U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB-273 585

Synthesis and Management Implications of the Colorado River Research Program

Grand Canyon National Park, Arizona Colorado River Research Program.

Sep 77

SHEET | CRRP-17 | | PB273585

4. Title and Subtitle
SYNTHESIS AND MANAGEMENT IMPLICATIONS OF THE COLORADO RIVER RESEARCH PROGRAM

5. Report Date
Sept 1977

6.

7. Author(s)
R. Roy Johnson

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Division of Resource Management
Grand Canyon National Park
Box 129
Grand Canyon, Arizona 86023

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address
Office of Chief Scientist
Western Regional Office
National Park Service
450 Golden Gate Avenue - Box 36063
San Francisco, California 94102

13. Type of Report & Period Covered
Final 1973 - 1976

14.

15. Supplementary Notes

16. Abstracts
Scientific data on the riparian and aquatic ecosystems of the Colorado River in Grand Canyon National Park were collected from 1973 through 1976. The Colorado River Research Program emphasized investigations of human uses and interrelationships between sociological, biological, physical and chemical parameters of the riverine ecosystem. In some situations, environmental degradation exceeded the system's capacity to adjust and therefore irreversible changes were occurring under existing use patterns. Impacts were a result of the increasing numbers of river recreationists and, primarily, the altered riverine regime produced by the operation of Glen Canyon Dam. Sociological analysis of river users revealed user attitudes, and background, crowding variables, and degree of wilderness perception. Status and distribution of mammals, birds, reptiles, amphibians, fishes, insects, vascular plants and aquatic micro-organisms are outlined.

17. Key Words and Document Analysis. 17a. Descriptors

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement
No restriction on distribution. Available from National Technical Information Service, Springfield, VA 22161

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

22. Price
PC A04 | MF A01

COLORADO RIVER RESEARCH PROGRAM
Grand Canyon National Park
Grand Canyon, Arizona 86023

The Colorado River Research Program was initiated by the National Park Service in 1974 to secure scientific data to provide a factual basis for the development and the implementation of a plan for appropriate visitor-use of the Colorado River from Lee's Ferry to Grand Wash Cliffs and for the effective management of the natural and cultural resources within the Inner Canyons. The intensified research program consists of a series of interdisciplinary investigations that deal with the resources of the riparian and the aquatic zones and with the visitor-uses including river-running, camping, hiking, and sight-seeing of these resources, as well as the impact of use and upstream development upon canyon resources and visitor enjoyment.

Final reports that result from these studies will be reproduced in a series of Program Bulletins that will be supplemented by technical articles published as Program Contributions in scientific journals.

Merle E. Stitt, Superintendent
R. Roy Johnson, Program Director

Cover Drawing by J.G. Carswell, University of Virginia

SYNTHESIS AND MANAGEMENT IMPLICATIONS OF THE COLORADO RIVER RESEARCH PROGRAM

R. Roy Johnson

Colorado River Research Program Report
Technical Report No. 17

Grand Canyon National Park
Colorado River Research Series
Contribution No. 47

SYNTHESIS AND MANAGEMENT IMPLICATIONS

OF

THE COLORADO RIVER RESEARCH PROGRAM

R. Roy Johnson
Project Director

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
GRAND CANYON NATIONAL PARK
GRAND CANYON, ARIZONA 86023
SEPTEMBER 1977

DEDICATION

To the memory of

F. YATES BORDEN
1929 - 1977

whose innovative and significant studies, coupled with his enthusiasm, optimism, and dedication, contributed substantially to the Colorado River Research Program.

ABSTRACT

Scientific data on the riparian and aquatic ecosystems of the Colorado River in Grand Canyon National Park were collected from 1973 through 1976. The Colorado River Research Program emphasized investigations of human uses and interrelationships between sociological, biological, physical and chemical parameters of the riverine ecosystem. In some situations environmental degradation exceeded the system's capacity to adjust and therefore irreversible changes were occurring under existing use patterns. Impacts were a result of the increasing numbers of river recreationists and, primarily, the altered riverine regime produced by the operation of Glen Canyon Dam. Major environmental impacts identified included: scouring and loss of natural river bed; loss of beaches through erosion; spread of exotic plants and vertebrates; trail proliferation and vegetation trampling; incorporation of human litter, waste and charcoal into beach deposits; and wildlife utilization of artificial food sources.

Sociological analysis of river users revealed user attitudes, and background, crowding variables, and degree of wilderness perception. Most users perceived the canyon as uncrowded at present use levels. Private and commercial users differed on a number of background variables, with most users defining their trip in terms of wilderness through a preference of non-motorized travel. Economic analysis of float trip concessioners revealed the profitability of river concessions as well as indicating that total conversion to oar travel is economically feasible. The effects of motor noise on the visitor's experience is discussed.

Status and distribution of mammals, birds, reptiles, amphibians, fishes, insects, vascular plants and aquatic micro-organisms are outlined. The Grand Canyon was considered by several biologists as one of the last remaining refuges for several species of endangered fish which flourished in the Colorado River prior to construction of Glen Canyon Dam. Physico-chemical data for the river indicates the development of a more stable system than existed before construction of the dam leading, in part, to increased recreational use. Recommendations to management and future research and monitoring needs are discussed.

FOREWORD

Major John Wesley Powell led a small scientific expedition on the first trip down the remote and heretofore unexplored length of the Colorado River and through the foreboding depths of the series of its mighty canyons in 1869. During the subsequent 80 years, no more than 100 venturesome river runners followed his pioneering course.

For decades, these stretches of the Colorado River in the Grand Canyon region continued to remain virtually untouched and undisturbed by the activities of modern man. In 1935 changes began; waters of Lake Mead, created by Hoover Dam, intruded for miles into the lower reaches of the Grand Canyon and made this section of the canyon readily accessible by boat.

Upper portions of the canyon remained essentially unimpacted by the few boaters who passed through. Here too, however, the situation began to change - at first, gradually and then with dramatic acceleration.

Bolstered by an awakening challenge of the thrills and delights of river running and the advent of the use of the rubber raft, with its multipassenger capacity, the numbers of boaters increased. Even so, by 1959 the river was annually floated by less than 100 individuals.

By the late 1960's, the Colorado River in Grand Canyon was being altered by environmental stress of two types. Construction of Glen Canyon Dam upstream of the park in 1963 had altered the aquatic ecosystem as well as impacting the physical riverine environment.

With management of water flows, river conditions became predictable; the previous uncertainty and hazards of earlier river-running were greatly reduced. These favorable factors attracted additional outfitters to enter into the business of providing services for river-runners. As a result, in 1965, 547 individuals "ran the river" and by 1972, this number had risen to 16,428. The ever-increasing use of the Colorado River by river runners was causing environmental impact in the streamside (riparian) habitat. Although changes in the riverine ecosystem were obvious, an observer could not determine which of these changes were attributable to the dam and which were impacts caused by river recreationists.

The National Park Service has the challenging responsibility to manage the resources and to regulate appropriate uses within Grand Canyon National Park along the section of the Colorado River that extends for 277 miles from Lees Ferry to the terminus of the Grand Canyon at the Grand Wash Cliffs. Scientifically sound data is a prerequisite for the park administrator to consider in the making of realistic management decisions and in the development and implementation of action plans for the management of resources associated with the Colorado River and the visitor uses of these park resources. Research had been conducted in Glen Canyon prior to its inundation by Lake Powell. However, comparable research was not conducted downstream in Grand Canyon. Thus, baseline information against which to measure post-dam environmental changes was inadequate at best.

Plans for riverine research on the Colorado River in Grand Canyon National Park were begun in the late 1960's, resulting in the initiation of organized research by 1970. In the meantime, the Service formulated an interim river management plan.

In 1970, the Grand Canyon Natural History Association and the Arizona Academy of Sciences jointly sponsored a river trip down the Colorado River through the Grand Canyon. The purpose of this expedition was to make a preliminary identification and evaluation of the ecological changes that were developing. Participating in this cooperative endeavor, directed by David Ochsner and Peter Bennett of the National Park Service, were scientists representing various disciplines. Several independent investigations resulted subsequently from enthusiasm generated by this trip.

In 1973, the National Park Service embarked upon the multi-phase Colorado River Research Program, designed to secure the information required. It was directed by Dr. R. Roy Johnson, Senior Research Scientist, Grand Canyon National Park.

Initially, the Museum of Northern Arizona conducted a literature review to locate and identify references to all previous scientific investigations in Grand Canyon National Park. This resulted in a preliminary bibliography, an account of previous research, and a summary of obvious "gaps" in available information.

The research program that developed included the following investigations: the sociological aspects of the participants in the river-running experience; an economic analysis of the river-running industry; environmental and ecological elements in the riparian and aquatic environments; status of endangered and threatened species; impacts of human use; campsite inventories; human carrying capacities; use scheduling; environmental quality; beach development and erosion; inventories of plant and animal life; and impacts of water flow regulation.

A multitude of investigators representing various academic institutions and agencies participated in these studies. Although the bulk of this work was accomplished under contract with the National Park Service, significant contributions were made to the effort by independently sponsored projects involving dozens of persons ranging from volunteer students to senior scientists, many of them leading authorities in their fields. The Colorado River Research Program by this time had evolved into a multi-institutional, multidisciplinary investigation of the river corridor in Grand Canyon.

Approximately three dozen investigators from at least 20 institutions and agencies were involved in 30 major projects and numerous smaller sub-projects. The list of contributors to the research program and their affiliations is lengthy and impressive. To date, approximately 50 scientific contributions in the form of reports or publications and a series of Technical Reports have resulted. Subsequently, additional papers will be published in scientific journals. Data contained in these contributions have provided information used in the development of the Colorado River Management Plan and accompanying environmental statement.

The greatest remaining challenge facing investigators on the Colorado River in Grand Canyon National Park is the evaluation of rates and magnitudes of impacts from Glen Canyon Dam. The assessment of these impacts is complicated by the great lack of pre-dam information on anything except water flow regimes and associated stream characteristics (e.g., suspended sediment) Thus, a long-range monitoring program, using baseline information gathered during the Colorado River Research Program, is currently underway. This monitoring program is designed to examine all phases of the human-altered riverine ecosystem resulting from recreationists as well as Glen Canyon Dam, and to yield more information on long-term environmental changes. Monitoring will serve as an "early warning system" in case of future changes or continuing conditions which may be damaging to the natural environment of this important water resource.

This Technical Report No. 17, "Synthesis and Management Implications of the Colorado River Research Program," contains abstracts of the major findings and conclusions from the principal research projects under the Colorado River Research Program.

Superintendent

August 16, 1977
Date

CONTENTS

ABSTRACT ii
FOREWORD iii
CONTENTS vii
MAP OF COLORADO RIVER IN GRAND CANYON NATIONAL PARK. .... Facing 1
I INTRODUCTION 1
II PRIMARY ENVIRONMENTAL ISSUES 7
Research Findings:
Physical Substrate, Beaches and Alluvial Fans. 7
Vegetation 8
Terrestrial Fauna 9
Water Quality 11
Aquatic Life 13
Waste Disposal and Fires 15
Sociological Issues 17
Summary and Conclusions: Environmental Impact. 18

III FACTORS RELATING TO COMMERCIAL VS PRIVATE VS EDUCATIONAL ALLOCATIONS 21
Research Findings:
Commercial vs. Private vs. Educational 21
Summary and Conclusions 21

IV NOISE FACTORS and Comparison of Motor and Oar Trips 23
Research Findings:
Noise 23
Other comparisons of motor and oar trips 24
Summary and Conclusions 25

V THE WILDERNESS QUESTION 27
Research Findings:
Wilderness 27
Summary and Conclusions 28

VI ECONOMICS OF FLOAT THIPS IN GRAND CANYON 29

VII FUTURE RESEARCH AND MONITORING 31

REFERENCES 33
Appendix A: Major Findings of Researchers 37
1. Riparian Ecosystems and Carrying Capacity Research 39
2. Socioeconomic Research 45
3. Aquatic Ecosystems Research 55
Appendix B: Contracted Research of the Grand Canyon. 63
Appendix C: Grand Canyon National Park Colorado River Research Series 69

CHAPTER I INTRODUCTION

The Colorado River today is vastly different from the river John W. Powell explored in the mid-1800's. Powell's Colorado remained fundamentally unchanged until Hoover Dam was completed in 1935.

Although the Hoover Dam reservoir, Lake Mead, extended into the lower reaches of the Grand Canyon, the upper reaches of the canyon remained in a natural state until the Glen Canyon Dam was completed in 1963. Since then the flow of the Colorado through the Grand Canyon has been completely altered. Rather than a river charged with mud and sand, "too thick to drink and too thin to plow," it is now a clear, cold, tidal flow completely dependent upon the release of water from Lake Powell. The environmental responses have been rapid and significant.

Prior to Glen Canyon Dam, resource management of the Colorado River and the riparian (streamside) ecosystems was not an issue of major importance to the National Park Service. The area was a true wilderness. It is also fair to say that the environmental changes occurring today would elicit only limited interest if man's use of the river were to continue as it was prior to the construction of Glen Canyon Dam. However, the number of people making Colorado River boat trips has increased dramatically in recent years. The 200th person to run the river did so in the early 1950'5; since then more than 100,000 people have made the trip. Due to this increased traffic, in addition to the more long-term impact of the altered regime of the Colorado, National Park Service resource managers concluded in the early 1970's that the carrying capacity of the riparian zone may have been reached i.e., environmental degradation was exceeding the system's capacity to adjust and therefore rapid irreversible changes were being initiated.

Irreversible changes caused by man's use of a natural resource within the Grand Canyon are unacceptable to the National Park Service because.

> "…The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations, hereinafter specified, by such means and measures as conform to the fundamental purpose of said parks, monuments and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."
>
> --National Park Service Act, 1916

In addition, the final Master Plan for Grand Canyon National Park, dated 1976, states that.

> "The goals for management of the Colorado River in Grand Canyon will be to perpetuate the wilderness river-running experience and to attempt to mitigate the influences of man's manipulation of the river."
>
> and, more specifically, "The preservation of the Grand Canyon natural environment is the fundamental requirement for its continued use and enjoyment as an unimpaired natural area. Park management therefore looks first to the preservation and management of the natural resources of the park. The management concept is the preservation of total environments, as contrasted with the protection of only a single feature or species."

