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Notes on the Human Ecology of Glen Canyon

By ANGUS M. WOODBURY

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ANTHROPOLOGICAL PAPERS

The University of Utah Anthropological Papers are a medium for reporting to interested scholars and to the people of Utah research in anthropology and allied sciences bearing upon the peoples and cultures of the Great Basin and the West. They include, first, specialized and technical record reports on Great Basin archeology, ethnology, linguistics, and physical anthropology, and second, more general articles on anthropological discoveries, problems and interpretations bearing upon the western regions, from the High Plains to the Pacific Coast, insofar as they are relevant to human and cultural relations in the Great Basin and surrounding areas.

For the duration of the archeological salvage project for the upper Colorado River Basin which the University has undertaken by contract agreement with the National Park Service, reports relating to that research program are being published as a series within a series, bearing numbers in the general sequence of the papers as well as their own identifying numbers.

The Glen Canyon subseries will represent a wider range of the sciences and humanities than the parent series itself. The project provides for studies of the natural history of the Glen Canyon area and its inhabitants so that the relations of the prehistoric cultures and their settings will be understood in depth. As contact with Western peoples and cultures has had a varying effect upon the native Americans and the land, some papers will be concerned with the Colorado in the more recent past. Most of the Glen Canyon publications, however, will be archeological reports.

NOTES ON THE HUMAN ECOLOGY

OF

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Department of Anthropology

University of Utah

Glen Canyon Reservoir

Upper Colorado River Basin

Notes on the Human Ecology

Of Glen Canyon

as a part of the

Upper Colorado River Basin Salvage Program

in accordance with

Memorandum of Agreement

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between

the National Park Service and the University of Utah

by

Angus M. Woodbury

University of Utah

PREFACE

In an attempt to correlate the inter-departmental studies conducted separately as a part of the Upper Colorado River Basin Archeological Salvage Project, Angus M. Woodbury and I decided the most feasible manner in which to relate animal, plant and human ecology of the Glen Canyon was to collaborate, and compare the data (all published in the University of Utah Anthropological Papers) collected by the Biological Sciences Division and the Department of Anthropology. Our intent was to pool our ideas and arrive at a comprehensive report of the relationships of climate, plants and animals to human occupance of the area.

This comprehensive report was not well underway when it was terminated by the untimely death of Woodbury in an unfortunate automobile accident in the summer of 1964. However, Woodbury had already roughdrafted most sections of his portion of the report and had presented his ideas and compiled his data. While I felt that these views should be presented, I also felt it would not be appropriate to alter his ideas and data by incorporating them with mine. Hence, this posthumous report is entirely Woodbury's contribution, even though certain editorial liberties were taken with the material. These include considerable format reorganization, deletion of repetitive statements and recombination and addition of conjunctive statements that seemed to be necessary for clarity.

Nevertheless, the report--the ideas, concepts and data--are Woodbury's.

Jesse D. Jennings

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INTRODUCTION

Archeological work has shown that the densest occupation of Glen Canyon and immediately adjacent highlands occurred between A.D. 900 and 1250, a relatively short period of time in the history of man on this continent. There were earlier inhabitants, probably during Basketmaker times, but sites of this age are scanty. There was also some sparse use of the area by historic tribes in northern Arizona during the sixteenth century.

Archeologists have assigned a preponderant number of the sites to the Pueblo II period, approximately A.D. 900 to 1100, and to the Pueblo III period, approximately A.D. 1050 to 1300. Both cultures were associated with pottery and antedated the coming of the Navajos, who have apparently wandered in and out of this basin area since their arrival, without establishing important habitation sites.

Schulman (1956, 69) indicates that there was an extraordinarily severe drought in the Colorado River Basin from about A.D. 1215 to 1299, except for occasional relief about mid-century, and an extraordinarily wet period from A.D. 1300 to 1396. According to his data, these excesses far exceeded in duration and intensity anything found in modern records. On this assumption, the decline and disappearance of these Glen Canyon people may have been part of a general exodus of Pueblo inhabitants southward from the Four Corners region and of a shrinkage of the area of Pueblo dominance, all of which corresponds with this long period of drought. If so, there would have been no population left in Glen Canyon to take advantage of the wet period of the next century.

But this hypothetical explanation is too simple. It has been challenged by Martin, et al. (1962, 191-206) and by Martin, Schoenwetter and Arms (1961, 78-92) on the basis of pollen analyses in eastern Arizona and western New Mexico. Their proposed climatic model for the arid Southwest differs largely in their interpretation of cycles indicated as drought by the tree ring studies because "it is difficult to reconcile the pollen record with a climatic interpretation of extreme drought." Neither do they agree with Antevs' (1955) hypothesis that in the Southwest during the intense cyclical droughts, the vegetation cover is reduced and, when rains occur, there are few plants left to absorb the water, resulting in its running off the surface cutting and denuding the flood plains. They propose that if climatic conditions have remained stable and changes in meteorological conditions are due to environmental shifts in weather, then "time horizons in which arroyo-cutting is widespread may be considered periods in which there were more numerous summer storms."

Lance (1963, 353) has analyzed the alluviation in Lake and Moqui tributaries to Glen Canyon, typical of many other canyons of the region. He indicates that alluviation to the depth of tens of feet followed bedrock cutting of the canyons during late Quaternary time and evidence of several cycles of filling and erosion still persists in the form of alluvial terraces along the walls. After describing and analyzing the sediments in relation to the archeological sites in the canyons, Lance (1963, 362) indicates that the stream in Lake Canyon, flowing over bedrock, is now in a down-cutting phase of an erosional cycle believed to have begun in late nineteenth or early twentieth century. This down-cutting cycle has extended through much of the previous fill, exposing the depth of the deposit and showing its stratification. Lance assumes that most of the sedimentary filling has been deposited by streams, some of which had been captured in lakes, and some by blowing sand. Vegetation along streamsides and in ponds and lakes had colored some of the fill.

Despite the suggestion by Cooley (1962) that there may have been a down-cutting cycle between A.D. 1100 and 1300, with refilling of as much as 30 ft. of sediment after that time, Lance, after estimating that filling of a previously cut canyon had begun early in the Christian era, concludes that the evidence does not indicate a down-cutting erosional cycle until the beginning of this century, certainly not one affecting the habitability of Lake Canyon during occupancy of the canyon by aborigines. Lance also has difficulty in correlating the erosional cycle here with the standard sequence described by Hack (1942; 1945) for the Tsegi Canyon farther south.

Interpreting the aboriginal ecology of the Glen Canyon is, at best, a complex problem, but conflicting interpretations based on meager data from tree rings, pollen analyses, and geoclimatic and alluviation studies add to the confusion. A satisfactory and comprehensive integration of all lines of evidence will require a great deal more investigative material than is available at present. But perhaps a few ideas derived from many years of ecological study in the semiarid West and specifically from investigations made by University of Utah expeditions into that rugged erosion-dissected terrain of the American Southwest will be useful. The detailed reports of the investigations made by the Division of Biological Sciences are found in the University of Utah Anthropological Papers (31, 36, and 40) and those by the Department of Anthropology in University of Utah Anthropological Papers (30, 39, 41, 43, 44, 49, 52, and 63).

The archeological investigations, under the direction of Jesse D. Jennings, included surveys and excavations of many of the sites used by aboriginal inhabitants that will be covered by storage waters of the Glen Canyon Reservoir (Lake Powell). Plant and animal remains collected from these sites were later correlated with studies of the present flora and fauna.

Collections of biological remains and artifacts include large numbers of plant parts and vertebrate bones and smaller numbers of hides, horns, fur, and feathers, some of which had been worked for special uses. Of the unworked plant remains, studied by Seville Flowers, many were inadequate for accurate identification. Those identified belonged to 67 species of 30 families of present-day native plants, mainly grasses, shrubs and trees. Of the unworked animal remains, nearly 2200 identifications or partial determinations have been made by S. D. Durrant. These represent individual bones, horns, hides or other animal parts and cannot be translated quantitatively into animal numbers but do represent qualitatively the kinds of animals present at the archeological sites. These indicate the presence of (unidentified) fishes, toads, lizards, and birds. In addition, two species of birds and 22 species of mammals belonging to 13 families were identified.

Biological investigations covering much of the same area, made under the writer's direction by biological specialists, emphasized the kinds, quantities, and distribution of terrestrial vegetation and the animals associated with it. Studies of aquatic life included that of the river; however the tributaries proved to be much more productive of aquatic life. The results of the biological investigations made possible the identification of much of the present-day flora and fauna, from which the correlation with the archeological collections was made.

KINDS AND DISTRIBUTION OF VEGETATION

The monotonous expanse of nearly uniformly spaced bushes of black brush on the mesas above the brinks of Glen Canyon is broken by small washes, gulleys, arroyos, and side canyon chutes draining upper catchment basins into the river. The only erosion-producing drainage flowing from these basins occurs either during rapid snow melt or heavy rains, such as summer thundershowers. Such drainage represents water loss from precipitation and hence loss to plant and animal use. Other water from precipitation soaking into the ground usually adds to the soil supply. On the mesas and sidehills there is no such thing as a water table derived from the meager precipitation in this semiarid climate.

In fact, in this highly dissected terrain, water tables rarely occur. Water of subterranean aquifers arising in distant mountains may find outlets as seeps or springs in cliffs, sidehills, or canyon bottoms. Run-off streams supply water to store in bed and banks while the water is running but the amount stored depends largely upon the size of the stream and length of the flow. Permanent streams also supply water to bed and banks but this generally flows in the soil of the banks slowly down canyon and, as the stream fluctuates, water in the banks follows suit with considerable lag.

The thrifty vegetation along the edge of the Colorado River in Glen Canyon depends upon this water in the banks and is not likely to be affected by local environmental shifts in weather since this water arises in distant mountains. It is the water in banks of arroyos and side canyons arising from run-off floods in local catchment basins that is subject to great fluctuation. Since the thunderstorms are so erratic in pattern of distribution, some catchment basins may be missed for several years at a time while others may be hit in rapid succession.

This erratic distribution of run-off producing rainfall should have an influence on the amount and kinds of vegetation produced in arroyos and side canyons in different years and this makes it difficult to draw general conclusions from vegetation in such places about the climatic conditions. Questions also arise about the catchment basins above these drainage pathways. How do the pelting rain drops of such heavy storms affect the surface of the exposed soil between the bushes in respect to soil absorption of the water and subsequent evaporation? How much more net storage of soil water useful to plants will be available from such storms? Only investigation can answer.

Cycles of sediment filling and erosional cutting are well known phenomena in washes, arroyos, and side canyons. It is also well understood that vegetation has much influence on the processes but differences exist in the interpretation of the causes and operation of the cycles. Observations during the writer's long experience suggest that after a cycle of cutting, temporary streams begin to aggrade their beds above obstructions of rocks, logs, brush or other things lodged in their paths. Building their beds higher may continue even during large floods if the lodgements hold. Vegetation along the beds and banks of the flood plain is especially helpful in holding the sediment as it builds, often shifting the course of the stream from side to side.

After a period of building, almost anything that will open the way for a flood stream to break out of its rock or vegetation bound course and let it cut through the plant root zone or around the obstructions in its path may start a cycle of cutting again. This is especially noticeable in game or livestock trails and in vehicle tracks and roadways. Once started, large floods, with more water, more sediment, and more force, will cut faster than smaller ones. Several such cycles of filling and cutting can be observed in many of the open arroyos and side canyons of the Glen Canyon region. It is very difficult to correlate these with wet and dry cycles of climate.

The falling pollen in Glen Canyon varies with the time of year, the kinds of pollen being produced, the amount available, the force and direction of winds, the flotability of pollen in the air, propinquity to pollen sources, and many other factors. It is probable that the pollen rain pattern changes continually during the season, changes radically from canyon to canyon and from place to place. It is difficult to see how pollen analyses from sites in high altitudes at the headwaters of streams can be generalized into climatic patterns that will apply to the lowland sites of Glen Canyon.

An intensive study of the vegetation in Glen Canyon, from the mouth of Dirty Devil River near mile 170 (measured in river miles above Lees Ferry, Arizona) to the Glen Canyon dam site at mile 15, covering about 28,000 acres, showed three general types of vegetation, the separation being indicative of the availability of water. As reported by Woodbury, Durrant, and Flowers (1959), the cliff walls of the canyon are mostly bare of seed plants except in cracks, crevices, and shelves, but most of the bare surfaces are covered with lichens or mosses. Most of the vascular vegetation occurs in the bottom of the canyon, on the taluses below the cliffs, or on the mesas above the canyons.

Vegetation on the hillside taluses, depending solely upon precipitation water, is widely spaced, covering only approximately one-fifth of the ground surface. The remainder of the surface is usually bare except when extra moisture in the soil supports a growth of annuals between the bushes. Otherwise the bare soil heated by the summer sun and pelted by infrequent summer rains is subject to run-off and erosion. Perennials that survive only on precipitation water are adapted to parsimonious use of water by limiting the evapo-transpiration losses or by storing water in the plant body when it is available and using it to tide over dry periods.

Along the edge of the stream, where conditions are propitious for plant growth the primary phreatophytic plants, with their roots immersed in percolating soil water supplied by the river to its banks, usually cover the ground completely so that the sun's rays cannot reach the soil. This dense vegetation usually provides a deep layer of litter on the ground that absorbs and holds all precipitation so that there is no run-off. Having plenty of water in the soil at their roots, the plants are not adapted to parsimonious use of water and use it freely in evapo-cooling by evapo-transpiration.

On the terraces behind the streamside vegetation, where secondary phreatophytes use capillary water drawn from percolating subterranean water sources, the plants are usually intermediate between the two extremes. They cover approximately one-half of the soil area and usually include heavier crops of annual vegetation between the perennial bushes than do those on the hillside. They usually have intermediate adaptations for limiting the evapo-transpiration losses and storage of water.

Actually there are many intergradations of plants in their adaptations for use of water. These range from the water edge sandbar willow outward through successive primary and secondary phreatophytes to the hillside vegetation (Fig. 1). Figure 1 depicts an idealized arrangement of plants in a cross section transect in Glen Canyon as reported by Woodbury, Durrant and Flowers (1959, 32). The depicted sequence represents gradations, in a general way, from the stream bed outward from (1) dense to less dense vegetation, (2) more to less litter on the ground, (3) more to less moisture in the soil, (4) little to much ground surface exposed to the sun's rays and surface erosion, and (5) cooler to warmer ground temperatures in the summer (reversed in the winter from warmer to cooler).

Those plants farthest out on these gradations, having less available water, can use less of the supply for evapo-cooling. Thus they face the danger of higher temperatures from the summer sun. Those with small stems and twigs may be able to re-radiate heat and keep temperatures relatively low but those with thick bodies, such as the hedgehog cactuses, may be heated by the sun to extremely high temperatures--as much as 130° to 135°F (Woodbury 1956, 15).

