include elimination of actual or potential nest sites, forage sites, and display sites through removal of living or dead vegetation. Large burns may kill or force movement of certain animals and may encourage the introduction of nonnative pioneer species.

Litter

Common litter items include:

1. Paper (namely, toilet paper, feminine napkins, cigarette butts)
2. Food scraps
3. Spilled fluids (e.g., gasoline, oil, lotion, juices from canned food)
4. Clothing
5. Plastic items (e.g., bottles, airmattresses)
6. Glass (bottles)
7. Metal products (e.g., cans, nails, motor parts, pop tops)

Some items may affect vertebrate populations through increasing the available food supply either directly by being eaten or indirectly by producing higher densities of insects. A few litter articles may be used as nesting material (e.g., paper) or may present hazards (e.g., broken glass).

Unfortunately most of the litter is practically indestructible, lasting years before decomposition sets in.

Trampling

A very obvious human impact is trampling of vegetation and disturbance of soil. Some of the riparian ground cover seems to be easily destroyed by a single footstep. Shrubs and trees suffer from being used as tent poles, moorings, and being broken back to form paths. Heavy use of trails can compact the soil to such an extent that vegetation can no longer grow there (Aitchison and Theroux, 1973).[1] Ground nesting vertebrates, particularly lizards, may suffer some nest site destruction from trampling. Rodent burrows may also be disturbed through intensive use of an area by humans.

Porta-potty Dumping

This refers to the problem of disposal of sewage. Since 1971, the NPS has required river parties to carry portable toilets or equivalent for the containerization of human waste. Most of these toilets must be emptied once a day. A hole is dug, the toilet paper is burned in the hole, and the sewage is poured in and covered. At least one outfitter carries a large enough holding tank on the river craft which eliminates the need of disposing sewage within the Canyon.

The impact of waste disposal on beaches includes increase in some insects particularly flies and ants, possible contamination of ground water, smell, and potential health problems. Also, disturbance of soil occurs and occasionally destruction of vegetation by digging the hole.

Noise

Generally manrelated noise in the canyon results from motors. Few studies have been done on the effects of noise on wildlife (Douglas and Johnson, 1972); however, conceivably noise could interfer with certain songs, calls, or territorial displays of birds. It appears that airplane noise may be the predominant type (Schroeder, 1973; Elden Bowman, pers. comm.).

River Level Fluctuation

The most dramatic impact is the controlled fluctuation

1/ Aitchison, S. W. and M. E. Theroux. 1973. Ecology of Oak Creek Canyon, Coconino Co., Arizona. Phase I Report, unpub. ms. for U. S. Forest Service.

of the Colorado River's flow by Glen Canyon Dam. The discharge may vary 30,000 CFS or more in 24 hours. This regulation of water quantity and quality (e.g., the silt load is minimal compared to pre-dam flows) has been a central factor in the establishment of a new riparian vegetation community. This new vegetation is in turn encouraging the proliferation of certain wildlife species. *Tamarix* is associated with a high productivity area and correspondingly an increase in lizard densities. *Tamarix* and *Salix* provide nest sites for Mourning Doves, Lucy's Warblers, Bell's Vireos, etc. Higher densities of small mammals occur in the riparian zone. Also, wildlife diversity is higher in the riparian habitat than adjacent habitats. (See Chapters I and II for further elaboration of the vegetational effects of Glen Canyon Dam.)

Moving of Natural Objects

This category includes rock moving for such purposes as holding down tarps and for making campfire rings. Also included would be removal of dead or living vegetation generally used in campfires. Although this type of impact seems to be minimal, nonetheless, actual or potential nesting sites, foraging sites, and display posts are disturbed and may prove detrimental to some species of wildlife. For instance, Desert Sping Lizards require elevated objects (e.g., rocks) for establishment of a functional social system.

People Presence

Heavy visitation of a particular area may cause stress in certain animals (Dennis S. Tomko, pers. comm.). This happens because the animals that would normally be spread out over a given area are forced to concentrate themselves in order to escape contact with humans. This artificial crowding may also cause behavioral changes. For example, usually territorial species of lizards may be inclined to establish social hierarchies (Brattstrom, 1974).

Specific experiments should now be devised to quantify each of the above types. (Studies concerned with sewage disposal and beach erosion are currently underway.)

STATISTICAL ANALYSIS

No significant correlation was found between the

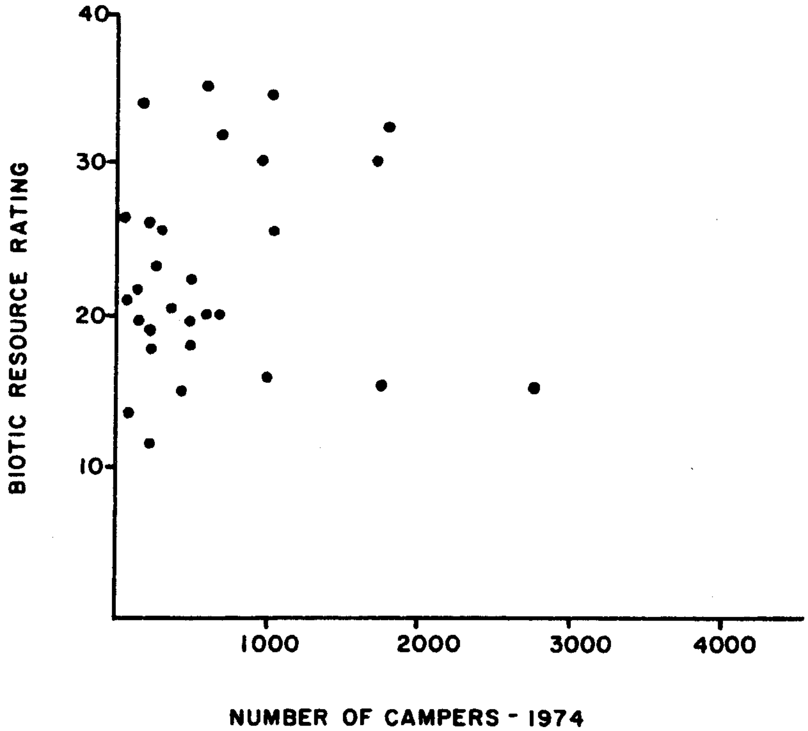

Figure XI-3.--Number of campers versus the biotic resource rating for specific campsites - 1974.

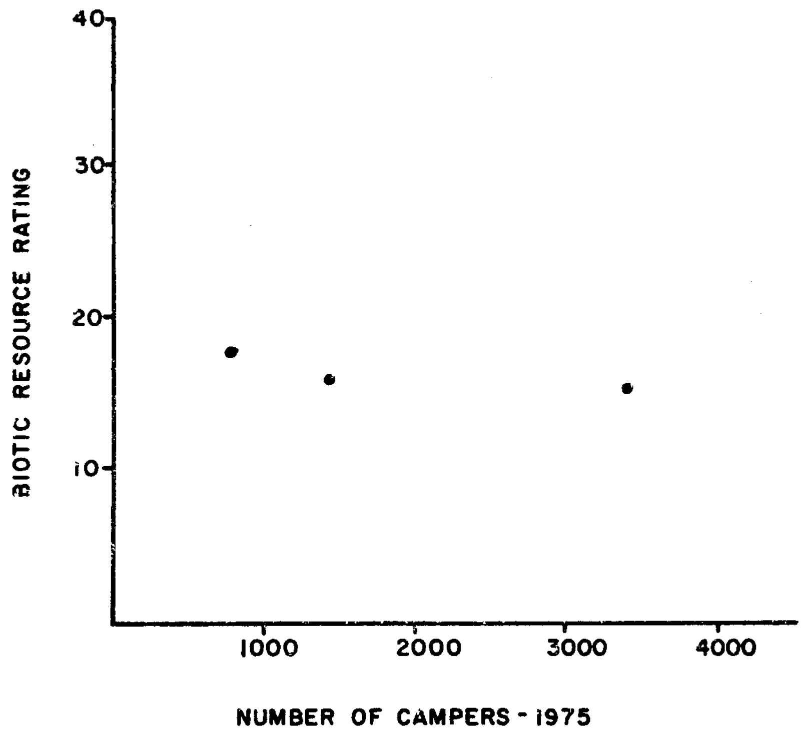

Figure XI-4.--Number of campers versus the biotic resource rating for specific campsites - 1975.

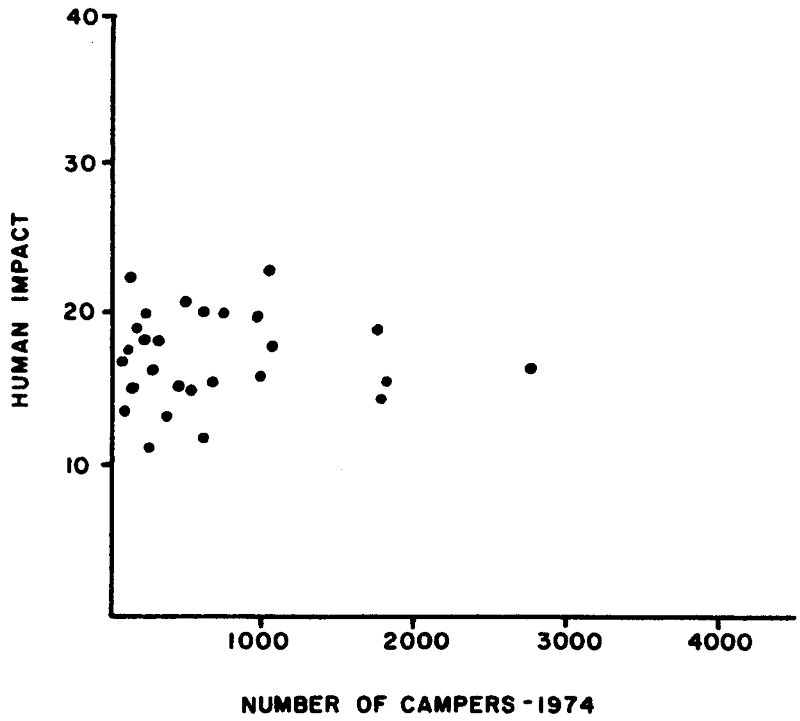

Figure XI-5.--Number of campers versus human impact rating for specific campsites in 1974.

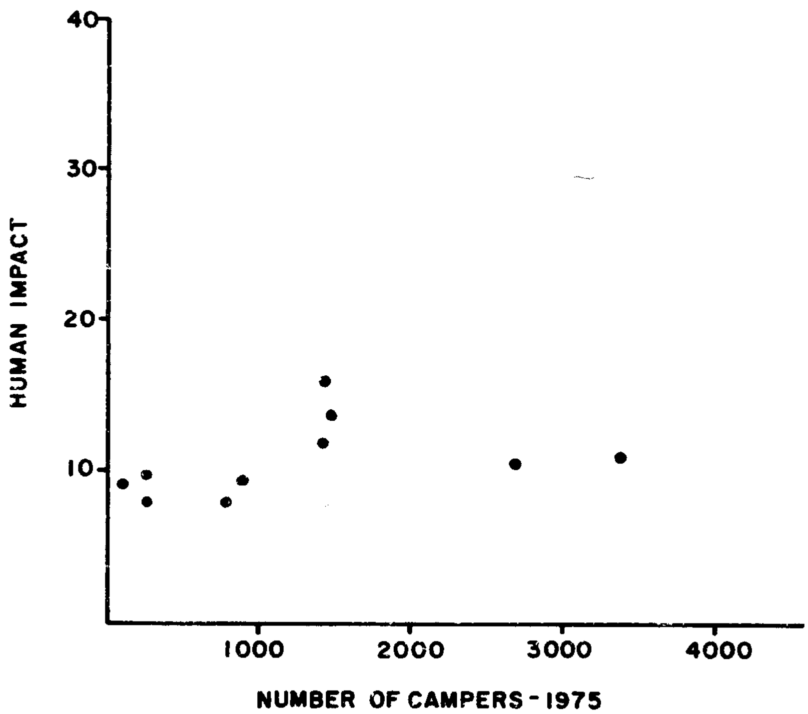

Figure XI-6.--Number of campers versus human impact rating for specific campsites - 1975.

number of campers and biotic resource rating nor between the number of visitors and the total amount of impact (Figure XI-3 through XI-6).

Figures XI-3 and XI-4 may indicate that campsites were not being chosen for their particular fauna and flora. This seems reasonable since campsite location is usually dictated by amount of room for sleeping, good mooring location, shelter, etc.

The lack of correlation between number of campers and impact is more difficult to explain. Perhaps, it is simply too small a sample site.

However, a very good correlation was found between the impact ratings and biotic resource ratings (Figure XI-7). Initially one might expect that as the impact increased the biotic interest would decrease. But just the opposite was revealed. One might be tempted to say this is because the more heavily camped at sites are the more biologically interesting ones; but, we have already seen there appears to be no correlation (Figures XI-3 and XI-4). So, what is happening?

By examining specific campsites low and high on the regression line (Figure XI-7) and reviewing the campsite evaluation forms, several points become clear that solve this apparent paradox. First, those areas that are biologically interesting are also areas easily damaged by human usage. Additionally, a few people may cause as much or more impact as a large group in these areas. (This is supported by Figures XI-5 and XI-6 if we draw a regression line. Although not statistically significant, the hypothetical regression line nonetheless has a slope close to zero for both years.) In other words, if a correlation does exist, it appears that it would indicate small to large groups of people can cause the same amounts of impact.

This suggests then that camping and river running pratices should be closely scrutinized rather than just thinking of human impact in terms of total usage.