In order to achieve these goals as set out in the enabling legislation of the National Park Service and the Master Plan for Grand Canyon National Park, the resource managers must have solid information quantifying the rates and magnitudes of environmental change. Since the riparian zone of the Colorado did not represent a significant management problem prior to Glen Canyon Dam, there was little encouragement or support for scientific investigations and thu8 little baseline information was gathered. For this reason, when management decisions concerning visitor use levels were called for in the 1960's and early 1970's, the information base was soon seen to be inadequate. Therefore, in 1973, the National Park Service initiated a comprehensive research program to provide specific answers to these questions:

1. In what manner and how rapidly are physical and biological resources of the riparian zone of the Colorado River adjusting to the new river regime?

2. How is the increased visitation impacting the riparian and aquatic resources?

3. What are the sociological effects of different visitor use patterns on the nature and quality of the river running experience?

The result of three years of research and analysis demonstrated that the presence of Glen Canyon Dam has resulted in a dramatically changed riverine regime and that irreversible physical and biological changes are occurring as a result of current use patterns not visitor use levels. Based upon this research, the measures necessary to eliminate the irreversible impacts are the following:

1. The cessation of human waste disposal in beach deposits.

2. The elimination of camp and cooking fires.

3. The control of chaotic patterns of foot traffic to side canyons, attraction sites, and beach terraces.

4. The reduction of high visitor density and congestion at attraction sites.

5. The more even dispersal of visitor densities at camping sites.

6. The establishment of an NPS sponsored education/licensing program for both private and commercial guides.

In addition, the investigations concerning motorized traffic on the Colorado River indicate that the use of motors is contrary to established health and safety standards and is clearly inconsistent with the guidelines provided for management of park resources as outlined in the NPS Grand Canyon National Park Master Plan. Therefore, use of motorized craft should be eliminated.

Supporting evidence for these conclusions is Summarized in this report. In the report, findings are listed by subject in the chapters, while Appendix A lists findings by individual projects. It must be stressed, however, that this report is a summary of the results of approximately 30 individual research Studies. Sixteen of these technical reports have been reproduced in limited numbers and are available for review at the following locations:

Department of the Interior library (Wash. D.C.), NPS Denver Service Center, Regional Director of NP5 Rocky Mountain Region (Denver), Director of NPS Washington Office, Cooperative NPS Resources Studies Unit at University of Nevada (Las Vegas), University of Arizona (Cooperative NPS Resources Studies Unit and library), NPS Western Archaeological Center (Tucson), NPS Western Regional Office (San Francisco),Lake Powell Research Project (Department of Geophysics, University of California at Los Angeles), NPS Southeastern Regional Office (Atlanta), NPS Southeastern Regional Office (Santa Fe), NPS Pacific Northwest Regional Office (Seattle), NPS Mid-Atlantic Regional Office (Philadelphia), NPS Mid-Western Regional Office (Omaha), Northern Arizona University library, Arizona State University library, and Grand Canyon National Park library.

In addition, copies of the 16 technical reports as well as this "Synthesis thesis and Management Implications of the Colorado River Research Program" (Technical Report Series #17) may be purchased in soft copy or microfiche from the National Technical Information Service.

NTIS
U.S. Department of Commerce
Springfield, Virginia 22161

Communications with NTIS should refer to the accession number (see list below) of the desired report(s).

The Grand Canyon National Park Colorado River Research Program Contribution Series (Appendix C) consists of contributions from various phases of this research program. These contributions include the 16 technical reports, this "Synthesis and Management Implications of the Colorado River Research Program" as well as other research reports, technical and scientific papers. Contact the authors to obtain reports and papers other than the following 17 reports available from NTIS.

COLORADO RIVER TECHNICAL REPORT SERIES (see also Appendix C)

1. Shelby, 3. and J. Nielsen. 1976. Design and method of the sociological research in Grand Canyon: part I, river contact study. 32 pp. (NTIS Access. No. PB267760AS)
2. Shelby, B. and J. Nielsen. 1976. Motors and oars in the Grand Canyon: part II, river contact study. 45 pp. (NTIS Access. No. PB267730AS)
3. Shelby, 3. and J. Nielsen. 1976. Use levels and crowding in the Grand Canyon: part III, river contact study. 51 pp. (NTIS' Access. No. PB267745AS)
4. Shelby, B. and J. Nielsen. 1976. Private and commercial trips in the Grand Canyon: part IV, river contact study. 32 pp. (NTIS Access. No. PB267729AS)
5. Suttkus, R. D., G. H. Clemer, C. Jones and C. R. Shoop. 1976. Survey of fishes, mammals, and herptofauna of the Colorado river and adjacent riparian areas of the Grand Canyon National Park. 48 pp. (NTIS Access. No. PB267718AS)
6. Czarnecki, D. B., D. W. Blinn and T. Toukins. 1976. A periphytic microfloral analysis of the Colorado Rivet and major tributaries in Grand Canyon National Park. 106 pp. (NTIS Access. No. P326776IAS)
7 Howard, A. D. and R. Dolan. 1976. Alterations of terrace deposits and beaches of the Colorado River in the Grand Canyon caused by Glen Canyon Dam and by activities during river float trips. 29 pp. (NTIS Access. No. P326?766AS)
8. Cole, G. A. and D. M. Kubly. 1976. Linnologic studies on the Colorado River and its main tributaries from Lees Ferry to Diamond Creek including its course in Grand Canyon National Park. 88 pp. (NTIS Access. No. PB267736AS)
9. Borden, P. *Y.* 1976. User carrying capacity for rivet running the Colorado River in the Grand Canyon. 79 pp. (NTIS Access. No. PB267744AS)
10. Carothets, S. W. 1976. An ecological survey of the riparian zone of the Colorado River between Lees Perry and the Grand Wash Cliffs. 251 pp. (NTIS Access. No. PB267770AS)
11. Phillips, R. and C. Sartor-Lynch. 1976. H~ waste disposal on beaches of the Colorado River in Grand Canyon. 79 pp. (NTIS Access No. P3267733AS)
l2. Sommerfeld, M., W. Crayton and N. Crane. 1976. Survey of bacteria, phytoplankton and trace chemistry of the lover Colorado River and tributaries in Grand Canyon National Park. 136 pp. (NTIS Access. No. P326773IAS)
13. Laursen, E. and E. Silverston. 1976. Hydrology and sedimentology of the Colorado River in Grand Canyon. 27 pp. (NTIS Access. No. P3267735A5)

14. Minckley, C. 0. and D. W. Blinn. 1976. Summer distribution and reproductive status of fish of the Colorado River in Grand Canyon National Park and vicinity during 1975. 17 pp. (NTIS Access No. PB267732AS)
15. Deacon, J. E. and J. R. Baker. 1976. Aquatic investigation on the Colorado River from Separation Canyon to the Grand Wash Cliffs, Grand Canyon National Park. 26 pp. (NTIS Access. No. PB267734AS)
16. Parent, C. R. and F. E. Robeson. 1976. An economic analysis of the river running industry in Grand Canyon National Park. 131 pp. (NTIS Access. No. PB268997)
17. Johnson, R. R. 1977. Synthesis and management implications of the Colorado River Research Program. 75 pp. (NTIS Access. No. pending)
18. Thompson, D. N., A. J. Rogers, Jr., and F. Y. Borden. 1974. Sound-level evaluations of motor noise from pontoon rafts in the Grand Canyon. 32 pp. (NTIS Access No. pending)

This page is blank

CHAPTER II PRIMARY ENVIRONMENTAL ISSUES

The primary factor responsible for the wide ranging environmental changes that are occurring along the Colorado River is Glen Canyon Dam. Superimposed on the systematic change associated with the dam are visitor impacts -

In brief, the research summarized in this section indicates that in addition to the dam, visitor use patterns are contributing significantly to rapid degradation of the riparian environment, but that visitors are not having significant impact on the water quality or aquatic life of the Colorado River. The sociological studies indicate clearly that visitor satisfaction is very high.

Research Findings: Physical Substrate, Beaches and Alluvial Fans

a. Lake Powell, behind Glen Canyon Dam, is trapping almost all of the former sediment load of the Colorado, resulting in erosion of former flood-stage terraces (beaches) below the dam (Howard and Dolan, 1976).

b. In segments of the Colorado River where a sufficient sediment load is still carried, such as toward the lower end of the canyon or below the Little Colorado during flood stages, beaches are continuing to build (Howard and Dolan, 1976; Laursen, 1976).

c. The majority of the approximately 160 rapids of the Colorado River in Grand Canyon National Park were created when alluvial materials too large to be moved by the parent stream were deposited in the channel by flash flooding of the tributaries. These materials were moved out of the rapids as long as peak floods in excess of 50,000 ft. 3/sec (cfs) occurred. With the modified regime, discharges of this level would be exceptional, therefore, the alluvial fans are growing and the rapids are becoming more severe. Analysis of pre-and post-dam aerial photographs show that between Mile 0 and Mile 176 there are 570 kilometers of fine grain (silt/sand) shoreline deposits and 250 kilometers of shoreline consisting of large alluvial material (mostly cobble/boulder sizes). The fine grained shorelines are changing: 16 percent are eroding rapidly (15 meters since the dam, or about 2-3 meters per year); 18 percent are eroding at a moderate rate (measurable but less than 15 meters since the dam); 50 percent are not changing; 9 percent are growing at a moderate rate and 6 percent are growing at a rapid rate. Ten percent of the coarse shoreline deposits are growing at a moderate rate and 73 percent show no change. None of the coarse grained shorelines are eroding (Howard and Dolan, 1976).

Preceding page blank

d. Shoreline river velocities are not high although in some cases they are certainly respectable. Natural riprapping is not especially large. In some riffles the size of the natural riprap is surprisingly small (Laursen, 1976).

e. With the present river regime most of the campsites are positioned above the present high water stage. The dominant natural erosion processes are aeolian (winds) and mass wasting (Howard and Dolan, 1976).

f. Direct visitor impact includes the incorporation of campsite litter into the beach deposits, burial of chemically treated wastes, and the direct stress associated with people walking on the unstable sedimentary deposits and the vegetation (Howard and Dolan, 1976).

g. The rates of erosion and degradation at the most heavily used 20 to 30 prime campsites exceed the capacity of the present processes to reestablish natural landscapes (Howard and Dolan, 1976).

h. Most of the foot traffic on the prime camping beaches is concentrated within 100 meters of the mooring sites and decreases outward exponentially with distance Use is concentrated along pathways that radiate outward from the main campsite. These pathways are commonly eroded .75 to 1.25 meters in depth. Destruction of the fragile soil profiles and delicate vegetation is almost total at most campsites except in areas protected by dense vegetation i.e., Tamarix (Howard and Dolan, 1976).

Research Findings: Vegetation

a. The interrelationship between trampling, impacted vegetation and aeolian erosion is evident at attraction sites and some heavily used camps (Carothers and Aitchison,1976; Howard and Dolan,1976).

b. The impact associated with multiple trails changes the plant community structure (Carothers and Mtchison,1976).

c. The most heavily used beaches have areas of 2,500 to 10,000 sq. ft. (233 to 930 sq. m) largely to completely devoid of vegetation (Howard and Dolan, 1976).

d. Visitor impact at campsites sometimes results in considerable disturbance to segments of the vegetation or even to their elimination. Vegetational disturbance may be due to trampling or the systematic removal or "pruning" of vegetation e.g., for sleeping areas (Carothers and Aitchison, 1976; Howard and Dolan, 1976).

e. On the 20 to 30 heavily used beaches vegetation is sometimes so affected by visitor activities that the further spread of either invasive exotics or native species is reduced or eliminated (Carothers and Aitchison, 1976). This disturbance may be either through destruction of the plants themselves, by uprooting of seedlings or through disturbance of soil structure which eliminates a suitable "bed" for germination (Howard and Dolan, 1976).

f. Visitor activities, including camping, hiking and lunch stops, causes disturbance to portions of the riparian vegetation (Carothers and Aitchison, 1976).

g. Destruction of vegetation from the digging of porta potty holes is evident (Carothers and Aitchison, 1976).

h. The practice of burning toilet paper has resulted in brush fires which produce a long-term effect on some vegetative elements (R. Johnson, 1976; Carothers and Aitchison, 1976).

Although over a score of exotic plants exist along the banks of the Colorado River and its tributaries, only Russian Thistle (Salsola kali), Camelthorn (Alhagi camelorum) and Russian Olive (Eleagnus angustifolium) are considered troublesome weed species that are spreading in distribution and are potentially injurious to the canyon visitor (Carothers and Aitchison, 1976; NPS studies in progress, Johnson).

i. The exotic Salt Cedar (Tamarix chinensis) is the dominant shrub/tree species on the majority of Colorado River beaches (Carothers and Aitchison, 1976).

j. The exotic Salt Cedar is distributed in proportions that are totally beyond control. This species provides cover for wildlife, stability for beaches and shade for visitors (Carothers and Aitchison, 1976; Dolan et al., 1976).

k. Within the past few years a new exotic has invaded the river corridor, the Russian Olive (Eleagnus angustifolium) This species has not become widely distributed in the canyon and could still be controlled if action is taken soon (Carothers and Aitchison, 1976; NPS studies in progress, Johnson).

Research findings: terrestrial Fauna

a. In general no adverse effects on vertebrate populations were detected (Suttkus et al., 1976; Carothers and Aitchison, 1976). There are two exceptions to this. The first is the feeding of Rock Squirrels (Spermophilus variegatus) and Mule Deer (Odocoileus hemionus) at Phantom Ranch, largely by hikers rather than river recreationists, resulting in abnormally high unhealthy populations (Carothers and Aitchison, 1976). The second is the reduction in lizard populations through reduction in driftwood on which the lizards rely for shelter, displaying, and foraging (Carothers and Aitchison, 1976).

b. Campsite scavengers such as the Ringtail (Bassariscus astutus), Spotted Skunk (Spilogale gracilis), Common Raven (Corvus corax), Harvester Ants (Pogonomyrmex californicus), Flesh Flies (Sarcophagidae), Blow Flies (Calliphoridae), etc., are found in high concentrations where visitors concentrate (Carothers and Aitchison, 1976).

c. Campsite scavengers generally help to clean food particles from the beach deposits, but intentional food hand outs should not be condoned (Carothers and Aitchison, 1976).

d. Human use causes destruction of nest sites and burrows of ground dwelling vertebrates and may cause stress or behavioral changes in territorial vertebrates (Carothers and Aitchison, 1976).

e. Two species of exotic birds, the House Sparrow (Passer domesticus) and Starling (Sturnus vulgaris), both of which are general indicators of continued human presence or occupation are beginning to appear with increasing frequency along the river corridor. Their presence is especially noted in areas where permanent human occupation is established i.e., Phantom Ranch, Havasu Creek (Carothers and Aitchison, 1976).

f. The exotic Feral Ass (Eguus asinus) is rapidly destroying riparian and desert habitat within the Grand Canyon (Carothers and Aitchison, 1976; Carothers et al., 1976; NPS Grand Canyon National Park Feral Burro Management Plan and Environmental Assessment, 1976).

g. Three species of endangered (USFWS, 1973) birds, the Bald Eagle (Haliaeetus leucocephalus leucocephalus), Peregrine Falcon (Falco peregrinus anatum), and Brown Pelican (Pelecanus occidentalis) (accidental) are known to utilize Grand Canyon environs. The status of these animals in the Park has been reviewed by Carothers and Johnson (1975).