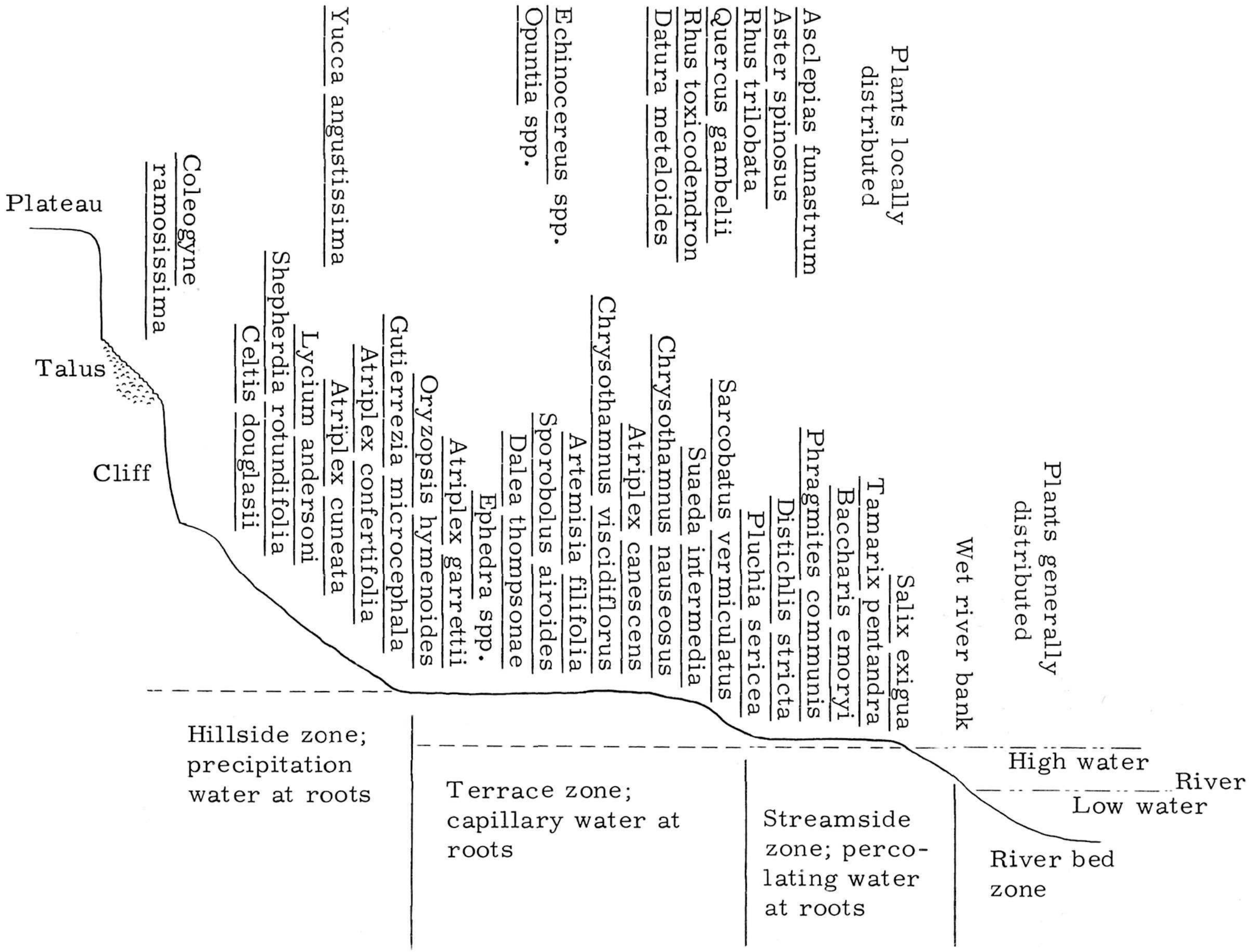

Fig. 1. Typical transect of vegetation in Glen Canyon, river edge to hillside. (Adapted from Woodbury, Durrant and Flowers [1959, 32].)

This theoretical cross section gives a general idea of the gradations of vegetation from streamside to hillside, but there are many irregularities in the environment that upset this idealized sequence. While there is a decrease in available water from river to hillside along the transect within the canyons, the sequence is, in general, reversed in climbing to the high plateaus and mountains above the canyon. There, with greater altitude and the consequent increase in precipitation, there is usually greater density of vegetation.

The vegetation in desert areas, with low quantities of precipitation, usually presents a low shrub pattern with the bushes widely spaced but with wide-spreading root systems that compete severely with one another for ground moisture. With an increase in precipitation, the root systems are usually able to support larger proportionate foliage systems and there is a consequent increase in density of foliage cover. When the foliage density reaches the stage of complete cover, then there is a general tendency for the foliage to lengthen upward. With sufficient water for this stage of competition, the dominant forms may be tall shrubs or trees, sometimes trees of huge size.

Among the things that may upset such orderly sequences are the irregularities in topography that are such outstanding features of the landscape in the Glen Canyon region. In the main canyon, the irregularities of the river are matched by irregularities of the land. In places, wide strips of streamside vegetation are surmounted by canyon terraces that extend backward to the slopes at the foot of high cliffs. In other places, the river washes the foot of steep taluses or even the foot of cliffs. In still other places, alluvial or talus fans may push across terraces and cause a mixing hillside vegetation with that of the terraces or even of the streamside.

Side canyons leading to the river are usually deep entrenchments in the rocks of the plateaus and their branches often dissect the uplands into irregular pieces with great diversity in steepness of slope and exposure. Where bare rock is exposed, runoff water from storms may concentrate extra water in cracks or on talus slopes below the bare rock, permitting denser vegetation cover to develop. Greater evaporation takes place on southern exposures than on northern; hence, denser vegetation may develop in the northern.

To show quantitative relations among the vegetation, the more important species of plants occupying at least 5% of the cover on any subdivision have been listed in Table 1. This shows the total estimated acreage each plant would cover separately in streamside, terrace, or hillside areas and the total in Glen Canyon. For further quantification, the mean height of each plant is given and the total foliage volume measured in acre feet--the total number of acres the foliage would cover in its natural spread one foot in depth.

FOLIAGE ACREAGE AND VOLUME

Table 1. Calculated cover acreage (100% cover) in each of three habitats and the calculated volume of foliage in acre-feet (cover acreage x foliage height).

Scientific name	Common name	Stream-side	Ter-race	Hill-side	Cover acres	Ht. ave.	Foliage acre-ft.
Equisetum spp.	horsetail	1.4	--	--	1.4	1.4	2.0
Ephedra spp.	ephedra	--	95.2	328	423.2	1.4	592.5
Typha latifolia.	cattail	18.4	--	--	18.4	5.0	92.0
Bromus tectorum	cheat grass	3.3	--	16	19.3	0.6	11.6
Distichlis stricta	salt grass	.9	36.7	--	37.6	0.5	18.8
Phragmites communis.	reed cane	21.6	.2	--	21.8	5.0	109.0
Sporobolus airoides	drop-seed grass	--	26.3	--	26.3	0.5	13.2
Oryzopsis hymenoides.	Indian rice grass	.7	36.3	221	258.0	1.2	309.6
Hilaria jamesii	galeta grass	--	--	13	13.0	0.4	5.2
Mixed grasses.	mixed grass	--	--	649	649.0	0.8	519.2
Carex spp.	sedge	42.3	--	--	42.3	1.2	50.8
Scirpus spp.	bulrush	11.0	--	--	11.0	1.2	13.2
Juncus spp.	rush	44.4	--	--	44.4	1.0	44.4
Populus fremonti	Fremont cottonwood	23.8	18.8	18	60.6	20.0	1212.0
Salix exigua	sandbar willow	998.1	32.8	--	1030.9	7.0	7216.3
Salix gooddingi	Goodding tree willow	80.2	9.4	--	89.6	15.0	1344.0
Quercus gambelii.	Gambel oak	48.9	523.4	27	599.3	8.0	4794.4
Celtis douglasii.	hackberry	20.9	158.8	20	199.7	8.0	1597.6
Eriogonum inflatum	bottle-stopper	--	--	66	66.0	0.1	6.6
Atriplex canescens	4-winged saltbush	5.1	558.4	--	563.5	2.7	1521.5
Atriplex confertifolia.	shadscale	1.3	99.5	976	1076.8	0.8	861.4
Atriplex cuneata	saltbush	--	--	47	47.0	0.5	23.5
Atriplex garrettii.	saltbush	--	.5	81	81.5	0.7	57.1
Sarcobatus vermiculatus	greasewood	--	64.1	--	64.1	2.0	128.2
Suaeda intermedia	seepweed	.8	216.6	--	217.4	1.5	326.1
Salsola kali	Russian thistle	.4	--	--	.4	0.6	.2
Lepidium montanum.	peppergrass	--	--	23	23.0	1.0	23.0
Lepidium spp.	peppergrass	--	5.0	--	5.0	3.0	15.0
Coleogyne ramosissima	black brush	--	--	207	207.0	1.0	207.0
Cercis occidentalis	redbud	.2	.7	--	.9	8.0	7.2
Dalea fremontii	Fremont indigo bush	--	5.8	21	26.8	1.2	32.2
Dalea thompsonae	Thompson indigo bush	--	--	201	201.0	1.2	241.2
Rhus toxicodendron	poison sumach	7.2	--	--	7.2	2.5	18.0
Rhus trilobata	three-lobed squawbush	44.4	32.8	--	77.2	5.0	386.0
Rhus utahensis.	Utah squawbush	--	2.4	--	2.4	4.5	10.8
Rhamnus betulaefolia	buckthorn	--	--	18	18.0	5.8	104.4
Tamarix pentandra	tamarix	404.2	17.9	--	422.1	8.0	3376.8
Opuntia spp.	cactus	--	22.5	3	25.5	0.4	10.2
Lycium andersoni	wolf-berry	--	--	156	156.0	1.5	234.0
Datura meteloides	sacred datura	2.0	--	--	2.0	2.0	4.0
Gutierrezia microcephala	matchweed	--	14.2	3	17.2	0.8	13.8
Chrysothamnus nauseosus.	rabbit brush	11.9	318.9	103	433.8	3.0	1301.4
Aster spinosus.	aster	.3	--	--	.3	0.6	.2
Baccharis emoryi	baccharis	187.7	22.8	--	210.5	5.5	1157.8
Pluchea sericea	arrowweed	122.6	139.9	--	262.5	2.5	656.3
Artemisia filifolia	sand sagebrush	5.0	65.2	70	140.2	2.0	280.4
Others	others	8.2	815.3	57	880.5	1.0	880.5
	TOTALS	2117.2	3340.4	3324	8781.6	20.0	29830.6

KINDS AND DISTRIBUTION OF ANIMALS

Preliminary lists of animals known to occur in the general regions of the "rough country" were published by Woodbury, et al. (1958, 124-219). Since that time, new studies more narrowly restricted to the environs of Glen Canyon have been made. From these studies, lists of animals have been prepared, based mainly upon collections made on University of Utah trips and expeditions in Glen Canyon and adjacent areas, but records of other collections made in the Canyon have also been used. Results of these studies of the flora and fauna in Glen Canyon prepared by specialists and students of the University were compiled and published. These reports and papers included records of geographical and ecological distribution and comments or annotations about the species listed. In some cases, anticipated effects of the reservoir upon the fauna were considered (Woodbury, et al., 1959).

Mammals

Study of the mammals was based mainly upon rodent trapping and gun hunting operations of the expedition but this was supplemented by observations of animals or their tracks, scats or workings, and by literature reports. In the operations, 434 rodents, 16 bats, and a cottontail rabbit were taken. Data on others were obtained by observation. The mammalian fauna of Glen Canyon as deduced from this study consists of animals belonging to 5 orders, 13 families, 26 genera, 41 species and 56 subspecies.

Bats known to belong to 2 genera and 3 species were so numerous in the canyon that Durrant concluded they were more numerous there than at any other place he had observed in Utah. There are many sheltering cracks or crevices in the cliffs where the bats can find resting places and shelter and there are good aerial feeding sources along the river banks.

Lagomorphs were not common in the canyon; only one jack rabbit was observed, and cottontails were very scarce.

Rodents were represented by 3 species of sciurids, 6 of heteromids, 10 of cricetids, 1 beaver and 1 porcupine, a total of 21 species. Porcupines seemed to be rare in the summer at the low altitudes found in the canyon, but the beavers were exceedingly numerous along the river banks and in many of the tributary creeks. They did not build dams nor houses along the river although feeble attempts at dam making were noted on some of the smaller streams. Instead, these willow-feeding bank dwellers dug tunnels in the bank, which usually opened below the water line but were often exposed as high water receded. It was estimated that there were about 10 active burrows per mile of river.

As a by-product of the rodent trapping program, the digestive tracts from 27 freshly caught rodents were preserved in formalin for endoparasitic study. These were examined by Albert W. Grundmann and James R. Crook (1959, 105-106), who found eight of the 27 tracts infested with endoparasites. Of these, one canyon mouse from the mouth of the San Juan River had been infested with an unidentifiable tapeworm. The other seven were infested with nematodes. The hosts included rock squirrel, chipmunk, canyon mouse, deer mouse, and pinyon mouse. The parasites included specimens of the genera *Aspiculuris*, *Syphacia*, and probably *Strongyle*. Judging from studies in other areas of the west, this list is inadequate to give an inkling of the complex and variable endoparasitic relationships in the fauna of this region.

Signs of carnivores were noted in many places. Tracks were found in soft sand or on muddy shores. Carnivores determined to be present in the canyon included the coyote, red fox, gray fox, ringtail, raccoon, weasel, badger, spotted skunk, and bobcat. It is very doubtful if the river otter now occurs there, although it has been listed in the literature.

Among the ungulates, the mule deer and the bighorn sheep doubtless occur sparsely in the canyon, although the main range of the deer is the brushy and forested slopes of higher altitudes and that of the sheep the more openly vegetated rough slopes and ledgy side canyons. The introduced bison that range in the Henry Mountain region may descend North Wash or Trachyte Creek into the reservoir area.

Birds

Of the 97 known Canyon birds, 24 are water or shore birds, found mainly along the river, and 73 are land birds; about 20 are considered to be permanent residents, 34 summer residents, 36 transient migrants and 7 winter visitants. Taxonomically by orders, they include: 1 grebe, 2 pelicans and allies, 4 herons and allies, 11 ducks and geese, 10 vultures, hawks and falcons, 1 coot, 5 shore birds, 1 dove, 2 owls, 2 caprimulgids (poor-will and nighthawk), 1 swift and 3 hummingbirds, 1 kingfisher, 2 woodpeckers, and 51 perching birds. The perching birds include: 8 flycatchers, 1 lark, 3 swallows, 2 corvids (a jay and raven), 2 parids (mountain chickadee and plain titmouse), 1 creeper, 1 dipper, 2 wrens, 2 mimids (mockingbird and catbird), 2 thrushes (robin and mountain bluebird), 1 gnatcatcher, 1 vireo, 5 wood warblers, 5 blackbirds, 1 tanager, and 14 fringillids. The fringillids include: 2 grosbeaks, 1 bunting, 1 finch, 1 goldfinch, 1 towhee, 1 junco, and 7 sparrows.

Reptiles

A small series of reptilian specimens was taken by the University expeditions, but the great bulk of the records came from reports and field notes of the Rainbow Bridge - Monument Valley expeditions of the American Exploration Society in 1937 and 1938. Additional records were obtained from the Museum of Northern Arizona and the Arizona - Sonora Desert Museum.

The known reptilian fauna consists of 1 turtle in the Colorado River, 14 lizards, and 7 snakes. Taxonomically, the lizards include 11 iguanids, 1 night lizard and 2 whiptails; the snakes include 6 colubrids and 1 rattlesnake. The iguanid lizards include the collared and leopard lizards, the wide flat crack-inhabiting chuckwallas, 3 spiny lizards, 3 uta lizards, and 2 horned lizards. The colubrid snakes include a garter snake, a whipsnake, a patch-nosed snake, a gopher snake, a king snake, and a night snake. Evidently all of these reptiles are native to this region.

Amphibians

As with the reptiles, a few records of amphibians were made by the University expeditions but the bulk of records came from reports and field notes of the Rainbow Bridge - Monument Valley expeditions of the American Exploration Society. The fauna known at present includes a salamander, a spadefoot, 2 toads, a treefrog, and a leopard frog. All of these amphibians are associated with water at certain stages and some of them continue this close association throughout their lives. The spadefoot and the desert toad have become so specialized that, by burrowing underground in moist soil, they can survive in desert areas where accessible water may be absent for weeks or months at a time.