SUMMARY

Basic types of human impact upon the Grand Canyon's riparian biota have now been delineated. Quantitative measurement of each type is the next step in eventually

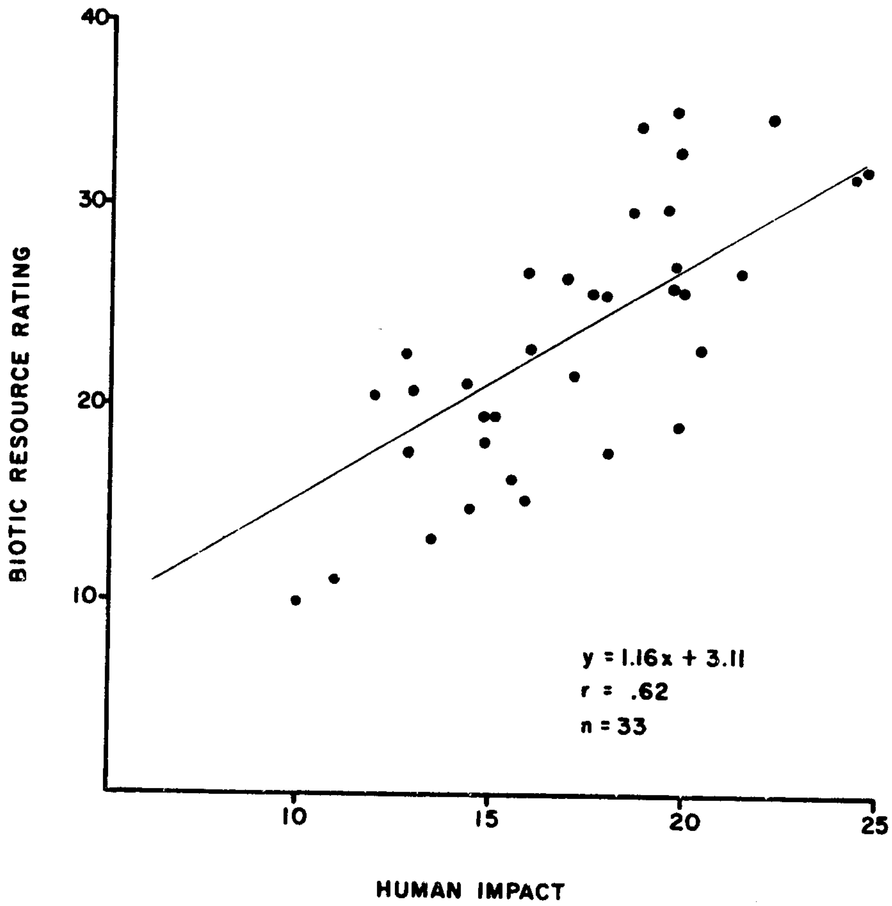

Figure XI-7.--Human impact versus the biotic resource rating for thirty-three campsites.

Table XI-6.--Preliminary list of biologically interesting and/or sensitive areas.

	Name	River Mile	Side
1.	Paria River	1.0	R
2.	---	17.5	L
3.	Vasey's Paradise	31.9	R
4.	Buck Farm	41.0	R
5.	---	43.2	L
6.	Saddle Canyon	47.0	R
7.	Nankoweap	52.0-53.0	R
8.	Little Colorado	61.5	R
9.	Furnace Flats	65.6	L
10.	Tanner Delta	69.0	L
11.	Cardenas Marsh	71.0	L
12.	Unkar Delta	72.5	R
13.	75-Mile Canyon	75.3	L
14.	Red Canyon	76.6	L
15.	Clear Creek	84.0	R
16.	Phantom Ranch	87.5	R
17.	Shinumo Creek	108.6	R
18.	Elve's Chasm	116.5	L
19.	Blacktail Canyon	120.0	R
20.	122 Mile Creek	122.0	R
21.	Stone Creek	132.0	R
22.	Tapeats Creek	133.7	R
23.	Deer Creek	136.2	R
24.	Matkatamiba	147.9	L
25.	Havasu Canyon	156.8	L
26.	National Canyon	166.5	L
27.	Lava Falls	179.5	L
28.	Granite Park	208.6	L
29.	Juniper Seep	215.0	R
30.	Travertine Canyon	229.4	L
31.	Spencer Canyon	246.0	L
32.	Surprise Canyon	248.4	R
33.	Maxson Canyon	252.4	L
34.	Burnt Canyon	259.3	R
35.	Bat Cave	266.4	R
36.	Emery Falls	274.4	L
37.	Grapevine	279.0	L

reaching an "ecological carrying capacity." Of course, social and physical carrying capacties will also have to be considered.

Overall impact does not seem to be mitigated by the total number of people but rather a combination of the sensitivity of the campsite and the specific activities of the campers.

In the Grand Canyon, biologically unique and/or important areas should be carefully monitored for changes due to man's influence. These areas would be places with high densities and/or diversities of plant and animal life and/or provide some kind of unique element required for reproduction and survival of indigenous populations. Although management should emphasize ways to minimize biotic damage, temporary closures may be needed to give these areas a "rest." A preliminary list of biologically interesting or sensitive area can be found in Table XI-6.

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CHAPTER XII

THE INTERRELATIONSHIPS OF MAN AND THE BIOTA

Steven W. Carothers
Stewart W. Aitchison
Dennis S. Tomko

INTRODUCTION

One of the primary objectives of this study was to determine the various kinds of human-related impact on the biota of the riparian zone of the Colorado River. The impact of man on the biota along the Colorado River and its tributaries is represented in two forms: (1) direct impacts of river runners and hikers in heavily used camping areas (see Chapter XI), and (2) the indirect impacts brought about by the recent changes in vegetation downstream from Glen Canyon Dam (see Chapter I).

The previous chapters have dealt with the gathering of baseline data on faunal and floral analysis of the riparian habitat and camper usage (i.e., river runners) of the beach areas. This chapter will discuss specific ecological interrelationships as they apply to human use of the beach resources of the river.

DIRECT IMPACTS OF RIVER RUNNERS AND HIKERS ON HEAVILY USED RIVER CAMPS

Vegetation

The outstanding direct impact man has on the vegetation is through disturbance by trampling. In many areas (e.g., Saddle Canyon, Nankoweap, and lower Havasu Canyon) multiple trails, all with the same ending and beginning place, are maintained simply through large numbers of people trampling the vegetation. In many cases, this condition invites accelerated soil erosion and dramatically changes the flora of these areas (see Chapter I). On the other hand, some beach areas would probably become uncampable if the vegetation were not held in check through this trampling (i.e., general use). Below Diamond Creek, most of the low use camping areas are covered by impenetrable stands of salt cedar.

Insects

Several specific problems with regard to man's impact on insect populations are arising along the Colorado River. Harvester ants (Pogonomyrex californicus), known commonly as red ants, usually occur in low densities along the beach/terrace interface near the river. On many of the heavily used beaches, however, the ant densities are much higher than they are on relatively unused beach areas. Preliminary investigations seem to indicate that this problem is directly related to human activity on these areas (improper organic garbage disposal). Because of their great numbers and painful sting this species represents a minor health hazard (could be a major problem for toxin-sensitive persons) and a definite source of discomfort for the many river runners and hikers affected.

The flesh fly (Sarcophagidae) and blow fly (Calliphoridae) populations also show this increase in density at heavily used camping areas. Both groups are frequently linked with sanitation problems, particularly with regard to fecal and organic waste disposal. These insects could definitely be the source of some fly-vectored health problems.

Reptiles and Amphibians

Direct impacts on these animals are brought about through changes in the available food at the heavily used beach areas. Ants, flies and gnats make up a large portion of lizard diets (see Chapter III). These insects thrive on organic garbage and fecal waste products, and where these insects are present in unusually high densities, there is a corresponding increase in lizard densities.

Many species of lizards utilize the rapidly dwindling supply of driftwood piles for foraging, display and basking areas. This is particularly true of the desert spiny lizard (Sceloporus magister). If the driftwood (particularly that in very large piles) is eventually removed from the Canyon, an important resource to the herpetofauna will be lost. We know of no apparent impacts on the amphibians and snakes. Most outfitters and private parties have adopted the policy of not killing rattlesnakes and this practice should be encouraged.

Birds

In the heavily used camping areas, three species of birds, the Starling, the Common Raven and the House Sparrow, are affected by man's activities.

From Lees Ferry to Lake Mead, at every major campsite, one can usually find at least one pair of semi-domesticated ravens. In the past, river runners have fallen into the habit of leaving organic garbage on the beaches, specifically for the purposes of feeding the wildlife. Our investigations indicate that the only bird species influenced by this practice is the raven. It is amusing to watch this intelligent and highly adaptable species boldly approach within a few feet of the commissary area of river camps and scold the human occupants until they are fed. All indications are that the ravens are in higher densities within the inner gorge than they would be if they were not fed. Feeding animals in a National Park is unlawful and leaving organic garbage on Grand Canyon beaches is against the National Park Service river running regulations.

House Sparrows, an exotic species that is well known for its preference of areas with heavy concentration of humans, are found in at least five areas along the Colorado River and its tributaries. The Phantom Ranch area contains hundreds of these birds, their concentration being centered around the corrals and mule barns. They are also well represented (about 6 pairs each breeding season) at Indian Gardens and again are found most frequently around the mule corral. In the main campground areas along Havasu Creek and the Havasupai Village area this species reaches its highest densities in Grand Canyon riparian habitats. As long as relatively permanent human/domestic livestock habitation of these areas exist, this exotic species will continue to proliferate in these areas.

More alarming, however, is the fact that the House Sparrow has been found for the first time (1976 breeding season) occupying the riparian vegetation on some of the heaviest used beach areas along the river. Our visitor usage forms (see Chapter XI) have indicated that the camp across from Deer Creek, 136.0L, is the heaviest used camp along the river. It is precisely this camp where we first noticed a pair of House Sparrows, giving all indications that they were going to nest in the area. Another heavily used camp, the Granite Park camp, mile 209.0L, has also yielded observations on House Sparrows. To stem an overall invasion of the House

Sparrow in the popular camping areas, it may be necessary to put some of these camps on a rest rotation basis and to eliminate these exotics as they are encountered. The specific factors the House Sparrow keys on before establishing in an area are unknown, there is little doubt, that these factors are somehow associated with man.

Another exotic species, the Starling, has not been observed along the river as of this writing except the Phantom Ranch community and the Havasupai Village. Like the House Sparrow though their presence should be carefully monitored and when possible eliminated.

Mammals

Four species of mammals (skunks, ringtails, rock squirrels and mule deer) show direct influences by man. The mule deer and rock squirrels are not influenced by river runners, but have reached unnaturally high population densities in the Phantom Ranch and Indian Gardens area. These animals are again responding to finding man as a source of food and in this situation are suffering for it. Both the deer and rock squirrels are in poor health and may present a serious health hazard to man.

Along the river, due to organic garbage accumulation and in some cases direct feeding, skunks and ringtails are found in unusually high numbers at heavily used camping areas. The small rodents (particularly ***Peromyscus*** spp. and *Neotoma* spp.) are also present in high densities, but we have found no definite correlation between use of an area and the densities of these rodents.

INDIRECT IMPACTS AS A RESULT OF GLEN CANYON DAM

There have been significant changes in the riparian communities along the river below Glen Canyon Dam since the Dam began functioning in 1963. These changes are discussed in detail in Chapters I and II. For the most part, it may be generalized that the Dam has acted to control high volume, beach scouring floods, and that the riparian community throughout the study area is increasing at a rapid rate. The increase in vegetative growth (increase in available habitat) brings with it a concomitant increase in the density and diversity of animal life along Colorado River.

How this "new" vegetative community has effected the animal life is discussed in the Chapters dealing with each faunal group.

Overall, Glen Canyon Dam has produced the most significant effects on the Grand Canyon biota. The impacts of river runners are generally concentrated in a very small unit area at each major campsite, except when they are involved in side canyon or special interest area hikes. Hiking the side canyons (e.g., Saddle Canyon, Tapeats Creek, Deer Creek, etc.) and visiting special interest areas (e.g., Stanton's Cave, Nankoweap, etc.) probably result in the most significant impact in terms of vegetation trampling that we have witnessed thus far in the canyon. With some minor trail construction and maintenance, this destruction can be significantly mitigated.

CHAPTER XIII

SUMMARY

The scope of this project was designed to cover two central themes. First, there was an effort to inventory the biotic resources of the riparian zone of the Colorado River, and second, there was an attempt to evaluate the ecological relationships between the biotic resources and Hoover and Glen Canyon Dams and river runners and other back country enthusiasts.

The following points have been discussed in the preceding chapters.

Chapter I. Vegetational Changes Along the Colorado River

a) The construction of Hoover Dam flooded out the existing vegetational belts and established two distinctive zones below mi. 240. The lower one is characterized by almost impenetrable thickets of salt cedar and the upper one is composed of the typical desert flora which existed there before Lake Mead.

b) The construction of Glen Canyon Dam in 1963 and thus the suppression of annual flooding from Lees Ferry downstream to mi. 240 has permitted the development of a new riparian community. This vegetational community characterized by salt cedar, arrowweed, coyote willow, desert broom and seep-willow has become more firmly established in the zone once subjected to periodic flooding. Variations in water released from the power plant at Glen Canyon Dam determine the lower boundary of this new community. These variations in flooding of the area below this zone have prohibited the establishment of any extensive communities; however, cattail and horse-tail have become established in some locations below the new salt cedar belt.

c) There are four visually distinct vegetation belts from Lees Ferry to mi. 240. The lowest is characterized by a salt cedar-willow-seep-willow zone; above this is the zone of ephemeral plants which is heavily utilized by man. We then find a mesquite acacia-Apache plume belt and beyond this we have the communities of typical desert species on the talus slopes.

Chapter II. Vascular Flora of the Grand Canyon

a) Botanical investigations within the riparian and adjacent habitats of the Colorado River study area have discerned the presence of 807 species of vascular plants representing 92 families.

b) Two species, previously undescribed, *Flaveria mcdougalii* and *Euphorbia rossii*, are presented.

c) A total of 210 species are new to the local flora, 74 of which resulted from collections during this project. The remainder are from refined herbaria and literature searches that took place during the contract period.

Chapter III. Dietary Characteristics of Some Grand Canyon Amphibians and Reptiles

a) The diets of eight insectivorous reptile and amphibian species showed considerable variability temporally and spatially.

Chapter IV. Demography of Three Species of Grand Canyon Lizards

a) Male and female reproductive cycles and intensity of predation display little difference from other Southwestern areas.

b) The spring season is the period of greatest reproductive activity in Grand Canyon lizards.

Chapter V. Mammals of the Colorado River

a) Demographic investigations on the rodent communities of beach and terrace areas indicate that beach communities tend to be more complex, less productive and less stable than those of the terrace areas.

b) *Peromyscus eremicus* appears to be the most successful small mammal in the riparian zone of the Grand Canyon.

c) Home range data indicate an inhibitory effect of high temperature upon rodent movement in at least two species.

d) Survivorship is very low and suggests a nearly annual population turnover rate.

e) Dietary analysis of 5 species of sympatric rodents indicate that green vegetation and insects are more important food items than seeds. The relative amounts of green vegetation and insects vary per species per area.

f) Analysis of reproduction in 9 species of rodents revealed larger mean litter sizes than what has been reported elsewhere for the same species. Also, reproduction in the Grand Canyon is generally confined to the spring and summer months.