Present visitor use levels in the Colorado River corridor have no apparent effect on these animals (R. Johnson, 1976).

h. The only threatened species (USFWS, 1973) encountered during this survey was the Prairie Falcon (Falco mexicanus). Its status is reviewed by Carothers and Johnson (1975). Present visitor use levels have no detectable negative effects on this species (R. Johnson, 1976).

i. Several species exist along the Colorado River in Grand Canyon whose status in Arizona may be in jeopardy in the near future (AGFD, 1976). These include the following:

River otter (Lutra canadensis Sonora)
Desert Bighorn Sheep (Ovis canadensis mexicana)
Snowy Egret (Egretta thula brewsteri)
Black-crowned Night Heron (Nycticorax nycticorax hoactli)
Osprey (Pandion hahaetus carolinensis)
Bonytail Chub (Gila elegans)
Desert Tortoise (Gopherus agassizi)
Gila Monster (Heloderma suspectum)

The fish and reptile species listed above were encountered during the research projects and are susceptible to disturbances resulting from increased human use of the riparian zone. At present, the Bonytail Chub is a species whose Status is considered to be in jeopardy by many southwestern ichthyologists, although it has not been placed on the Federal Register as endangered or threatened (Miller, 1975).

Research Findings: Water Quality

a. Due to impoundment of the Colorado River above Glen Canyon Dam, levels of suspended materials increase as one proceeds downstream from Glen Canyon Dam (Blinn et al., 1976).

b. River temperatures are 20 to 10^0C (4^0-18^0F) cooler than pre-Glen Canyon Dam temperatures (Deacon and Baker, 1976).

c. Consumption of untreated Colorado River water above Diamond Creek and tributary waters presents potential bacteriological health hazards (Federal Water Pollution Control Administration standards, USD1 1968) although, based on the elements monitored, the dissolved chemical quality of the river and tributaries does meet current water quality standards for drinking water (Sommerfeld et al., 1976).

d. A number of diatoms described as indicator organisms were found in the river and tributaries and may be of future use in assessing water quality changes in the river system (Sommerfeld et al., 1976).

e. Most of the 15 chemical elements monitored in the river and tributaries remained relatively stable on a temporal and spatial basis (Sommerfeld et al., 1976).

f. A detectable increase in the concentration of the element sodium occurs with distance downstream from Lees Ferry (Sommerfeld et al., 1976).

g. The 11 tributaries differed chemically in various degrees from each other and from the river. The Paria River, Little Colorado River and Kanab Creek exhibited large fluctuations in chemistry that was associated with their flow conditions. The flooding Little Colorado exceeds recommended standards of water quality for the elements iron and manganese (Sommerfeld et al., 1976).

h. Saturated dissolved oxygen levels, low nutrient concentrations and bacterial numbers indicate natural unpolluted conditions of the Colorado River below Diamond Creek (Deacon and Baker, 1976).

i. Cooler water temperatures have probably changed the density relationships of the Colorado River and Lake Mead, changing current patterns and limnological conditions in Lake Mead (Deacon and Baker, 1976).

j. Turbidity and suspended solids were extremely variable due to spring rains and runoff (Deacon and Baker, 1976).

k. Biological oxygen demand and chemical oxygen demand were generally very low in the Colorado River below Diamond Creek (Deacon and Baker, 1976).

1. Sewage effluent from porta-potty dumps has minimal overall effects on Colorado River water quality due to dilution and biological decay, but potential health hazards may exist at some campsites below Diamond Creek (Deacon and Baker, 1976).

m. Colorado River water is rich in plant nutrients, but there is some evidence that the water might become nitrogen-limited if massive algal growths occurred; phosphorous is abundant (Cole and Kubly, 1976).

n. The increase in salinity from the Little Colorado is lessened by tributaries entering downstream resulting in the Colorado River below Diamond Creek having only a slightly greater (about 5%) salt load than it had at Lees Ferry (Cole and Kubly, 1976).

o. The $C0_2$ concentration was in excess of saturation at Lees Ferry. There is a tremendous loss of free $C0_2$ from the river downstream of Lees Ferry (Cole and Kubly, 1976).

p. Water quality below Glen Canyon Dam is much more stable than it was before the dam was constructed (Cole and Kubly, 1976).

q. The Colorado River can be considered a high alkalinity and conductivity system (Blinn et al., 1976).

r. Indications of pollution occasionally occur under special conditions.

(1) Paria River, Bright Angel, Shinumo, Havasu, and Diamond Creeks show occasional presence of pollution indicator algal associations (Blinn et al., 1976).

(2) Potential health hazards may exist at some river campsites in the form of adjacent high total coliform counts, possibly due to seepage from porta-potty disposal (Deacon and Baker, 1976).

(3) Total viable coliform bacterial numbers exceeded desirable water quality standards at several river sampling sites and in most of the tributaries throughout the year (Sommerfeld et al., 1976).

Research Findings: Aquatic Life

a. No observations were recorded in which float parties had any direct effect upon the fishes except for visitors who caught the endangered Humpback Chub (Gila cypha) at the mouth of the Little Colorado on hook and line (Suttkus et al., 1976; Minckley and Blinn, 1976; R. Johnson, 1976).

b. Aquatic habitat restoration, complete or partial, is an absolute pre-requisite to a recovery program for fishes of the genus Gila (presently endangered or rare) in the Grand Canyon area (Suttkus et al., 1976).

C. Members of the genus Gila exist and breed only in tributaries or in the river immediately below such tributaries, where conditions closely approximate the original unaltered habitat of the Colorado River (Minckley and Blinn, 1976; Suttkus et al., 1976).

d. Nineteen fish species plus one hybrid sucker combination and one hybrid trout combination are known to exist in the Grand Canyon area of the Colorado River system; 15 of the species are introduced (Suttkus et al., 1976).

e. Reproduction was verified in all native fish species collected, with the exception of the Humpback Chub, by collection of the young of the year fish; reproduction was verified in three species of exotics by collection of juveniles (Minckley and Blinn, 1976).

f. Native fish were distributed throughout the system with the exception of the genus Gila which was confined to the vicinity of Shinumo Creek and/or the Little Colorado River; exotic fish were also distributed throughout the system (Minckley and Blinn, 1976; Suttkus et al., 1976).

g. Although more species of introduced fish were taken in the samples, larger numbers of some native fish were taken (Suttkus et al., 1976; Minckley and Blinn, 1976).

h. All captured fish were examined for ectoparasites and none were found (Minckley and Blinn, 1976). Attached copepods were present on one Gila specimen and one Carp (Cyprinus carpio) specimen (Suttkus et al., 1976).

i. There is some evidence that the tributaries entering the Colorado River serve as refugia for several unique (and endangered) species of native fish that flourished in the river prior to the Glen Canyon Dam (Minckley and Blinn, 1976). This is true at least for the endangered Humpback Chub (Suttkus et al., 1976) and possibly the Bonetail Chub (Miller, 1975).

j. The Bonytail Chub and Humpback Chub are declining in numbers (Minckley and Blinn, 1976).

k. No specimens of the Humpback Sucker (Xyrauchen texanus) or Colorado River Squawfish (Ptychocheilus lucius) were collected on any of the research trips (Suttkus et al., 1976; Minckley and Blinn, 1976; Miller, 1975).

1. Introduction of exotic species of fish has exerted biological pressure on native species (Minckley and Blinn, 1976).

m. Visitors use of soap, when concentrated in tributaries, is potentially detrimental to fish reproduction (Suttkus et al., 1976) and presently against NPS regulations.

n. The river is rich in plant nutrients throughout, yet there is no evidence of excessive algal growth (Cole and Kubly, 1976).

o. Total viable bacterial numbers in the river and tributaries ranged from 10^1 to 10^6/ml (Sommerfeld et al., 1976).

p. On the basis of phytoplankton numbers, the Colorado River and the 11 tributaries studied must be considered relatively unproductive (Sommerfeld et al., 1976).

q. A diverse phytoplankton population occurs in the system, with 122 species identified In the river and 137 species identified in the tributaries. Bacillariophycean algae (diatoms) dominated the phytoplankton flora (Sommerfeld et. al., 1976). (See U. below).

r. Phytoplankton numbers never exceeded 3,OOO/liter in the river and 12,000/ml in tributaries (Sommerfeld et al., 1976).

5. Overall, the phytoplankton population was diverse, but sparse, and decreased with distance downstream from Lees Ferry (Sommerfeld et al., 1976).

t. Primary productivity is extremely variable and generally shows an inverse relationship with turbidity (Deacon and Baker, 1976).

U. A relatively high algal diversity (approximately 345 taxa) plus a low number of pollution-tolerant species indicates a relatively clean and possibly oligotrophic system (Blinn et al., 1976; Czarnecki and Blinn, 1976). (See q. above).

v. Major differences exist in algal taxa above and below Glen Canyon Dam (Blinn et al., 1976).

w. The system can be characterized as a Diatoma vulgare - Cocconeis pediculus - Rhoicosphenia curvata - lotic-assemblage indicative of high alkalinity and conductivity subject to seasonal variation with highest diversity in the spring and lowest diversity in the late summer (Czarnecki and Blinn, 1976).

Research Findings: Waste Disposal and Fires

a. The health of river runners is potentially endangered due to the numbers of fecal coliform bacteria and associated pathogens which have been found capable of surviving up to 11 months of burial in porta-potty dumps located on or near camping beaches (Knudsen, 1976; K. Johnson, 1976).

b. The death-rate of fecal coliforms was very rapid. After one month, at nine out of ten sites the fecal coliform concentrations were less than 14/g. Using the 800,0OO/g estimate for original density, this means that only .002 percent of the FC survived one month (99.998% reduction) (Sartor-Lynch and Phillips, 1976).

c. Fecal contaminants are not restricted to the actual porta-potty dumpsite, but have been found to migrate up to 8 inches away from the dumpsite (Knudsen, 1976).

d. Random sand samples taken from sleeping, eating and cooking areas at some campsites contain viable fecal coliform bacteria (K. Johnson,
1976).

e. To assess the general level of beach contamination, 52 beach samples were collected in July, August and September, 1976. A high proportion (32%) of beach samples had fecal coliforms present. This is significant in that the occurrence of fecal coliforms in the soil is directly related to human or animal pollution (Sartor-Lynch and Phillips, 1976).

f. The beach samples indicate that high temperatures (>40^{0}C) and/or low moisture (<1% moisture) conditions result in low fecal coliform counts. Only 10 percent of the samples had fecal coliform concentrations greater than one per gram and the highest density was ^{5}.4/g (Sartor-Lynch and Phillips, 1976).

g. Under cooler and moister weather conditions (spring or fall), concentrations of enteric organisms would remain at higher levels for a longer period (Sartor-Lynch and Phillips, 1976).

h. The disinfectant chemicals presently used in porta-potties do not provide for total disinfection of pathogens associated with fecal wastes (Knudsen, 1976).

i. There was no indication that disinfection of the porta-potty contents effects a significant reduction in fecal coliform densities. On the average, chemically treated dumps had higher numbers of organisms (Sartor-Lynch and Phillips, 1976).

j. Viable fecal coliform bacteria have been isolated from the top 3-6 inches (8-l5 cm) of porta-potty dumpsites (Knudsen, 1976).

k. Because of colloidal interactions between sand and porta-potty effluents, the porta-potty holes do not drain adequately resulting in solid fecal material being buried very close to the surface. In some cases, these materials have erupted to the surface of the beach deposit (Knudsen, 1976; Aitchison et al., 1974).

1. Approximately 5000 porta-potty burials per year take place within the river corridor. Each dumpsite contributes to further destruction of the soil profile and the microbiology of the beaches (Knudsen, 1976).

m. Extrapolation of visitor use data indicates that as many as 100 to 150 dumpsites per season are placed on some of the more heavily used camping areas (Carothers and Aitchison, 1976).

n. Porta-potty dumpsites are so numerous on some of the smaller camping areas that repeated use of the same dumpsite is a common occurrence (Carothers and Aitchison, 1976).

0. By the end of the river season August-September, urine and fecal odors are apparent in many of the more popular camping areas, attraction sites and rapid overlooks (Carothers and Aitchison, 1976)

p. There are currently no adequate regulations regarding human waste disposal when parties are not in camp leading to undesirable levels of contamination at attraction sites and lunch stops (Knudsen, 1976; Sartor-Lynch and Phillips, 1976; R. Johnson, 1976).

q. Brush fires within the Colorado River corridor have been caused by the careless incineration of toilet tissue (Knudsen, 1976; K. Johnson, 1976; Carothers and Aitchison, 1976).

r. Regulations regarding organic garbage disposal, trash and litter, dishwashing waste water, firepan wastes, and other organic wastes (canned food juices, etc.) are not being followed (Carothers and Aitchison, 1976).

5. Organic food wastes and garbage have caused dramatic increases in Harvester Ant, Blow Fly, and Flesh Fly populations (Carothers et al., 1976).

t. The most heavily used campsites are approaching "sandbox" conditions by the systematic incorporation of charcoal and human wastes into the beaches at rates that exceed the purging capacities of natural processes (Howard and Dolan, 1976).

u. During the past 5 years there has been a sharp decline in available driftwood for fires which has affected populations of lizards who use it for shelter, display, and foraging (Carothers and Aitchison, 1976).