Terrestrial Insects

Taken during a University trip was a small collection of terrestrial insects belonging to 7 common orders: 2 orthopterans, 1 bug, 1 aphid, 7 beetles, 3 butterflies, 7 two-winged flies, and 18 wasps, bees and ants (Woodbury, *et al.*, 1959, 223-226).

This list of animal life here summarized presents only a small sample of the varied and rich fauna that may be expected in such an ecologically variable environment.

THE COLORADO RIVER

To the aborigines, the Colorado River must have been a barrier to be crossed only at favorable points during low water. The stream in Glen Canyon is relatively calm compared with the turbulent sections in Cataract Canyon above it and Marble Canyon below it. The average fall of the river in Glen Canyon is about two feet per mile, compared with nine feet per mile in Cataract Canyon.

However, even in Glen Canyon the current is not evenly graded. Near Lake Canyon, it runs over a solid rock bottom and, at the mouths of side canyons where incoming sediment makes deltas, there is often still water above and rapid water below. These rapids are often filled with boulders, around which the water churns or whirls away in eddies with funnels in the center or boils up in mounds that soon flatten out, floating away in never-ending procession. Such areas would be very difficult to swim.

At the time (1776) of Escalante's crossing of the Colorado River in Glen Canyon, the Ute Indians had a well beaten trail from southern Utah that crossed the river at the mouth of Kane Creek (river mile 40.6) at a ford used in low water. Escalante found another ford about a mile farther downstream. It seems certain that the aborigines knew of many other fords usable at favorable seasons.

The Glen Canyon complex with its side canyons cuts the sedimentary rock layers in so many places that nearly all subterranean waters find outlets in the bottoms or sides of the canyons. Because most subterranean water comes from distant mountains, springs are relatively scarce in Glen Canyon itself since most aquifers find outlets in side canyons. Many of these are sources of streams that flow out of these canyons into the river.

Men acquainted with this region know that springs arising in or at the foot of the Navajo and Wingate sandstones usually contain good potable water but those arising from the Chinle and Moenkopi formations are usually heavily impregnated with a variety of soluble salts and are often unpotable. The distribution of suitable water sources had important influence upon the distribution of aboriginal inhabitants (Gunnerson, 1959, 332-3).

The Colorado is normally a muddy river but may become relatively clear during periods of low water. However, whether muddy or clear, it rolls sand along the bed of the stream at all times. This sand scours the bed of the river and makes it difficult for living organisms to find suitable microhabitat for themselves. The mud and the ubiquitous sand together so reduce the biological productivity of the river that it may be considered to be an aquatic desert. The streams inside canyons are usually much more productive biologically than is the river itself, even though the side canyons have occasional floods that scour the bottom severely.

Fishes

Of the 17 species of fishes collected during the University survey, young or small fish of all species were found in the tributaries while specimens of only 5 were taken in the river. This difference may have been due in part to easier sampling in the smaller streams. Only 6 of the 17 species encountered are native to the Colorado River system. The others were doubtless introduced during recent history and would not have been present when the aborigines were inhabiting the region. How much the introduced species have affected the native populations is difficult to evaluate but if the sampling methods used have any significance, it is obvious that the introduced channel catfish and carp have dominating positions today and have crowded the native fish into subordinate places. Fish bones in archeological excavations were rare, having been found to date in only two sites in this region.

Aquatic Insects

Of more than 2300 specimens of aquatic insects collected, 247 were taken in the river; the balance of 2053 was taken in tributaries. This may in part represent more intensive collecting in the smaller streams but it also represents greater productivity in the tributaries. These insects belong to eight orders that include mayflies, dragonflies and damselflies, bugs, Dobson flies, caddisflies, butterflies and moths, beetles and two-winged flies. Significantly missing from the collections are the stoneflies which are known to inhabit the canyon.

These insects are of primary interest as food for fishes, amphibians, semiaquatic snakes and aquatic birds. They were probably of minor direct significance in the lives of the aboriginal inhabitants.

DIFFICULTIES OF ABORIGINAL LIFE

Study of the plant and animal life, the physiographic features, the terrain and desert climate, makes it obvious that the prehistoric pueblo-type people of the Glen Canyon region were faced with an environment almost identical with that of today. The region was marginal in natural productivity, the terrain exceedingly rough and erosion-scarred, the climate variable and arid, the area available for horticulture limited, and the natural foods restricted to the same desert plants and animals now found in the region. The harsh environment would have required a high expenditure of energy to obtain the necessities of life and would have kept the people close to the "bread line" much of the time, especially during the winter when storage crops were not abundant and fresh foods were difficult to obtain. Such food shortages probably had a culling effect upon the population, weeding out those who could not survive on malnutritional diets. In addition, other biological factors, such as pollens, pests, parasites, and diseases must have affected the welfare and survival of the aborigines.

Obnoxious Pollens

Air pollution by windborne pollens and the resulting allergic diseases of hay fever and asthma are of considerable concern to public health specialists today. Unless the aborigines of Glen Canyon region had been so culled by natural selection that they were immune to the effects of these airborne irritants, they were no doubt affected in similar ways. It is entirely probable that a small percentage of their population was subject to allergies produced by local pollens of the region.

In the Glen Canyon region, windborne pollen originates mainly from low desert perennials or small annuals, except along the stream courses and in foothills and mountains. In general, the stream courses are lined with tall brush and trees, the foothills with pigmy forests of junipers and pinyon pines, and the mountains with firs and spruces. The desert areas are dominated by a few species of small shrubs.

The amount and kinds of pollens in the air vary a great deal depending upon time, place, and proximity of one type of vegetation to that of another type. There is little or no pollen in the air during the winter. It generally appears in the early spring with the blooming period of early-flowering spring plants, rises during the summer, and tapers off in the fall.

Lindsay (1959, 63-72) listed 125 species of plants actually collected in Glen Canyon. Flowers (1959, 21-62), in describing the vegetation of the canyon, indicated that a large number of additional plants was present. For the general region including adjacent mountains, Woodbury, et al. (1958, 46-123), listed 862 pollen-bearing plants. Many of these are insect pollinated and do not produce such vast quantities of pollen as do those that are wind pollinated.

Many of these species occur in small proportions of the vegetation and the quantities of pollen produced are negligible compared with those of the ubiquitous dominant species. For study of potential sources of pollen dissemination, the ten plants with greatest cover acreage given in Table 1 have been listed in descending order as follows:

		Foliage cover acres
Atriplex confertifolia	shadscale	1076.8
Salix exigua	sandbar willow	1030.9
Quercus gambelii	Gambel oak	599.3
Atriplex canescens	4-winged saltbush	563.5
Chrysothamnus nauseosus	rabbit brush	433.8
Ephedra spp.	ephedra	423.2
Tamarix pentandra	tamarix or salt cedar	422.1
Pluchea sericea	arrowweed	262.5
Oryzopsis hymenoides	Indian rice grass	258.0
Suaeda intermedia	seepweed	217.4

When the foliage was translated into acre-feet, the top 10 fell in the following order:

		Foliage acre-feet
Salix exigua	sandbar willow	7216.3
Quercus gambelii	Gambel oak	4794.4
Tamarix pentandra	tamarix or salt cedar	3376.8
Celtis douglasii	hackberry	1597.6
Atriplex canescens	4-winged saltbush	1521.5
Salix gooddingi	Goodding tree willow	1344.0
Chrysothamnus nauseosus	rabbit brush	1301.4
Populus fremonti	Fremont cottonwood	1212.0
Baccharis emoryi	baccharis	1157.8
Atriplex confertifolia	shadscale	861.4

The ubiquitous shadscale, first in the coverage list, was last in the foliage volume list, but the willow that was second in the first list became first in the second list. Others were rearranged accordingly and some species missing from the first appeared in the second list.

The introduced tamarix, a heavy pollen producer, would not have been present in prehistoric times. Those listed above are primarily streamside and desert plants and no doubt furnished the great bulk of pollen in the canyon, but the cover acreage or the foliage quantity relations cannot be considered as determining the effects of the pollen on the inhabitants. They are only indicators of the quantities of vegetation from which pollen could arise. The oaks, hackberry, willows and cottonwoods have their stamens and pistils in different flowers and the latter two have them on different trees. They depend in part upon wind pollination but many insects assist in the process. These are doubtless more prolific sources of pollen than many of the small shrubs with stamens and pistils together in complete flowers, such as the shadscale, which has so much acreage cover.

On the plateaus above the canyon are immense stands of black brush, <u>Coleogyne ramosissima</u>, which have complete flowers and are insect pollinated. At higher altitudes above the blackbrush are immense stands of the big sagebrush, <u>Artemisia tridentata</u>, which also has complete flowers but is also a prolific source of pollen. These sagebrush stands are often intermixed with junipers and pinyon pines, which are wind pollinated and produce immense crops of pollen from staminate flowers. In the mountains, these pigmy forests are usually surmounted by dense forests of firs and spruces, which are also wind pollinated and produce enormous quantities of pollen, but occupy relatively small areas compared with the pigmy conifers, sagebrush and black brush. During the pollinating period, winds carry pollen long distances over surrounding regions.

Since no studies of pollination have been made in the Glen Canyon region, a study of the pollen distribution in Salt Lake County, Utah (Peck, 1959, 1-16) will be used for comparative purposes. This study showed that smut and other fungus spores were much more common air pollutants than were the pollens of any species of plant in that region. It was also shown that the Fremont and narrow-leafed cottonwoods were prolific sources of pollen. The former is common in side tributaries of Glen Canyon, the latter at higher altitudes, above 6000 feet, in the same side canyon tributaries. The boxelder, an occasional tree in the region, was shown to produce much more pollen than other maples in the Salt Lake vicinity.

Further interesting finds of the study included these: (1) each of the five stations at which pollen counts were made had radically different profiles of of the pollens present, (2) a station at the mouth of a canyon in the Wasatch

Mountains showed a consistently different profile in the morning after exposure to down canyon night winds than in the afternoon after exposure to up canyon daytime zephyrs, and (3) there was a progressive seasonal change in kinds of pollens during the period of pollen dissemination.

For convenience in comparison, the following data are extracted from Peck's table showing order and time of pollination:

ORDER AND TIME OF POLLINATION

Common Name	Scientific Name	Onset of Pollination
Juniper	Juniperus osteosperma	March 12-20
Aspen	Populus tremuloides	March 15-25
Box Elder	Acer negundo	April 5-15
Willow	Salix sp.	April 10-20
Scrub Oak	Quercus gambelii	May 15-25
Pine and Spruce	Pinus and Picea sp.	May 21-30
Grasses	Gramineae	May 25 - June 5
Smuts	Ustilago sp.	June 1-15
Greasewood	Sarcobatus vermiculatus	June 15-25
Saltbush	Atriplex sp.	June 15-25
Russian Thistle	Salsola kali	July 5-15
Ragweed	Ambrosia and Franseria sp.	August 1-10
Sagebrush	Artemisia sp.	September 5-15

By extrapolating from Peck's table to vegetation of the Glen Canyon region, the following plants have been arranged to show the probable sequence of pollen entering the air seasonally from March to September: cottonwood, juniper, willow, oak, pines, grasses, greasewood, shadscale and sagebrush. While this is only an approximation, there is little doubt that there would be plentiful supplies of pollen throughout the summer season, not only in Glen Canyon but in side canyons, mesas and plateaus of the region.

Closely associated with the pollen problem is the possible poison from the poison sumach, Rhus radicans L. var. rydbergii Small, that may have affected the skin of some individuals. This plant occurs in many places in suitable habitat of canyons and terraces. It would be especially dangerous along stream-side trails.

Parasites

The role of parasites and pests in the ecology of the aborigines is more difficult to assess than other aspects because there has been less emphasis on the problem in this region, and background for such assessment must come from indirect sources, mainly from studies in the Great Basin and the Navajo Country. Studies made by the University of Utah indicate that endoparasites among native reptiles, birds, and mammals of the western Utah deserts include tapeworms, nematodes, flukes, spiny-headed worms, and blood parasites; ectoparasites include fleas, lice, mites and ticks; and so-called free-living parasites include mainly blood-sucking flies and flesh flies whose larvae are parasitic under the skin. In the Navajo Country, it is known that modern Indians are infected with protozoans, tapeworms and liver flukes.

Some of these parasites not only draw food or blood from their hosts but may also be vectors that transmit disease organisms from one host to another. The aborigines living so close to nature may have been affected by some of these deleterious species either as principal or as incidental hosts.

Endoparasites

In the western Utah deserts, it is known that 2 species of lizards are hosts of 3 species of tapeworms, and 5 species of lizards are hosts to 7 species of nematodes. Among birds, 15 species are hosts to tapeworms, 3 species to nematodes, and 8 species to 6 species of the spiny-headed worms. Relations with mammals are better known. Of these, 23 species are known to be hosts to 24 species of tapeworms and 21 species hosts to 25 species of nematodes.

Among rodents, it is known that 17 species are hosts to 13 species of protozoans and 3 species hosts to 1 species of spiny-headed worm. One of the rodents, the ubiquitous deer mouse, of both mountain and desert habitats, is known to be parasitized by 7 species of nematodes, 9 species of tapeworms (cestodes), 1 species of fluke (trematode), 1 spiny-headed worm (acanthocephalan), 1 bot fly (insect), and a fungus infection (Haplosporangium). Of 75 coyotes, Butler and Grundmann (1954) found 54 infested with 1321 tapeworms of 7 species and 255 nematodes of 5 species. More work in Utah would no doubt yield much larger lists. Most of these species, both of hosts and parasites, doubtless occur in the Colorado River Basin also, and the aborigines would have been closely associated with many of the vertebrates and must have been exposed to infection. Those types of endoparasites reported from the western Utah deserts are not known to infect man.

At the present time, infections among the Navajos include the protozoan, *Giardia lamblia*; the dwarf tapeworm, *Hymenolepis nana*; and the sheep liver fluke, *Fasciola hepatica*. The protozoans of the genus *Giardia* are regarded as being highly host specific but it is very difficult to separate the strains of different hosts from one another. The infection is believed to be transmitted directly from hand to mouth and by contaminated foods or drinking water. In addition to a high incidence among the modern Indians, a case has occurred in which an Anglo-American working in Glen Canyon in October 1959 contracted an infection, probably from drinking water from "Spring Canyon," river mile 45.8. He states (letter November 20, 1959) that beaver and sheep were present. Since sheep had been herded in the canyon, it is probable that human contamination was present, from which the infection could have been obtained.

The dwarf tapeworm is a common parasite over nearly all the world. In the United States, it is relatively more prevalent in the southern states than elsewhere. There is a heavy infection among the Navajo Indians. The infection is transmitted directly from hand to mouth and also through contamination of food and water. The parasite needs no intermediate host and the heavy infection is not necessarily associated with sheep handling, as is the liver fluke, but it also infects insects, which may act as intermediate hosts in transmission to birds and mammals that eat them.

The sheep liver fluke, which also infects many other mammals including man, has a very complex life history in which the eggs and early development ordinarily occur in wet pastures where snails that act as intermediate hosts are present. However, it is possible that early stages may develop in sheep watering troughs if the snails are present. This could be a source of contamination of both man and animals and might yield a higher rate of infection than that from wet pastures. In a desert region such as that of Glen Canyon, environmental conditions are not propitious for its propagation unless it is around natural watering places such as springs, pools and marshy areas where aquatic snails and aquatic vegetation can be maintained. Since these conditions are rare in that region, it is doubtful if it would have produced any widespread infection among the prehistoric inhabitants or animals with which they were associated.

It seems possible that parasites of wide distribution today, such as pinworm, hookworm, and other nematodes or additional tapeworms, may have been present in prehistoric times. If so, they would have been additional hazards to health of those people.