Chapter VI. Birds of the Colorado River

a) One hundred seventy-eight species of birds utilize the Colorado River and its riparian habitats. Of these, only 41 are breeding species.

b) The majority (74 percent) of breeding species are primarily restricted to or prefer the narrow band of vegetation existing from the high water line to the banks of the river, while the remainder are restricted to the desert scrub, the talus slopes or the vertical cliffs of the canyon walls.

c) Approximately 14 percent of the total breeding bird community restricted to the "green" vegetation of the river bank, the vegetation that has proliferated since the construction of Glen Canyon Dam.

d) The breeding season within the area is April through August, with most activity occurring from April through June.

e) The most common breeding birds of the area are the Lucy's Warbler, accounting for almost 20 percent of the total population, followed by the House Finch (15 percent) and the Canyon Wren (11.5 percent).

f) The total population density of the 225 mile breeding bird study area was determined to be 3.93 pairs/mile, bird species diversity (H') was 2.69 and the eveness of distribution of the species (J') was .76.

g) Exotic bird species, the House Sparrow and Starling are only found in areas of heavy human concentration.

Chapter VII. An Insect Inventory of Grand Canyon

a) Over twelve thousand insect specimens in 20 orders and 247 families have been prepared and identified.

Chapter VIII. Insect Production of Native and Introduced Dominant Plant Species

a) *Tamarix chinensis* is not evenly incorporated into the riparian ecosystem. Within its cycles *T. chinensis*' insect production fluctuates dramatically in comparison to the more harmonious shifts noted on dominant native plant species.

Chapter IX. Distribution of Feral Asses

a) The areas occupied by feral asses in the Grand Canyon are from Tanner Canyon to Crystal Creek on the south side of the river. From Crystal Creek to Tapeats Creek, asses inhabit both sides of the river. This area between Crystal Creek and Tapeats Creek is the only area where feral asses appear above the Redwall of the canyon in any numbers. Havasupai Point and Pasture Wash on the South Rim have resident ass populations. On the north side of the river, asses occasionally go above the Redwall on Point Sublime and Swamp Point.

b) From Tapeats Creek to Havasupai Creek, asses inhabit only the south side of the river. From Whitmore Canyon to 220 Mile Canyon, asses occur on the north side of the river. From 215 mile to Lake Mead, asses inhabit the south side of the river.

c) Areas of highest feral ass densities appear to be from Red Canyon to Hermit Canyon on the south side of the river, the Shinumo Amphitheater, Parashant Canyon to 220 Mile Canyon on the north side of the river, and mile 215 to Bridge Canyon on the south side of the river.

d) The area from mile 215 to Lake Mead is part of the Hualapai Indian Reservation and is not included in Grand Canyon National Park. However, this area appears to contain extremely large populations of feral asses.

Chapter X. Feral Asses on Public Lands: An Analysis of Biotic Impact

a) The results of this investigation demonstrate conclusively that the feral ass has a negative effect on the natural ecosystem of the lower reaches of the Grand Canyon. The principal impact of the feral ass is habitat destruction through grazing and trampling.

b) On the study area where feral asses occur the vegetation cover and rodent populations were significantly reduced when compared to the study area where feral asses were absent. On the control plot, 28 species of vascular plants were found compared to 19 on the impact plot. The total vegetation cover on the control plot was 80 percent, compared to 20 percent on the impact plot. The mean area (m^2) occupied by each individual catclaw or mesquite shrub was 27.9m^2 on the control plot and 20.7m^2 on the impact plot.

c) The mammal species diversity (H') was higher on the control plot (.78652) than it was on the impact plot (.69022). In addition, the average absolute density of small mammals from March 1974 to January 1975 on the control plot was 128 mammals/acre (51.8/ha.) approximately four times the 32.6/acre (13.2/ha.) found on the impact plot. Thus, differences between the two areas in mammalian species composition and diversity were attributed to the depauperate flora, particularly the forbs and grasses, on the 209 Mile Canyon impact area.

Chapter XI. Campsite Usage and Impact

a) Human impact on the riverine ecosystem seems to be a function of visitor activities (e.g. campfires, sewage disposal, etc.) and the specific biotic sensitivity of the use area rather than a function of the total number of users. Therefore, management to minimize impact should be resource and education oriented instead of simply stressing a carrying capacity figure for the entire Colorado River within the Grand Canyon.

b) In 1974, 395 different campsites were reported between Lees Ferry and Pierce Ferry, in 1975 350 different campsites were used.

c) The following types of human impact on the beach ecosystem have been identified: fire, litter, trampling of vegetation, sewage disposal, noise, moving of naturally occurring objects and the presence of people. An indirectly related impact to man's activities, that of the fluctuation river level due to differing water releases from Glen Canyon Dam are also discussed.

Chapter XII. Interrelations of Man and the Biota

a) The primary impact of river runners has been determined to be excessive trampling of vegetation at special interest areas and many popular tributaries.

b) Other negative impacts include the feeding of some wildlife species by improper organic garbage disposal that has resulted in an increase in population densities of Common Ravens and House Sparrows.

c) Flies and red ants are positively correlated with human densities at major campsites and are probably a result of improper organic garbage disposal and possibly an accumulation of human waste products.

General Summary Statement

Although the inventories and descriptions of the biotic resources of the riparian zone of the Colorado River from Lees Ferry to the Grand Wash Cliffs will never be completed, the results of this study have greatly added to the "state of knowledge" regarding these resources.

As outlined in this report, the negative impacts on the ecology of the riparian resources resulting from the annual invasion of over 15,000 river-runners is relatively small. The greatest impacts result from off river vegetation destruction at special interest areas and frequently visited tributaries of the Colorado River, and the accumulation of fecal waste products on the heavily used beach areas.

It is our belief that these impacts may be significantly mitigated by (a) construction and maintenance of an adequate trail system in the areas of heavy vegetation impact, (b) the future removal of all fecal waste material from the beach areas of the river, and (c) the initiation of an education program for both private and commercial outfitters and boatmen (particularly the latter) regarding current and future National Park Service river-running regulations and general conservation practices and behavior.

Finally, it must be stressed that this project surveyed the impact of man only after a relatively short period of heavy Colorado River use. The impacts of man on the riverine ecosystem over the next several years should be carefully monitored for an evaluation of the long-term effects of man on this valuable resource.

APPENDICES

APPENDIX 1

Publications and related manuscripts resulting from this study.

Aitchison, S. W. 1976. Human impact in the Grand Canyon. Down River, April, 3(4):18-19.

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Wertheimer, D. B. and J. H. Overturf. 1975. A history of biological research in the Grand Canyon region. Plateau 47(4):123-139.

APPENDIX 2

Professional papers presented and/or abstracted.

Aitchison, S. W. 1974. Campsite evaluation forms and visitor usage forms. Grand Canyon Research Symposium, Flagstaff.

Aitchison, S. W. 1975. Human impact on wildlife. Arizona Academy of Science, Tempe.

Aitchison, S. W. 1975. River-running and wildlife. Grand Canyon Research Sympsoium, Grand Canyon.

Carothers, S. W. 1974a. Wild Burros, vegetation cover and small mammal populations. their interrelationships along the Colorado River. Grand Canyon Research Symposium, Grand Canyon.

Carothers, S. W. 1974b. MNA Ecological Survey: an overview and progress report. Grand Canyon Research Symposium, Flagstaff.

Carothers, S. W. and R. R. Johnson. 1974. Recent observations on the status and distribution of some birds of the Grand Canyon region. Grand Canyon Research Symposium, Flagstaff.

Carothers, S. W., R. R. Johnson, and M. E. Stitt. 1976. Feral asses on public lands: an analysis of biotic impact. 41st Annual North American Wildlife and Natural Resource Conference, Washington, D. C.

Carothers, S. W. and G. A. Ruffner. 1975. Feral asses, vegetation, and small mammals: their interrelationships in the Grand Canyon. 55th Annual State Meeting of the American Society of Mammalogists, Missoula, Montana.

Carothers, S. W., M. E. Theroux, D. S. Tomko, and G. A. Ruffner. 1975. Feral asses, vegetation, and small mammals: their interrelationships in Grand Canyon. Arizona Academy of Science, Tempe.

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Turner, R. and M. M. Karpiscak. 1975. Vegetational changes in the Grand Canyon. Journal of Arizona Academy of Science, Tempe.

APPENDIX VI-1

A checklist of the birds occurring along the Colorado River from Lee s Ferry (mile 0.0) to the Grand Wash Cliffs of Lake Mead (mile 279.0).

Species marked with an asterisk (*) indicate those not included in recently revised checklist of birds of the Grand Canyon (see Johnson et al., 1976).

Abundance: C = Common; easily found in proper habitat in right season.
F = Fairly common; may be found in low numbers or scattered through the proper habitat in right season.
U = Uncommon; may or may not be found with difficulty in proper habitat in right season.
R = Rare, not to be expected, occurrence unpredictable.
A = Accidental; completely out of normal range
[] = Hypothetical; alledged occurrence in area not substantiated.

Status: PR = Permanent Resident
SR = Summer Resident
W = Winter Visitant
I = Irregular
T = Transient (Migrant)

SPECIES	Abundance/	Status	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GREBES														
Eared Grebe	U	T				x	x						x	
Western Grebe	R	T			x	x			x					
Pied-billed Grebe	R	T			x									
PELICANS														
Brown Pelican	A								x					
White Pelican*	A					x								
CORMORANTS														
Double-crested Cormorant	R	T	x		x									

SPECIES	Abundance/Status		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
HERONS & BITTERNS														
Great Blue Heron	F	T	x		x	x	x		x	x	x	x	x	x
Green Heron	R	T			x						x			
Common Egret	R	T				x								
Snowy Egret	U	T				x	x	x			x	x		
Black-crowned Night Heron	U	SR	x		x			x			x			
[American Bittern]							[x]							
IBISES														
White-faced Ibis	U	T										x		
SWANS, GEESE & DUCKS														
Canada Goose	U	T	x		x	x							x	
Mallard	F	T	x		x	x		x	x		x	x	x	
Gadwall	R	T			x									
Pintail	U	T	x		x		x							
Green-winged Teal	U	T	x		x	x	x		x	x	x	x	x	x
Blue-winged Teal	U	T			x	x	x			x		x		
Cinnamon Teal	F	T			x	x	x	x	x	x	x	x		
American Widgeon	R	T			x	x						x	x	
Shoveler	U	T	x				x	x						
Canvasback	R	T			x									
Common Goldeneye*	R	T	x		x									
Redhead	R	T	x		x									
Ring-neck Duck	R	T	x		x			x						
Lesser Scaup	R	T				x								
Bufflehead	U	T	x		x	x							x	
Common Merganser	F	T	x	x	x	x	x	x	x	x	x	x	x	x
Ruddy Duck	R	T	x							x				

SPECIES	Abundance/Status		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AMERICAN VULTURES														
Turkey Vulture	F	SR			x	x	x	x			x			
HAWKS														
Sharp-shinned Hawk	U	T	x		x	x			x		x			
Cooper's Hawk	U	SR			x	x	x			x	x	x	x	
Red-tailed Hawk	F	PR	x	x	x	x	x	x	x	x	x	x	x	x
Swainson's Hawk	U	T			x			x						
Golden Eagle	U	PR	x	x	x	x	x	x	x	x	x	x	x	x
Bald Eagle	R	T	x	x	x	x	x	x	x	x	x	x	x	x
Marsh Hawk	R	T	x											
Osprey	R	T									x	x		
FALCONS														
Prairie Falcon	R	PR				x	x	x	x	x	x			
Peregrine Falcon	R	PR			x	x	x	x	x		x			
Kestrel	C	PR	x	x	x	x	x	x	x	x	x	x	x	x
COOTS														
American Coot	U	T	x		x	x	x		x			x	x	
KILLDEER														
Killdeer	U	T	x		x	x			x	x	x	x		
SNIPE & SANDPIPERS														
Wilson's Snipe	U	T			x	x	x						x	
Spotted Sandpiper	F	SR			x	x	x	x	x	x	x	x		
Willet	R	T				x								
Long-billed Curlew	R	T	x											
Greater Yellowlegs	R	T				x								
Least Sandpiper	R	T				x			x					

SPECIES	Abundance/Status		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AVOCETS AND STILTS														
American Avocet	U	T				x	x				x			
Black-necked Stilt	R	T					x				x			
PHALAROPES														
Wilson's Phalarope	R	T									x			
GULLS & TERNS														
California Gull	R	T			x									
Bonapart's Gull*	R	T				x								
Herring Gull*	R	T				x	x							
Ring-billed Gull	R	T							x				x	
Black Tern	R	T						x						
Forster's Tern*	R	T									x			
PIGEONS AND DOVES														
Band-tailed Pigeon	R	T					x							
Mourning Dove	F	SR				x	x	x	x	x	x	x		
ROADRUNNER														
Roadrunner	R	PR									x		x	
OWLS														
Screech Owl	R	T			x	x		x					x	
Great-horned Owl	U	PR	x	x	x	x	x	x	x	x	x	x	x	x
Long-eared Owl	R	T				x	x							
Flammulated Owl	R	T					x							
GOATSUCKERS														
Poorwill	R	T			x						x			
Lesser Nighthawk*	R	T							x					

SPECIES	Abundance	Status	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SWIFTS														
Vaux's Swift	R	T				x								
White-throated Swift	C	SR			x	x	x	x	x	x	x	x		
HUMMINGBIRDS														
Black-chinned Hummingbird	F	SR			x	x	x	x	x	x				
Costa's Hummingbird	R	T			x									
Broad-tailed Hummingbird	U	T							x		x			
KINGFISHERS & WOODPECKERS														
Belted Kingfisher	U	T	x		x	x	x		x	x	x	x	x	
Flicker	U	W	x		x						x	x		
Yellow-bellied Sapsucker	U	T	x		x				x		x	x	x	
Hairy Woodpecker	U	T			x									
Ladder-backed Woodpecker	R	SR				x				x				
TYRANT FLYCATCHERS														
Eastern Kingbird	R	T					x	x	x					
Western Kingbird	U	SR					x	x	x	x	x			
Cassin's Kingbird	U	SR					x			x	x			
Ash-throated Flycatcher	F	SR				x	x	x	x	x				
Weid'sCrested Flycatcher	U	T				x	x	x	x					
Black Phoebe	C	BR	x	x	x	x	x	x	x	x	x	x	x	x
Say's Phoebe	FC	T & SR			x	x	x	x	x	x	x			
Western Flycatcher	U	T						x	x					
Western Wood Pewee	U	T			x		x				x			
SWALLOWS														
Violet-green Swallow	C	?			x	x	x	x	x	x	x	x		
Tree Swallow	R	T			x	x	x			x				
Bank Swallow	R	T				x	x				x			
Rough-wing Swallow	R	T				x	x		x	x	x			
Barn Swallow	R	T			x	x	x					x		
Cliff Swallow	U	T & SR			x	x	x		x	x				