Research Findings: Sociological Issues (Shelby and Nielsen, 1976b)

a. Different use levels have a pervasive effect on the character of the Grand Canyon experience in terms of river and attraction site contacts. Use level does not yet affect campsite contacts, but does affect the number of adjustments for crowding made by trip leaders.

b. Thirty percent of river travelers see the canyon as crowded, but this is unrelated to the number of people they saw during their trip.

c. Satisfaction levels in the canyon are high, with most (85%) rating their trip as "excellent" or "perfect." Satisfaction is not related to perceived crowding or actual density.

d. The lack of relation between contacts, perceived crowding, and satisfaction is attributed to several factors. First, it is possible that present use levels are not high enough to have a detrimental effect on the contemporary user 's experience. Second, there is lack of agreement about how crowded the canyon "should" be. Most river runners are making the trip for the first time; over half didn't know what to expect in terms of contacts with other groups, and there was little consensus among those who had some expectations about number of encounters with other trips. Finally, it is possible that the present (1975) use level (considered high by experienced river runners) may have already discouraged users who are extremely sensitive to crowding, thereby excluding the opinions of that user group from data collected in this study.

e. Satisfaction with river trips is based on the personal benefits, social atmosphere, and wilderness character provided by the trip.

f. Use tends to be concentrated both in certain areas and at certain times. Specifically, those areas that roughly correspond to the bottleneck areas identified by Yates Borden in his campsite inventory show high contact. Certain days of the week also show higher use.

g. Management of the crowding situation on the river can best be aimed at controlling the character of the experience (contacts among groups).

h. Choosing a use level requires definition of the kind of experience to be provided and selection of a contact level "appropriate for that experience.

(Shelby and Nielsen, 1976a)

a. There are differences between motor and oar trip passengers in their opinions, preferences, and perceptions about use, density, and contacts. Those on oar trips preferred to have less contact with other groups, and were more sensitive to crowding and human impact.

b. Because there are few pre-trip background differences between motor and oar passengers (see Motor-Oar section) the previous finding suggests that the river experience itself (motor versus oar, in this case), rather than pre-trip experience affects preferences and attitudes regarding contacts, use levels and perceived crowding. In short, users leave the canyon with density preferences or opinions that are very much like their own experience.

<u>Summary and Conclusions:</u> <u>Environmental Impact</u>

All phases of this research project show that rapid irreversible physical and ecological changes are occurring as a result of the present visitor use patterns along the Colorado River. However, the rate and <u>magnitude</u> of these irreversible changes can be reduced and in some cases eliminated if some of the use patterns are modified. It has been documented by this research program that the irreversible changes are not a function use levels. Therefore, if the decision is made to either increase, decrease or maintain the present use levels, the following changes in use patterns must be implemented in order to minimize both the rates and magnitude of environmental degradation:

1. The incorporation of human wastes in beach deposits must be eliminated not only at camps but at lunch stops and attraction sites. Human waste include food particles, liquid waste, and porta-potty effluent.

2. Regardless of the present NPS regulations, charcoal and ash is accumulating in the beach deposits at rates that exceed the purging capacities of natural processes. In addition, the rate of replenishment of driftwood, an important component of the ecosystem, is less than the rate of consumption. Therefore, open and pan fires must be eliminated.

3. The fragile desert ecosystem (physical and biological) cannot withstand the current uncontrolled patterns of off-river use. Therefore, the present chaotic patterns of foot traffic to side canyons, attraction sites, and beach terraces must be controlled.

4. High visitor densities at prime attraction sites have been found to be detrimental to both the physical and biological preservation of the resource as well as user satisfaction. Therefore, action must be taken to mitigate this congestion.

5. There are approximately 400 campable beaches along the Colorado River in Grand Canyon. However, 3/4 of the visitor use is concentrated on approximately 100 beaches. Therefore, mitigating measures must be taken to distribute the environmental stresses associated with concentrated high use levels.

This page is blank

CHAPTER III: FACTORS RELATING TO COMMERCIAL VS. PRIVATE VS. EDUCATIONAL ALLOCATIONS

Research results summarized in this section show that private and commercial trip passengers differ on several pre-trip background characteristics, the most significant of these being that private passengers have a good deal more river-running and outdoor recreation experience, Private trips are smaller, spend more time in the canyon and visit more attraction sites than do commercial trips (commercial oar trips differ from commercial motor trips in the same way, but the difference is not as great as that between private and commercial trips). Private users are similar to commercial oar users in terms of attitudes and perceptions in regard to contacts, crowding, etc.

Research Findings: Commercial vs. Private (Shelby and Nielsen, 1976c)

a. Compared to commercial users, private users are slightly younger and more predominantely male. They report slightly lower incomes and are less likely to live in cities. They are more likely to belong to outdoor clubs and report having had their first wilderness experience earlier. They have had more experience running other rivers and are more likely to have been down the Colorado River in the Grand Canyon before. Private river users participate more frequently in other outdoor activities.

b. Private trips have fewer people, more boats, and less people per boat than the average commercial trip. They spend a longer time in the canyon and visit a greater number of attraction sites.

c. Private users differ from the commercial group as a whole in their attitudes and perceptions. However, they share many ideological positions with the commercial oar group. That is, they were more likely to object to motor noise and show strong preference for oar travel. They were more likely to say they had met too many people during their trip and were more likely to perceive the canyon as affected by use.

d. Commercial river travelers in the Grand Canyon are a select socioeconomic group; they have high incomes and high educational achievement levels. They would be considered "tipper" and "upper-middle class" by most standards. Average age is 33; both sexes are equally represented; and the majority live in or around large cities.

Summary and Conclusions

Differences and similarities between commercial and private trips were documented through sociological research. However, an equitable means of distribution of allotments between these two user groups was not addressed under the Colorado River Research Program.

Preceding page blank

Although there are no present provisions for educational allocations, there is an ever increasing demand for use by universities, research institutions and other similar groups. Current plans are for analysis of the growing demand rates for educational as well as commercial and private usage.

CHAPTER IV: NOISE FACTORS
and
COMPARISON OF MOTOR AND OAR TRIPS

The natural noise level along the Colorado River is extremely low. The quiet and stillness of the canyon is one of its major attributes.

Natural sounds of wind, water (e.g. rapids) and birds, range from low to very loud and stand out prominently against the nearly noiseless background.

Noises from outboard motors, low flying aircraft, helicopters and subsonic and supersonic airplanes are superimposed upon and mask the natural sounds.

Motorboat sounds impede normal communication between boat/operator and passengers on motor-powered boats and thus prevent safety warnings, interpretation of natural features and relaxed conversations; expose boatmen to sound levels that border on present health standards and provide an unnatural intrusion and distraction for participants on non-motorized trips.

Overall, passengers indicate a preference for oar travel and the reasons given for this preference suggest that oar travel is seen as more consistent with a wilderness experience. This conclusion is based on two sources of data, a comparison between standard motor and oar trip passengers and a group who experienced both motor and oar travel.

Oar trip passengers knew more names of places and features in the canyon than did motor trip passengers. There were no differences between the motor and oar passengers however, in the percent who carried guide books or the number of books and articles they read about the canyon.

It can be assumed from the above that the greater knowledge of oar passengers is due to the boatman's role as one who interprets the canyon (e.g. biologically, geologically, etc.) for the passengers. Presumably, motor noise decreases the amount of information a boatman on motor trips is able to provide.

<u>Research Findings:</u> <u>Noise</u>

a. Noise levels of motors near boat pilots are near the national health standard's maximum allowable limits (Thompson et al., 1976).

b. There exists the potential for permanent hearing losses in pilots of motorized craft (Thompson et al., 1974).

c. Significant temporary hearing losses occur for pilots and some passengers on motorized craft (Thompson et al., 1974).

d. On motorized craft, pilot to passenger communication is possible but the reverse is difficult or impossible when motor is operating (Thompson et al., 1974).

e. Motor noise is detrimental to normal relaxed conversation and frequently affects interpretation of park resources (Thompson et al., 1974; Shelby and Nielsen, 1976; R. Johnson, 1976). Oar trip passengers knew more names of places and features in the canyon than did motor trip passengers, supporting the conclusion that motor noise decreases the amount of information a boatman on motor trips is able to provide. (The possibility of differences in pre-trip knowledge or amount of available written material about the river and canyon between motor and oar passengers is ruled out) (Shelby and Nielsen, 1976a).

f. Because of motor noise, passengers on motorized trips are denied the aural dimension of a wilderness almost entirely during their on-river exposure to the resource (Borden, 1976).

g. Motor noise levels may have adverse effects on pilot performance, resulting in a potential safety hazard (Thompson et al., 1974).

Research Findings: Other comparisons of motor and oar trips

a. Non-motorized travel is more compatible with a wilderness experience (Shelby and Nielsen, 1976a).

b. Seventy-nine to 91 percent of the visitors experiencing both motorized and non-motorized modes of travel preferred non-motorized travel. (Shelby and Nielsen, 1976a).

c. Visitors discerned no difference in personal safety between motorized and non-motorized traffic (Shelby and Nielsen, 1976a). NPS has been unable to document a difference in numbers and degree of injuries between the two types of craft (NPS records).

d. Motor and oar passengers are similar in terms of background characteristics (socioeconomic status, age, marital status, number of children, outdoor and wilderness recreation experience, and attitudes toward development in wild areas), indicating that the same social-demographic selection factors operate for both kinds of trips (Shelby and Nielsen, 1976a).

e. There are a number of structural differences between the usual motor and oar trips. Motor trips are larger, have more people per boat, have more contact with other parties each day, spend less time in the canyon, make fewer and shorter side stops, and make more adjustments for crowding (Shelby and Nielsen, 1976a).

f. A greater portion of oar trip passengers, compared to motor passengers, (35%) agreed that "the canyon would be more of a wilderness if motor travel were banned" (Shelby and Nielsen, 1976a).

g. Ninety-two percent of those on oar trips preferred to meet other oar trips on the river. Among those on motor trips, 18 percent preferred to meet oar trips and 9 percent preferred motor trips, while most (73%) said it makes no difference (Shelby and Nielsen, 1976a).

h. Those on motor trips were Less likely to say that they had met too many people during the trip and they perceived the canyon as less affected by over-use and the presence of man (Shelby and Nielsen, 1976a).

<u>Summary and Conclusions</u>

Unnatural noise intrusions within the canyon and along the river can be reduced or eliminated by:

1. Elimination of outboard motors or the provision for the muffling of motors.

2. Restriction of use of helicopters to emergencies.

3. Regulation of use of low flying aircraft.

4. Control of military airplane and re-routing of civilian airplane flights over the Colorado River.

This page is Blank

CHAPTER V: THE WILDERNESS QUESTION

Wilderness is a concept that is basic to and underlies much of the research reported in this document. Legally defined, wilderness is an area in which natural forces outweigh human impact. Most writers agree that wilderness areas are by definition those with (1) low density and (2) little or no human development. These two characteristics are often subjectively defined. Since river-running is generally considered a wilderness recreation, the subjective and social-psychological dimensions of river-running as a wilderness experience are important to explore.

Three issues related to wilderness aspects of river-running were explored in the sociological study. The first had to do with whether users currently perceive the Grand Canyon-Colorado River area as a wilderness. A second question was how the wilderness setting related to the user's evaluation of the experience. Finally could some users who are more committed to wilderness values be identified. That is, are some users wilderness "purists" (as defined by previous recreational research) and do they perceive the river running experience any differently than "nonpurists. 'I

There is substantial evidence to support the general conclusion that most users define the Grand Canyon as a wilderness and that this perception is based at least partly on perceived density and the absence of human artifacts. The following list of findings supports this statement:

<u>Research Findings:</u> <u>Wilderness</u> (Shelby and Nielsen, 1976b)

a. Ninety-one percent of all users consider the Grand Canyon area of the Colorado River as wilderness.

b. Very few users (15%) thought the canyon was too crowded to be considered wilderness.

c. Over 40 percent of all users thought the canyon would be more of a wilderness if use was more restricted and if motor travel was banned.

d. Thirty-four percent of all users preferred to see no other parties on the river.

e. Ninety percent of all users preferred to camp out of sight and hearing of others.

f. A majority (57%) said they would rather run the river with a small (20 persons or less) party.

Preceding page blank

Summary and Conclusions

The fact of experiencing a wilderness is crucial to the user's positive evaluation of the river trip. The wilderness character of the experience was one of three dimensions associated with overall trip rating by the user. Specifically, the extent to which being in the wilderness was an important reason for the trip, the leisurely pace, and the perception of the river trip as a nature experience were all positively related to user satisfaction. On the other hand, to the extent that the trip was perceived as noisy, use impact perceived as high, and a preference for more conveniences was strong, user satisfaction decreased.

Since individual user satisfaction is high, managing for increased total user satisfaction implies higher use levels (thus raising total or aggregate user satisfaction). This may not be a realistic alternative, however, because using user satisfaction as a barometer of appropriate or inappropriate use levels is based on the assumption that at some point increased use will negatively affect the user's experience. This assumption may be incorrect due to social psychological processes and the possible changing nature of the user population. In short, higher use levels may not affect the individual user's trip evaluation. For example, rather than rating the river trip negatively, a person may redefine the experience as a non-wilderness (but nevertheless satisfactory) one. Furthermore, other factors shown to contribute to user satisfaction in this study may continue to be more important than density or contacts as determinants of the user's overall satisfaction with the river trip. Finally, a comparison of the motor and oar passengers suggests that the river trip experience itself may help determine what the user sees a8 "appropriate" density and contact levels.

Although wilderness purists could be identified, the relation between contacts, perceived crowding, and user satisfaction was no different for wilderness purists than for non-purists.

CHAPTER VI: ECONOMICS OF FLOAT TRIP IN GRAND CANYON

In 1972, the National Park Service tabulated the percentage of commercial trips vs. private trips. It was found that 92 percent of the user days were utilized by commercial operators while only 8 percent were used by private river runners. This large commercial allocation consists of 89,000 user days. The 21 river concessioners represent a multi-million dollar industry. A recent analysis was made to determine some of the economic parameters of the river running business in Grand Canyon.

In was found that most firms are profitable with some earning large and/or excess profits. The average industry profitability is not unreasonable, considering size of the average firm, with small firms being more variable in their performance. Further, consumers are getting their monies worth. The economics of oar trips is basically as sound as motor tripe, for although motor trips earned 2.1 percent more than oar trips and 1.5 percent more than combination trips, (measured as percent of sales) this difference is smaller than the total variability among trips. In addition, this profit difference may be due to allotments instead of type of trip. The data indicate, however, that profitability is more closely correlated with sound business management techniques than mode of locomotion.