Studies of rodents in northwestern Utah (Frandsen and Grundmann, 1961) have shown that at least nine species are infected with blood parasites (Haemoprotista) of at least five kinds. These include trypanosomes of the lewisi group, cell inclusions of the unknown organism named Grahamella Brumpt, 1911, bacteria of the "typhique - coli" group, a non-human malarial parasite, and an unknown organism with cigar-shaped bodies free in the blood plasma.

These parasites are so poorly known that little significance can be attached to their role in the rodents, but they are mentioned because it can be confidently predicted that some of them will be found in rodents of the Glen Canyon region. If they have any role in producing disease or otherwise affecting human welfare, it is likely to have been played among the aborigines.

Ectoparasites

There is ample indirect evidence to indicate that the aborigines may have been infested with ectoparasites. In the University studies of the western Utah deserts, it has been shown that ectoparasites are abundant on many birds and on mammals with fur while relatively few species are found on the reptiles.

Among the reptiles, 2 species of lizards and 2 species of snakes were found to be infested with 2 and 4 species of mites respectively but no lice, fleas or ticks were observed. Ticks of 5 species were found on 20 species of birds and lice of 60 species were found on 75 species of birds.

The mites were much more numerous and showed greater variety. Nine species of analgesid feather mites were found on 34 species of birds and 5 species of dermanyssid mites on 37 species. Also 9 species of dermoglyphid and proctophyllodid mites were found on 45 species, and 8 species of trombiculid mites on 25 species. In addition, at least 7 species of other kinds of mites in other families were found on 20 species of birds. These lists are far from complete, but are sufficient to give the assurance that mites are exceedingly numerous on birds.

The mammals also harbor large numbers of ectoparasites in their fur. Out of 600 mammals of 18 species examined in one study, 649 lice, 981 fleas, 1394 ticks and 1271 mites were removed for study. Many specimens were undoubtedly missed, especially of the small lice and mites. Additional work has shown that 11 species of mammals harbored 13 species of lice, 25 species had 19 species of fleas, 25 species had 8 species of ticks and 18 species had 23 species of mites.

When working with such vertebrate animals, handlers have ample opportunity to become infested with some of the parasites unless they use protective measures. Many of these ectoparasites have no attraction to human beings, but some have no repugnance to them either and may infest their clothing or hair. It is almost certain that the aborigines did not have a clear conception of these parasitic relationships and could not have developed effective anti-infestation procedures. The artifacts found in the salvage operations of the archeological sites indicate clearly that the aborigines were closely associated with many animals and could have become infested easily.

It is certain from history of early contact with modern Indians that they were infested with the human louse, as the Navajos are today, and this doubtless extended backward to the aborigines. It is well known today that young wood ticks, Dermacentor andersoni Stiles, climb to the tips of branches of tall shrubs and cling to passing animals, including man. This is a common method of tick infestation and doubtless applied also to aboriginal man. It is not to be expected that the close-to-nature aborigines escaped all of the other ectoparasites besides those specifically mentioned.

Free-living Parasites

There are several groups of free-living, blood-sucking, scavenging and flesh-eating two-winged flies that must be considered as potential pests or vectors of disease. These groups include the mosquitoes, of which about a dozen species are known to occur in the general region. Since the immature stages are aquatic, the adults are usually concentrated around areas where still water is available for the larvae to develop. They may breed in almost any water where streams will not carry the larvae away. This may include small springs, small slowly moving streams, pools left after storms, or pools along the river bank left by high water. As a result, the adults may appear irregularly during warm weather and may be localized around the breeding places unless they drift with warm winds. Females of most adult mosquitoes bite man and some of them are known to be vectors of disease. There is little doubt that they served both as pests and vectors to the aborigines.

The heleid gnats, punkies, or biting midges (family Ceratopogoniidae or Heleidae), the black flies or buffalo gnats (Simuliidae), the snipe flies (Rhagionidae), and the horse flies (Tabanidae), like the mosquitoes, all breed around wet places, but the immature stages of most of them may develop in mud or damp soil. The free-living adults of all four groups may be found around their breeding places, but some of the stronger fliers may get much farther afield. There is little doubt that they were pests and possibly vectors of disease among the aborigines.

The bot flies (Cuterebridae) and flesh flies (Sarcophagidae) lay their eggs where the newly hatched larvae can penetrate the host and develop as flesh parasites under the skin of vertebrate hosts. The blow flies (Calliphoridae) may also parasitize vertebrate hosts, but the local species usually lay eggs on carcasses or decaying matter. The tachinid flies (Tachinidae or Larvaevoridae) are similarly parasitic in invertebrate hosts, often in other insects. These groups must have been a serious plague to the aborigines.

A sarcophagid fly, *Wohlfahrtia opaca* (Coquillet), which is known to occur in that region, lays its eggs on young animals, including human children. The larvae actually penetrate the skin. Two of the Calliphorid screwworms, *Callitroga americana* (Cushing and Patton) and *C. macellaria* (Fabricius) lay their eggs in cuts or wounds of many animals, including man, especially children. All three are serious parasitic pests. Other calliphorids, especially the blow flies of genus *Calliphora*, lay eggs on meat or carcasses, producing maggots; hence meat kept by the aborigines must have been constantly subject to such infestation. In general, these parasites, pests, and scavengers were probably abundant around the aboriginal home sites.

Endemic Diseases

It is well known that archeological skeletons of pre-Columbian days have shown the effects of the diseases of tuberculosis, arthritis, and possibly rickets. Broken bones have also been detected. Diseases that did not affect the skeleton would of course not be evident and knowledge of them must be obtained from other sources.

It is also well known that certain diseases endemic in native animals today may be transmitted to man. Unless they have been introduced to the region since the time of the aborigines, any of these diseases present in the Glen Canyon region at the present time must be presumed to have been manaces to the aborigines. The history of specific diseases occurring in this region begins when they were first identified, mostly in this and the preceding century. Occurrence of diseases prior to their identification and their relationship to the prehistoric inhabitants must be deduced from present knowledge.

Among the more important diseases transmittible to man and present in animals of the Southwest today that may have been present in the days of the aborigines are tularemia, coccidioidomycosis, leptospirosis, spotted fever, Q fever, Colorado tick fever, rabies, and, to append a few that are debatable, anthrax, brucellosis, western equine encephalomyolitis (blind staggers), and St. Souis encephalitis. Each will be treated individually. Such diseases as plague, cholera, smallpox, measles, and glanders have not been included here because they are assumed to have been introduced in post-aboriginal times.

Among the many ways in which disease may be disseminated among native animals and transmitted to man, a few are illustrated in Fig. 2. Here some ecological relations between a rabbit and associated animals are shown. A disease infecting the rabbit may be transmitted through any of the routes shown unless there is some mechanism of resistance that interferes. Much of the following treatment of disease has been condensed from an unpublished manuscript by the author.

Anthrax

The disease known as anthrax is a rare but widespread disease in livestock and some of the native warm-blooded animals. It is caused by the bacterium Bacillus anthracis, which is unique in being the only pathogenic aerobic sporeforming species. Herbivorous animals are especially susceptible to infection and many of them have a high mortality rate. The spores of the organism, occurring in animal secretions and excretions shortly before death and in carcasses after death, as well as in dust from sheep wool, may be widely disseminated by winds, floods, bloodsucking arthropods, especially tabanid flies, and other animals, and may persist as a potential source of infection, through inhalation or eating infected vegetation or animal carcasses, for many years.

This rare disease is best known today from livestock losses and rare human cases; it is not known among cold-blooded animals. It was first noted in Switzerland in 1879, in Paris in 1888, in New Hampshire and Brazil in 1904 and in Germany in 1930. Cases are known from many parts of the world, including Asia, Europe, Africa, South America, Mexico, and nearly all of our own states. With this background, it seems probable that this disease should be included among those to which the aborigines may have been exposed.

Tularemia

Tularemia is a widespread disease known in many parts of the world. The causative organism, Pasteurella tularensis, was first recognized in rodents by McCoy near Tulare, California in 1911, but human cases derived from horsefly bites were reported in the same year near Brigham, Utah, by R. A. Pearse. Thereafter, it was studied intensively in Millard County, Utah, by Edward Francis (1922), who concluded that human cases were derived from reservoirs in the native animals. Since that time studies in other parts of the world have led to its recognition as a wide spread disease, known to occur in Scandinavia, Russia, Japan, and Turkey, as well as in North America. It may be world wide.

Studies in Utah have shown that tularemia is an uncommon human disease but has occurred in all counties of the state. During the 17 years on record from 1937-1953, a total of 641 cases was reported by physicians, an average of nearly 38 cases per year and a range of 20 to 73 (Fig. 3). There may have been many cases not reported. Judging from its present day ecology and distribution, there is little doubt that the disease occurred in the Glen Canyon region in the days of the aborigines.

Studies in the region of the Great Salt Lake Desert indicate that the native virulent strain of the disease kills all infected lagomorphs and rodents in a very short time, usually in three to five days, but carnivores are usually immune. Fleas are not good vectors of the disease but ticks and tabanid flies are and mosquitoes may be. In other sections of the country, some of the jack rabbits and snowshoe hares are believed to be more resistant. If so, there may be some survivors, but in the Great Salt Lake Desert, infected lagomorphs and rodents can act as carriers of the disease organism only a very few days. It is the ticks that have been proved to be long time carriers. Fleas are probably negligible and the roles of lice and mites in transmission are not well understood. It is known that some birds may have natural infections, but experimental work has not yet provided a clear understanding of their role in carrying and transmitting the organisms.

During the course of the disease in rabbits and rodents, the bacteria usually enter the blood stream a day or two before death, and parasites taking blood meals at that time are likely to take the organism into their digestive tracts. In most ticks getting it by this means, the organism perpetuates itself for long periods of time and the ticks may be potential sources of infection for the rest of their lives. The infection may be transmitted either by biting or being eaten by a new host. Fleas may become infected in a similar manner,

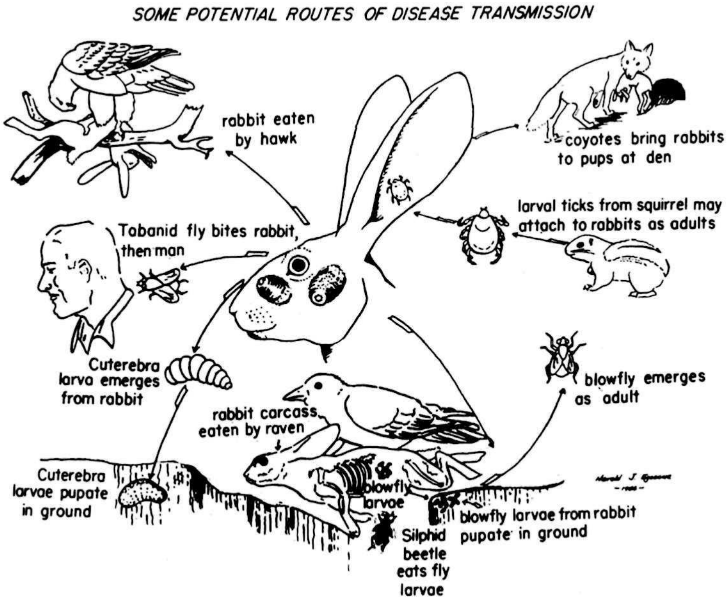

Fig. 2. Some of the author's ideas about how diseases may be disseminated among wild animals and transmitted to man. Sketch by H. J. Egoscue.

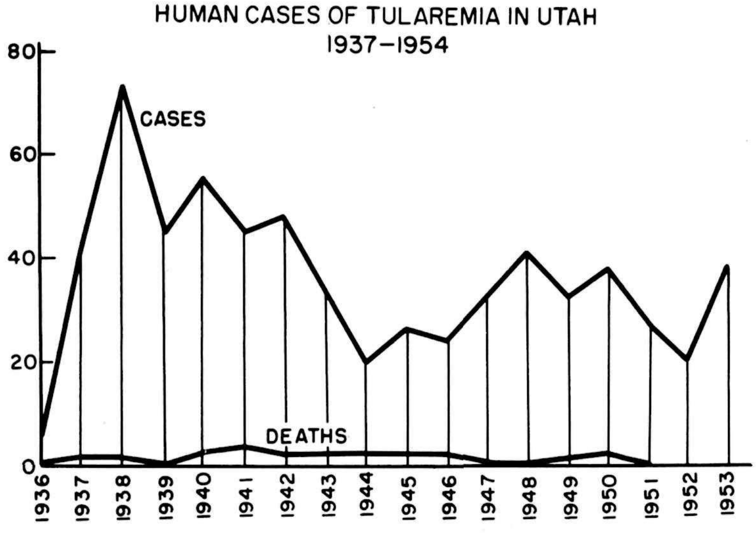

Fig. 3. Distribution of human cases of tularemia in Utah reported by physicians to the State Board of Health during the years 1936 to 1953.

but they usually clear themselves within 10 days and are not thereafter potential sources of infection. They probably play no significant role in the tularemic cycle.

Among the ticks that may be carriers, the most common one on rodents and lagomorphs of the Great Salt Lake Desert is Dermacentor parumapertus Neumann, which is believed to play an important role in the tularemic cycle but which seldom, if ever, bites man and is therefore not a likely source of infection in human cases. A close relative, the wood or sheep tick, Dermacentor andersoni Stiles, of the mountains and higher altitudes is a common pest of man and probably a constant source of potential tularemic infection. Several other ticks may be minor potential sources.

As understood at present, ticks probably play the principal role in perpetuating the organism in nature but there must be many supplemental or auxiliary means of sustaining the tularemic cycle. If an infected tick attaches to a lagormorph or rodent infested with a large number of larval ticks, they may become infected before the host dies. After death of the host, they may drop off and infect new hosts to which they attach, or the carcass of the host may be eaten by other rodents and spread infection to them. They, in turn, may infect other larval ticks before they die. This sequence, if expanded fast enough, might lead to an epizootic.

Such an epizootic might be obvious among the rabbits which die above ground but would not be obvious among the rodents which die in their burrows. After the lagomorph and rodent population is reduced to the point (probably about 25% of the previous population) where the disease spreads rapidly, the epizootic subsides and the surviving population may be free from infection. In some cases the disease is difficult to find after an epizootic and it may actually disappear, but it is more likely to be reduced to minimum proportions and to be surviving in smoldering condition somewhere, to reappear when conditions again become propitious for more rapid spread.

With this present-day knowledge, a plausible picture of tularemia among the aborigines can be presented. The bones from the archeological salvage operations (Appendix I) indicate that the aborigines handled the carcasses of large numbers of mammals that might transmit tularemia. There is a high probability that the handlers of the raw meat of these animals would have had a small percentage of tularemic infection.

There is also a high probability that there would have been a small source of infection from tabanid flies and mosquitoes, although the role of the latter in tularemic transmission is not well understood. In the aborigines' lowland homes within the range of *D. parumapertus*, ticks may not have been of much significance, but the degree of probable infection would have increased when the aborigines went hunting in the mountains in the range of the wood tick. In summary, the aborigines probably were exposed to tularemic infection from handling game animals, from free living tabanid flies and mosquitoes, and from wood ticks in highlands and mountains.

Brucellosis

Brucellosis is a disease known as undulant fever in man. It is known best from its manifestations in livestock but it is also known to occur in wild rodents. The common group name of brucellosis includes diseases caused by three or more species of the genus *Brucella*, which cannot be distinguished morphologically. Of these, *Brucella abortus* is primarily a disease of cattle but does occur in other livestock and is usually transmitted to man through milk. *Brucella suis* is primarily a disease of swine but also may occur in other animals. *Brucella melitensis* is primarily a disease of sheep and goats but is also suspected to occur in cattle. Whether it occurs in bighorn sheep seems not to be known, but it is known to have occurred in modern times in domestic goats of Indian tribes in northeastern Arizona and southeastern Utah. It was also found in wild hares in France. A fourth species, *Brucella neotomae*, closely related to *Br. abortus*, has been isolated in desert wood rats in the Great Salt Lake Desert.