SPECIES	Abundance	Status	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CROWS & JAYS														
Steller's Jay	R	T									x			
Scrub Jay	U	T			x	x	x				x	x		
Raven	C	PR	x	x	x	x	x	x	x	x	x	x	x	x
Pinyon Jay	U	T	x		x	x	x		x		x			
CHICKADEES & BUSHTITS														
Mountain Chickadee	U	T			x						x			
Common Bushtit	F	W	x	x	x		x							
DIPPERS														
Dipper	F	PR	x	x	x	x	x	x	x	x	x	x	x	x
WRENS														
House Wren	U	T				x	x				x			
Winter Wren	R	T	x		x									
Bewick's Wren	U	T	x		x	x	x				x		x	
Cactus Wren	R	T								x				
Long-billed Marsh Wren	R	T	x		x		x		x					
Canyon Wren	C	PR	x	x	x	x	x	x	x	x	x	x	x	x
Rock Wren	C	PR	x	x	x	x	x	x	x	x	x	x	x	x
MOCKINGBIRDS & THRASHERS														
Mockingbird	U	T				x	x	x	x	x				
ROBINS & THRUSHES														
Robin	U	T	x		x	x							x	
Hermit Thrush	R	T			x									
Western Bluebird	U	T	x		x	x							x	
Mountain Bluebird	U	T			x	x								
Townsend's Solitaire	U	T	x		x	x					x			

SPECIES	Abundance	Status	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GNATCATCHERS AND KINGLETS														
Blue-gray Gnatcatcher	F	PR	x		x	x	x	x	x	x	x			
Golden-crowned Kinglet	R	T											x	
Ruby-crowned Kinglet	U	T	x		x	x					x		x	
PIPITS														
Water Pipit	R	T	x			x				x				
SILKY FLYCATCHERS														
Phainopepla	U	ISR & T	x		x		x						x	
SHRIKES														
Loggerhead Shrike	U	T				x			x	x	x		x	
Northern Shrike	R	T	x											
STARLINGS														
Starling	Local	SR			x	x	x	x						
VIREOS														
Bell's Vireo	C	SR			x	x	x	x	x	x	x			
Gray Vireo	R	T				x								
Solitary Vireo	U	T				x					x			
Warbling Vireo	U	T					x				x			
WOOD WARBLERS														
Orange-crowned Warbler	U	T					x				x			
[Blackburnian Warbler]*	A					[x]								
Virginia's Warbler	R	T									x			
Lucy's Warbler	C	SR			x	x	x	x	x	x	x			
Yellow Warbler	F	SR				x	x	x	x	x	x			
Yellow-rumped Warbler	U	T					x				x	x		

SPECIES	Abundance	Status	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WOOD WARBLERS (cont.)														
Black-throated Gray Warbler	U	T				x								
Ovenbird	A							x						
Northern Waterthrush	U	T			x		x	x			x			
MacGillivray's Warbler	U	T					x				x	x		
Yellowthroat	F	SR				x	x	x	x	x	x	x	x	
Yellow-breasted Chat	F	SR					x	x	x	x				
Wilson's Warbler	U	T					x				x			
American Redstart	R	T					x							
WEAVER FINCHES														
House Sparrow	Local	PR	x	x	x	x	x	x	x	x	x	x	x	x
BLACKBIRDS & ORIOLES														
Yellow-headed Blackbird	U	T							x	x				
Redwing Blackbird	U	T	x		x	x			x			x		
Hooded Oriole	U	T				x	x		x	x	x			
Scott's Oriole	U	T				x	x							
Northern Oriole	U	SR				x	x		x	x	x			
Brewer's Blackbird	U	T				x	x				x			
Great-tailed Grackle	R	T				x	x	x			x			
Brown-headed Cowbird	F	SR				x	x	x	x	x	x			
TANAGERS														
Western Tanager	F	T					x	x	x	x	x			
Summer Tanager	R	T					x	x		x				
GROSBEAKS, FINCHES, SPARROWS & BUNTINGS														
Rose-breasted Grosbeak	R	T							x					
Black-headed Grosbeak	U	T				x	x	x			x			
Blue Grosbeak	F	SR					x	x	x	x	x			

SPECIES	Abundance/Status		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GROSBEAKS, FINCHES, SPARROWS & BUNTINGS (cont.)														
Indigo Bunting	U	SR					x	x						
Lazuli Bunting	U	SR					x	x		x				
House Finch	C	PR	x	x	x	x	x	x	x	x	x	x	x	x
Pine Siskin	R	T											x	
Lesser Goldfinch	I	SR		x	x	x	x				x	x		
Green-tailed Towhee	U	T				x	x				x			
Rufous-sided Towhee	U	T			x	x					x			
Brown Towhee	R	T			x									
Savannah Sparrow	R	T			x									
Vesper Sparrow	R	T				x								
Lark Sparrow	R	T					x		x		x			
Rufous-crowned Sparrow	R	T			x						x			
Black-throated Sparrow	F	PR			x	x	x	x	x	x	x			
Sage Sparrow	R	T			x									
Oregon Junco	U	WT	x		x	x								
Gray-headed Junco	U	W			x									
Chipping Sparrow	U	T					x					x		
Brewer's Sparrow	U	T			x		x			x	x			
Black-chinned Sparrow	R	T				x	x							
Fox Sparrow	R	T	x											
Lincoln's Sparrow	U	T	x		x	x	x				x			
Song Sparrow	U	T	x		x									
Harris Sparrow	A										x			
White-crowned Sparrow	F	T	x		x	x	x	x			x	x		
White-throated Sparrow	A										x			

APPENDIX VI-2

Annotated list of breeding species found along the Colorado River from Lees Ferry (mile 0.0) to Diamond Creek (mile 225.0).

Turkey Vulture

The Turkey Vulture is rarely seen at river level. The preferred habitat for this species is the high cliff areas of the rim, usually in the Kaibab and Toroweap limestone formations. We have sufficient records in the lower canyon area (mile 180-225) during the breeding season that would possibly indicate some breeding activity by isolated pairs far below the rim. Observation dates are from March through September.

Cooper's Hawk

Individual Cooper's Hawks have been recorded throughout the canyon from March to November, suggesting that this species may occasionally winter in the area. The preferred breeding habitat for this species consists of any area with large trees, from the desert to the boreal forests. The only positive breeding record we have for the inner canyon, is upper Deer Creek, mile 136, where a pair of this species nested in the large cottonwood trees in every year from 1973 to 1976. Preliminary searches along Havasu Creek and Tapeats Creek have failed to produce any additional breeding pairs.

Red-tailed Hawk

The Red-tailed Hawk is rarely seen at river level, however, it is the most common large hawk seen soaring high above the river as one traverses the canyon by boat. The preferred nesting habitat for this species consists of large trees, from the deserts to the high mountains, but it will utilize cliffs and ledges in the absence of trees. Our surveys indicate that the Red-tail is a permanent resident in the canyon, and is observed with regularity during float trips. Our data indicate that there are about 10 locations within the study area where this species is repeatedly seen.

Golden Eagle

The Golden Eagle is similar in distribution to the Red-tailed Hawk, occurring throughout the study area, rarely seen at river level, and preferring to nest on the high cliffs of the canyon country. The eagle is a permanent resident in the canyon and is repeatedly seen from several specific locations within the canyon.

Prairie Falcon

Throughout the United States, populations of the Prairie Falcon have been on the decline in recent years (Carothers and Johnson, 1975). For this reason, this species is officially listed in the compendium of "threatened" wildlife of the United States, that has been compiled by the Department of Interior (U.S.F. and W.S. Resource Publication, 114). During our investigation we have observed this falcon several times within the inner gorge of the Grand Canyon. Our observations indicate the possible presence of two eyrie sites along the Colorado River in Marble Canyon. The preferred habitat of this species consist of high cliffs for nesting sites and an abundant supply of small diurnal mammals nearby for food. Clearly, the canyon country contains an abundance of high cliffs, but compared to other desert areas, small diurnal mammals are present in relatively low densities (pers. observations).

Peregrine Falcon

The Peregrine Falcon is currently on the U.S.F. and W.S. "endangered" species list. The Grand Canyon may represent one of the few areas in the state, if not the entire Southwest, where active Peregrine Falcon eyries occur.

American Kestrel

Also known as the Sparrow Hawk, this is the most common and regularly distributed falcon along the Colorado River. Although we have evidence that the Sparrow Hawk will occasionally nest in potholes or crevices along cliff faces, its preferred nest sites consist of cavities in trees. This species is a permanent resident in the canyon, however some migrants also pass through the area during April and September. Our censusing data indicate that there are at least 7 or 8 pairs of these small falcons nesting along the 225 mile study area.

Spotted Sandpiper

Although Spotted Sandpipers may be observed along the upper Colorado River any month of the year, we have determined that the ones that breed during June are most likely summer residents only. During January and March, there are fewer than 5 or 6 of these birds observed on the entire 225 mile section of river with which we are concerned. By mid April, however, their densities increase to about 15 individuals observed and by early May, they are present in densities that average 1 bird per 2 miles of river. These high densities are maintained until mid September when the majority of the birds migrate out. The Spotted Sandpiper lays its eggs in a nest placed on the ground, usually in grassy clumps, and most often very close to the water.

Mourning Dove

The Mourning Dove is a common summer resident of the heavily vegetated areas of the Colorado River and its tributaries. It is one of the few species that is capable of utilizing the tamarix or salt cedar for nesting habitat. This species begins to appear in early April in flocks consisting of 5-15 individuals. Although a few pairs will break from the flocks and begin breeding in late April, or early May, the general flocking pattern persists until the end of May. The highest densities of the dove are reached in April and May, then their numbers decline steadily through September when they disappear, not to be seen again until the following April. The high densities recorded in April and May, reflect not only the arrival of the summer resident birds, but the migration of others that continue moving through the canyon to their northern breeding grounds. It is interesting, that this is probably a one-way migration, as our data do not indicate that the doves returning from their breeding grounds in the fall utilize the canyon for southward migration.

Roadrunner

Our observation records do not provide sufficent information on this species to draw any definite conclusions. The Roadrunner is known to live in the Sonoran zones throughout the Southwest, but its occurrence within the Grand Canyon area is very sporadic and rare. Although it is known to breed in the desert around Lake Mead, the Roadrunner has not penetrated the upper reaches of the canyon to any extent. Our observation records are as follows: 13 July 1973, scats seen at mile 74.0; 16 July 1973, scats seen at mile 123.8; 13 November 1975; 1 adult seen at mile 260.0; September 1975, one adult seen at mile 209.0.

Great-horned Owl

This owl is a permanent resident of the inner canyon, preferring the more heavily wooded areas, usually in tributaries of the main river, for its nesting area. Although it is almost never seen, this owl may be heard almost any summer night near Cardenas Creek, Bright Angel Creek, Indian Gardens or Spencer Canyon. The nest of this species is usually placed on a high cliff, frequently overlooking its favorite hunting areas, such as the marsh area near Cardenas Creek.

White-throated Swift

Although this species is probably the single most common bird in all of the canyon country, its behavior and distribution patterns are very enigmatic. Our records indicate that it can be seen in large flocks foraging above the Colorado River, and occasionally dropping down to water level to drink or forage, from early March through September. We have not observed this species in the inner canyon from September to March, yet there are sporadic sightings during the winter on the rim of the canyon. For the most part, this species is a summer resident, nesting in deep crevices in the high cliffs of the rim and inner canyon. It will frequently forage in close association with the Violet-green Swallows.

Black-chinned Hummingbird

The Black-chinned Hummingbird is the only hummingbird we have found nesting along the Colorado River from Lees Ferry to Lake Mead. It arrives in early March, is seen all spring and summer and then departs for the warmer south by mid September. We have never found a nest of this species along the main Colorado River, but they are commonly found in the tributary canyons. The nests, placed on either rock shelfs or in vegetation, usually contain eggs by late April and the young are hatched and off the nest by early May.

Ladder-backed Woodpecker

This woodpecker is a rare summer resident of the inner canyon, found only occasionally along the Colorado River (Cardenas Creek, Nankoweap). Our only verified breeding records for this species are from Indian Gardens and Upper Deer Creek. It prefers the larger cottonwood trees for nest sites, and these trees are usually only found in the tributary canyons. Our records are not sufficiently complete to determine the arrival and departure dates for this species.

Ash-throated Flycatcher

The Ash-throated Flycatcher is a summer resident, preferring to construct its nest in abandoned woodpecker holes in large and small trees. In the Grand Canyon area, it may also nest in cavities in rocks. This flycatcher arrives on the breeding grounds in early April, and departs by late August. Although this species may be found along the entire length of the study area, it reaches its greatest densities in the areas of heavy concentration of woody vegetation, particularly the vegetated tributaries. Thus, it is almost never seen in the Marble Canyon area, and only a few may be found from Nankoweap (mile 52.0) to Red Canyon (mile 76.0), and almost none in the Precambrian rocks from Red Canyon to the area just below Deer Creek (mile 136.0). In the area from Kanab Creek (mile 143.0) to Diamond Ceek (mile 225.0) the Ash-throated Flycatchers are frequently ecountered and evenly distributed. They reach their highest densities in these areas primarily because of the proliferation of woody vegetation that may be found in this lower section of the canyon.

Black Phoebe

This flycatcher is a permanent resident of the inner gorge of the Grand Canyon. It is exclusively restricted to breeding areas where there is running water and moderate to extensive amounts of riparian vegetation. The Black Phoebe may be found in every side canyon that contains water from Lees Ferry to Lake Mead. For some unknown reason, it does not prefer to nest along the main part of the Colorado River even when it appears all the nesting and feeding requirements have been met. The one exception to this, is that in 1974 a pair of Phoebes constructed their nest on the north side of the large boulder that forms Boulder Narrows (mile 18.5). Also, they will nest along the Colorado River when there is a spring dripping or running directly into the river; e.g., springs in Marble Canyon (ca. mile 36.0) and the spring dripping into the river from the north side of the canyon at mile 155.0.