<u>Research Findings:</u> <u>Economics</u> (refer to Appendix A, pgs. 51-53).

This page is Blank

CHAPTER VII:FUTURE RESEARCH AND MONITORING

Present research projects on the Colorado River have delineated the status of the present system, as well as inferring possible future biological and sociological trends. The physical and biotic inventories have aided in pointing out areas in which future research and monitoring is desirable. Future research and monitoring will be instrumental in indicating the ecological responses brought about by changing management procedures or environmental conditions.

The various research projects have determined that irreparable damage is being inflicted on the natural system in the Colorado River corridor. This includes the dumping of fecal waste material in campsites and the destruction of vegetation at attraction sites, rapid overlooks, tributaries, trails, and camping areas. With proper education of the river guides and a regulation calling for total removal of most human waste products from the system, most of the detrimental impacts can be alleviated. Of necessity, a resource monitoring program must be designed in such a way as to detect deterioration in the resource quality. In addition, it must be emphasized that these results gathered for the past 3 years, were obtained on a system that has been heavily used for only a short period of time (6 to 11 years). The resource alterations that will or could take place over a long period of time (15 to 20 plus years) are unknown and can only be determined by careful monitoring of the system.

Of highest priority is a monitoring program that is designed to provide an annual assessment of the environmental health of the campsites. This program would consist largely of study areas consolidated in a single series of research sites along the river. These study sites would allow a single visit at sites which have a high biotic resource rating, thus lending themselves to multi-disciplinary investigations with fishes, terrestrial vertebrates, water quality, algae, vascular plants, beach erosion, etc. This would have the added advantage of providing reasonably complete biological information on several areas as they undergo changes, enabling analysis of the complete system rather than individual aspects.

A great need exists for additional baseline data concerning the physical substrate. This would be provided by high resolution vertical color aerial photography taken at a scale of between 1:500 and 1:1,100 at metric, or near-metric standard with stereo coverage. Photography covering 20-50 beaches selected to provide a cross-section of geomorphic setting, vegetational characteristics, and human use density could resolve changes in species. composition and distribution, changes in human impact, movement of surface materials, and erosion. Aerial photography provides the lowest cost per unit of information when extensive areas are under consideration, however, field surveying in geomorphological, macrofloral, and human impact studies is essential to establish detailed calibration data to correlate with photographic data. Aerial photography

Preceding page blank

should be reflown at least once between 1980 and 1985 to provide a documentation of all major changes taking place along the river. Several heavily impacted beaches should be placed off-limits, or on a rest-rotation system, to study recovery rates. Also, a resurvey of all beach profiles on the 20 benchmark beaches should be undertaken sometime in the period of 1978 to 1981 to allow an accurate assessment of erosion and deposition rates. Campsite monitoring should continue in order to show changes in size of impacted areas.

Water quality monitoring should continue to assess any future changes in water quality parameters in both the river and tributaries. This would provide human impact data and habitat data regarding aquatic life, especially endangered fish species affected by water quality alterations brought about by Glen Canyon Dam.

Further studies should be initiated to better define the relationships, both intra- and interspecific, of fish occurring in the region. This would include surveys of the river in addition to systematic surveys of selected tributaries and the collection of fish for analysis of food habits, general health and reproductive conditions.

Benthic samples should be taken at each tributary to aid in identification of fish stomach contents, to help define key tributaries and to determine why they are utilized by certain fish. This would provide information concerning endangered fish species, particularly the genus Gila. Immediate efforts should be made to obtain a brood stock of both the Bonytail and Humpback Chub to be placed at the Willow Beach National Fish Hatchery for the purpose of maintaining the species. Restoration of habitat is essential to the survival of Gila in the Grand Canyon area. Monitoring studies of both chub species should be carried on to determine population trends and spawning success.

Further terrestrial biotic inventories should be implemented which will indicate the nature of the ecological responses brought about by changing management procedures or environmental pressures. For example, terrestrial population trends could be detected and serve as an indication of the state of the entire riparian system. In addition, future biotic inventories would add to the state of knowledge regarding the riparian habitat of the Colorado River.

Basic research considerations must be a part of any future research program, as the Grand Canyon presents an unrivaled natural history laboratory. Biogeographical, evolutionary, and taxonomic theories can be tested using the 280 mile long corridor of the canyon. Academic riparian research is experiencing a growth fostered by environmental necessity. The Grand Canyon presents a rich riparian habitat containing nearly captive communities of plants and animals. Investigations into the natural dynamics of riparian ecology should be encouraged in this contained environment.

REFERENCES

[Note: See instructions in introduction and Appendix B for information regarding copies of references with NTIS accession numbers.]

Arizona Game and Fish Department. 1976. Threatened wildlife of Arizona. 9pp.

Aitchison, S. W. and S. W. Carothers. 1974. An ecological survey of the Colorado River and its tributaries between Lees Ferry and the Grand Wash Cliffs - Phase I. Unpublished Colorado River Research Report, Grand Canyon National Park, Arizona. 172pp.

Blinn et al. 1976 (See Czarneki et al., 1976).

Borden et al. 1976 (See Weeden et al., 1976).

Borden, F. Y. 1976. Carrying capacity for river running the Colorado River in the Grand Canyon
Colorado River Technical Report No. 9, Grand Canyon. National Park. 79pp. (NTIS Access. No. PB267744 As).
Bowman, E. G. August 1975. Arizona

Bowman, E. G. 1975 Aircraft noise evaluation grand Canyon, May – August 1975. Unpublished research report, Grand Canyon National Park, Arizona.. 50pp.

Bowman, E. G. 1976. Statistical summary aircraft's noise evaluation, May – august 1975 Unpublished research report, Grand Canyon National Park, Arizona. 36pp.

Carothers, S. W. and S. W. Aitchison. 1976. An ecological survey of the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, Arizona. (Reports by S. W. Aitchison, S. W. Carothers, M. M. Karpisak, G. A. Ruffner, N. J. Sharber, P. L. Shoemaker, and L. E. Stevens, *M.* E. Theroux, and D. S. Tomko). Colorado River Technical Report No. 10, Grand Canyon National Park, Arizona. 251pp. (NTIS Access. No. PB267770 AS).

Carothers, S. W., J. H. Overturf, D. S. Tomko, D. B. Wertheimer, 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 Colorado River Research Report, Grand Canyon National Park, Arizona. 137pp.

Carolhers, S. W. and R. R. Johnson. 1975. Recent observations on the status and distribution of some birds of the Grand Canyon region. Plateau 47(4) :140-153.

Cole, G. A. and D. M. Kubly. 1976. Limnologic studies on the Colorado River and its main tributaries from Lees Ferry to Diamond Creek including its course in Grand Canyon National Park. Colorado River Technical Report No. 8, Grand Canyon National Park, Arizona. 88pp. (NTIS Access. No. PB267736 AS).

Czarneki, D. B., D. W. Blinn and T. Tompkins. 1976. A periphytic microflora analysis of the Colorado River and major tributaries in Grand Canyon National Park and vicinity. Colorado River Technical Report No. 6, Grand Canyon National Park, Arizona. 106pp. (NTIS Access. No. PB267761 AS)

Deacon, J. E. and J. R. Baker. 1976. Aquatic investigations on the Colorado River from Separation Canyon to the Grand Wash Cliffs, Grand Canyon National Park. Colorado River Technical Report No. 15, Grand Canyon National Park, Arizona. 26pp. (NTIS Access. No. PB267734 AS).

Dolan, R., B. Hayden, A. D. Howard and R. R. Johnson. In press. Man's impact on the Colorado River fluvial deposits within the Grand Canyon. In Proceedings of the First Conference on Scientific Research in the National Parks, USD1, National Park Service, Washington D.C. 17 ms. pp.

Dolan, R., A. Howard and A. Gallenson. 1974. Man's impact on the Colorado River in the Grand Canyon. Amer. Sci., 62(4):392-401.

Howard, A. D. and R. Dolan. 1976. Alterations of terrace deposits and beaches of the Colorado River in the Grand Canyon caused by Glen Canyon Dam and by camping activities during river float trips. Colorado River Technical Report No. 7, Grand Canyon National Park, Arizona. 29pp. (NTIS Access. No. PB267766 AS).

Johnson, K. 1976. A bacteriological survey of portable toilet burials in Grand Canyon: summer phase research. Unpublished Colorado River Research Report, Grand Canyon National Park, Arizona. 50pp.

Johnson, R. R. 1976. Miscellaneous memos and unpublished research reports. Grand Canyon National Park, Arizona.

Johnson, R. R. and S. P. Martin. 1976. The Colorado River Research Project: A National Park Service multidisciplinary interdisciplinary research project. In Proceedings of the third Management Conference, Southwestern Regional Superintendents Conference, Southwestern Region, National Park Service, Santa Fe, New Mexico, pp.29 - 42.

Knudsen, A. B., R. Johnson, K. Johnson and N. Henderson. 1977. A bacteriological analysis of portable toilet effluent at selected beaches along the Colorado River, Grand Canyon National Park, Arizona. Proceedings of the River Recreation Management and Research Symposium, USDA Forest Service, North Central Forest Experimental Station, Minneapolis, Minnesota. pp.290-295.

Laursen, E. M. and E. Silverston. 1976. Hydrology and sedimentology of the Colorado River in Grand Canyon. Colorado River Technical Report No. 13, Grand Canyon National Park. 27pp. (NTIS Access. No. PB267735 AS).

Miller, R. R. 1975 and 1976. Letters regarding status of certain fishes in the Colorado River. Grand Canyon National Park, Arizona.

Minckley, C. 0. and D. W. Blinn. 1976. Summer distribution and reproductive status of fish of the Colorado River and its tributaries in Grand Canyon National Park and vicinity during 1975. Colorado River Technical Report No. 14, Grand Canyon National Park. l7pp. (NTIS Access. No. PB267732 AS).

Parent, C. R. Michael and F. E. Robeson. 1976. An economic analysis of the river running industry in Grand Canyon National Park. Colorado River Technical Report No. 16, Grand Canyon National Park, Arizona. 131pp. (NTIS Access. No. PB268997).

Phillips, R. A. and C. Sartor-Lynch. 1976. Human waste disposal on beaches of the Colorado River in Grand Canyon. Colorado River Technical Report No. 11, Grand Canyon National Park, Arizona. 79pp.
(NTIS Access. No. PB267733).

Shelby, B. and J. M. Nielsen. 1976a. River contact study part II: Motors and oars in the Grand Canyon. Colorado River Technical Report No. 2, Grand Canyon National Park, Arizona. 46pp. (NTIS Access. No PB267730 AS).

1976b. River contact study part III: Use levels and crowding in the Grand Canyon. Colorado River Technical Report No. 3, Grand Canyon National Park, Arizona. 5lpp. (NTIS Access. No. PB267745 AS).

1976c. River contact study part IV: Private and commercial trips in the Grand Canyon. Colorado River Technical Report No. 4, Grand Canyon National Park, Arizona. 32pp. (NTIS Access. No. PB267729 AS).

Sommerfeld, M. R., W. M. Crayton and N. L. Crane. 1976. Survey of bacteria, phytoplankton and trace chemistry of the lower Colorado River and tributaries in the Grand Canyon National Park. Colorado River Technical Report No. 12, Grand Canyon National Park, Arizona. 136pp. (NTIS Access. No. PB267731 AS).

Suttkus, R. D., G. H. Clemmmer, C. Jones and C. R. Shoop. 1976. Survey of fishes, mammals, and herperofauna the Colorado River and adjacent riparian areas of the Grand Canyon National Park. Colorado River Technical Report No. 5, Grand Canyon National Park, Arizona. 48pp. (NTIS Access. No. PB267718 AS).

Thompson, D. N., A. J. Rogers, Jr., and F. Y. Borden. 1974. Sound-level evaluations of motor noise from pontoon rafts in the Grand Canyon. Colorado River Technical Report No. 18. Grand Canyon National Park. 32pp. (NTIS Access. No. pending).

U.S. Fish and Wildlife Service. 1973. Threatened wildlife of the United States. Resource Publ. 114, U.S. Gov. Print. Off., Washington, D.C. 289pp. (and supplemental lists published periodically in the Federal Register).

Weeden, H. A., F. Y. Borden, B. J. Turner, 0. N. Thompson, C. H. Strauss and R. R. Johnson. 1975. Grand Canyon National Park campsite inventory. Unpublished Colorado River Research Report, National Park Service, Washington, D.C. 72pp.

APPENDIX A

MAJOR FINDINGS FROM RESEARCH PROJECTS

1. RIPARIAN ECOSYSTEMS

AND

CARRYING CAPACITY

This page is Blank

CARRYING CAPACITY FOR RIVER-RUNNING THE COLORADO RIVER IN THE GRAND CANYON REGION

By: Dr. F. Yates Borden
Department of Forest Resources
Pennsylvania State University

Major Findings

1. The upper limit on carrying capacity was determined to be three groups of 40, one of 20, and one of eight (per day).

2. The five groups should average 21 miles per day; camping 11 nights.

3. For a season of 182 departure days, the total number of users for the season amounts to 26,936.

4. A list of 13 policy statements is given to form the basis for the carrying capacity evaluation.

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

Edited by: Dr. Steven W. Carothers and Stewart W. Aitchison Harold S. Colton Research Center, Museum of Northern Arizona, Flagstaff, Arizona.

Major Findings

1. Construction of Glen Canyon Dam has permitted the development of a new riparian community.

2. 807 species of vascular plants have been found in the riparian and adjacent habitats.

3. Two previously undescribed species of vascular plants were discovered.

4. Rodent communities on beaches tend to be less productive and less stable than those of the terrace areas.

Preceding page blank

5. Peromyscus eremicus appears to be the most successful small mammal in the riparian zone.

6. Rodent survival is very low and suggests a nearly annual population turnover.

7. 178 species of birds utilize the riparian zone, of these 41 breed there.

8. Lucy's Warbler is the most common bird of the riparian zone.

9. 12,000 + insect specimens in 20 orders and 247 families were collected.

10. Insect production on the exotic Salt Cedar fluctuates dramatically in comparison to insect production on dominant native plants.