There is little probability that the aborigines of Glen Canyon region would have been exposed to brucellosis by contact with domestic livestock but the discovery of a strain of *Brucella* in native wood rats may mean that they were exposed through handling the native wood rats of Glen Canyon. Studies have shown the presence of five species of wood rats in the region, and bones salvaged from the aborigines' archeological ruins indicate that wood rats were commonly handled by those people.

Coccidioidomycosis

Coccidioidomycosis or desert fever is a fungus disease of man known to occur mainly in the hot, dry lowland climates of the Southwest but may occur sparingly elsewhere in the United States, Canada and South America. It is caused by the coccidia-like fungus, Coccidioides immitis, which is known to infect cattle, sheep, dogs, wild rodents and other animals. It has been found in mice near St. George, Utah. The organism is found in the soil and is probably disseminated in dust in arid areas. It does not appear to spread from animal to animal or from animal to man. It is not known whether it is propagated saprophytically in the soil or whether it comes from animal excretions.

The disease is thought to be contracted generally by inhalation of conidia spores carried by the wind. These usually produce a lung infection but occasionally are spread through the blood and may develop nodules or tumor-like masses in any of the internal organs, around bone, or under the skin, which break down and ulcerate, usually leaving a scar when they heal. The lung infections vary a great deal in severity. Mild cases with minimal manifestations may be overlooked. Some severe cases show low-grade fever, accompanied by other manifestations of pulmonary disease. In lungs, the nodules resemble the tubercles of tuberculosis but can be distinguished by the presence of fungus growths.

Glen Canyon is a dusty region and is in a zone where the causative organism might occur. Furthermore, it is in the path of winds from the low deserts of the Southwest where the spores could originate. The aborigines could have been exposed to infection from this source.

During the archeological investigations in Lake Canyon, a crew of about 20 men was exposed for some days to gale force winds that blew clouds of dust day and night. Crew members from eastern states were afflicted with a fever, later identified as coccidioidomycosis, doubtless derived from the windborne dust. Most patients exhibited headache, deep congestion of the chest, resembling bronchial pneumonia, moderate to high fever, and general malaise lasting two or three days, symptoms generally like those of a cold. The patients quickly recovered. The only members not afflicted were westerners, who seemingly had already been exposed and were resistant to the attack.

Leptospirosis

Spirochete organisms belonging to the genus Leptospira of uncertain classification, lying intermediately between bacteria and protozoans, are known to include kinds that infect both animals and man. These pathogenic Leptospira organisms, which cannot be distinguished by morphological, cultural or biochemical means, can be differentiated on the basis of their serological properties. Some of these serotypes are associated with various mammals.

The organisms seem to be well adapted to their native hosts since a host may carry a number of serotypes without showing symptoms of infection. They appear to spread from leptospiral organisms emitted in the urine of the host. Human infection from this source may produce the disease, with symptoms that run the gamut from mild fevers to severe infections. Since the infections are so widespread in native rodents, there is little doubt that the aborigines were exposed to the dangers of such infection.

Spotted Fever

Rocky Mountain spotted fever is caused by a rickettsial organism, *Rickettsia ricketsii* (Bengston, 1948). The only known natural method of transmission among animals and man is by means of infected ticks, especially the wood tick, *Dermacentor andersoni*. The diesease is characterized by a typhus-like fever, skin rashes, dark blotches due to lesions of blood vessels, and nervous symptoms. In man, it is essentially an infection of the small peripheral blood vessels. Mild cases may be ambulatory but, in general, it is recognized as being one of the severest of all infections.

So far as known, the infection is maintained naturally by ticks and their hosts, principally rabbits and rodents. Man is an incidental victim and plays no part in its maintenance in native animals. In contrast to tularemia, which appears to kill all infected rabbits and rodents in western deserts, these animals apparently survive spotted fever infections without showing clinical symptoms.

From laboratory testing in the Great Salt Lake Desert, at least 10 species are known to survive infections. In an infected rabbit or other rodent, the rickettsia circulate in the blood stream for a short time before recovery. During this time ticks become infected and carry the infection indefinitely. Females probably pass it by trans-ovarian transmission to the next generation. Serology indicates the infection to be widespread in rabbits and rodents, but it is difficult to isolate the rickettsial organism in them although it has often been isolated in ticks.

Despite the fact that spotted fever is so common in the desert fauna, human cases are very rare. One reason for this anomaly may be that the common ticks of the lowland deserts do not normally bite man although they may carry the disease from host animal to host animal. In higher altitudes where the wood tick, *D. andersoni*, is present, there may be more danger. In all probability this relationship would apply to the aborigines of the Glen

Canyon region. Those who went hunting in the mountains, especially during late spring and early summer when ticks are spread out on limbs of bushes actively seeking hosts, would have been exposed to a low ratio of infection from tick bites.

Q Fever

Q Fever is a cosmopolitan disease of man that was first discovered in Australia in 1937 and found in western United States in 1938. By 1955, it had been found in 51 countries on five continents. The disease is commonly known all over the world as "flu" or atypical pneumonia. The rickettsial agent of the disease, Coxiella burnetii or Rickettsia burneti, is known to occur in domestic livestock and in at least 11 species of lagomorphs and rodents in western America. It is also known to occur in 22 species of ticks but there is no evidence to indicate that they are important vectors of the disease agent.

This widespread disease appears to be transmitted by dust carrying the rickettsia from secretions or excretions of infected animals, by unpasteurized milk, or by personal contact with excreta or diseased livestock. It is considered to be primarily an occupational disease of livestock handlers and laboratory workers.

While nothing is known of its occurrence in the Glen Canyon region, this disease must be considered to have been a possible hazard to the aboriginal people because of its widespread occurrence in rodents, rabbits, ticks and big game, and its probable transmission in dust.

Colorado Tick Fever

Colorado tick fever is the only known tick-transmitted virus disease in the Americas. The disease has probably been known in Colorado and Wyoming for at least a century, but it was not until about 1930 that it began to be distinguished from other clinically similar diseases. The causative virus has been recognized in the wood tick, Dermacentor andersoni and it is generally assumed that it is transmitted by this tick (Rivers and Horsfall, 1959).

The virus of this disease has been isolated from the blood of human patients in all of the western states within the range of this tick, including California, Oregon, Washington, Idaho, Montana, Wyoming, Colorado, Utah and Nevada. Since the tick occurs in the mountains surrounding Glen Canyon, it is almost certain that aboriginal hunters going into the mountains would have been exposed to this disease.

Rabies

Rabies is a type of encephalitis caused by a viral infection occurring primarily in salivary glands of carnivorous animals, from which it is transmitted from animal to animal or from animal to man by biting. It has been known in Europe and Asia since ancient times, and at present is known in all the continents except Australia.

The disease impairs the nervous system. After a relatively long incubation period (10 days to 6 months in man), it produces symptoms which usually pass through two changes in behavior patterns and soon lead to death. The first of these changes is usually to antagonism and violence that leads the infected carnivore to attack and bite other animals. This is typically followed by quiescence, paralysis and death.

The present state of knowledge indicates that rabies is reservoired in wild animals, principally in the carnivores and bats. It was stated in the report of a conference on bat rabies held July 10-11, 1959 at the National Institutes of Health, Bethesda, Maryland, that "Probably all bats are either actual or potential vectors of rabies." There may be many unapparent infections which may last for months before symptoms appear. The infection appears to be so widespread among bats that it is almost certain to have been endemic in America before its introduction from Europe by early colonists' dogs. The exceedingly numerous bats of Glen Canyon must certainly have been a potential reservoir of infection to the aborigines.

Western Equine Encephalitis (WEE)

This encephalitis was at first regarded as a viral disease of horses and mules transmissible to man but it is now known to infect many other animals including pigs, birds, rodents and lagomorphs. The principal reservoir in nature may be in birds. The main vectors of the disease are believed to be mosquitoes, including *Culex tarsalis*, but other possible vectors are the wood tick, *Dermacentor andersoni* and bugs of the genus *Triatoma*. This is one of the arthropod-borne (arbor) animal viruses in which the virus multiplies in the vector. It is probably obtained by the vector from a host at the time the virus is circulating in the host's blood. After a period of multiplication, without apparent damage to the vector, it is passed on to a new host.

The distribution of this virus is not well known but since it is so widespread in western America and is disseminated by vectors common in the Glen Canyon region, it is probable that the aborigines were exposed to its hazards.

St. Louis Encephalitis (SLEE)

This is a human viral disease which is reservoired in native animals and transmitted to man principally during warm weather by mosquito, tick and mite vectors. Its symptoms are similar to those of western equine encephalitis. Sporadic outbreaks of the disease have occurred in the central and western parts of the United States. In these outbreaks, many unapparent infections occur in addition to those of clinical significance.

Because of its widespread reservoir in native animals and the abundance of suitable vectors in the Glen Canyon region, it is included here as a possible danger to the health and welfare of the aboriginal inhabitants.

Ornithosis (Psittacosis)

This is a human viral disease which has its primary reservoir in many kinds of birds. It was first found in psittacine birds (parrots and parakeets), hence the name psittacosis, but since it has been found in so many other kinds of birds, the more general name ornithosis has become more appropriate. Many birds may have the disease without apparent symptoms, but others, especially young birds, may be more severely affected and in some cases the effects may be lethal.

In the early history of the disease, it was thought to have been spread from South America by parrots and parakeets shipped over much of the world but, since it was later found in so many other birds in so many places, it may well be assumed that it was already a disease of wide distribution. It has been found in domestic pigeons, turkeys and chickens, as well as in wild birds, including ducks, seagulls, and even fulmar petrels in the Faroe Islands. It is common in Mexico. Since it is so wide-spread, it must be included in the list of diseases that may have been menaces to the aborigines.

ADJUSTMENT TO ENVIRONMENT

When the aborigines entered the Glen Canyon area, they must have entered natural living communities which were more or less ecologically balanced. The scanty vegetation produced sparse food for herbivorous animals; they, in turn, fell prey to carnivorous animals, parasites and diseases that tended to limit excessive animal populations. But apparently human techniques were adequate for entering this natural competition for a share of the necessary products, for the aborigines were able to persist intermittently in the region for three or four centuries. They seem to have prospered best at intermediate elevations on the highlands of the Kaiparowits Plateau, the Navajo Mountain Uplift, and the highland triangle between the Colorado and San Juan rivers, where the least submarginal conditions of the environment occurred. The people that entered the low canyons of the Glen Canyon Basin seem to have been temporary overflows from the highlands. The aborigines became an integral part of the natural communities and survived the handicaps of marginal natural resources, pollens, pests, parasites and diseases. They met their needs both through farming and careful use of natural resources, and their survival is a tribute to their inherent capacity and adaptability.

Farming

Since the human share of the scanty crops from sparse vegetation in this desert region was inadequate to maintain dense populations, the aborigines must have exploited all pieces of available land that their limited means of cultivation made profitable for growing crops. Excavations have revealed the presence of corn cobs, both in sheltered and open sites. At some of the sites in Glen Canyon, the cobs were unripe, indicating that green corn was on the menu. Cotton was almost as commonly found as corn, and beans and cucurbits were also found.

That the aborigines probably also reared domestic turkeys, as was done in other places in the Southwest, is indicated by the presence of turkey feathers in the Talus Ruin at mile 59.4 and the Loper Ruin in the mouth of Red Canyon, mile 150.2.

Farming areas must have been limited to relatively small size because of the limitation of available water, the nature of the terrain, and the limited farming tools. Since sandy soil makes a larger proportion of the water applied to it available for plant use than other soils of the region, it is to be expected that the farms would usually have been located on the more productive sandy soil.

Conditions under which farms might have been successful include: (1) terraces along stream banks where crops could be started when top soil was moist from precipitation water and able to receive supplements from capillary water drawn from the stream into the root zone of the plants; (2) soils along the foot of sloping rock where runoff from storms would be added to the moisture received from direct precipitation and could be stored in the soil until used by the crops; (3) soils irrigated from springs or small streams that could be diverted and regulated; (4) sand bars or sandy beaches within the high water mark of large streams where roots could reach moist soil underneath -- these would be temporary farms to be used after spring high water subsided and before late summer floods could inundate them; (5) dry farming, especially on sandy soils, at higher altitudes where precipitation was sufficient to provide adequate water for crops.

It should not be supposed that these farming lands comprised any significant proportion of the total area of the region. They were scattered in small patches wherever local conditions provided a suitable combination of ecological factors. One of the largest areas studied to date was found in the mouth of Red Canyon, river mile 149.7, where the farm land used by the aborigines was later used by Bert Loper. Most of the other aboriginal farms would have been smaller than this so it can be safely concluded that the farming operations would have made little, if any, significant change in the overall ecological conditions and productivity of the region.

The Glen Canyon conditions and proportions of farming operations may have been roughly comparable to those of the Southwest Paiute Indians on the Virgin River at the advent of white men during the discovery and exploration periods. This is discussed by Woodbury (1950). The first reference to the Virgin River Indians was made by the Spanish padre, Escalante, in October, 1776. As the Spanish party descended Ash Creek to its junction with the Virgin River, the members found a well-made platform with a large supply of corn ears and husks stored upon it. These had evidently been harvested from three nearby patches of corn, which still had the stalks standing. The three small fields had well-made irrigation ditches. Escalante stated in his journal: "From here down the stream (Virgin River) and on the mesa and on both sides for a long distance, according to what we learned, these Indians apply themselves to the cultivation of maize and calabashes" (Woodbury 1950, 117).

The next known traveler down the Virgin River, Jedediah Smith, 50 years later, in 1826 at the mouth of the Santa Clara Creek encountered a group of Paiutes "who wore rabbit skin robes and raised a little corn and pumpkins" (Woodbury, 1950, 127). Another quarter century later, Parley P. Pratt, leading an exploring party, met a group of Indians on the lower Santa Clara, January 1, 1850. "The Indians were . . . well armed with bows and poison arrows and nearly equalling us in numbers. We fed them, sung for them. . . . The chief made us a speech, bidding us welcome to his country. . . . He strongly urged our people to settle with them and raise 'tickup' (food). They returned again next morning, piloted us all day . . . they cultivate small patches only, raise good crops by irrigation" (Woodbury, 1950, 134).

About two years later, on February 3, 1852, with another exploring party on the lower Santa Clara, John D. Lee states "On this stream, we saw about 100 acres of land that had been cultivated by the Paiute Indians principally in corn and squashes" (Woodbury, 1950, 140).

One further incident will be cited. When the Mormon missionaries settled at Santa Clara to work with the Indians in 1854, they began building a dam across the creek to divert water for irrigation. As the dam, 100 ft. long and 14 ft. high, approached completion in the spring of 1855, a group of about 500 Indians gathered to watch the event. As the water rose and began to run out into irrigation ditches, half on one side for the Indians and half on the other side for the missionaries, it aroused much enthusiasm among them and a great shout of exultation went up from the dusty spectators (Woodbury, 1950, 145).

Use of Natural Resources

In addition to farming a small portion of the land, the aborigines made extensive use of the natural resources of the region. It is probable that seasonal movements occurred in order to use these resources to best advantage. There must have been carefully directed forays after natural products of the biotic communities in which the aborigines lived. It is not to be supposed that they restricted themselves to one of the communities; it is more likely that they took what they wanted or what they could get from all communities from canyon bottom to mountain top. Often, it was probably family groups or sometimes groups of families that moved although it can be expected that a man might go alone or in company with other males on hunting trips or after special materials or products needed at home or in camp.

