A PERIPHYTIC MICROFLORA ANALYSIS OF THE COLORADO RIVER AND MAJOR TRIBUTARIES IN GRAND CANYON AND VICINITY

David B. Czarnecki, Dean W. Blinn, Terrill Tompkins

Colorado River Research Program Final Report

Technical Report No. 6

Colorado River Research Program

REPORT SERIES
GRAND CANYON NATIONAL PARK

United States
Department of the Interior
National Park Service

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

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

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Grand Canyon National Park
Colorado River Research Series
Contribution Number 35

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Submitted to

GRAND CANYON NATIONAL PARK

NATIONAL PARK SERVICE

DEPARTMENT OF THE INTERIOR

by

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June 1976

The research described in this report

was supported by funds provided by

The National Park Service under

contract number CX821060008

ABSTRACT

A periphytic microflora analysis was conducted seasonally at sites near the confluence of 12 major tributaries and the Colorado River in Grand Canyon National Park and vicinity. Twenty-one additional locations along the 225 mile stretch of the Colorado River were also examined. A relatively high algal diversity was displayed by a variety of microhabitats yielding 345 taxa (224 diatoms, 83 blue-greens, 34 greens, 3 yellow-greens and 1 red alga). The high diversity in combination with the overall scarcity of pollution tolerant species indicates a fairly young and possibly oligotrophic system. Distributional extensions, notes on ecological preferences and general distributional patterns in Arizona are reported for a number of representatives. Major differences in taxa exist above and below Glen Canyon Dam. These differences are attributed to the lentic nature of the system above the dam, variable flow characteristics below the dam, and increasing levels of suspended materials downstream. A relative ranking scheme was designed to characterize site important and system important periphytic diatoms. Taxa with high site importance values (e.g. *Epithemia sorex*, *Mastogloia smithii*, *Fragilaria capucina* var. *mesolepta*) were generally considered to be good indicators of specific sites and habitat types. Taxa with high system and low site importance values (e.g. *Synedra ulna*, *Nitzschia dissipata*, *Navicula tripunctata*) were generally considered to have wide ranges of ecological tolerance while taxa with both high site and system importance values (e.g. *Diatoma vulgare*, *Cocconeis pediculus*, *Rhoicosphenia curvata*) were considered to be characteristic of the system. Based on ecological preferences of major taxa, the Colorado River can be considered to be a high alkalinity and conductivity system. An overall system importance index was calculated for each major tributary to determine those systems most important in contributing to the present diatom microflora of the Colorado River. Those determined to be of greatest significance include: Vasey's Paradise (mi 32.0), Bright Angel (mi 87.5), Shinumo (mi 108.0), Elves Chasm (mi 116.5), Tapeats Creek (mi 134.0), and Deer Creek (mi 136.0).

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INTRODUCTION

Of all the components of aquatic ecosystems, the periphyton community ranks among the most important. This community is somewhat difficult to delimit because of interaction with the other communities normally present (i.e., phytoplankton). However, this community is normally considered to comprise that assemblage or organisms growing upon free surfaces of submerged objects in fresh water and covering them with a slimy coat. Various terms have been employed to further delimit this extremely diverse community, notably the following: (1) epiphyton, organisms attached to or moving on submerged plant material; (2) epilithon, organisms attached to or moving on submerged rock or rock-like material; (3) epipelon, the sediment organisms; (4) psammon, the organisms found in the sand grain fraction; (5) neuston, the organisms associated with the air-water interface.

The importance of this community is greatly enhanced in shallow systems where available light allows for plant growth. (Plants, i.e., algae, are the major biotic component of the periphyton). In terms of composition, the algae most commonly represented are the diatoms (Bacillariophyta), the blue-greens (Cyanophyta), and the greens (Chlorophyta). Other groups, notably the golden-browns (Chrysophyta), yellow-greens (Xanthophyta), and reds (Rhodophyta), may also be represented but rarely in the diversity exhibited by the diatoms, blue-greens, and greens.

The algae of this community have frequently been employed as ecological indicators. The rationale for this type of characterization is based on the fact that living organisms exist under continuous environmental conditions, normally not determined by instantaneous chemical evaluations. In this way, although fluctuations in environmental parameters may occur, their duration may be of such minor importance as to not affect the biota even though a chemical change may be determined. Also, minor chemical changes may go undetected, but because of their duration, will affect the biota. Therefore, in the characterization of systems where available biotic components are in sufficient quantity, it becomes evident that the utilization of these organisms will yield a more valid concept of the ecological status and nature of the system.