11. Feral Ass distribution was found to be greater than previously believed.

12. Feral Asses are destroying riparian and desert habitat through trampling and overgrazing.

13. Human impact seems to be a function of visitor activities and the specific biotic sensitivity of the use area rather than a strict function of the total number of users.

14. In 1974, 395 campsites were used. In 1975, 350 campsites were used.

15. There has been an increase in ants and flies.

16. Trampling of vegetation by humans has increased the number and extent of secondary trails.

A BACTERIOLOGICAL ANALYSIS OF PORTABLE TOILET EFFLUENT AT
SELECTED BEACHES ALONG THE COLORADO RIVER
GRAND CANYON NATIONAL PARK, ARIZONA

By: Dr. A. Bruce Knudsen, Kimberly Johnson, Dr. R. Roy Johnson, Norman Henderson
Grand Canyon National Park

Major Findings

1. Over a period of 8 months, viable total and fecal coliform bacteria were found 84 percent of the time in dump holes.

2. Actual coliform numbers ranged from 1 to "too numerous to count" (TNTC) at specific dilution levels.

3. Migration of bacteria of up to 8 inches laterally occurred at 22 percent of the sites.

4. Disinfectant: chemicals were found to be ineffectual in reducing a significant number of indicator bacteria.

5. Porta-potty dumping presents a potential health hazard

Summer Phase (Kimberly Johnson, NPS, 1976).

1. In some instances portable toilet effluent is being buried in violation of NPS regulations.

2. Due to colloidal interactions between sand and porta-potty effluent, dump holes do not drain adequately, resulting in floating, solid fecal material being buried close to the surface.

3. Some random beach samples (away from burial sites) are positive for total and/or fecal coliforms (Phillips).

4. Distribution of fecal material from dumpsites occurs when boatmen disrupt previous; dumpsites while looking for areas in which to bury.

5. Disinfectant chemicals do not provide for total disinfection of fecal indicator bacteria and possible pathogenic micro-organisms.

6. Raw fecal material is accumulating (during the day when the porta-potty is unavailable) at heavily used lunch stops and attraction sites.

7. Human waste carry-out systems are currently being successfully used by a large commercial motor company. Carry-out Systems have been successfully used on an experimental basis by a commercial rowing company.

8. Total and fecal coliform bacteria and potential pathogens are capable of surviving on beaches or in dumpsites for at least 12 months.

9. Pathways exist for contamination of river travelers by pathogens from porta-potty dumps. Methods of transmission include direct contamination, wind-blown contaminated sand, insect transmission and food preparation.

10. Diseased river travelers, possibly asymptomatic, and unaware of their condition, may excrete pathogenic organisms in large numbers. As a small number of pathogenic organisms may produce certain diseases, the possibility exists that river travelers may ingest infective doses through these existing pathways of contamination.

GRAND CANYON NATIONAL PARK RIVER CAMPSITE INVENTORY

By. Dr. H. A. Weeden, Dr. F. Y. Borden, Dr. B. J. Turner,
D. N. Thompson, Dr. C. U. Strauss, and Dr. R. R. Johnson
Department of Forest Resources
Pennsylvania State University
and Grand Canyon National Park

Major Findings

1. From Lees Ferry to Separation Canyon (240 miles), 354 campsites were found for an average of 1.5 per mile.

2. Campsites with capacities of 20 or more campers averaged 1.1 per mile.

3. Campsites are very unevenly distributed with four river stretches having critically few campsites. The critical stretches are Upper Marble Gorge, Granite Gorge, Mile 143 to Mile 175, and Lower Granite Gorge. The distribution for campsites in 20 mile sections for each is shown in the following figure.

4. Of campsites visited for on-site evaluation, 9 percent had not been used for camping, 75 percent had light to moderate use, and 16 percent had been heavily used.

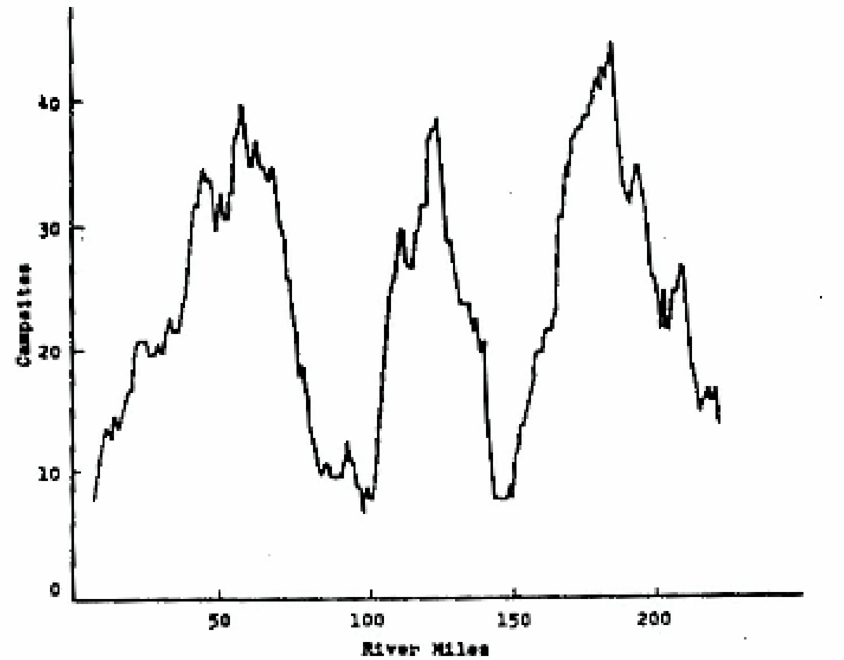

Figure 1. Number of campsites with a capacity of 20 or more along 20-mile sections of the Colorado River.

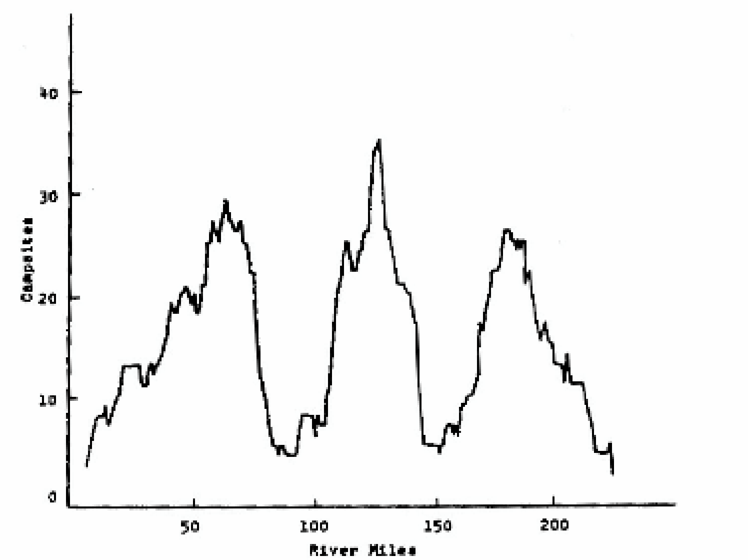

Figure 2. Number of campsites with a capacity of 30 or more along 20-mile sections of the Colorado River

This page is blank

APPENDIX A

MAJOR FINDINGS FROM RESEARCH PROJECTS

2. SOCIOECONOMIC

This page is blank

AIRCRAFT NOISE EVALUATION
AND STATISTICAL SUMMARY

By: Dr. Eldon G. Bowman, Department of Social Science, Northern Arizona University

Major Findings:

1. Helicopter flights caused the most distracting aircraft motor noise (as used in the Inner Canyon and around Indian Gardens).

2. After helicopter flights, light single-engine planes caused the most attention-getting motor noise, being somewhat noisier than the two-engine sight-seeing aircraft common to the Grand Canyon.

3. Noise from large commercial jets contributed 25 percent of the total noise times recorded on a given day, occasionally approaching 35 percent. However, jet noise seemed the least objectionable, or least noticed by hikers.

4. Military aircraft did not seem to make a significant contribution to the noise picture, although aircraft identified as military did attract attention due to the different noise quality produced and the fact that military aircraft flew lower than large commercial jets.

5. During the observation periods around the middle of the day two, three, and sometimes four aircraft could be seen and/or heard at any one time.

6. Light plane noise predominates during the early morning hours; two-engine plane noise is second to light plane noise in the morning, rivaling it in the afternoon; jets show a noise pattern which is strong and clearly predominates all other noise sources between 12:00 and 1 p.m.

7. Aircraft noise combinations exhibit a pattern of strangest activity during mid-morning and mid-afternoon.

8. Phantom Ranch receives more aircraft noise than any other location examined in the Inner Canyon.

Preceding page blank

SOCIOLOGICAL CARRYING CAPACITY OF THE GRAND CANYON - COLORADO RIVER AREA

Research conducted under Dr. J. Eugene Haas
Human Ecology Research Services, Inc., Boulder, CO.

By: Dr. Joyce M. Nielsen Department of Sociology
University of Colorado, Denver

Dr. Byron Shelby
Department
of Resource Recreation Management
Oregon State University

Major Findings

1. Ninety-one percent of all users say they consider the Grand Canyon area of the Colorado River as wilderness.

2. Very few users (15%) thought the canyon was too crowded to be considered wilderness.

3. Over 40 percent of all users thought the canyon would be more of a wilderness if use was more restricted and if motor travel was banned.

4. Thirty-four percent of all users preferred to see no other parties during their trip.

5. Ninety percent of all users preferred to camp out of sight and hearing of others.

6. A majority (57%) said they would rather run the river with a small (i.e., 20 persons or less) party.

7. Motor noise is detrimental to normal relaxed conversation and frequent affects interpretation of park resources. Oar trip passengers knew more names of places and features in the canyon than did motor trip passengers, supporting the conclusion that motor noise decreases the amount of information a boatman on motor trips is able to provide. (The possibility of differences in pretrip knowledge or amount of available written material about the river and canyon between motor and oar passengers is ruled out.)

8. Different use levels have a pervasive effect on the character of the Grand Canyon experience in terms of river and attraction site contacts. Use level does not yet affect campsite contacts, but does affect the number of adjustments for crowding made by trip leaders.

9. Thirty percent of river travelers see the canyon as crowded, but this is unrelated to the number of people they saw during their trip.

10. Satisfaction levels in the canyon are high, with most (85%) rating their trip as "excellent" or "perfect." Satisfaction is not related to perceived crowding or actual density.

11. Passengers who had experience with motor and oar travel in the canyon preferred the oar trip (79 to 91% chose oar, 4 to 6% chose motor, in response to four different questionnaire items).

12. Combination trip passengers preferred the oar trip because of the slower, more relaxed pace; the quiet, more sensitive (the river or canyon) trip environment; and the smaller, more comfortable, fortable, social groupings.

13. The motor and oar trips were perceived as equally safe by combination trip passengers. Twenty-five percent considered the oar trip safer, 25 percent the motor, and 46 percent felt there was no difference.

14. Combination trip passengers were reasonably representative of river travelers in general.

15. In comparison to oar trips, motor trips generally are larger, have more people per boat, have more contact with other parties each day, spend less time in the canyon, make fewer and shorter side stops, and make more adjustments for crowding.

16. Passengers on oar trips found motors and their accompanying noise less appropriate in the canyon, preferred to have less contact with other groups, and were more sensitive to crowding and human impact.

17. A majority of oar trip passengers prefer to meet other oar trips on the river; for a majority of those on motor trips, the kind of trip contacted makes no difference.

18. Commercial river travelers in the Grand Canyon are a select socioeconomic group; they have high incomes and high educational achievement levels. They would be considered "upper" and "upper-middle class" by most standards. Average age is 33; both sexes are equally represented; and the majority live in or around large cities.

19. Motor and oar passengers are remarkably similar in terms of background characteristics, indicating that the same social demographic selection factors operate for both kinds of trips.

20. Eliminating either motor or oar trips would not appear to exclude any specific group, as described by measured demographic variables.

21. A major increase in the proportion of oar travel in the canyon could cause significant changes in the river running setting, including party structure, encounters with other groups, and numbers of people running the river. Specifically, this would mean smaller parties, fewer contacts with others but more time in sight of other parties, and probably fewer people running the river per season.

22. Compared to commercial users, private users are slightly younger and more predominantly male. They report slightly lower incomes and are less likely to live in cities. They are more likely to belong to outdoor clubs and report having had their first wilderness experience earlier. They have had more experience running other rivers and are more likely to have been down the Colorado River in the Grand Canyon before. Private river users participate more frequently in other outdoor activities.

23. Private trips have fewer people, more boats, and less people per boat than the average commercial trip. They spend a longer time the canyon and visit a greater number of attraction sites.
in

24. Private users differ from the commercial group as a whole in their attitudes and perceptions. However, they share many ideological positions with the commercial oar group. That is, they were more likely to object to motor noise and show strong preference for oar travel. They were more likely to say they had met too many people during their trip. They were more likely to perceive the canyon as affected by use.

25. The lack of relation between contacts, perceived crowding, and satisfaction is attributed to several factors. First, it is possible that the present use levels are not high enough to have a detrimental effect on the contemporary user S experience. Second, there is lack of agreement about how crowded the canyon "should" be. Most river runners are making the trip for the first time; over half didn't know what to expect in terms of contacts with other groups, and there was little consensus among those who had some expectations about number of encounters with other trips. Finally, it is possible that the present (1975) use level (considered high by experienced river runners) may have already discouraged users who are extremely sensitive to crowding, thereby excluding the opinions of that user group from data collected in this study.

26. Satisfaction with river trips is based on the personal benefits, social atmosphere, and wilderness character provided by the trip.

27. Use tends to be concentrated both in certain areas and at certain times. Specifically, those areas that roughly correspond to the bottleneck areas identified by Yates Borden in his campsite inventory show high contact. Certain days of the week also show higher use.

28. There are differences between motor and oar trip passengers in their opinions, preferences, and perceptions about use, density, and contacts. Those on oar trips preferred to have less contact with other groups, and were more sensitive to crowding and human impact.

29. Because there are few pre-trip background differences between motor and oar passengers (see Motor-Oar section) finding #7 above suggests that the river experience itself (motor versus oar, in this case), rather than pre-trip experience affects preferences and attitudes regarding contacts, use levels and perceived crowding. In short, users leave the canyon with density preferences or opinions that are very much like their own experience.

30. Management of the crowding situation on the river can best be aimed at controlling the character of the experience (contacts among groups).