That these aboriginal people utilized nearly every conceivable natural resource is attested by abundant evidence. The natural rock shelters so abundant in this region were favorite camp sites. In the open, the flat rocks so common almost everywhere were used in hearths, around the edges of camp sites, and in small shelters. Stones of special types taken from cliffs, talus, or stream wash, sometimes brought from considerable distance, were used for making tools such as axes, mauls, drills, hammers, cutters, scrapers, and the like, as well as for making hunting equipment and weapons such as arrowpoints, atlatl dart points, and the like.

The scarcity of water in this desert region may have been reflected in the aborigines' parsimonious use of water in their camps and habitation sites. Water had to be carried from a water source, usually some distance away. In few, if any, cases was water ever present in the habitation sites. Judging by the water-holding equipment and the distance it had to be carried, water was used for drinking and cooking, but probably for little else in routine living. If the aborigines washed or bathed, they probably went to the water source (spring, pool, stream or river).

Non-domesticated organic products were also gathered for many purposes. Wood was used for fuel, buildings, tools, and weapons; fibrous products for strings and ropes; herbs for dietary supplements and medicines; animals for food, their furs for clothing, their bones for tools; coloring substances for dyes and body paint; and, of course, edible products for food. For example, there is good reason to suppose that the aborigines spent a good deal of time in mid-autumn gathering winter supplies of pine nuts from the pinyon pines, which ordinarily did not grow in the low canyons but were abundant in many parts of the adjacent highlands. They probably also made annual hunts into the foothills or mountains after deer. Perhaps lesser forays were made after big-horn sheep, rabbits, acorns, berries, grass seeds, andother edibles. Some of these wild plant crops were doubtless harvested by the women and children. The lack of specialization and exchange of products and the requirement of doing everything for themselves made a high degree of comprehension of the values and products of their biological resources necessary in order to time their movements and harvest the natural crops to good advantage.

In the following discussion of the specific uses to which the various plants and animals were probably put by the aborigines, several sources of evidence have proved helpful. The number and kinds of flora and fauna available to the pre-historic people of the Glen Canyon region can be estimated from the University of Utah studies in that area, from other excavations in comparable regions, mainly in the drainage of the Little Colorado River in northeastern Arizona, and from literature listing plants and animals used by modern Indians. Consideration has been given to salvaged and modern artifacts, to the ecological background of the plants and animals, and to their inherent properties of use under the technology of the culture prevailing at that time.

Vegetation

It is not always possible to tell from excavated plant parts (Appendix I) the precise uses to which the plants were put, but there are some general considerations which help in assessing their possible values. Plants would ordinarily be used for purposes to which they are well adapted, e.g., wood or timber would be used in buildings and for making tools, weapons and the like, not for food. Many of the uses of plants can be deduced from their inherent properties, but the extent of the primitive technology in converting them into secondary products is not always discernible. Some plants may have been used in many ways. There seems to be no direct correlation between the abundance of plants and their value for human use; many of the more useful plants were less abundant.

Non-seedbearing plants

Little, if anything, is known about the uses, if any, of primitive non-seedbearing plants, the algae, mosses and ferns. Algae are common in wet places and could have been gathered by scraping wet rock surfaces or by gathering filamentous types from stagnant waters by hand or with simple tools if the aborigines had any use for algae. Lichens are common on dry rock surfaces almost everywhere. Mosses are common not only around wet rocks but also on rocks and soils of the desert, especially on shaded sides of large rocks or cliffs. Ferns are common on wet shaded rock faces but exceedingly rare elsewhere. It may be expected that a people so close to and dependent upon "natural crops" found some uses for plants of this type, but so far, such uses have not come to the writer's attention.

Coniferous plants

Many aboriginal uses of these plants can be surmised on the basis of known uses by modern Indians. For example, modern Indians ground horsetails into a flour and made mush. Pines were used for timbers and firewood, and the seeds of all local species were eaten. Remnants of pine seeds were found in human feces from a Glen Canyon site. Seeds may have been eaten raw, roasted, or made into pine nut butter. Limber pine limbs were sometimes used (by Navajos) for making bows. Pine gum or resin, especially from pinyon pines, has been found and is thought to have been chewed for gum or used for calking, especially in woven basketware or in repairing cracked pottery.

Juniper wood was also used for timber and for firewood, where it was available, and juniper bark was especially useful. When ruffled into a fine fluff, it was very good for tinder and kindling in starting fires and, wrapped into bundles, could be used for torches or carrying fire short distances. It was also used in cordage and basketry. It might also have been used for chinking in buildings or for cushioning purposes. Modern Indians used the cone fruits for food, either fresh or cooked, and made beverages, tonics or medicines by steeping fruits or leaves in hot water. Seeds of ephedra plants may have been roasted, ground into flour, and made into bread; leaves were steeped to make a beverage.

Flowering plants

Monocots. Cattails were doubtless rare in Glen Canyon but from the few suitable habitats, young roots, shoots, stem bases, flowers, and seeds could have been utilized for food while the leaves and stems may have served other purposes, indicated by the fact that they were found in many habitation ruins. The five kinds of grasses and bulrushes found in the ruins to date are very inadequate representatives of those that were available for use. The aborigines probably utilized many of the 28 species of grasses, sedges and rushes known to have been used by modern Indians. Seeds of nearly all species were eaten -- fresh, parched, or gound into flour and made into bread, cakes or mush. Some may have been stored. Rootstalks from sedges and rushes may have been eaten raw or made into flour for breadmaking. Even some of the pollen may have been used. Coarse stalks of some species could well have served as matting.

Wild onions and sego or mariposa lilies may have been eaten for greens, or the bulbs may have been dried for winter use or roasted in hot ashes. The fleshy flower stalks and fruits of yuccas eaten by modern Indians, either raw or cooked, were sometimes stored for winter use. These stalks and fruits contain enough saponins to give them a soapy flavor that makes them unpalatable to us but were probably used by the aborigines for food despite the flavor. Yucca rootstalks may have been used for soap, ripe seeds ground into flour, and fibrous leaves used for cordage, sandals, basketry and other purposes.

Dicots. Cottonwoods, willows, oaks, and hackberries were probably much used because there were prolific sources of supply near many of the habitation sites. Timber could have been used in construction work and wood for fires. Smaller sticks could have been made into tools and other implements. The inner bark of cottonwoods may have been a palatable food. Oak sticks would have been especially suited for digging sticks, bows, war clubs, and handles. Acorns and hackberries doubtless made nutritious foods that could be stored for winter. Flexible willow twigs were suitable for weaving and basketry.

There is a great variety of plants in the buckwheat and goosefoot groups that could have furnished greens or seeds for food. Some of both kinds could have been eaten raw and others would have been better cooked. Some of the seeds could have been parched, ground into flour, and made into bread. Others were suitable for winter storage.

Small tubers of the early spring could have been obtained in the mountains. Many plants of the mustard group could have been picked young and cooked for greens. Water cress would have been available for uncooked greens. Some dicots would have been suitable for eating raw, storing for winter, or grinding into flour.

The roses and related groups have a good deal to offer. Currants, service berries, wild raspberries, rose hips, and choke cherries would have provided tempting fruits in season. Some could have been dried and stored for winter; others might have been left and picked in winter. The cliffrose has a shreddy bark that makes good tinder and could have been used like juniper bark. A yellow-brown dye can be obtained from leaves and twigs.

The common legumes of the region, including such products as lupine beans, wild peas, licorice root, and prairie clover furnished nutritious foods that could have been gathered in season in areas where they occurred. The poisonous locoweed was doubtless avoided. Roots or rootstalks of prairie clover and licorice might have been chewed, eaten raw, or mixed with other food.

The geraniums probably supplied some herbs, the flaxes some fibers, and the spurges some medicines or liniment. Poison sumac was doubtless avoided but closely related squaw-bushes must have been very useful. The flexible twigs so fine for basketry were strengthened by use of stiffer twigs that helped to hold more rigid form. The sour berries might have been eaten fresh, dried or gound into a meal. A special drink from the berries and a dye from boiled leaves and twigs are not beyond the realm of probability.

Parts of the boxelder tree, relatively scarce in Glen Canyon, were obtained in salvage operations, but there is no indication of extensive use. Where available, it was probably used for wood or timber, and the sap may have been used for sugar and the seeds for food. Ceanothus and grapes were rare in the canyon but seeds and fruits may have been gathered where available. Mallows were relatively common and no doubt the tasty green seeds were eaten raw or gathered when ripe. The blazing star furnished both herb and seeds.

Of the good variety of cactuses in the region, some certainly must have been utilized. From some, a nutritiously rich wet pulp harvested almost anywhere with a stick or sharp-edged rock could have been used to quench thirst. Some cactuses provide fleshy fruits that could have been eaten, dried or stored. After being roasted to burn off the thorns, some of the prickly pear sections of stems could have been eaten. The thorns of some species could well have been used like pins or awls.

Buffalo berries may have been eaten and some of the evening primrose and wild parsnip groups may have furnished edible seeds or herbs. Seeds of manzanita and the single-leaf ash would both have been available, the former on lower mountain slopes, the latter in lower rough country. The dogbanes and milkweeds would have furnished a milky gum and also usable fibers. Many other herbs and seeds might have been available at times from such plants as those of the phlox, waterleaf, borage, and mint groups. Variety in flavor could have been obtained from the mints.

The nightshade group furnished a variety of products. Wolf-berries were relatively common and might have been eaten fresh or dried and made into soup or mush. Groundcherries and nightshade berries might have been found in the mountains. Datura leaves and fruits were probably available all through the region but how much they were used is not easily assessable. Their poisonous properties probably prevented widespread use, but it is known that they were used farther south among modern Indians in producing a stupefying beverage used in their ceremonies. Ripened seeds might have been eaten but Navajo Indians recognized their bad effects. Wild tobacco also may have been used for its narcotic properties.

Pentstemon leaves were probably used medicinally by chewing or pounding into a poultice. Monkey flower leaves may have been eaten raw. Other relatives in the Figwort family may have had similar uses. When green, the entire plant of the broomrapes, which occur sparingly from canyon bottoms to the mountains, was edible or could be made into a liniment. Green plantain plants may have been eaten. It is suspected that the bedstraws of the Madder family may have yielded dyes. The pleasant tasting fruits of honeysuckle, elderberry and snowberry were almost certainly utilitzed either fresh or dried for winter.

The plants with composite flowers had much to offer the prehistoric peoples. Those that provided edible seeds either fresh, stored, ground into meal, or cooked are too numerous to mention. Green leaves and stems such as those of balsamroot, senecio, thistle, and wild dandelions may have been eaten raw, made into salad-like foods or boiled as greens. The roots of such plants as balsamroot might have been eaten raw or cooked. Beverages might have been made from such plants as rabbitbrush, sagebrush, or Thelesperma. Chewing gum might have been made from the roots of Hymenopappus or the bark of lower stems and roots of rabbitbrush. A dye might have been obtained from the same plant. Dried and pulverized aster plants might have been used as a snuff. Concoctions made from cocklebur might have been used medicinally for diarrhea and vomiting. Oil might have been extracted from seeds of such plants as native sunflower or wormwood.

Animals

The native animal life among the native desert vegetation consists largely of lizards, rodents and small birds. These are not prolific sources of food suitable for human use but were probably dependable sources of supplements to the diets of the prehistoric people. They may also have served to supply feathers and small furs useful in many supplemental or auxiliary ways for other purposes. The chief source of meat was probably mule deer in the mountains and foothills and mountain sheep in the lower rough country although rabbits were commonly used also. Game birds such as quails and ducks were doubtless used whenever available, especially along the rivers and tributaries. Large feathers and furs may have had many uses. Fishes and amphibians may have added variety to the diet.

Fishes and amphibians

That fishes were used extensively by modern Indians in some parts of the West is well known, but there is little evidence to indicate that the prehistoric inhabitants of Glen Canyon made extensive use of them. So far, fish bones have been reported from only three sites, located at the mouth of Grand Gulch, about river mile 63 upstream on the San Juan River, and at Forked Stick and Shady Alcove sites on the Colorado River.

Of the native fishes known today, three are suckers, family Catostomidae, and three are minnows, family Cyprinidae. Before modern introduction of 11 other species, the native fishes must have been much more numerous than they are now. They are not considered by us to be choice food fishes and no evidence has been found to date to indicate that the aborigines had developed any important techniques for catching them, although the bow and arrow might have been used on occasion.

Bones of an unidentified toad were found in the excavations at Gates Roost site in Twenty-five Mile Wash, a tributary of the Escalante River, at about 35 airline miles above its junction with the Colorado River. This suggests the idea that amphibians, like fishes, were occasionally used, probably for food or for secretions as an ingredient in a poison mixture for arrow tips. Amphibians can usually be captured by hand without special apparatus. All three of the toads and the two frogs of the region have well developed behavior patterns of human avoidance.

Reptiles

Bones of an unidentified lizard were found in the excavations of the Davis Pool site in Davis Gulch, which enters the Escalante River a few miles above its mouth. As a young man, the writer personally recalls seeing Indians of the Virgin River region cooking small animals in their campfires by covering them in the live coals, and hearing old timers tell about the Indians hunting small game. "Hyrum Leany, who settled in Harrisburg in 1862, relates how the Indians used to go hunting lizards and chipmunks. . . . The boys would tuck the heads under their belts and sometimes would come home with a beltful. The chuckwalla lizards were regarded as delicacies and the Indians had learned the art of removing them from the crevices in . . . the rock" (Woodbury, 1950, 119).

It is probable that the aborigines also hunted lizards in similar fashion, catching them by hand, by the use of sticks, or by other simple methods. No doubt they used the chuckwallas, which are common inhabitants of Glen Canyon, and probably other large lizards, such as the collared lizard, the leopard lizard, the spiny lizard, the horned lizards and the whiptails. Perhaps they even used the smaller lizards on occasion (Woodbury 1959, 142-146). All of the larger lizards have well developed behavior patterns of avoidance of man, but some of the smaller ones show much less reaction to human presence.

Birds

Few of the bird bones (Appendix I) found at habitation sites have been identified. The number of bones and feathers found indicates that birds were commonly used by the prehistoric people. Remains were found in 23 of the 77 sites covered in reports to date. The bones of 30 kinds of birds reported in the literature based on excavations in northern Arizona (Appendix II) indicate widespread use of birds by former inhabitants of that neighboring region.

Among the bird remains identified are feathers of Gambel quail, red-breasted merganser, and turkey from Talus Ruin (42Ka 274); a feather of a scarlet macaw, a series of feathers from a Mexican duck, and a wing bone of another duck (probably mallard or Mexican duck) from Lizard Alcove (42Ka 276); a feather from a snowy egret from Hermitage Site (42Ka 443); a bone from a horned owl and a feather necklace from rufous-sided towhee, found at Catfish Canyon Site (42Sa 395); a feather from a Swainson thrush and three pieces of feather-wrapped cordage made from turkey feathers, found at Loper Ruin (42Sa 364).

Wild turkeys might have been hunted in distant mountains, but it seems more likely that domestic turkeys may have been the source of the turkey feathers. Bones of other birds indicate possible uses for food while the thrush feather necklace suggests the idea of feather use in ornamentation or ceremonies.

Mammals

Lagomorphs. Of 191 bones of lagomorphs identified, 25 were those of cottontails, 9 those of jack rabbits, but the balance could not be definitely identified. The number of individuals represented in the collections could not be accurately determined but probably is more than 50. Hare and rabbit bones were so common in so many sites that there is little doubt that they furnished an abundant source of food, fur, and bones. The skins were cut into narrow strips, twisted into long strings and sewed together to make robes. Judging by methods of cooking used by historic Indians of the Southwest, the aborigines probably cooked the meat in the coals of their fires and probably consumed all edible parts of the animal, including the internal organs.