The objectives of this study are therefore based on the importance and utilization of the algal periphyton. The identification of the algal periphyton was of prime concern. The data obtained in this identification serves as the first inventory of its kind in Grand Canyon National Park and at the same time furnishes baseline information from which, through continued monitoring, changes in the system may be determined. The second objective of this study was to determine which adjacent areas of the Colorado River are significant in terms of contribution and impact to the total system. By continued monitoring of these areas, a more realistic assessment of the ecological conditions can be achieved. In this way, adverse conditions may be predicted early enough and effectively prevented so that the Grand Canyon will remain relatively unspoiled and truly one of the seven wonders of the world.

Mr. Chuck Minckley and Mr. Bob Minckley assisted in the collection of periphyton material during the summer period. Spring and summer float trips were made with members of the Museum of Northern Arizona Ecological Survey, while the National Park Service provided space for the November trip. Appreciation is extended to the National Park Service for providing funds to conduct the research described in this report.

MATERIALS AND METHODS

The study was initially designed to quantitatively sample the periphytic algal communities (attached microflora) of Grand Canyon National Park in order to provide an estimate of algal numbers and distribution for sites at the confluence of major tributaries entering the Colorado River. From the information assembled, a comprehensive algal species list of the entire system was also to be prepared. The primary requirement, however, for quantitative periphyton estimates is collection from an area of known dimension. One way to accomplish this is through the use of artificial substrates placed in a natural area, thus allowing attachment by algal species. However, two major problems develop when employing artificial substrates. Firstly, artificial substrates may not duplicate the natural conditions available hence an unnatural selective force is added to the system, presenting the probability of obtaining populations not representative of the natural microflora. Secondly, and just as difficult to overcome is the problem of retrieval. The periodic fluctuation in water flow in the Grand Canyon system and general logistic difficulties associated with site visitation make recovery of artificial substrates difficult. Therefore, based on the above considerations, collections were made from various naturally occurring substrates encountered at each site including neustonic (micro-surface layer), epilithic (rock), epiphytic (vegetation), psammon (sand association) and wood. This sampling procedure provided a true evaluation of the species present and substrate preferences within each system.

Collections were made during the following periods: spring (22 April-5 May), summer (7 July-21 August), and fall (17 November-24 November) of 1975. During each visit, samples approximately of uniform size were taken from substrates available within each system and preserved in an alcohol: formalin: acetic acid (AFA) solution. Water temperatures were also recorded for each collection site. Samples were transported to Northern Arizona University where each was separated for diatom and non-diatom algal analyses. All taxonomic determinations were made with a Zeiss phase contrast optical system. Taxonomic references used for algae, excluding diatoms, include: Prescott, 1951; Tiffany and Britton, 1952; Bourrelly, 1966, 1968, and 1970; Desikachary, 1959; and Whitford and Schumacher, 1968.

In order to provide an estimate of the relative abundance of non-diatom species within a given sample, taxa were ranked according to the following scheme: 1 = rare, 2 = present, 3 = common, 4 = dominant. Per cent occurrences were also calculated for species within each system. In combination, these values give an estimate of the significance of a particular taxon in the system and the areas in which it occurs.

Samples separated for diatom analyses were laboratory processed in the following manner: each aliquot chosen for diatom examination was placed in a beaker to which was added 30% hydrogen peroxide (a volume approximately equal to the aliquot volume) and approximately 0.1g potassium dichromate. After the ensuing reaction had ceased, the "cleaned" aliquots were alternately centrifuged and rinsed with distilled water until all visible trace of the dichromate solution was removed. The resulting "cleaned" concentrates were resuspended in 50% ethyl alcohol (v/v H_2O) and stored in glass vials. An aliquot (1-2ml) was removed (for each sample) from the vial and placed on a glass coverslip for mounting in Hyrax (Patrick and Reimer, 1966). The samples prepared in this manner were then ready for microscopic examination.

In an effort to standardize numeration from the diverse volumes of samples employed and to allow for comparison of various sample compositions, a fixed-sum counting technique (Barkley, 1934; Martin,1963) was employed for the numeration of specimens. The number of frustules to be counted from each sample was arbitrarily chosen as 200. Specimens were identified when possible employing standard taxonomic references (Van Heurck, 1899; Shonfeldt, 1913; Hustedt, 1930; Huber-Pestalozzi, 1942; Cleve-Euler, 1951-1953; Sovereign, 1963; Hohn and Hellerman, 1963; Weber, 1966; Patrick and Reimer, 1966 and 1975). Percentage composition could therefore be established for each taxon observed in each sample. For comparative purposes, the following abundance values (av) were assigned for each sample: taxa representing less than 1% although present received a value of 1; 1% to less than 5% a value of 2; 5% to less than 10% a value of 3; 10% to less than 25% a value of 4; 25% to less than 50% a value of 5; 50% and above a value of 6.