Say's Phoebe

Most of the Say's Phoebes we have observed along the Colorado River are migrants, utilizing the Grand Canyon corridor as a migratory route to their northern breeding grounds. During January, one may see fewer than 5-6 Say's Phoebes on a complete traverse of the 225 mile study area. These few birds are probably some eccentric winter residents. By early March, the migration is on. All through March and to a somewhat lesser extent in April, Say's Phoebes are in extremely high densities all along the Colorado River. During mid

March of 1975, this phoebe was seen in densities as high as 1 or 2 individuals per mile. During their migration, they frequently appear to be in pairs, and by mid April we have observed definite courtship behavior. The densities drop off dramatically by May, and remain relatively low for the remainder of the year, until the heavy migration begins again in early March. The birds that remain to breed in the Grand Canyon area build their nests on ledges above the river and in permanently flowing side canyons. They do not need vegetation to the extent other flycathers do, but may frequently construct their nests in areas completely lacking in vegetation. Our breeding bird census data indicate that approximately 24 pairs of Say's Phoebes nest from Lees Ferry to Diamond Creek. This figure is probably an over estimation as it is based on observed courtship behavior which may not reflect breeding activity within the study area.

Willow Flycatcher

This Willow Flycatcher is the only member of the genus Empidonax known to breed along the upper Colorado River and its tributaries. It is a rare summer resident, arriving sometime in May and leaving by late September. The only areas from which we have verified breeding records are Cardenas Creek Marsh (mile 71.0), Upper Deer Creek (mile 136.0) and Havasu Creek (mile 157.0). We have previously published additional information on the status of this species in the Grand Canyon region (see Carothers and Johnson, 1975).

Violet-green Swallow

Although the Violet-green Swallow is seen from March through September along the Colorado River, we know surprisingly little about its breeding habits in the canyon country. Typically, this species prefers to nest in cavities in trees in the ponderosa pine and spruce-fir forests of both the north and south rims of the Grand Canyon and surrounding boreal forest areas. We have no positive evidence that it does breed within the inner canyon, yet they are present in large numbers throughout the breeding season and we have on occasion observed pairs copulating in mid flight above the river. They reach their greatest densities in April and May, often occurring in mixed flocks with White-throated Swifts, Cliff, Barn, Tree, Rough-wing and Bank Swallows. By late May, their densities are noticeably lower, but large flocks are still commonly seen throughout the remainder of the spring and summer. Our feeling is that some of these birds do breed in rock crevices in the inner canyon, but this conjecture awaits verification.

Cliff Swallow

This swallow is an uncommon migrant during April and May and September when it is seen in mixed flocks with other swallows. It is also an irregular and rare summer resident in the Marble canyon area. We have records of one small breeding colony near mile 28 in 1975. With all the available nesting sites and apparently abundant supply of food we are at a loss to explain why this species is not more common as a breeding resident along the Colorado River.

Common Raven

The Raven, a permanent resident in the canyon country of the Southwest, prefers to build its nest of large and small sticks on north facing rock ledges 100 to several hundred feet above the river. The Raven has learned to frequent the areas camped in by river parties along the Colorado River. In the past, it was common for river groups to leave quantities of organic garbage on the beaches, specifically for the ravens. Present National Park Service regulations forbid this practice, but the ravens still remain at the periphery of major campsites, waiting for a handout. If river parties have not contributed to increasing the densities of ravens in the canyon, they have certainly caused these birds to select nest sites based on areas of high human concentrations. Nest building begins in late March and continues into April The young are usually off the nest by early June.

Dipper

This bird, also known as the Water Ouzel, is a permanent resident of the flowing tributaries of the Colorado River. During the winter months of November through February it may be frequently seen along the main portion of the Colorado River, and we suspect that these winter birds are the same ones that will nest in the tributaries during the spring. Nest building begins as early as late February, as by late March, the young are already off the nest. The nest is usually constructed under a small or large waterfall and consists of a mossy dome. The highest densities of these birds during the breeding season may be found along Bright Angel Creek.

Canyon Wren

The distinctive laughing or mocking song of the Canyon Wren may be heard at any time of the year along the upper

Colorado River. This wren prefers the vertical cliff areas for its permanent residency, thus the highest densities are found in the Marble Canyon area and from Red Canyon (mile 76.0) to Kanab Creek (mile 143.0). Although the Canyon Wren occurs sympatrically with the Rock Wren, there seems to be no direct competition, the Rock Wren preferring the loose talus slope areas to the vertical cliffs. The nests of the Canyon Wren are placed deep into rock crevices and the young are usually off the nest by early June. Due to its inaccessible nesting habitat very little is known about the behavior and natural history of this species.

Rock Wren

The breeding activities of the Rock Wren closely correspond with those of the Canyon Wren, with the exception of the specific preference of breeding habitat. Like the Canyon Wren, they also sing all year, but the frequency of their songs increase dramatically in March and continue at a high level until mid June. The Rock Wren is slightly less common than the Canyon Wren.

Blue-gray Gnatcatcher

The Blue-gray Gnatcatcher occurs only along the Colorado River and in the tributary canyons that contain large numbers of mesquite and/or acacia trees and some running water. We have never observed a nest in the Grand Canyon area that was placed in any other type of vegetation. This characteristic then clearly limits the overall distribution of the gnatcatcher along the upper Colorado River. The gnatcatchers arrive on the breeding grounds in mid March, nest construction begins in early April and most young are fledged by mid April Both young and adults remain in the canyon area until late September when the fall migration begins.

Phainopepla

The distribution, breeding activities and migration patterns of this species are extremely confusing throughout its range (see Phillips et al., 1964). In the Grand Canyon area, we have two positive breeding records, both in mid March, 23 March 1975, Mohawk Canyon (mile 174.0) and 28 March 1975, 209 Mile Canyon. Other than those nesting dates, the Phainopepla has been but rarely observed in along the upper Colorado River. The only other observation records are in May, when a few scattered individuals have been seen at a variety of locations within the canyon.

Phainopeplas are drawn to mistletoe, as a primary item in their diet consists of mistletoe berries. In areas that have been heavily overgrazed by wild burros, we find abundant mistletoe infestation in the mesquite and acacia shrubs, and it is in these areas where the Phainopeplas are seen.

Starling

The Starling was introduced into the United States from Europe in the very late 1800's. Although it was introduced on the east coast, it had reached the west coast by the early 1960's. Our research in the Grand Canyon and other areas of the Southwest, confirm that the Starling will only nest in close association with man. To this date, its breeding activities have been confined to Lees Ferry, Phantom Ranch, Indian Gardens, and Havasu Creek, particularly in the vicinity of the campground and village. The migratory periods for this species are confusing, but it begins breeding as early as late February in Havasu Canyon and then forms flocks and remains in the area often throughout the winter.

Bell's Vireo

This species is evidentally a relative newcomer to the avifauna of the Grand Canyon region. In their treatment of the birds of Arizona, Phillips et al. (1964) state that the Bell's Vireo was not present in the bottom of the Grand Canyon, but that it was present throughout the rest of the state, occupying low shrubby vegetation, particularly mesquite and acacia. Our data indicate that the Bell's Vireo is a common summer resident within the lower section of the study area (from mile 143.0 to Lake Mead), and that its preferred habitat consists of the true phreatophytic vegetation such as Salix, Baccharis, and to some extent the tamarisk, that grows on the banks of the Colorado River. The vireo arrives in mid April, begins nesting in May and by early June the young are fledged. The fall migration begins in August and by late September, almost all the vireos have departed south.

The distribution of the Bell's Vireo in the Grand Canyon region is enigmatic. Although it is possible to find the vireos in mid summer in almost any location within the canyon's riparian system, they don't occur in high densities until the area just above Kanab Creek (143.0). From that point downstream to Lake Mead, one may find a pair of Bell's Vireos spaced no more than 100 meters apart in areas where green vegetation proliferates.

Lucy's Warbler

This small gray warbler is the most common breeding bird of the riparian habitat of the Colorado River from Lees Ferry to Lake Mead. Although it characteristically places its nests in cavities in trees, in the Grand Canyon area it will also utilize crevices and cavities in rocks, and will also occasionally weave a nest in riparian vegetaion. The Lucy's Warbler arrives on the breeding ground in early March and the fall migration begins in late July. By September, most of the Lucy's have left the Grand Canyon region. As with the Blue-gray gnatcatcher, the distribution of the Lucy's Warbler is very closely associated with the distribution of the mesquite and acacia trees and shrubs. This warbler is usually not in evidence as one travels Marble Canyon, until about mile 39.0 where the mesquite/acacia association begins. Unlike the gnatcatcher, however, the Lucy's Warbler will nest in other riparian areas that are lacking the mesquite and acacia.

Yellow Warbler

The western race of the Yellow Warbler possesses a breeding song that is very similar to that of the Lucy's Warbler. To even the most experienced observer, these two species are difficult to distinguish based on song alone. A general rule of thumb is that the Yellow Warbler song is shorter and louder than that of the Lucy's. In the riparian habitats of the Grand Canyon there are some subtle differences in habitat selection between these two species as well. Basically, the Yellow Warbler prefers the dense, tall green vegetation that may be found at the Cardenas Creek marsh area, the marshy area at Mohawk canyon etc., but not the dry mesquite/acacia areas that are preferred by the Lucy's. The Lucy's Warbler will also inhabit the areas preferred by the Yellow Warbler, but the reciprocal is rare.

The Yellow Warbler arrives on the breeding ground in mid April and remains until mid September. The nest is placed near the top of the highest branch of green vegetation the bird can find. They occur very irregularly along the banks of the Colorado River until just below Kanab Creek (mile 143.0) where the increasing amounts of green riparian growth provide them with nesting habitat. From this point downstream to Lake Mead, they occur in regular intervals wherever the vegetation is bushy and thick.

Yellowthroat

This bright and noisy warbler is limited in distribution in the Grand Canyon area to the marshy areas of the upper canyon (Cardenas Creek, mile 71.0, north end of Nankoweap Delta, mile 52.0) and the very dense growths of Baccharis, Salix and Tamarix near the lower end. The Yellowthroat arrives in late April and has usually departed by late September, although we have scattered observations from as late as November.

Yellow-breasted Chat

The habitat requirements for this large, raucous warbler are identical to those of the Yellowthroat, thus their distribution patterns in the Grand Canyon are similar. The chat does not arrive on the breeding grounds until late April or early May and by mid September, most birds have already begun their journey south.

House Sparrow

Like the Starling, this sparrow is an introduced species that does not fare well in the wild without the presence of man. Where it does occur in the Grand Canyon area, it is a permanent resident, raising up to three broods of young per year. Areas of heavy House Sparrow concentrations are the same as those listed for the Starling, Lees Ferry, Phantom Ranch, Indian Gardens and Havasu campground and village. In addition, we have recently discovered a pair of House Sparrows building a nest in the large group of tamarisk trees in the camping area across from Deer Creek Falls (mile 136.0). It is probably not coincidental that our visitor usage forms (see Chaper XI, this report) indicate that this camping area receives more river groups per year than any other campsite along the Colorado River.

Northern Oriole

The Cardenas Creek marsh is the only locale along the Colorado River where this species may be found regularly during the breeding season. This oriole prefers to breed in the heavily vegetated side canyons (Clear Creek, Tapeats, Deer Creek, Havasu etc.) where large cottonwood trees provide the favored nesting sites. The Northern Oriole arrives on its breeding grounds in late May and remains until late August.

Brown-headed Cowbird

This member of the blackbird family is a nest parasite. They do not build a nest of their own, but lay their eggs in the nest of another species (very commonly the Yellow Warbler and Bell's Vireo). The result is usually that the young of the host bird die while the host parents raise the young cowbird. Cowbirds are present along the Colorado River from May through September. Our data indicate that they are more commonly found in the vegetated tributaries than on the main part of the Colorado River.

Blue Grosbeak

The Blue Grosbeak is a late arriving summer resident that breeds along the full length of the Colorado River and to a lesser extent, the vegetated tributaries. It does not arrive on the breeding grounds until late May or early June. Nesting is not underway until July and the birds remain on the breeding grounds until late September. They are one of the few species that seem to be adapting to using the tamarisk tree.

Indigo Bunting and Lazuli Bunting

These two species are treated together here because they are identical in distribution, abundance and habitat preferences. They are summer resident species, rarely occuring along the Colorado River and definitely not breeding there. They seem to prefer almost exclusively the vegetation in upper Tapeats Creek, for it is here that they both reach their highest densities. Further work needs to be done on the interactions of these two birds.

House Finch

Although it is not uncommon to find House Finches in and along the Colorado River during the winter, there is a heavy influx of spring migrants moving into the preferred breeding areas in early April. Very high breeding densities are maintained until early July then the low densities remain until following April. For this reason then, we consider the House Finch to be a summer resident. This species is the second most abundant of all the breeding species. It will nest in a variety of habitat types, ranging from rocky talus slopes to heavily vegetated tributaries.

The preferred habitat seems to be the areas that support large mesquite, acacia or hackberry trees.

Lesser Goldfinch

The Lesser Goldfinch is an uncommon and irregular member of the breeding avifauna of the Grand Canyon region. As with the House Finch, it is not uncommon for some of these birds to appear along the Colorado River during the winter. During the spring however,(early April) a few birds, usually in small local flocks, will move into some of the tributary areas and breed. Our records are not sufficiently complete to delineate the full migratory-breeding cycle in the Canyon, but we do have breeding records from the following localities: Cardenas Creek marsh, Phantom Ranch, Deer Creek and Tapeats Creek.

Black-throated Sparrow

This species is probably one of the most common breeding birds of the desert environments adjacent to the Colorado River riparian habitats (e.g., Tonto Platform). Occasionally, a few individuals will nest close enough to the riparian habitat that they are detected in our breeding bird censuses. We have a few records of nesting activity in the Granite Park (mile 209.0) area, and a few scattered localities elsewhere. The Black-throated Sparrow is a permanent resident in the Grand Canyon desert communities.

KEY TO APPENDICES VII-1 and VII-2.