Rodents. Among the 200 bones of rodents identified (Appendix I), marmots, rock squirrels, ground squirrels, chipmunks, pocket gophers, kangaroo rats, beavers, deer mice, wood rats, muskrats, and porcupines were all represented. Some of these rodents may have been disregarded inhabitants of the habitation sites, but many of the bones probably represent animals used by the aborigines.

What they did with these animals is largely conjectural, but it is assumed that the meat must have been used for food. Some of the bones were doubtless made into tools. The smaller rodents may have been roasted, sometimes without removing the skin, but it may have been removed from the larger animals, such as marmot, beaver, muskrat, and porcupine. However, any one who has removed skins from these large rodents with modern steel knives realizes that it would be a very slow and tedious process with the aborigines' primitive tools of stone or bone. The pelt from a rock squirrel found in the excavated site (42Ka 433) at the mouth of Catfish Canyon on the bank of the Colorado River at mile 58.3 had been made into a pouch. This contained a smaller pouch, made of deer skin, which in turn contained some white clay and red ochre, and was probably used as a body paint kit.

Carnivores. Of the 50 bones of carnivores identified, coyotes, two kinds of foxes, ringtails, badgers, spotted skunks, and bobcats were all represented. Some bones had been burned, as if thrown into a fire. While it is possible that some carnivore bones were introduced to the sites while they were not occupied by humans, the evidence indicates human introduction of the majority. Although these animals are not considered suitable for human food today, there is little doubt that they were occasionally eaten by the aboriginal inhabitants. What they did with the furs and bones has not yet been established for this region.

Ungulates. Bones of mule deer and/or bighorn sheep were found in nearly all excavations and in some of the surveyed sites. Bighorn sheep bones were usually more common in the lower altitudes. This is to be expected on the hypothesis of propinquity determining much of the take. The sheep habitat in the rough country of the lowlands lies below that of the deer, whose main range is in the mountains in summer and in the foothills in winter. In nearly all sites studied, ungulate bones were found, 158 of which were deer, 1135 of which were bighorn sheep, and 354 of which could not be classified.

These big game animals were almost certainly a favorite source of food and their pelts were no doubt used also. This conclusion about pelts is justified on the basis of what other prehistoric cultures and modern Indians did with them, even though the only evidence from Glen Canyon comes from a small pouch of deer skin inside a larger pouch of squirrel skin. Some of the larger bones were used for tools.

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APPENDIX I

Salvaged Biological Artifacts

		Plants	Garfield County																	Kane County				San Juan County		
		Region / Site	Harris Wash	Harris Wash							Harris Wash	Harris Wash	Harris Wash	Harris Wash			Harris Wash			Alvey Site	Davis Kiva Site	Talus Ruin	Benchmark Cave	1959 Excavations	1960 Excavations	1961 Excavations
		Number	276	277	278	279	280	281	283	284	286	288	289	290	291	295	298	299	302	172	241	274	433			
1		Equisetaceae (family) ... Horsetails																								
	1	Equisetum kansanum ... Kansas horsetail						x																		
	2	Equisetum praealtum ... Tall horsetail																					1		x	
2		Pinaceae (family) ... Conifers																								
	3	Abies concolor ... White fir																				2				
	4	Pinus edulis ... Pinyon pine	x				x		x											x		1	1		x	
	5	Pinus ponderosa ... Ponderosa pine																				2				
	6	Pseudotsuga douglasi ... Douglas fir																				1				
3		Cupressaceae (family) ... Junipers																								
	7	Juniperus osteosperma ... Utah juniper			x							x										9	1		x	
	8	Juniperus scopulorum ... Red juniper																		x						
4		Ephedraceae (family)																								
	9	Ephedra viridis ... Green ephedra													x						x	3	1		x	
5		Typhaceae (family) ... Cattails																								
	10	Typha sp. probably ... Wideleaf cattail			x					x		x	x		x							6				
6		Graminae (family) ... Grasses																								
	11	Agropyron spicatum ... Bunch wheatgrass																							x	
	12	Agropyron trachycaulum ... Slender wheatgrass																							x	
	13	Andropogon sp. ... Blue stem grass																				1	2			
	14	Muhlenbergia asperifolia ... Scratchgrass																				1				
	15	Oryzopsis hymenoides ... Indian rice grass																					6		x	
	16	Phalaris arundinacea ... Reed canary grass																							x	
	17	Phragmites communis ... Reed cane			x		x			x	x	x					x			x	x	72	7		x	
	18	Stipa neomexicana ... Needlegrass																							x	
7		Cyperaceae (family) ... Sedges																								
	19	Scirpus americanus ... American rush																						x		
		Scirpus sp. ... Bulrush																		x					x	
	20	Scirpus validus ... Mat bulrush																		x						
8		Lilliaceae (family) ... Lillies																								
	21	Allium sp. ... Wild onion																							x	
	22	Yucca angustissima ... Narrowleaf yucca																		x	x		31		x	
	23	Yucca harrimassiae ... Harriman yucca																		x	x					
		Yucca sp.										x										14	5			
9		Amaryllidaceae (family) ... Amaryllids																								
	24	Agave utahensis ... Utah yant																								
10		Salicaceae (family) ... Willows																								
	25	Populus fremonti ... Fremont cottonwood									x	x				x				x	x	26	22		x	
		Populus sp. (probably fremonti)																				5				
	26	Salix exigua ... Narrowleaf willow																		x	x	30			x	
	27	Salix gooddingi ... Goodding willow																		x		15			x	
		Salix sp.	x								x	x			x		x					33	20			
11		Betulaceae (family) ... Birches																								
	28	Betula fontimalis ... Water birch																		x						
12		Fagaceae (family) ... Beeches																								
	29	Quercus gambelii ... Gambel oak		x							x	x	x	x	x						x	4	3		x	
	30	Quercus turbinella ... Shrub liveoak																				2			x	
	31	Quercus undulata ... Wavy leaf oak																							x	
13		Ulmaceae (family) ... Elms																								
	32	Celtis reticulata ... Hackberry																				1			x	
14		Polygonaceae (family) ... Buckwheats																								
	33	Eriogonum sp. ... Wild buckwheat																							x	

APPENDIX I

Salvaged Biological Artifacts — Plants	Garfield County																	Kane County				San Juan County		
Region	Harris Wash	Harris Wash							Harris Wash	Harris Wash	Harris Wash	Harris Wash			Harris Wash			Alvey Site	Davis Kiva Site	Talus Ruin	Benchmark Cave	1959 Excavations	1960 Excavations	1961 Excavations
Site Number	276	277	278	279	280	281	283	284	286	288	289	290	291	295	298	299	302	172	241	274	433			
15 Chenopodiaceae (family) ... Goosefoots																								
34 Atriplex canescens ... Four-wing saltbush																		x		6	10			
35 Atriplex confertifolia ... Shadscale																					3			
36 Chenopodium album ... Lambs quarters																							x	
37 Sarcobatus vermiculatus ... Greasewood									x				x							5	4		x	
16 Berberidaceae (family) ... Barberry																								
38 Berberis fremonti ... Weump berry																				1	1			
17 Saxifragaceae (family) ... Alumroot																								
39 Ribes cereum ... Wax currant																		x						
18 Rosaceae (family) ... Roses																								
40 Amelanchier alnifolia ... Service berry																		x						
41 Amelanchier utahensis ... Utah service berry																		x						
42 Cercocarpus montanus ... Mt. mahogany																								
43 Cercocarpus sp. ... Desert mahogany																				1				
44 Coleogyne ramosissima ... Blackbrush																				1				
45 Cowania mexicana ... Cliff rose																		x						
46 Fallugia paradoxa ... Apache plume																				1				
47 Peraphyllum ramosissimum ... Squaw apple																				1			x	
19 Leguminosae (family) ... Legumes																								
48 Lupinus sp. ... Lupine																					5			
20 Anacardiaceae (family) ... Cashews																								
49 Rhus trilobata ... Squawbush			x					x	x		x		x					x	x	5	5		x	
21 Aceraceae (family)																								
50 Acer negundo interius ... Boxelder								x										x		1			x	
22 Cactaceae (family) ... Cactus																								
51 Echinocactus sp. ... Hedgehog cactus																					3			
52 Opuntia rhodantha ... Prickly pear																				1				
Opuntia sp. ... Prickly pear																				1	28		x	
23 Elaeagnaceae (family) ... Oleaster																								
53 Sheperdia rotundifolia ... Buffaloberry																				1				
24 Umbelliferae (family) ... Carrot allies																								
54 Aulospermum sp. ... Indian parsnip																					1			
25 Oleaceae (family) ... Olives and ashes																								
55 Fraxinus anomala ... Single-leaf ash																							x	
56 Fraxinus coriacea ... Ash																							x	
26 Apocynaceae (family) ... Dogbane																								
57 Apocynum cannabinum ... Dogbane																		x						
27 Asclepiadaceae (family) ... Milkweed																								
58 Asclepias funastrum ... Climbing milkweed																					1			
28 Solanaceae (family) ... Potatoes and allies																								
59 Datura meteloides ... Sacred datura																				1			x	
29 Caprifoliaceae (family) ... Honeysuckles																								
60 Symphoricarpus sp. ... Snowberry																							x	
30 Compositae (family) ... Composites																								
61 Artemisia tridentata ... Big sagebrush																					1			
62 Baccharis emoryi ... Baccharis										x										9	2			
63 Chrysothamnus nauseosus ... Big rabbitbrush																				1				
64 Chrysothamnus viscidiflorus ... Varnishleaf rabbitbrush																x	x							
65 Franseria acanthicarpa ... False ragweed				x																1				
66 Pluchea sericea ... Arrow weed				x	x			x										x	x	72	2			
67 Xanthium saccharatum ... Cocklebur																							x	

Salvaged Biological Artifacts

		Animals / Site Number	San Juan River Mile 63 264	S E Bears Ears 277	No Name 303	Fortress 316	Steer Pasture 323	Loper Ruin 364	Husted's Well 366	Backyard Site 368	Wasp House 373	Oakleaf Alcove 374	Hawk Hollow 375	Fence Ruin 377	Catfish Canyon 395	Forked Stick 413	No Name 443	Green Water Spring 444	Iceberg Canyon 503	Iceberg Canyon 507	Iceberg-Lake Ridge 514	Unnamed Canyon 530	Pagahrit Dune 540	Toad Shelter 543	Horsefly Hollow 544	Surrey Terrace 550	Daves Site 564	Ledge Ruin 566	Ledge Ruin 567	Ledge Ruin 568
		Fishes																												
		Fish bones	1													10														
		Amphibians																												
		Toads																												
		Reptiles																												
		Lizards																												
		Birds																												
		Eagle																						3					
		Parrot																											
		Bones							2		4			3	1	6								1	11					
		Mammals																												
1		Leporidae (family) ... Hares and rabbits																												
	1	Lepus sp., ... Jack rabbit																												
	2	Sylvilagus audubonii ... Audubon cottontail																												
		Sylvilagus sp., probably the preceding						17											1											
		Rabbit, undetermined				5		3			2		5	6		22		4							33		7	2		
2		Sciuridae (family) ... Squirrels																												
	3	Marmota flaviventris ... Marmot																												
	4	Citellus lateralis ... Golden-mantled ground squirrel																												
	5	Citellus variegatus grammurus ... Rock squirrel				1																			1					
	6	Citellus sp., probably leucurus ... Antelope ground squirrel							2																					
	7	Eutamias quadrivittatus ... Colorado chipmunk																												
3		Geomyidae (family) ... Pocket gophers																												
	8	Thomomys sp., probably bottae ... Botta pocket gopher															1								1					
4		Heteromyidae (family) ... Heteromyids																												
	9	Dipodomys sp., probably ordii ... Kangaroo rat																		1										
5		Castoridae (family) ... Beavers																												
	10	Castor canadensis ... Beaver																						1				3		
6		Cricetidae (family) ... Native rats and mice																												
	11	Peromyscus sp., probably deer mice								1				1		9											1			
	12	Neotoma sp., ... Wood rat						1							3										2					
	13	Ondatra sp., ... Muskrat																												
7		Erethizontidae (family) ... Porcupines																												
	14	Erethizon dorsatum ... Porcupine						1																						
8		Canidae (family) ... Canids																												
	15	Canis latrans ... Coyote																												
	16	Vulpes macroura ... Red fox														2														
	17	Urocyon cinereoargenteus ... Gray fox		1																										
9		Procyonidae (family) ... Procyonids																												
	18	Bassariscus astutus ... Ringtail																												
10		Mustelidae (family) ... Mustelids																												
	19	Taxidea taxus ... Badger																							3					
	20	Spilogale gracilis ... Spotted skunk																												
11		Felidae (family) ... Cats																												
	21	Lynx rufus ... Bobcat						1			1	1																		
12		Cervidae (family) ... Cervids																												
	22	Odocoileus hemonius ... Mule deer			1			3	6		3		2	3		12		3			1	1		2	26	9				
13		Bovidae (family) ... Bovids																59												
	23	Ovis canadensis ... Bighorn sheep			1	3	3	59	32	1	7	2	3	18	6	71		21		1	1		3	7	129	59		3	1	8
			1	1	2	9	3	85	42	2	17	3	10	31	10	132	1	87	1	2	2	1	3	11	209	68	8	8	1	8

Salvaged Biological Artifacts

Animals / Site	Shady Alcove	Echo Cave	Doll Ruin	No Name	Crumbling Kiva	Defiance House	Mouse Alcove	Lost Ladder	Gourd House	Weirs Mural	Oven Alcove	Lyman Flat	Penthouse	Dead Tree Flats	Mosquito Cave	Mat House	Grid Alcove	Red Ant Kiva	Copter Ledge	Hiboy House	Rehab Center	Ax Groove Alcove	Stevens Terrace	Flatrock House	Bernheimer Alcove	Honeycomb Alcove	Tamarix Dune
Number	576	583	585	588	597	598	615	616	619	620	622	623	624	627	643	646	662	675	678	679	681	693	695	729	736	754	781
Fishes																											
Fish bones	3																										
Amphibians																											
Toads																											
Reptiles																											
Lizards									4												2				1		
Birds																											
Eagle																											
Parrot																											
Bones	2	3	3	6	1	8					1	1		1				1				3					
Mammals																											
1 Leporidae (family) ... Hares and rabbits																											
1 Lepus sp., ... Jack rabbit																											
2 Sylvilagus audubonii ... Audubon cottontail																											
Sylvilagus sp., probably the preceding																											
Rabbit, undetermined	2	9	1			3	2	1	2		8			4					1	1	4	6		1	2	1	
2 Sciuridae (family) ... Squirrels																											
3 Marmota flaviventris ... Marmot	1																		1						29		
4 Citellus lateralis ... Golden-mantled ground squirrel																											
5 Citellus variegatus grammurus ... Rock squirrel																											
6 Citellus sp., probably leucurus .:. Antelope ground squirrel	1	3				2																					
7 Eutamias quadrivittatus ... Colorado chipmunk						1																					
3 Geomyidae (family) ... Pocket gophers																											
8 Thomomys sp., probably bottae ... Botta pocket gopher						1			1			1							1						1		
4 Heteromyidae (family) ... Heteromyids																											
9 Dipodomys sp., probably ordii ... Kangaroo rat		1																									
5 Castoridae (family) ... Beavers																											
10 Castor canadensis ... Beaver	6			1	2																10						
6 Cricetidae (family) ... Native rats and mice																											
11 Peromyscus sp., probably deer mice		6	4		5	9									2	4									1		
12 Neotoma sp., ... Wood rat									1								1		7		2				3		
13 Ondatra sp., ... Muskrat											1																
7 Erethizontidae (family) ... Porcupines																											
14 Erethizon dorsatum ... Porcupine																											
8 Canidae (family) ... Canids																			1						1		
15 Canis latrans ... Coyote					1	1												2									
16 Vulpes macroura ... Red fox		1		2		2						1															
17 Urocyon cinereoargenteus ... Gray fox												1															
9 Procyonidae (family) ... Procyonids																											
18 Bassariscus astutus ... Ringtail						1																					
10 Mustelidae (family) ... Mustelids																											
19 Taxidea taxus ... Badger						1								1		1	1										
20 Spilogale gracilis ... Spotted skunk																											
11 Felidae (family) ... Cats																											
21 Lynx rufus ... Bobcat						1			2					2											3		
12 Cervidae (family) ... Cervids																											
22 Odocoileus hemonius ... Mule deer	6	6	2	3	3	3			4		1	4	2	5	2	1					9	1					
13 Bovidae (family) ... Bovids																		71	19	13	185			1	2		4
23 Ovis canadensis ... Bighorn sheep	66	24	18	16	19	46	2	3	9	2	2	11	7	26	6	1	5	7			64	13	5	3	6	3	
	87	53	28	28	31	79	4	4	23	2	13	19	9	39	10	7	7	81	29	14	276	23	5	5	48	4	4