31. Choosing a use level requires definition of the kind of experience to be provided and selection of a contact level "appropriate" for that experience.

ECONOMIC STUDY OF FLOAT TRIP CONCESSIONS IN GRAND CANYON NATIONAL PARK

By: Dr. Michael Parent, Department of Business
Utah State University
Dr. Franklin Robeson, Department of Business
University of Maryland

<u>Major Findings</u>

1. Most float trip concessions are earning healthy profits.

2. Some firms appear to earn excess profits, that is, profits above the normal return expected given their investment and risk.

3. Profitability (as measured by percent of sales) is not significantly related to size (in sales) of the float trip concessions.

4. Profitability (as measured by percent of sales) is <u>not</u> significantly related to type of trip (i.e., oars or motors).

5. Float trip companies are more labor intensive than capitol intensive. The major outlay is for current operating expenses, food, transportation, and labor; not interest expense on money borrowed for long term investment in fixed assets.

6. Because investment is not sizeable and cash flows are excellent (several concessions have large cash reserves), most concessions have been able to self-finance investment in new equipment in current (less than one year) time periods.

7. Most firms would be financially capable of making the shift from motor to oar operation.

8. Most concessions have depreciated over half of their total fixed investment.

9. Any concession which is adversely affected in any large measure by the oar/motor decision or by an administrative decision to cut user/days would be so affected due to the poor overall financial position of the firm due to market situations in other than the Grand Canyon environment.

10. Consumers receive their money's worth on float trips.

11. Advertising is a <u>very low</u> percentage of sales.

12. Problems would be expected to occur which would change consumer satisfaction and the current economic performance of concessions if:

   a. demand shifts and capacity is limited.
   b. demand shifts and prices are regulated.
   c. price is reduced without a decrease in demand or an increase in capacity.

13. Allotments are not related statistically with rates of profits but are associated with absolute levels of profit.

14. Smaller concessions are relatively more risky than large concessions.

15. A 3-year phase out of motors would allow most concessions to fully depreciate their remaining investment and allow a gradual conversion to oars.

16. It is conceivable that some motor concessions could retool for oar trips within 6 months and show no economic hardship in so doing. . perhaps even profit.

17. Future capital expenditure patterns will probably follow current patterns.

18. It would be to the consumers benefit to standardize the type of information in concessions advertising brochures.

19. It seems reasonable to conclude that mast firms could reduce the size of their rafting parties without seriously impairing their profit position.

20. There is no evidence to suggest that too many passenger days mean a poor service will be provided.

21. There is no justification for a theory that large firms provide an, more or any less costly trip.

22. There is some evidence to suggest that average economic performance would be improved slightly and stabilized if firms with small allotments were combined.

23. It is difficult to measure trip quality as it is related to profit and loss.

SOUND-LEVEL EVALUATIONS OF MOTOR NOISE FROM PONTOON RAFTS IN THE GRAND CANYON

By: Don N. Thompson, A. J. Rogers, Jr.,
Dr. F. Yates Borden
Department of Forest Resources
Pennsylvania State University

Major Findings

1. Noise levels of motors near boatmen are near the national health standards maximum allowable limits.

2. Significant temporary shifts in the hearing threshold of boatmen and passengers occur.

3. Vital boatmen to passenger communication is possible against a motor noise background, but the reverse is very difficult.

4. Noise levels are such that they may have adverse effects on the performance of the boatmen.

5. The motor noise is detrimental to normal, relaxed conversation and presents a safety hazard and health hazard.

This page is blank

APPENDIX A

MAJOR FINDINGS FROM RESEARCH PROJECTS

3. AQUATIC ECOSYSTEMS

This page is blank

LIMNOLOGIC STUDIES ON THE COLORADO RIVER AND ITS MAIN TRIBUTARIES FROM LEES FERRY TO DIAMOND CREEK INCLUDING ITS COURSE IN GRAND CANYON NATIONAL PARK

By: Dr. Gerald A. Cole and Dennis M. Kubly Department of Zoology Arizona State University

Major Findings

1. Salinity of the Colorado River is lessened by the streams entering below the Little Colorado River. The river leaves the Diamond Creek junction with a greater salt load than it had at Lees Ferry, but not so great as might have been extrapolated from some upstream data. The increase is about 5 percent from Mile 0. The total dissolved solids surpass the arbitrary 500 mg/liter, a standard set by the USPUS for the upper limit of acceptability for continued human consumption, throughout the stretch of river from Mile 0 to Diamond Creek.

2. Concentrations of salt have not always been considered when discussing salinity of the Colorado River. Although tributaries do contribute salts, their volume of water actually helps to dilute the total concentration.

3. It is possible that the upper reaches of the river would be a productive area. The water is rich in nutrients but might become nitrogen limited if excessive plant growth occurred.

4. The calculated $C0_2$ was far in excess of saturation at Lees Ferry and its diminishing downstream, therefore, cannot be attributed solely to carbon fixation by green plants.

5. Fluctuations of limnological parameters have been reduced by Glen Canyon Dam. The decrease in turbidity, lowering of temperatures, and increased free $C0_2$ content of the water are the major alterations, other than an increased stability.

6. The Paria and Little Colorado Rivers show gross fluctuations in water quality and flow. They are the main contributors of silt to the river.

Preceding page blank

A PERIPHYTIC MICROFLORA ANALYSIS OF THE COLORADO RIVER AND MAJOR TRIUTARIES IN GRAND CANYON NATIONAL PARK AND VICINITY

By: Dr. David B. Czarnecki, Dr. Dean W. Blinn, and Terrill Tompkins
Department of Biology
Northern Arizona University

Major Findings

1. 345 taxa of algae were collected.

2. High diversity plus low numbers of pollution tolerant algal species indicate a fairly clean and possibly oligotrophic system.

3. Major differences in taxa exist above and below Glen Canyon Dam.

4. Paria, Bright Angel, Shinumo, Havasu, and Diamond Creek show occasional presence of pollution indicator algal associations.

5. The Colorado River displays a high alkaline and conductivity system.

AQUATIC INVESTIGATION ON THE COLORADO RIVER FROM SEPARATION CANYON TO THE GRAND WASH CLIFFS, GRAND CANYON NATIONAL PARK

By: Dr. James E. Deacon and John R. Baker
Department of Biology
University of Nevada, Las Vegas

Major Findings

1. River temperatures 2 to 10^0C cooler than pre-Glen Canyon Dam.

2. Dissolved 02, nutrient concentrations, and total bacteria numbers generally indicate natural and unpolluted conditions.

3. One exception to item #2 occurred on January 4, 1976, when high phosphorus and total coliform levels were recorded.

4. Sewage effluent from visitor use has minimal overall effects on Colorado River water quality due to dilution and biological decay.

5. Potential health hazards may exist at some campsites.

6. Primary productivity of the Colorado is extremely variable and inversely related to the river's turbidity.

SUMMER DISTRIBUTION AND REPRODUCTIVE STATUS OF FISHES OF THE COLORADO RIVKR AND ITS TRIBUTARIES IN GRAND CANYON NATIONAL PARK AND VICINITY DURING 1975

By: C. 0. Minckley and Dr. Dean W. Blinn Department of Biology
Northern Arizona University

Major Findings

1. Grand Canyon National Park represents one of the few remaining refuges for several unique species of native fish.

2. Forty percent of the ichthyofauna collected were native fish: in order of abundance, Rhinichthys osculus, Pantosteus discobolus, Catostomos latipinnis, and Gila elegans.

3. G. elegans appears restricted to the vicinity of the Little Colorado River which may represent the only suitable spawning habitat left in the area for this species.

4. Although more species of exotic fish exist, larger numbers of native fish exist.

5. Native fish populations were similar to 1968 levels.

6. Reproduction was verified in all native fish species collected; reproduction of three exotic fish was verified by collection of young-of-the-year.

7. All fish were examined for ectoparasites and found to be negative.

SURVEY OF BACTERIA, PHYTOPLANKTON, AND TRACE CUEMISTRY OF THE LOWER COLORADO RIVER AND TRIBUTARIES IN TUE GRAND CANYON NATIONAL PARK

By: Dr. M. R. Sommerfeld, W. M. Crayton, and N. L. Crane
Department of Botany and Microbiology
Arizona State University

Major Findings

1. Total viable bacterial numbers were similar to those reported for other river systems.

2. Total coliform bacterial numbers exceeded desirable water quality standards at several sampling sites on the Colorado River and in most of the tributaries throughout the year.

3. On the basis of phytoplankton numbers, the Colorado River and the 11 tributaries must be considered relatively unproductive.

4. 122 species of phytoplankton were identified from the Colorado River. 137 species of phytoplankton were identified from the 11 tributaries. The phytoplankton flora of both the Colorado and tributaries was dominated by bacillariophycean algae (diatoms).

5. Most of the 15 chemical elements monitored remained relatively stable on a temporal and spatial basis, except for sodium, which increased in concentration with distance downstream from Lees Ferry.

6. The 11 tributaries differed chemically in various degrees from each other and from the Colorado River. The Paria, Little Colorado, and Kanab exhibited extremely large fluctuations in their chemistry that was associated with their flow conditions.

7. The Little Colorado, under flooding conditions, exceeds recommended standards of water quality for the elements iron and manganese.

8. The dissolved chemical quality of the river and tributaries, based on the elements monitored, meets current water quality standards for drinking water.

SURVEY OF THE FISHES, MAMMALS, AND HERPETOFAUNA OF THE COLORADO RIVER AND ADJACENT RIPARIAN AREAS OF THE GRAND CANYON NATIONAL PARK

By

Dr. Royal D. Suttkus
F. Edward Hebert Research Center
Tulane University
New Orleans, Louisiana

Dr. Glenn H. Clemmer
Department of Biology
Mississippi State University
State College, Mississippi

Dr. Clyde Jones
U.S. National Museum
Washington, D.C.

Dr. C. Robert Shoop
Department of Zoology
University of Rhode Island
Kingston, Rhode Island

<u>Major Findings</u>

1. 19 species of fishes were collected; 4 native and 15 introduced.
2. 24 species of mammals were collected, many new locality records.
3. 19 species of herptiles were collected, representing several new locality records.
4. Two new plant records were turned over to the Museum of Northern Arizona.
5. Two new exotic plants (Tomato and Palm) were collected.
6. The major impact on fish is a result of Glen Canyon Dam.
7. There is no evidence of river runners affecting fish (except possibly soap in side tributaries and angling in vicinity of Little Colorado River), small mammals, or herptiles.

This page is blank

APPENDIX B

LIST OF

CONTRACTED RESEARCH PROJECTS

Preceding page blank

This page is blank

APPENDIX B

Contracted Research of the

COLORADO RIVER RESEARCH PROGRAM

Each project is listed below with: the title of the project, the contract or purchase order number; the organization to which the contract is issued; the principal investigator; the period covered by the study; the cost; and the reports received or anticipated.

1. Ecology of the riparian zone of the Colorado River including 1) vegetation mapping, 2) interrelationships of visitors with plants and animals, 3) successional changes in plants as a result of Glen Canyon Dam, 4) population densities, home ranges and demography of important vertebrates, 5) impact of wild burros on beaches, 6) impact of burros on vegetation, 7) an inventory of insect species; CX21550007; Museum of Northern Arizona; Steve Carothers; July 1, 1974 to June 30, 1976; $128,776.

2a. Sociological carrying capacity of the Grand Canyon-Colorado River area (commercial use); CX821040104; Human Ecology Research Services, Inc.; Drs. Eugene Haas and Joyce Nielsen; April 1, 1974 to June 30, 1976; $135,000.

2b. Sociological carrying capacity of the Grand Canyon-Colorado River area (private use); change order; Human Ecology Research Services, Inc.; Drs. Eugene Haas and Joyce Nielsen; None; $9,713; results incorporated into the final report of the commercial use.

3. Grand Canyon National Park campsites inventory; CXOOO-3-0061; Penn. State University; Dr. F. Yates Borden; FY-75; funded by Washington Office. Dr. Borden has completed a physical carrying capacity model.

4. Human waste disposal analysis (porta-potty) along the Colorado River; CX821060029; University of Arizona; Dr. Robert Phillips; $9,893.

5. Analysis of human waste disposal with special reference to public health and bacteriology; Bruce Knudsen and Grand Canyon National Park science staff; $15,000.

6. Sound level evaluations of motor noise from pontoon rafts in the Grand Canyon; CX0001-3-0061; Penn. State University; Don Thompson; FY-75; funded by Washington Office.

7. History with bibliography of biological research in the Grand Canyon region with emphasis on the riparian zone; PX821040040; Museum of Northern Arizona; Dr. Steve Carothers; FY-74; $1,200.

Preceding page blank

8. Riparian feasibility study; CX821050079; Museum of Northern Arizona; Dr. Steve Carothers; FY-74; $30,000 part of major MNA study.

9. Number and distribution of burros in the Grand Canyon; PX821050830; Museum of Northern Arizona; Dr. Steve Carothers; FY-76; $4,995.25.

10. Proposed burro follow-up study; damage and recommendations for protection of the Grand Canyon ecosystem; Museum of Northern Arizona; Dr. Steve Carothers; FY-76/77; PX821060722; PX821060722; $9,585.

11. Status survey of vertebrates and associated plants of the riparian area and Inner Gorge of the Grand Canyon, with emphasis on fishes; CX821060006; Tulane University; Dr. Royal Suttkus; FY-76; $15,437.

12. Aquatic investigations on the Colorado River from Separation Canyon to the Grand Wash Cliffs; PX821060350; University of Nevada at Las Vegas; Dr. James Deacon; FY-76; $8,793.

13. Survey of fish and their breeding status in the Colorado River; PX821060298; Dr. Royal Suttkus; $1,800.

14. Study of status of fish in the Colorado River; collaborator; University of Michigan; Dr. Robert Miller; per diem and travel costs.

15. A preliminary survey of fishes of the Colorado River in the Grand Canyon (feasibility study); PX821050965; Dr. Royal D. Suttkus; FY-75; $2,500.

16. Limnologic studies on the Colorado River in the gorge of the Grand Canyon, Grand Canyon National Park (feasibility study); PX821050862; Arizona State University; Dr. Gerald Cole; FY-75; $5,558.

17. Continued studies on the limnology of the Colorado River in Grand Canyon National Park; PX821060263; Arizona State University; Dr. Gerald Cole; July 1, 1975 to June 30, 1976; $9,969.