1. Location Range -- River miles between which specimens were collected.
2. Distribution (from field observation as well as specimen data)
   - U -- Upper section of Grand Canyon, Lees Ferry (mile 0.0R) to Phantom Ranch (mile 87.8R).
   - M -- Middle section of Grand Canyon, Phantom Ranch (mile 87.8R) to Diamond Creek (mile 225.9L).
   - L -- Lower section of Grand Canyon, Diamond Creek (mile 225.9L) to Pierce Ferry (mile 280.0L).
   - G -- Entire length of Colorado River.
3. Relative Abundance of Insects (estimated from field observation as well as specimen data)
   - R -- Rare
   - N -- Uncommon
   - C -- Common
   - A -- Abundant
4. Date Range -- Dates between which specimens were collected (includes both adult and larval insect data).
5. Elevation Range -- Elevations between which specimens were collected.
6. Habitat.
   - a -- General Beach Habitat
   - b -- Terrace (Bench)
   - c -- Talis Slope
   - d -- Burned Area
   - e -- Marsh Area
   - f -- In or Under Driftwood
   - g -- Near Colorado River
   - h -- In Colorado River
   - i -- Under Stones
   - j -- Near a Side-Stream
   - k -- In a Side-Stream
   - l -- Near a Seep or Spring
   - m -- In a Pool (Lentic Situation)
   - n -- In Mule Dung
   - o -- In *Equus asinus* Dung
   - p -- Parasitic on *Anas platyrhynchos*
   - q -- Parasitic on *Aeronautes saxatalis*
   - r -- Parasitic on *Plecotus townsendii*
   - s -- Parasitic on *Antrozous pallidus*
   - t -- Parasitic on *Peromyscus eremicus*
   - u -- Parasitic on *Peromyscus maniculatus*
   - v -- Parasitic on *Peromyscus crinitus*
   - w -- Parasitic on *Neotoma lepida*
   - x -- Parasitic on *Neotoma albigula*
   - y -- Parasitic on *Bassariscus astutus*

7. Vegetation Associations of Insects (if any were noted):

1 -- Equisetum spp.
2 -- Juniperus osteosperma
3 -- Ephedra spp.
4 -- Typha spp.
5 -- Bromus spp.
6 -- Sporobolus airoides
7 -- Oryzopsis hymenoides
8 -- GRAMINEAE
9 -- Yucca angustissima
10 -- Agave utahensis
11 -- Populus fremontii
12 -- Salix exigua
13 -- Salix gooddingii
14 -- Salix spp.
15 -- Atriplex canescens
16 -- Abronia nana
17 -- Lepidium montanum
18 -- Rorippa nasturtium-aquaticum
19 -- Stanleya pinnata
20 -- CRUCIFERAE
21 -- Cercis occidentalis
22 -- Acacia greggii
23 -- Prosopis juliflora
24 -- Astragalus lentiginosus
25 -- Alhagi camelorum
26 -- Melilotus albus
27 -- Larrea divaricata
28 -- Ptelea pallida
29 -- Sphaeralcea spp.
30 -- Tamarix chinensis
31 -- Opuntia phaeacantha
32 -- Sarcostemma cynanchoides
33 -- Datura meteloides
34 -- Lycium spp.
35 -- Mimulus cardinalis
36 -- Franseria acanthicarpa
37 -- Aster spp.
38 -- Baccharis sergilcides
39 -- Baccharis sarothroides
40 -- Baccharis glutinosa and emoryi
41 -- Baccharis spp.
42 -- Brickellia longifolia
43 -- Encelia spp.
44 -- Erigeron spp.
45 -- Gutierrezia spp.
46 -- Haplopappus heterophyllus
47 -- Pluchea sericea
48 -- Senecio spp.

49 -- Xanthium strummarium

8. Collection Methods:
   - A -- General Collection
   - B -- Sweeping with Canvas and Mesh Collecting Nets
   - C -- Malaise Trap on Ground
   - D -- 15 Watt Ultra-Violet Light Trap
   - E -- White Light Trap
   - F -- Carrion Trap
   - G -- Parasite Removed from Host Species
   - H -- Bufo punctatus Stomach Contents Analysis
   - I -- Sceloporus magister Stomach Contents Analysis
   - J -- Urosaurus ornatus Stomach Contents Analysis
   - K -- Uta stansburiana Stomach Contents Analysis

Appendix VII-1.--Families of Insects Collected in Grand Canyon National Park[A]

TAXON	LOCATION[1] RANGE DISTRIBUTION[2]	RELATIVE[*3] ABUNDANCE	DATE[4] RANGE	ELEVATION[5] RANGE (FT.)	HABITAT[6]	VEGETATION[7] ASSOCIATION(S)	COLLECTION[8] METHOD
THYSANURA							
Lepismatidae	71.0R-136.2R (U,M)	C	4-V 27-VII	2500 2700	b,c,i	---	A
COLLEMBOLA (After Brues, Melander and Carpenter, 1954)							
Arthropleona							
Entomobryidae	0.9R-116.4L	N	24-I	2140	a,i,l,m	---	A
Isotomidae	34.9L-145.5L (U,M)	N	26-I 13-VIII	1850 2850	c	4	A,B
Poduridae	34.9L-65.2R (U)	N	13-VIII 18-I	2680 2850	e,g	4,12	A,B,D,
Symphypleona							
Sminthuridae	34.9L-246.0L (G)	C	11-V 12-XI	1100 2850	e	1,4,6,27,34	A,B
EPHEMEROPTERA (After Usinger, 1956)							
Heptageniidae	31.9R-133.8R (U.M)	N	23-IV 17-VIII	1980 2870	m	---	B
Baetidae	31.9R-246.0L (G)	C	17-I 13-XI	1100 2890	i,k,m	4,40	A,B,C,D,
ODONATA							
Anisoptera							
Aeshnidae	0.9R-246.1R (G)	C	5-VIII 8-IX	1100 4000	m	---	A,E

*see Key

A--Phylogenetic order based on Borror and Delong (1964) unless otherwise indicated. For text used in identification of insects see Appendix VII-3.

Gomphidae	208.6L (M)	N N	6-VIII	1500	---	---	A
Libellulidae	31.9R-248.4R (G)	C	4-III 26-IX	1090 2890	a,m	---	A
Zygoptera							
Agrionidae	116.4L (M)	R	19-V 16-VIII	2250 2300	j	---	A
Lestidae	0.9R-47.0R (U)	N	10-IX 24-IX	3600 3600	j	---	A
Coenagrionidae	31.8R-248.4R (G)	A	17-I 22-IX	1090 2890	j,k,l,m	---	A,B
ORTHOPTERA							
Caelifera							
Tridactylidae	53.0R-208.6L (G?)	N	24-V 31-VIII	1510 2800	j,l	---	B,D
Tetrigidae	225.8L-246.0L (L)	N	7-X 21-XI	1100 1330	---	1,6,12,40	B
Acrididae	0.9R-208.6L (G)	C	6-III 5-X	1500 3200	a,b,c,e	5,6,8,14,15 25,30,43	A,B,D,E,
Ensifera							
Tettigoniidae	124.0L-208.6L (G?)	N	22-V 16-VII	1510 2100	a	11,12,23,27	A,B
Gryllidae	31.9R-269.5R (G)	C	29-I 14-XI	1000 2880	a,e,f,i,j,l	13,35,40	A,B,D,K

Phasmatodea							
Phasmatidae	87.8R (M)	N	fall'74	2450	observation by M. Langdon		
Mantodea							
Mantidae	0.9R-187.0L (U,M,L?)	R	28-IX 5-X	1610 3100	---	47	A,E
Blattaria							
Blattellidae	276.0L (L)	N	31-I	1000	f	---	A
undet. Blattaria	70.8L	R	11-VII	2620	b	---	A
ISOPTERA							
Kalotermitidae	52.5R-124.0L (U,M)	N	2-VII 14-VII	2050 2800	1	---	A,I,K
Rhinotermitidae	0.7R-218.0 (U,M)	C	8-III 19-IX	1400 3100	a,f	20	A
DERMAPTERA							
Forficulina							
Labiidae	214.2R (M)	R	7-X	1420	a	---	A
PLECOPTERA (After Usinger, 1956)							
Filipalpia							
Nemouridae	29.0L-116.4L (U,M)	R	16.I 8-III	2140 2890	j	---	A
Setipalpia							
Perlodidae	133.8R & Thunder R. (M)	N	15-VII 1-X	1980 3600	i,j,k	---	A
Perlidae	136.2R (M)	R	10-III	2500	k	---	A

PSOCOPTERA							
Troglomorpha							
Psyllipsocidae	120.0R (M)	N	31-VII	2100	---	---	D
undet. Family	133.8R-171.4R (M)	N	6-VI 4-X	1710 1980	---	---	C,D
MALLOPHAGA (After Brues, Melander and Carpenter, 1951)							
Amblycera							
Menoponidae	166.0	N	18-VIII	1750	q	---	G
Laemobothriidae	39.0	N	17-I	2840	p	---	G
THYSANOPTERA (After Brues, Melander and Carpenter, 1951)							
Terebrantia							
Aeolothripidae	0.9R-174.3L (G?)	C	16-IV 4-X	1730 3100	---	3,21,37,43,46 48	B
Thripidae	0.9R-246.0L (G)	A	26-I 12-XI	1100 3200	a,j	13,19,21,23,25 27,30,31,40,43 46,47,48	B,C,D
HETEROPTERA (HEMIPTERA)							
Hydrocorizae							
Corixidae	34.9L-246.0L (G)	N	29-I 6-VIII	1120 2870	k,m	---	A
Notonectidae	34.9L-208.5L (U,M)	C	8-III 22-IX	1200 3000	l,m	---	A,D
Belostomatidae	246.0L (L)	N	21-III 8-VIII	1100 1130	k	---	A

Gelastocoridae	0.8R-246.0L (G)	C	9-III 15-IX	1100 3100	e,j,k,l	---	A
(Ochteridae, reported by J.T. Polhemus, 1976)							
Amphibicorizae							
Gerridae	34.9L-124.0L	C	5-III	1930	m	---	A
(Macroveliidae, recorded by J.T. Polhemus, 1976)							
Veliidae	31.9R-246.0L (G)	C	17-I 23-IX	1100 2890	i,j,k,m	---	A
Hebridae	156.8L (M)	R	17-VII	1900	j	___	A
Saldidae	31.9R-171.4L (U,M)	C	23-V 23-IX	1750 2890	e,l,j	4	A,E
Geocorizae							
Anthocoridae	0.9R-246.0L (G)	C	27-I 4-X	1100 3100	a,l	2,8,12,13,17 19,21,22,25, 30,39,40,44,46,47	B,D
Miridae	0.0R-246.0L (G)	A	23-IV 12-XI	1000 3600	a,j	1,3,7,8,11,12, 13,14,15,16,17, 18,19,22,23,27, 30,33,34,35,36, 39,40,44,46,47,48	A,B,C,D,F,
Nabidae	0.0R-208.6L (U,M)	C	12-III 28-IX	1500 3100	a,d,j	5,25,30	A,B,D,E

Reduviidae	0.9R-274.4L (G)	C	5-III 5-X	1000 3600	a,c,j	5,8,14,19,25 30,36,39,40, 43,47	A,B,C,D
Phymatidae	166.5L-246.0L (M,L)	C	5-VIII 12-XI	1100 1750	a	40	A
Tingidae	0.9R-198.5R (U,M)	C	23-V 25-IX	1530 3200	a	14,36,39,46,49	A
Lygaeidae	0.9R-269.5R (G)	A	11-V 12-XI	1000 3100	a,j	1,5,6,15,22, 30,39,40,44, 46,47	A,B,C,D,E
Berytidae	72.5R-208.6L (U,M)	N	11-V 5-X	1510 2600	a,c,j	30	A,B,D
Largidae	198.5R (M,L)	N	25-IX	1530	---	39	A
Pyrrhocoridae	246.0L (L)	N	12-XI	1100	j	---	B
Coreidae (incl. Coris-cidae & Corizidae)	0.9R-208.6L (G)	C	10-V 28-IX	1100 3200	a,j,l	13,30,31,36 40,43,47,39	A,B,D
Pentatomidae	72.5R-246.0L (G)	C	13-III 12-XI	1100 2610	---	1,6,7,8,15 27,39,40	A,B
Cydnidae (incl. Corimelaenidae)	41.0R-269.5R (G)	C	24-IV 18-VIII	1100 3000	a	---	A,D,E

(HOMOPTERA)							
Auchenorrhyncha							
Cicadidae	0.9R-248.4R (G)	C	10-VII 4-X	1090 3100	a,e	22,39,40	A,D,E,I
Membracidae	0.9R-151.6R (U,M)	N	22-IX 28-IX	1850 3100	a,l	---	B
Cicadellidae	0.0R-269.5R (G)	A	29-I 13-XI	1000 3200	a,c,g,j	1,3,5,6,7,8, 12,13,14,15, 16,19,22,24, 26,27,30,33, 34,35,36,39, 40,42,47	A,B,C,D
Cercopidae	171.4L-274.4L (M,L)	N	22-V 15-XI	1000 1730	---	40	A
Delphacidae	35.0L-246.0L (G)	C	19-V 28-IX	1100 2850	e.j	1,4,6,8,40	A,B,
Cixiidae	0.9R-269.5R (G)	C	13-V 1-X	1000 3100	a,j	11,12,13,14, 23,25,30,39,47	B.C.D.
Kinnaridae?	18.1L-61.5L (U)	N	7-VII 22-IX	2170 3000	---	---	C,D
undet. Fulgor-oidea	0.9R-259.5R (G)	N	5-V 14-XI	1010 3100	e.f.i	---	A
Sternorrhyncha							
Psyllidae	0.0R-203.6L (G?)	A	9-V 1-X	1510 3100	j,l	11,12,13,22, 23,25,26,30, 34,39,42,47	A,B,C,D

Aphididae	0.0R-274.4L (G)	A	16-IV 15-XI	1000 3600	a	3,8,12,13,18 19,25,26,30, 32,33,38,40, 42,43,44	A,B,C,D
Margarodidae	4.4L (U)	N	11-VIII	3080	---	---	A
undet. Coccoidea	214.5R (M)	N	27-I	1800	---	2	A
COLEOPTERA (After Arnett, 1960)							
Adephaga							
Cicindellidae	40.9R-166.5L (G)	C	11-VI 2-X	1750 2850	a,e	---	A,D,K
Carabidae (incl. Omophronidae)	0.0R-274.4R (G)	C	24-I 14-XI	1000 3700	a,c,e,f,i,j	12,13,30	A,B,D,E,F,
Haliplidae	94.9L-246.0L (M,L)	N	16-IV 8-VIII	1100 2340	k	---	A
Dytiscidae	34.9L-259.5R (G)	C	19-I 14-XI	1010 2870	e,i,k,m	13	A
Noteridae	116.4L-246.0L (M,L)	N	29-I 7-X	1100 2140	k,m,	---	A
Myxophaga							
Sphaeriidae	1.0R (U)	R	15-IX	3200	---	8	B