		Salvaged Biological Artifacts	Garfield County													Kane County									Sub-totals			Totals
		Animals / Site Number	Spencer Site 51	Horse Canyon 91	Harris Wash 276	Harris Wash 277	Harris Wash 286	Harris Wash 288	Harris Wash 289	Harris Wash 290	Harris Wash 297	Harris Wash 298	Harris Wash 302	North Wash 315	Buried Olla 367	Alvey Site 172	Coyote Gulch 174	25 Mile Gulch 178	Davis Pool Site 235	Davis Kiva Site 241	Talus Ruin 59.4 274	Lizard Alcove 59.7 276	Benchmark Cave 59.5 433	Hermitage 61.8 443	Page 55	Page 56	Page 57	
		Fishes																										
		Fish bones																							11	3		14
		Amphibians																										
		Toads																1									1	1
		Reptiles																										
		Lizards																	1							7	1	8
		Birds																										
		Eagle and Mexican duck																				4			3		4	7
		Parrot (red and blue macaw)																				1					1	1
		Bones	1		2						1	1			3										28	30	8	66
		Mammals																										
1		Leporidae (family) ... Hares and rabbits																										
	1	<u>Lepus</u> sp., ... Jack rabbit														7		1	1								9	9
	2	<u>Sylvilagus</u> <u>audubonii</u> ... Audubon cottontail																										
		<u>Sylvilagus</u> sp., probably the preceding														6			1						18		7	25
		Rabbit, undetermined											1			17			2						89	48	20	157
2		Sciuridae (family ... Squirrels																										
	3	<u>Marmota</u> <u>flaviventris</u> ... Marmot															1	1	1							31	3	34
	4	<u>Citellus</u> <u>lateralis</u> ... Golden-mantled ground squirrel																							1			1
	5	<u>Citellus</u> <u>variegatus</u> <u>grammurus</u> ... Rock squirrel																							1			1
	6	<u>Citellus</u> sp., probably <u>leucurus</u> ... Antelope ground squirrel														1									2	6	1	9
	7	<u>Eutamias</u> <u>quadrivittatus</u> ... Colorado chipmunk														1										1	1	2
3		Geomyidae (family) ... Pocket gophers																										
	8	<u>Thomomys</u> sp., probably <u>bottae</u> ... Botta pocket gopher										1	1			5	1		1						2	5	9	16
4		Heteromyidae (family) ... Heteromyids																										
	9	<u>Dipodomys</u> sp., probably <u>ordii</u> ... Kangaroo rat														1									1	1	1	3
5		Castoridae (family) ... Beavers																										
	10	<u>Castor</u> <u>canadensis</u> ... Beaver													6	1			2		1		12		4	19	22	45
6		Cricetidae (family) ... Native rats and mice																										
	11	<u>Peromyscus</u> sp., probably deer mice														2									12	31	2	45
	12	<u>Neotoma</u> sp., ... Wood rat						1	2							12		1	1	3					6	14	20	40
	13	<u>Ondatra</u> sp., ... Muskrat																		2						1	2	3
7		Erethizontidae (family) ... Porcupines																										
	14	<u>Erethizon</u> <u>dorsatum</u> ... Porcupine														1									1		1	2
8		Canidae (family) ... Canids																										
	15	<u>Canis</u> <u>latrans</u> ... Coyote													1						1					4	2	6
	16	<u>Vulpes</u> <u>macroura</u> ... Red fox										1	1												2	6	2	10
	17	<u>Urocyon</u> <u>cinereoargenteus</u> ... Gray fox																					3		1	1	3	5
9		Procyonidae (family) ... Procyonids																										
	18	<u>Bassariscus</u> <u>astutus</u> ... Ringtail																								1		1
10		Mustelidae (family) ... Mustelids																										
	19	<u>Taxidea</u> <u>taxus</u> ... Badger										1				2		1							3	4	4	11
	20	<u>Spilogale</u> <u>gracilis</u> ... Spotted skunk														1											1	1
11		Felidae (family) ... Cats																										
	21	<u>Lynx</u> <u>rufus</u> ... Bobcat				1																2	2		3	8	5	16
12		Cervidae (family) ... Cervids																										
	22	<u>Odocoileus</u> <u>hemonius</u> ... Mule deer										5			15	7			1		3	2		1	72	52	34	158
13		Bovidae (family) ... Bovids																							59	295		354
	23	<u>Ovis</u> <u>canadensis</u> ... Bighorn sheep	1	2			2			1	1	1		1	103	56		1	19	13	84	21	24	2	439	364	332	1135
			2	2	2	1	2	1	2	1	2	10	3	1	128	120	2	6	30	18	89	30	41	3	758	932	496	2186

APPENDIX II

ANIMAL REMAINS FOUND IN ARCHEOLOGICAL CONTEXTS IN GLEN CANYON AND SURROUNDING REGION EXTRACTED FROM REFERENCES CITED

BIRDS

Recent records of birds in the Navajo Country may be found in Woodbury and Russell, 1945.

Podilymbus podiceps podiceps (Linnaeus) . . . . . Pied-billed grebe
Femur, tarsometatarsus and coracoid, probably of a single individual, from Grand Falls; Hargrave (1939, 207).

Branta canadensis (Linnaeus) . . . . . Canada goose
Femur, coracoid and ulna, representing one individual each from Poncho House, Turkey Tank and Winona Village; the sizes of these bones indicate the race canadensis; Hargrave (1939, 207).
Five from Winona Ruins; McGregor (1941, 258).

Chen hyperborea (Pallas) . . . . . Snow goose
1 femur from Turkey Tank Caves; white geese appear to be rare in Arizona; Hargrave (1939, 207).

Anas platyrhynchos platyrhynchos (Linnaeus). . . . . Mallard
1 from Winona Ruins; McGregor (1941, 258).

Cathartes aura teter (Friedmann). . . . . Turkey vulture
An ulna from Awatobi Pueblo; Hargrave (1939, 207).

Accipiter striatus velox (Wilson) . . . . . Sharp-shinned hawk
Femur, ulna and tibiotarsus, representing one individual each from Kiet Siel, Grand Falls and Winona Village; Hargrave (1939, 207).
2 from Winona Ruins; McGregor (1941, 258).

Buteo jamaicensis calurus (Cassin) . . . . . Red-tailed hawk
A humerus from Awatobi Pueblo; Hargrave, (1939, 207). Found in excavations in Big Hawk Valley; Smith, (1952, 181).

Buteo swainsoni Bonaparte . . . . . Swainson hawk
1 from Winona Ruins; McGregor (1941, 258).

Buteo regalis (Gray) . . . . . Ferruginous hawk
An ulna from Wupatki Pueblo; Hargrave (1939, 207).

Aquila chrysaetos canadensis (Linnaeus) . . . . . Golden eagle
A scapula, carpometacarpus, 2 tarsometatarsi, and 2 pedal phalanges representing 6 individuals from 4 sites: Awatobi Pueblo, 2; Turkey Tank Caves, 2; Nalakihu, 1; and Wupatki Pueblo, 1; Hargrave (1939, 207). 1 from Winona Ruins; McGregor (1941, 258).

Circus cyaneus hudsonius (Linnaeus) . . . . . . Marsh hawk
An ulna from Wupatki Pueblo (HH); Hargrave (1939, 207).

Falco mexicanus (Schlegel) . . . . . Prairie falcon
1 from Winona Ruins: McGregor (1941, 258).

Falco columbarius (Linnaeus) . . . . . Pigeon hawk
1 from Winona Ruins; McGregor (1941, 258).

Falco sparverius sparverius (Linnaeus) . . . . . Sparrow hawk
Coracoid, carpometacarpus, 2 ulnae, 3 humeri, 2 tarsometatarsi and a femur representing 8 individuals from 3 sites: Turkey Tank, 1; Winona Village, 5; and Wupatki Pueblo, 2; Hargrave (1939, 207). 6 from Winona Ruins: McGregor (1941, 258). Found in excavations in Big Hawk Valley; Smith (1952, 181).

Fulica americana americana (Gmelin). . . . . American coot (Mud hen)
A tarsometatarsus from Wupatki Pueblo; Hargrave (1939, 208).

Grus canadensis . . . . . Little brown crane
Coracoid, ulna and radius (HH) Turkey Tank, 1; Wupatki Pueblo, 2; Hargrave (1939, 208). 1 from Winona Ruins; McGregor (1941, 258).

Zenaidura macroura marginella (Woodhouse) . . . . . Mourning dove
A sternum, 2 carpometacarpi, 2 coracoids, 2 humeri, 1 ulna and 1 tibiotarsus of 7 individuals from 3 sites: Turkey Tank Caves, 1; Winona village 4, and Wupatki Pueblo, 2; Hargrave (1939, 208); 4 from Winona Ruins; McGregor (1941, 258).

Geococcyx californianus (Lesson) . . . . . Roadrunner
1 from Winona Ruins; McGregor (1941, 258). Found in excavations in Big Hawk Valley; Smith (1952, 181).

Bubo virginianus (Gmelin) . . . . . Great horned owl
Nearly complete skeletons of 2, 1 from Grand Falls and 1 from Nalakihu Pueblo; and 2 coracoids, 1 humerus, 1 tarsometatarsus and 1 tibiotarsus of 3 others: Poncho House, 1; Awatovi Pueblo, 1; and Deadman's Cave, 1; Hargrave (1939, 208).

Chordeiles minor henryi (Cassin) . . . . . Western nighthawk
An ulna from Deadman's Cave; Hargrave (1939, 209).

Colaptes cafer collaris (Vigors) . . . . . Red-shafted flicker
1 incomplete, dessicated body from Betatakin Pueblo and an ulna and radius of 1 individual from Winona Village; Hargrave (1939, 209). 3 from Winona Ruins; McGregor (1941, 258).

Eremophila alpestris leucolaema-occidentalis . . . . . Horned lark
9 from Winona Ruins; McGregor (1941, 258).

Cyanocitta stelleri macrolopha (Baird) . . . . . Steller jay
A humerus from Kiet Siel Pueblo; Hargrave (1939, 209).

Corvus corax sinuatus (Wagler) . . . . . Common raven
A total of 117 bones of 16 individuals from 8 sites: Betatakin Pueblo, 1; Kiet Siel Pueblo, 2; Awatobi Pueblo, 3; Walnut Canyon Pueblo, 1; Winona Village, 2; Citadel Pueblo, 1; Nalakihu Pueblo, 2; and Wupatki Pueblo, 4; Hargrave (1939, 209). 6 from Winona Ruins; McGregor (1941, 258). Found in excavation in Big Hawk Valley; Smith (1952, 181).

Corvus brachyrhynchos hesperis (Ridgway) . . . . . Common crow
1 humerus from Walnut Canyon Pueblo; Hargrave (1939, 209). 1 from Winona Ruins; McGregor (1941, 258).

Gymnorhinus cyanocephala (Wied) . . . . . Pinyon jay
A carpometacarpus of 1 individual and a humerus of another, both from Winona Village; Hargrave (1939, 209). 2 from Winona Ruins; McGregor (1941, 258).

Nucifraga columbiana (Wilson) . . . . . Clark nutcracker
Lower mandible and premaxillary from Wupatki Pueblo; Hargrave (1939, 209).

Lanius ludovicianus gambelii (Ridgway) . . . . . Loggerhead shrike
1 humerus from Wupatki Pueblo; Hargrave (1939, 209).

Carpodacus mexicanus frontalis (Say) . . . . . House finch
1 from Winona Ruins; McGregor (1941, 258).

Junco sp. . . . . . Junco
1 from Winona Ruins; McGregor (1941, 258).

MAMMALS

Lepus californicus (Mearns) . . . . . Black-tailed jack rabbit
Found in excavations in the Big Hawk Valley; Smith (1952, 181).
Found in Winona Ruins: McGregor (1941, 256).

Sylvilagus sp. . . . . . Cottontail rabbit
Found in Winona Ruins; McGregor (1941, 256).
Found in excavations in the Big Hawk Valley; Smith (1952, 181).

Sciurus sp. . . . . . Three squirrel
Found in Winona Ruins; McGregor (1941, 256).

Citellus sp. . . . . . Rock Squirrel or ground squirrel
Found in the Winona Ruins; McGregor (1941, 256). Found in eastern part of area; Steward (1938, 40). Found in excavations in the Big Hawk Valley; Smith (1952, 181).

Eutamias sp. . . . . . Chipmunk
Found in the Winona Ruins; McGregor (1941, 256). Found among rocks, hills and mountains; Steward (1938, 40). Found in excavations in the Big Hawk Valley; Smith (1952, 181).

Thomomys sp. . . . . . Pocket gopher
Found in Winona Ruins; McGregor (1941, 256).

Dipodomys . . . . . Kangaroo rat
Found in Winona Ruins; McGregor (1941, 256).

Peromyscus sp. . . . . . Deer mouse
Large-eared deer mouse found in Winona Ruins; McGregor (1941, 256). Deer mouse found in excavations in the Big Hawk Valley; Smith (1952, 181).

Neotoma sp. . . . . . Wood rat
Found in Winona Ruins; McGregor (1941, 256). Found in excavations in the Big Hawk Valley; Smith (1952, 181).

Erethizon dorsatum epixanthum (Brandt) . . . . . Porcupine
Found in the Winona Ruins; McGregor (1941, 256).

Canis sp. . . . . . Coyote
Found in the Winona Ruins; McGregor (1941, 256). Excavations in Big Hawk Valley; Smith (1952, 181).

Taxidea taxus taxus (Schreber) . . . . . Badger
Found in the Winona Ruins; McGregor (1941, 256).

Spilogale gracilis gracilis (Merriam) . . . . . Spotted skunk
Found in the Winona Ruins; McGregor (1941, 256).

Lynx rufus baileyi (Merriam) . . . . . Bobcat
Found in the Winona Ruins; McGregor (1941, 256).

Odocoileus hemionus hemionus (Rafinesque) . . . . . Mule deer
Found in the Winona Ruins; McGregor (1941, 256). Found in excavations in Big Hawk Valley; Smith (1952, 181).

Antilocapra americana americana (Ord) . . . . . Prong-horned antelope
Found in excavations in Big Hawk Valley; Smith (1952, 181). Found in the Winona Ruins; McGregor (1941, 256).

Cervus canadensis nelsoni (Bailey) . . . . . Wapiti (elk)
Found in Winona Ruins; McGregor (1941, 256).

Bison bison bison (Linnaeus) . . . . . Bison
Found in Winona Ruins; McGregor (1941, 255).

Ovis canadensis canadensis (Shaw) . . . . . Mountain sheep
Found in Winona Ruins; McGregor (1941, 255). Found in the excavations in Big Hawk Valley; Smith (1952, 181).

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