18. A proposal for periphytic microfloral analysis of the Colorado River-Lake Powell to Lake Mead; CX821060008; Northern Arizona University; Dr. Dean Blinn; September 1, 1975 to June 30, 1976; $14,185.

19. Analysis of periphyton and certain physico-chemical parameters from the Colorado River system between Lakes Powell and Mead (feasibility study); PX821050861; Northern Arizona University; Dr. Dean Blinn; January 1, 1975 to July 1, 1975; $7,969.

20. Survey of phytoplankton, bacteria and trace chemistry of the lower Colorado River and tributaries in the Grand Canyon (feasibility study); PX821050863; Arizona State University; Dr. Milton R. Sommerfeld; FY-75; $7,889.

21. Survey of bacteria, phytoplankton, and trace chemistry of the lower Colorado River and tributaries in the Grand Canyon; CS821060007; Arizona State University; Milton Sommerfeld; July 26, 1975 to June 30, 1976; $14,000.

22. An annotated bibliography of limnologically related research on the Colorado River and its major tributaries in the region of Marble and Grand Canyons; PX821041350; Arizona State University; Dr. Gerald Cole; FY-74; $2,490.

23. An inventory of large and small bird bones from Stanton's Cave; PX821050967; University of Arizona; Amadeo Rea; FY-75-76; $800.

24. Camelthorn control; no contract; NPS-GRCA; Roy Johnson; two trips through canyon; mechanical removal by students, more trips and a written report anticipated.

25. The establishment of bench marks and GCNP techniques for measuring erosion along the Colorado River; PX821060262; University of Virginia; Dr. Alan Howard; FY-76; $4,900.

26. Changes in fluvial deposits of the Colorado River in the Grand Canyon; continuation of Washington-funded project CX821060009; University of Virginia; Alan Howard and Robert Dolan; September 1, 1975 to June 30, 1976; $14,609.

27. Hydrology and sedimentology of the Colorado River; CX821060030; University of Arizona; Dr. Emmett Larsen; $9,416.

28. Analysis of backcountry trail use in Grand Canyon National Park; CX821060027; Museum of Northern Arizona; Dr. Steve Carothers; $8,991.

29. Economic analysis of river companies running the Colorado River in Grand Canyon National Park; CX821060028; Utah State University; Dr. Michael Parent; $7,604.

This page is blank

APPENDIX C

LIST OF

COLORADO RIVER RESEARCH CONTRIBUTIONS

This page is blank

APPENDIX C

GRAND CANYON NATIONAL PARK COLORADO RIVER RESEARCH SERIES

[Note: Reports followed by an NTIS accession number may be purchased from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.)

Contribution Number

1. Maim, W. C. 1974. Air movement in the Grand Canyon. Plateau 46(4) :125-132.

2. Guse, N. C., Jr. 1974. Colorado River bighorn sheep survey. Plateau 46(4) :135-138.

3. Euler, R. C. 1974. Future archaeological research in Grand Canyon. Plateau 46(4):139-148.

4. Phillips, B. G. and M. Phillips, III. 1974. Spring wildflowers in the Inner Gorge, Grand Canyon, Arizona. Plateau 46(4): 149-157.

5. Slawson, C. C., Jr. and L. C. Everett. 1974. Water quality perspectives in recreation management. Plateau 46(4):158-l67.

6. Johnson, R. R.,1 L. T. Haight, E. L. Smith and D. S. Tomko. 1977. First Ovenbird specimens from Arizona. Auk 94:142.

7. Shelby, B. and J. M. Nielsen. 1975. Progress Report II: River contact study. National Park Service, Grand Canyon National Park. 69 pp.

8. Nielsen, J. M., B. Shelby and J. E. Haas. 1975. Sociological carrying capacity and the last settler syndrome. National Park Service, Grand Canyon National Park. 15 pp.

9. Kubly, D. M. 1975. An annotated bibliography of limnologically related research on the Colorado River and its major tributaries in the region of Marble and Grand Canyons. National Park Service, Grand Canyon National Park. 27 pp.

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

11. Carothers, S. W. and R. R. Johnson. 1975. Recent observations on the status and distribution of some birds of the Grand Canyon Region. Plateau 47(4):140-153.

12. Ruffner, C. A. and S. W. Carothers. 1975. Recent notes on the distribution of some mammals of the Grand Canyon Region. Plateau 47(4) :154-160.

13. Tomko, D. 5. 1975. The reptiles and amphibians of the Grand Canyon. Plateau 47(4):161-166.

14. Carothers, S. W., M. E. Stitt and R. R. Johnson. 1976. Feral asses on public lands: an analysis of biotic impact, legal considerations and management alternatives. Transactions of the 41st North American Wildlife and Natural Resource Conference, Wildlife Management Institute, Washington, D.C. 41:396-406.

15. Brew, N. 1975. Biological and sociological investigations of backcountry recreation: an annotated bibliography. National Park Service, Grand Canyon National Park. 48 pp.

Preceding page blank

16. Aitchison, S. W., S. W. Carothers and R. R. Johnson. 1977. Some ecological considerations associated with river recreation management. In Proceedings of the River Recreation Management and Research Symposium. USDA Forest Service North Central Forest Experiment Station, Minneapolis, Minnesota. pp. 222-225.

17. Knudsen, A. B., R. Johnson, K. Johnson and N. R. Henderson. 1977. In a bacteriological analysis of portable toilet effluent at selected beaches along the Colorado River, Grand Canyon National Park, Arizona. Proceedings of the River Recreation Management and Research Symposium, USDA Forest Service North Central Forest Experiment Station, Minneapolis, Minnesota. pp. 290-295.

18. Nielsen, J. M. and B. Shelby. 1977. River running in the Grand Canyon: how much and what kind of use. In Proceedings of the River Recreation Management and Research Symposium, USDA Forest Service North Central Forest Experiment Station, Minneapolis, Minnesota. pp. 168-177.

19. Borden, F. Y., B. J. Turner and C. H. Strauss. 1977. Colorado River campsite inventory. In Proceedings of the River Recreation Management and Research Symposium, USDA Forest Service North Central Forest Experiment Station, Minneapolis, Minnesota. pp. 226-231.

20. Borden, F. Y. 1976. User carrying capacity for river running the Colorado River in the Grand Canyon. Colorado River Technical Report No. 9, National Park Service, Washington, D.C. 79 pp. (NTIS Access. No. P3267744AS).

21. Kubly, D. M. and G. A. Cole. In press. Limnological research on the Colorado River and selected tributaries in Grand Canyon National Park. In Proceedings of the First Conference on Scientific Research in the National Parks. National Park Service. Washington, D.C.

22. Carothers, S. W., S. W. Aitchison and R. R. Johnson. In press. Natural resources in Grand Canyon National Park and river management alternatives on the Colorado River. In Proceedings of the First Conference on Scientific Research in the National Parks. National Park Service, Washington, D.C.

23. Dolan, R. B., Hayden, A. Howard and R. R. Johnson. In press. Man's impact on Colorado River fluvial deposits within the Grand Canyon. In Proceedings of the First Conference on Scientific Research in the National Parks. National Park Service, Washington, D.C.

24. Suttkus, R. D., G. H. Clemmer, C. Jones and C. R. Shoop. In press. Survey of fishes, mammals, and herptofauna of the Colorado River and adjacent riparian areas of the Grand Canyon National Park. In Proceedings of the First Conference on Scientific Research in the National Parks. National Park Service. Washington, D.C.

25. Howard, A. and R. Dolan. In press. Fluvial Regime of the Colorado River in the Grand Canyon and its modification by Glen Canyon Dam. In Proceedings of the First Conference on Scientific Research in the National Parks. National Park Service, Washington, D.C.

26. Publication pending.

27. Johnson, R., S. W. Carothers, R. Dolan, B. Hayden and A. Howard. 1977. Man's impact on the Colorado River in the Grand Canyon. National Parks and Conservation Magazine 51(3):13-16.

28. Publication pending.

29. Publication pending.

30. Shelby, B. and J. Nielsen. 1976. Design and method of the sociological research in Grand Canyon: part I, river contact study. Colorado River Technical Report No. 1, Grand Canyon National Park. 32 pp. (NTIS Access. No. PB267760AS)

31. Shelby, B. and J. Nielsen. 1976. Motors and oars in the Grand Canyon: part II, river contact study. Colorado River Technical Report No. 2, Grand Canyon National Park. 45 pp. (NTIS Access. No. PB267730AS)

32. Shelby, B. and J. Nielsen. 1976. Use levels and crowding in the Grand Canyon: part III, river contact study. Colorado River Technical Report No. 31 Grand Canyon National Park. 51 pp. (NTIS Access. No. PB267745AS)

33. Shelby, B. and J. Nielsen. 1976. Private and commercial trips in the Grand Canyon: part IV, river contact study. Colorado River Technical Report No. 4, Grand Canyon National Park. 32 pp. (NTIS Access. No. PB267729AS)

34. Suttkus, R. D., G. H. Clemmer, C. Jones and C. R. Shoop. 1976. Survey of fishes, mammals, and herptofauna of the Colorado River and adjacent riparian areas of the Grand Canyon National Park. Colorado River Technical Report No. 5, Grand Canyon National Park. 48 pp. (NTIS Acces. No. PB267718AS)

35. Czarnecki, D. B., D. W. Blinn and T. Tomkins. 1976. A periphytic microfloral analysis of the Colorado River and major tributaries in Grand Canyon National Park. Colorado River Technical Report No. 6, Grand Canyon National Park. 106 pp. (NTIS Access. No. PB267761AS)

36. Howard, A.D. and R. Dolan. 1976. Alterations of terrace deposits and beaches of the Colorado River in the Grand Canyon caused by Glen Canyon Dam and by activities during river float trips. Colorado River Technical Report No. 7, Grand Canyon National Park. 29 pp. (NTIS Access. No. PB267766AS)

37. Cole, G. A. and D. M. Kubly. 1976. Linnologic studies on the Colorado River and its main tributaries from Lees Ferry to Diamond Creek including its course in Grand Canyon National Park. Colorado River Technical Report No. 8, Grand Canyon National Park. 88 pp. (NTIS Access. No. PB267736AS)

38. Carothers, S. W. 1976. An ecological survey of the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs. Colorado River Technical Report No. 10, Grand Canyon National Park. 251 pp. (NTIS Access. No. PB267770A5)

39. Phillips, R. A. and C. Sartor-Lynch. 1976. Human waste disposal on beaches of the Colorado River in Grand Canyon. Colorado River Technical Report No. 11, Grand Canyon National Park. 79 pp. (NTIS Access. No. PB267733AS)

40. Sommerfeld; M., W. Crayton and N. Crane. 1976. Survey of bacteria, phytoplankton and trace chemistry of the lower Colorado River and tributaries in Grand Canyon National Park. Colorado River Technical Report No. 12, Grand Canyon National Park. 136 pp. (NTIS Access. No. PB26773IA5)

41. Laursen, E. and E. Silverston. 1976. Hydrology and sedimentology of the Colorado River in Grand Canyon. Colorado River Technical Report No. 13, Grand Canyon National Park. 27 pp. (NTIS Access. No. PB267735AS)

42. Minckley, C. 0. and D. W. Blinn. 1976. Summer distribution and reproductive status of fish of the Colorado River in Grand Canyon National Park and vicinity during 1975. Colorado River Technical Report No. 14, Grand Canyon National Park. 17 pp. (NTIS Access. No. PB267735AS)

43. Deacon, J. E. and J. R. Baker. 1976. Aquatic investigation on the Colorado River from Separation Canyon to the Grand Wash Cliffs, Grand Canyon National Park. Colorado River Technical Report No. 15, Grand Canyon National Park. 26 pp. (NTIS Access. No. PB267734A5)

44. Parent, C. R. Michael and F. E. Robeson. 1976. An economic analysis of the river running industry in Grand Canyon National Park. Colorado River Technical Report No. 16, Grand Canyon National Park. 131 pp. (NTIS Access. No. PB268997)

45. Publication pending.

46. Weeden, H. A., F. Y. Borden, B. J. Turner, 0. N. Thompson, C. H. Strauss and R. R. Johnson. 1975. Grand Canyon National Park campsite inventory. Unpublished Colorado River Research Report, National Park Service, Washington, D.C. 72pp.

47. Johnson, R. R. 1977. Synthesis and management implications of the Colorado River research program. Colorado River Technical Report No. 17, Grand Canyon National Park. 75 pp. (NTIS Access. No. pending)

48. Thompson, D. N., A. J. Rogers, Jr., and F. Y. Borden. 1974. Sound-level evaluations of motor noise from pontoon rafts in the Grand Canyon. Colorado River Technical Report No. 18. Grand Canyon National Park. 32 pp. (NTIS Access. No. pending)

49. Miller, R. R. 1975. Report on fishes of the Colorado River drainage between Lees Ferry and Surprise Canyon, Arizona. Unpublished Colorado River Research Report, Grand Canyon National Park, Arizona. 4 pp.

50. Aitchison, S. W. and S. W. Carothers. 1974. An ecological survey of the Colorado River and its tributaries between Lees Ferry and the Grand Wash Cliffs - Phase I. Unpublished Colorado River Research Report, Grand Canyon National Park, Arizona. 172 pp.

51. Bowman, E. G. 1975. Aircraft noise evaluation Grand Canyon, May -August 1975. Unpublished research report, Grand Canyon National Park, Arizona. 50 pp.

52. Bowman, E.' G. 1976. Statistical summary aircraft noise evaluation, May - August 1975. Unpublished research report, Grand Canyon National Park, Arizona. 36 pp.

53. Carothers, S. W., J. H. Overturf, D. S. Tomko, D. B. Wertheimer, 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 Colorado River Research Report, Grand Canyon National Park, Arizona. 137 pp.

54. Dolan, R., A. Howard and A. Callenson. 1974. Man's impact on the Colorado River in the Grand Canyon. Amer. Sci., 62(4):392-401.

55. Rea, A. M. 1976. The micro bird bones from Stanton's Cave, Grand Canyon, Arizona. Unpublished Colorado River Research Report, Grand Canyon National Park, Arizona. 11 pp.

56. Hargrave, L. L. and A. M. Rea. 1976. The large bird bones from Stanton's Cave, Arizona. Unpublished Colorado River Research Report, Grand Canyon National Park, Arizona. 21 pp.