Polyphaga							
Hydrophilidae	31.8R-259.5R (G)	C	17-I 14-XI	1010 3600	a,h,i,j,k,l,m	---	A,B
Staphylinidae	18.1L-269.7R (G)	A	18-I 14-XI	1000 3600	a,c,e,f,i,j, n,o	10,30	A,B,D,F,I
Pselaphidae	124.0L-208.4L (M)	N	14-VII	1800	m	---	A,D
Scydmaenidae	20.1L (U)	R	16-IX	2990	---	---	D
Histeridae	53.0R-219.2R (G)	C	17-V 6-X	1420 2700	a,o	12	A,F
Scarabaeidae	18.1L-274.6L (G)	C	19-III 6-X	1000 3000	a,f,i,j,o	11,30	A,D,E
Dascillidae	65.2R-208.6L (U,M)	C	4-V 18-IX	1500 2700	c	22,31	A,B
Byrrhidae?	34.9L (U)	R	23-IX	2850	---	---	D
Psephenidae	136.2R (M)	R	10-III	2500	i,k	---	A
Heteroceridae	246.0L (M,L)	N	12-XI	1100	---	1,6	B
Elmidae	Thunder R. (M)	N	15-VII	3600	i,k	---	A

Buprestidae	34.9L-133.8R (G?)	C	24-IV 15-VIII	2020 3200	a,d	22,31	A,B,C
Elateridae	49.8R-274.4L (G)	C	25-IV 19-IX	1000 3000	a,i	---	A,D,E
Throscidae	49.9L-208.6L (M)	N	16-IV 5-VIII	1500 2340	a	41	A,B
Eucnemidae	124.0L (M)	R	14-VII	2060	---	---	D
Phengodidae	72.0R (U)	R	11-VII	2610	---	---	D
Lampyridae	0.0R-133.8R (U,M)	N	7-VII	1960	j	26	A,B
Dermestidae	72.6R-246.0L (G)	C	9-V 21-VII	1100 3600	---	13,19,30	A,B,F,
Anobiidae?	19.1L-208.6L (U,M)	N	23-IV 5-VI	1500 3600	---	21,22,30,31,37	A,B,
Ptinidae	2.8R-166.5L (U,M)	N	17-VII 16-IX	1750 3100	a	45	B,D
Bostrichidae	53.0R (U)	N	26-VI	2810	b,d	23	A
Ostomidae	94.9L (M)	R	17-IV	2340	a	---	F
Cleridae	12.0L-171.4L (U,M)	N	22-IV 11-VII	1750 3050	a	19,28,31	A,B,D

Melyridae	0.9R-246.0L (G)	A	15-IV 12-XI	1000 3600	a,b,c,i,j	1,3,5,8,9,10, 11,13,15,17, 19,21,22,23, 28,29,31,34, 37,40,44,46,47	A,B,C,D
Meloidae	70.9R-269.5R (G)	C	27-IV 29-IX	1010 2630	a	47,48	A,B,H
Mordellidae	0.9R-269.5R (G)	C	11-V 5-X	1000 3600	a	8,12,15,30, 40,46	A,B,C,D
Tenebrionidae	0.9R-274.4L (G)	C	29-I 7-X	1000 3400	a,b,c,d,f,g,i	14,23	A,D
Alleculidae	18.1L-274.4L (G)	C	2-VI 21-IX	1000 3000	a,e	4	A,C,D
Melandryidae	75.3L-Thunder R. (U,M)	N	15-V 30-IX	2590 3600	j	---	B,D
Oedemeridae	70-5L-274.4L (G)	C	5-V 8-VIII	1000 2700	a,b,m	30,31	A,C,D
Anthicidae	34.9L-269.5R (G)	C	9-III 22-IX	1000 2850	a,e,j	4	A,C,D,E
Nitidulidae	25.5L-208.6L (G)	C	24-IV 20-IX	1500 2950	a,b,c	19,31,41	A,B,C
Cucjidae	133.8R (M)	R	2-VI	1980	---	---	B

Coccinellidae	0.0R-246.0L (G)	A	12-III 12-XI	1100 3600	a,c,l	1,3,8,13,14 15,23,25,26, 30,39,40,41, 44,45,47	A,B,C,D,E
Phalacridae	222.1L-269.5R (M,L)	N	21-VII 26-IX	1000 1360	---	---	D
Lathridiidae	269.5R (L)	R	21-VII	1000	---	---	D
Colydiidae?	190.4L (M)	N	19-VIII	1800	---	---	F
Cerambycidae	18.1L-156.8L (U,M)	N	25-VI 23-IX	1850 3000	---	---	A,C,D
Chrysomelidae	0.9R-246.0L (G)	A	23-IV 12-XI	1000 3600	a,b,d,e,f,j,l	1,3,4,6,8,9 12,13,14,17 19,27,39,40, 41,42,46	A,B,C,D,E,
Bruchidae	12.0L-208.6L (G?)	C	16-IV 5-X	1500 3040	a	17,20,21,24, 30,40	A,B
Anthribidae	49.8R (M)	R	24-IV	2800	a	---	A
Brentidae	52.5R (M)	R	24-VII	2700	j	---	A
Curculionidae	0.9R-246.0L (G)	A	7-III 12-XI	1100 3700	a,b,c,di,j	5,8,17,22,23, 29,40,41,46	A,B,C,K

Scolytidae	56.1R (M)	R	21-IX	2750	---	---	C
NEUROPTERA							
Megaloptera							
Corydalidae	52.5R-248.4R (G)	C	29-I 8-VIII	1100 3200	i,j,k	---	A,E
Planipennia							
Hemerobiidae	56.1R-246.0L (G)	C	23-I 13-XI	1100 2850	a	30,46	C,D
Chrysopidae	0.9R-246.0L (G)	C	23-I 5-X	1100 3500	a,j	3,5,8,13,17, 25,30,46,47	A,B,D,C,E
Myrmeleontidae	0.0R-269.5R (G)	C	24-IV 28-IX	1010 3770	a	---	A,D,E
TRICHOPTERA (After Usinger, 1956)							
Philopotamidae	65.2R-136.2R (U,M)	C	11-V 24-IX	1930 3200	k	---	A,D
Psychomyiidae	109.0R-133.8R (M)	C	2-VI 30-IX	1980 3600	j	---	B,C,D
Hydropsychicae	87.8R-133.8R (M)	N	21-I 16-VII	1980 2470	k	---	A
Hydroptilidae	65.2R (U)	R	18-IX	2680	---	---	D
Limnephilidae	41.0R-246.0L (G)	C	29-I 30-IX	1100 3600	j,k,m	---	A,B

Lepidostomatidae	Thunder R. (M)	N	30-IX	3600	j	---	B
Brachycentridae	Thunder R. (M)	N	15-VII	3600	j	---	B
(Heliopsychidae, recorded by D. Kubly, 1976, pers. comm.)							
LEPIDOPTERA							
Frenatae							
Papilionidae	52.5R-109.0R (G)	C	10-VII 30-VII	2100 3000	a	30	A
Pieridae	40.9R-246.0L (G)	C	12-III 24-IX	1110 2850	a	39	A
Danaidae	87.0L-209.0L (G)	C	17-V 28-IX	1500 2430	a	30,40	A
Satyridae	122.8L (U?,M)	N	30-IX	2080	a	---	A
Nymphalidae	49.8R-209.0L (G?)	C	5-III 28-VII	1500 2810	a	40	A,E
Libytheidae	166.5L-252.4L (M,L)	C	4-X 13-XI	1020 1750	j	39,43	A
Riodinidae	174.3R-181.5R (M)	N	24-IX	1600 1700	a	39	A
Lycaenidae	0.9R-252.4L (G)	C	24-V 13-XI	1010 3100	a	22,29,37,39	A

Hesperiidae	40.9R-246.0L (G)	C	9-VII 4-X	1110 2800	a,l	39	A
Megathymidae	75.4L(-108.5R) (U,M)	N	15-V (22-IX)	(2200) 3600	(a),c	---	A
Sphingidae	75.3L(-208.6L) (G?)	C	15-V (5-VIII)	(1510) 2580	a	16	A,D,E
Saturnidae	40.9R (U,M)	N	9-VII	2840	---	11	A
Ctenuchidae (incl. Amatidae)	19.1L-198.5R (G)	C	15-V 4-X	1710 3000	a	---	A,D
Arctiidae	53.0R-208.6L (G?)	C	15-V 24-IX	1510 2800	a	---	D
Noctuidae	0.0R-274.4L (G)	A	16-IV 4-X	1000 3100	a	30	A,C,D,E
Liparidae?	174.3R (M)	N	4-X	1710	a	---	A
Geometridae	18.1L-274.4L (G)	C	5-III 4-XI	1000 3000	a,l	12,14,23,30,39	A,B,C,D,E
Limacodidae?	73.4R-246.0L (G)	C	8-V 13-XI	1100 2850	a,c	---	C,D
Thyrididae?	80.6L (U)	R	27-VII	2600	a	---	E

Pyralidae	18.1L-274.4L (G)	A	6-V 4-X	1000 3000	a,j	25	A,C,D,E
Pterophoridae	0.0R-20.0L (U,M?)	C	16-IX 28-IX	2990 3100	a	---	A,D,E
Olethreutidae	65.2R-222.1L (G?)	C	4-VI 26-IX	1400 2700	a	---	C,D
Tortricidae	20.0L-274.4L (G)	C	2-VI	1000 2990	a	---	C,D,E
Cossidae?	93.4L (M)	N	28-VII	2400	a	---	E
Gelechiidae	34.9L-246.0L (G)	A	7-V 13-XI	1100 3200	a,b	3,8	A,B,C,D
Yponomeutidae	18.1L (U)	N	7-VII	3000	---	---	D
Gracilariidae	47.0R-274.4L (G)	C	18-I 26-IX	1000 2820	---	---	C,D,E
Opostegidae	166.5L (M)	N	17-Vii	1750	a	---	D
Lyonetidae?	147.9L (M)	N	1-X	1900	j	---	A
Psychidae?	19.1L-34.9L (U)	N	22-IX 23-IX	2850 3000	---	---	D

Incurvariidae?	246.0L (L)	N	13-XI	1100	---	---	C
DIPTERA (After Cole, 1969)							
Nematocera							
Tipulidae	16.5R-246.0L (G)	C	17-I 13-XI	1100 3600	a,c,j,k,l	12,39	A,B,C,D,E
Psychodidae	116.4L-Thunder R. (M)	N	8-III 30-IX	2140 3600	j	---	B
Ptychopteridae	31.9R (U)	R	12-VIII	2880	l	---	B
Culicidae	71.0L-239.0L (G)	C	21-I 27-VII	1110 2610	l,m	30	A,E
Ceratopogonidae	19.1L-274.4L (G)	A	18-I 4-X	1000 3020	a,j	3,13,30,46	B,D,E
Chironomidae	0.0R-246.0L (G)	A	17-I 12-XI	1100 3600	a,b,h,j,l,m	3,5,7,8,12,13 14,17,19,22, 23,25,26,30 33,39,40,42,47	A,B,C,D,E
Simuliidae	34.9L-225.9L (G)	A	22-I 6-X	1330 2850	a,b,j	13,23,25,27, 30,39,40,47	A,B,C,D,E
Mycetophilidae?	34.9L (U)	R	9-VII	2850	---	30	B
Sciaridae	25.5L-246.0L (G)	A	7-V 12-XI	1100 2950	a,j,l	17,30,42	A,B,C,D

Cecidomyiidae	0.0R-274.4L (G)	A	18-I 4-X	1000 3600	a,l	26,27,30,47	A,B,C,D,E
Brachycera							
Coenomyiidae?	145.5L (M)	R	10-III	1850	g	---	A
Stratiomyidae	84.1R-246.0L (G)	C	23-V 12-XI	1100 3200	a,j	13,39,40	A,B,C
Tabanidae	0.0R-246.0L (G)	N	21-VII 10-IX	1110 3600	a,j	---	A
Therevidae	61.5L-171.3L (G?)	C	11-V 22-IX	1720 2780	a	13,23,39	A,B,C
Mydidae	243.0 (L)	N	21-VII	1050	g	---	A
Asilidae	18.1L-208.6L (G)	C	8-VI 25-IX	1500 3000	a,j,l	---	A,J,L
Bombyliidae	0.0R-208.6L (G)	A	13-III 26-LX	1500 3600	a,j	5,7,8.16,19 22,26,30,37, 39,46,47	A,B,C,D
Empididae	31.9R-208.6L (U,M)	C	9-III 4-X	1500 3600	g,j	13,15,30	A,B,C
Dolichopodidae	0.0R-246.0L (G)	C	29-I 4-X	1120 3600	a,g,j,k	5,12,14,26,30 40	A,B,C,D
Cyclorrhapha							
Lonchopteridae	133.8R (M)	R	17-VIII	1980	j	---	B

Phoridae	71.0L-166.5L (U,M)	N	5-V 31-VII	1750 2610	---	---	D,F
Platypezidae	133.8R (M)	R	17-VIII	1980	j	---	B
Pipunculidae	49.8R-246.0L (G)	N	25-IV 12-XI	1100 2810	d	1,5,6,8	B
Syrphidae	19.1L-246.0L (G)	C	9-III 13-XI	1100 2880	a,c,d	5,12,30,39, 40,43	A,B,C
Conopidae	0.0R-166.5L (U,M)	N	7-VII 4-X	1750 3100	---	26,40	B
Otitidae?	72.6R-222.1L (U,M)	N	12-V 26-IX	1360 2610	a	---	A,C
Tephritidae	0.0R-252.4L (G)	A	16-IV 13-XI	1000 3600	a,e,j	4,5,12,13,18, 22,23,25,26, 27,30,39,43,47	A,B,C
Sepsidae	72.5R-208.6L (U,M)	C	11-V 24-V	1500 3600	---	13,19,30	A,B
Sciomyzidae?	34.9L (U)	R	13-VIII	2850	e	4	A
Lauxaniidae	0.0R-133.8R (U,M)	N	19-V 21-IX	1980 3100	j	26,39	B,C
Chamaemyiidae?	72.5R (U)	R	11-V	2600	---	13	B

Piophilidae	72.5R-208.6L (U,M)	N	12-V 26-V	1500 2620	---	3,13	B
Lonchaeidae	0.0R-171.4L (U,M)	N	22-V 7-VII	1720 3100	---	26,43,47	B
Sphaeroceridae	19.1L-174.3R (U,M)	N	12-VIII 4-X	1750 3000	1	---	B,D
Tethinidae	19.1L-171.4L (U,M)	C	7-V 16-VIII	1750 2990	c	20	A,B,D
Milichiidae	72.0R-208.6L (U,M)	N	11-VII 5-VIII	1500 2610	---	30	B,D
Ephydridae	0.0R-208.6L (G?)	A	24-LV 5-X	1500 3600	a,b,c,j	8,17,19,25,26, 30,42	A,B,C,D
Drosophilidae	0.0L-208.6L (G?)	A	15-V 5-X	1500 3600	a,b,j,l	8,26,30,33,40, 42,45	A,B,D
Diastatidae?	208.6L (M)	R	26-V	1500	---	22	B
Chloropidae	0.0R-208.6L (G?)	C	24-IV 28-IX	1500 3100	j	8,13,19,22,26, 30	A,B,C,D
Agromyzidae	0.0R-208.6L (G?)	C	16-IV 30-IX	1500 3600	j	7,12,13,19,26, 30,33,43	A,B,C,D
Heleomyzidae	56.1R-171.4L (G?)	C	22-V 21-IX	1720 2750	---	47	B,C

Trizoscelidae	0.0R-208.6L (G?)	C	9-V 7-VII	1500 3100	---	13,22,26,30, 40	B,C,F
Anthomyzidae?	208.6L (M)	R	26-V	1510	---	---	F
Opomyzidae	18.2L-174.3R (G?)	C	9-V 4-X	1710 3020	---	11,13,30	A,B,D
Chyromyidae?	72.5R (U)	R	12-V	2620	---	3	B
Asteiidae	0.0R-171.4L (U,M)	N	23-V 7-VII	1750 3100	---	26	A,B
Scatophagidae	0.0R-133.8R (U,M)	N	15-V 19-IX	1980 3100	---	26	A,B,C,D
Anthomyiidae	0.0R-246.0L (G)	A	29-1 13-XI	1100 3600	a,b,g,i	8,13,18,26,30, 36,40	A,B,C,D,F
Muscidae	0.0R-208.6L (G?)	C	6-VI 4-X	1500 3100	a	26,30,39,40	A,B,C,D
Nycteribiidae	35.3L-166.5L (G)	N	9-VII 29-VII	1750 2920	r,s	---	G
Calliphoridae	71.0L-246.0L (G)	A	22-I 12-XI	1100 3600	a,g	12,30,40	A,B,F
Sarcophagidae	0.0R-246.0L (G)	A	16-IV 12-XI	1100 3600	a,b,c,i,j	12,26,30,40,46	A,B,C,D,F

Tachinidae	0.9R-274.4L	A	4-V 13-XI	1000 3600	a,b,c,i,j	12,13,14,26, 30,39,40	A,B,C,D,E,F
Cuterebridae	40.9R-274.4R (G)	N	20-I 18-IX	1000 2830	j,t,u,w	---	A,G
SIPHONAPTERA							
Pulicidae	18.0L-274.4R (G)	C	18-I 12-IX	1000 2990	f,t,u,v,w,x,y	---	A,G,
HYMENOPTERA							
Symphyta							
Siricidae	0.0R (U)	R	28-IX	3200	---	47	A
Apocrita							
Braconidae	1.0R-246.0L (G)	A	8-III 12-XI	1100 3600	a,l	1,5,8,11,12,13 13,17,23,27,30 39,40,46,47	A,B,C,D
Ichneumonidae	**1.0R-246.0L** (G)	**C**	**24-IV** 13-XI	**1100** 3200	**a,m**	**5,8,19,23,30,** **40**	**A,B,C,D,E,I**
Mymaridae	34.9L (U)	R	9-VII	2850	---	30	B
Eulophidae	49.8R-208.6L (U,M)	N	24-IV 26-V	1510 2800	---	8,23,27,30,40	B
Encyrtidae	34.9L-246.0L (G)	C	15-V 12-XI	1100 2850	a	13,19,30,40	A,B
Eupelmidae	222.1L (M)	N	26-IX	1360	---	23	B

Torymidae	61.5L-94.9L (U,M)	N	15-V 23-IX	2330 2720	---	12,19,24,30	B,C
Pteromalidae	18.2L-246.0L (G)	A	25-IV 12-XI	1100 3600	a	5,8,12,13,15, 19,22,27,30, 40,43	A,B,D
Eurytomidae	71.0L-208.6L (U,M)	N	24-V 26-IX	1510 2610	a	---	B
Chalcididae	49.9R-198.5R (G?)	C	24-IV 25-IX	1530 2800	a	13,19,23,30, 39,46	B
Leucospidae	75.4L-181.5R (G?)	N	15-V 24-IX	1700 2580	a	30,39	A
Figitidae	72.6R-208.6L (G?)	N	12-V 26-V	1500 2700	---	12,13,19	B,C
Platygasteridae	181.5R (M)	R	24-IX	1650	---	39	A
Diapriidae	75.3L (U)	R	15-V	2800	---	42	B
Chrysididae	34.9L-246.0L (G)	N	15-V	1530	a,l	7,30,39,47	A,B,
Trigonalidae	72.5R (M)	R	11-V	2610	---	15	B
Tiphiidae	18.1L-269.5R (G)	A	15-V	1000	a	12,30,39,40	A,B,C,D,E

Sierolomorphidae	93.4L-171.4L (U,M)	N	22-V 2-VIII	1730 2400	---	9,14,30	B
Mutillidae	53.0R-222.1L (G)	C	24-VII 26-IX	1350 2800	a	---	A
Scoliidae	52.5R-180.0R (G)	C	31-VI 13-VIII	1660 2800	a	30,40	A
Sapygidae?	208.6L (M)	N	4-VIII	1500	a	---	A
Formicidae	0.0R-259.4R (G)	A	8-III 4-X	1010 3100	a,b,c,f,i,l	4,5,14,23,26, 30,32,40,42,46	A,B,C,D,F
Vespidae	41.9R-246.0L (G)	C	24-IV 5-X	1100 2840	a	19,30,39,40	A,B
Pompilidae	0.9R-225.9L (G)	C	11-V 6-X	1330 3400	a,e	30,39,40	A,C
Sphecidae	0.0R-246.0L (G)	C	8-V 6-X	1100 3100	a,c	8,13,25,26, 30,39,40	A,B,C,D,K
Colletidae	75.4L-246.0L (G)	C	24-IV 12-XI	1100 3600	a,l	1,30,39,40	A,B
Andrenidae	49.8R-208.6L (G)	C	11-V 26-IX	1500 3600	a	12,13,30,39,40	A,B
Halictidae	0.0R-208.6L (G)	A	18-I 28-IX	1010 3600	a,c,l	8,12,19,24,25, 26,30,39,40, 46	A,B,C,D

Melittidae?	133.8R-171.4L (M)	N	22-V 8-VI	1730 3600	---	7,30	B,C
Megachilidae	53.0R-109.0R (U,M)	C	5-V 30-VII	2200 3600	a	23,24,25,30,31	A,B
Apidae	0.9R-208.6L (G)	C	16-IV 6-X	1600 3100	a,l	19,21,24,30, 31,39,40	A,B

Appendix VII-2.--Some Arachnida of the Colorado River Riparian Zone in Grand Canyon National Park

TAXON	LOCATION[1] RANGE DISTRIBUTION[2]	RELATIVE[3] ABUNDANCE	DATE[4] RANGE	ELEVATION[5] RANGE (FT.)	HABITAT[6]	VEGETATION[7] ASSOCIATION(S)	COLLECTION[8] METHOD
SCORPIONIDA (After Williams, 1967 and Francke, 1973). Specimens identified by Oscar F. Francke.							
Buthidae	1.0R-246.0R (G)	C	5-V 12-IX	1100 3100	a,c,i,k	---	A
Centruroides sculpturatus sculpturatus Ewing							
Vaejovidae	1.0R-71.0R (U,M?)	N	4-V 19-IX	2610 3100	a,b,c,f	---	A
Vaejovis confusus Stahnke *Serradigitus wupatkiensis* Stahnke *Paruroctonus* sp. *Hadrurus spadix* Stahnke							
SOLPUGIDA (After Kaston, 1972). Specimens identified by Maryclaire Maltese.							
Eremobatidae	0.0R	N	---	3100	---	---	---
ARANEIDA (After Kaston, 1972). Specimens identified by Maryclaire Maltese.							
Orthognatha							
Dipluridae	31.6R (U)	N	17-IX	2800	---	---	A
Brachythele longitarsus							
Labidognatha							
Filistatidae	75.3L (U,M?)	N	5-V	2650	c	---	A
Filistata arizonica							

Phlocidae	87.0L-171.4L (G?)	N	17-V 22-V	1740 2450	a,f	---	A
Psilochorus sp.							
Theridiidae	17.5L-208.6L (G)	N	13-V 5-VIII	1550 3400	c,l	---	A
Latrodectus hesperus *Latrodectus mactans*							
Micryphantidae	0.0R-190.0R (G?)	N	24-V 12-VIII	1700 3100	a,e,i	4	A
Araneidae	1.0R-208.6L (G?)	N	9-V 21-IX	1510 3250	a,c	3,22,27,30,35, 39,47	A,B,C
Eustala rosea *Eustala* sp. *Neoscona oazacensis*							
Tetragnathidae	31.9R-Thunder R. (U,M)	C	24-IV 12-VIII	2830 3600	j	17,35,49	A,B
Tetragnatha versicolor							
Lycosidae	17.5L-190.0R (G)	A	14-V 24-V	1450 3400	a,f,j	23,30,39	A,D
Paradosa distincta *Paradosa* sp.							

Clubionidae	49.8R-81.2L (U,M?)	C	15-V 16-V	2550 2880	a	22,41	A
Anyphaenidae	81.0L-246.0L (G)	N	--- 13-XI	1100 2460	a,j	---	C
Anyphaena sp.							
Thomisidae	18.2L-208.6L (G)	A	24-IV 15-IX	1510 3600	a,i,j	7,12,15,17 18,22,23,25, 27,30,47	A,B,C
Misumenops sp. *Philodromus* sp.							
Salticidae	18.2L-208.6L (G)	A	12-V 15-V	1510 3100	a,j,l	3,12,13,26, 30,35,41,46,47	A,B

Appendix VII-3.--Texts used in identification of insects.

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APPENDIX XI-I

DIRECTIONS FOR CAMPSITE EVALUATION SHEET-2

1. Fill in your name, date, river mile, side of river (N or S), and profession.

2. The rating scale used for the following parameters ranges from 1 to 5 on an integer basis. Although descriptions are given only for ratings of 1, 3, and 5, intermediate values of 2 and 4 are permissible.

Man's Impact:

Litter
- 1 - No litter
- 3 - Apparent upon inspection
- 5 - Litter obvious

Trampling
- 1 - None
- 3 - Apparent upon inspection
- 5 - Obvious paths and/or trampled vegetation

Rock moving (this includes rock walls, cairns; does not include campfire sites)
- 1 - None
- 3 - Apparent upon inspection
- 5 - Obvious rock structures

Campfire sites
- 1 - None
- 3 - Campfire sites or rings but no or little charcoal
- 5 - Campifire sites and/or charcoal present

Wildlfire
- 1 - None
- 3 - Partial burn or ground fire
- 5 - ENtire area burned or crown fire

Human waste
- 1 - None present nor any smell
- 3 - Evidence such as chemical stain, smell, toilet paper
- 5 - Feces exposed, strong offensive odor

Wildlife and Habitat Criteria:

Habitats

1 - Homogeneous habitat types with no more than one of the habitat types in the immediate vicinity so that it has little or no influence on increasing species diversity. The habitat supports low densities.

3 - Homogeneous habitats with only moderate to low amounts of interspersion of different life forms, and intermediate species density and diversity.

5 - a. Three or more different habitat types in close proximity which provide for maximum species diversity, or

b. Homogeneous habitat types with high density and low to moderate diversity.

Special areas

1 - Habitats and broad geographic areas which contain general, non-specific requisites for wildlife. Non-critical needs are provided in these areas (as opposed to the criteria under 5a, b and c).

3 - Critical wildlife habitat requisites (food, cover, water, space, etc.) may be present but are either in low amounts or are widely scattered. The critical requisites provide for only a few species.

5 - Habitats and geographic areas where special requisites (food, cover, water, space) occur that are needed by the species to complete their life cycle.

a. Habitats which provide the specific items required for successful reproduction of each species. Examples include fawning areas, nesting areas, rearing areas, courtship areas.

b. Habitats which provide for the energy demands of the species during the harsh periods of the year.

c. Habitats which provide for the needs of migrating animals.

Unique combinations

1 - Habitats of broad homogeneous geographic distribution supporting what is generally

considered as "common organisms." No unique species interactions occur within the communities nor do they support rare or endangered species.

3 - Habitats of either small geographic area containing unique combinations of plants and animals or habitats of broad geographic area that contain few unique combinations.

5 - Areas of "unique combinations" of plants and wildlife. Criteria for defining uniqueness should include the following:

a. Areas that support rare or endangered species.

b. Areas that have not been modified to any great areas are in dynamic equilibrium.

c. Plants and animals that are existing at or near the edges of their geographic ranges.

d. Plants and animals that are restricted to specific geographic areas of the region.

e. Areas where unusual interactions of species occur. The species are usually spearated in their geographic distribution or by local habitat conditions.

Modifications

1 - Habitats significantly modified by man's activities, resulting in low animal species density and diversity.

3 - Habitats showing only limited modifications by man. These areas, if left to their own dynamic interactions, will return to natural conditions.

5 - No modification of habitat by man.

Value and needs

1 - Habitats that provide minimal wildlife related experiences or products for man.

3 - Areas that support a moderate number of organisms which satisfy human needs and values.

5 - Habitats which support plants and animals that satisfy various human needs (i.e., esthetic, scientific, hunting, long range stability of the ecosystem).