For a given seasonal period these values were used to compare taxa from various samples. A site importance value (sIV) was derived by summing the total abundance for a given taxon and dividing the result by the number of samples in which the taxon occurred as formulated below:

$$\frac{\sum av}{n_{(av>0)}} = sIV, \text{ where } n = \text{number of samples of occurrence}$$

The greater this value, the greater the specificity a taxon has for a given sample type.

In order to determine which taxa were well distributed and/or important to the study area in the Grand Canyon, a system importance value (SIV) was derived by summing the total abundance values and dividing by the total number of samples collected during a given period as formulated below:

$$\frac{\sum av}{n} = SIV, \text{ where } n = \text{the number of total samples}$$

The greater this value, the greater the importance a taxon has throughout the entire canyon system. Tabulation of the top 25 taxa for both sIV and SIV allowed for a general comparison of individual sites.

RESULTS AND DISCUSSION

The southwestern section of continental USA provides innumerable habitats for algal occupation with a wide diversity of environmental regimes from hot desert regions to heavily forested mountainous areas. Many of these zones encompass the unique geological features of the Grand Canyon with the Colorado River traversing through a variety of geochemical formations of differing chemical composition, hardness, and durability. These features are coupled with a myriad of seeps and waterfalls cascading the steep canyon walls providing a variety of micro-biotic refugia and further expanding the diversity of potential algal habitats for the Southwest. The magnitude of diversity within this unexplored system is evident from the species list presented in Appendix Table I. A total of 345 taxa are reported (224 diatoms, 83 blue-greens, 34 green algae, 3 yellow-greens and 1 red alga) from only 33 major collecting sites throughout Grand Canyon National Park and vicinity. Due to the incomprehensible magnitude of the Grand Canyon system, this compilation of species undoubtedly represents a very conservative estimate of taxa in the system but probably is inclusive of the more common representatives. A comprehensive literature search of published articles on algae of the Southwest (Taylor and Colton, 1928; Wein, 1959; Cameron and Fuller, 1960; Cameron, 1960; Hevly, 1961; Kidd and Wade, 1963; Wade and Kidd, 1963; Cameron, 1963; 1964 a & b; Kidd, 1964; Kidd, 1965; Kidd and Wade, 1965; Whiteside, 1965; Patrick and Reimer, 1966; Cole, 1968; Hostetter, 1968; Rickert and Hoshaw, 1968, 1970; Olsen and Sommerfeld, 1970; Weber, 1971; Markey and Hevly, 1973; Button and Blinn, 1973; Patrick and Reimer, 1975; Sommerfeld et al., 1975; Johnson et al., 1975 and Button and Blinn, 1975) reveals that 152 (96 diatoms, 47 blue-greens and 9 green algae) of these taxa are previously unreported for Arizona and probably to most of the Southwest.

Due to the nature of the study, non-diatom and diatom periphyton communities will be discussed separately with each major tributary treated individually within each section.

A. Periphytic Algae, Excluding Diatoms

Paria River (mi 0.3)

The total number of non-diatom algal species present in this heavily sedimented drainage (Kubly and Cole, 1976) was among the lowest of all collection sites. Species composition was quite unstable, with different species present each season (Tables 1-3). This is probably due to the influence of the consistently turbid water and variable flow characteristics of the stream. The area of the stream sampled offered little variety in available substrate beyond psammon (microflora associated with sand), benthic, and scattered rocks. All species recorded were entangled among filaments of the green alga, Cladophora glomerata, collected from submerged rocks at the confluence with the Colorado River. Even though C. glomerata was dominant during all three seasons, its occurrence was restricted to the mouth of the Paria River, inhabiting only the area that was frequently innundated by Colorado River water. Thus, the majority of the flora present in the sampling area was most probably derived from the Colorado River.

The Paria River manifests its influence in the fact that each seasonal flora is made up of different species (Tables 1-3). Common in the summer was the blue-green Oscillatoria tenuis, a species that is listed by Palmer (1969) as tolerating organic pollution. Oscillatoria tenuis var. teregestina was also common in the summer but is not known as a pollution tolerant species. Although quantification of cells is necessary to indicate the existence of organic input, the presence of a pollution tolerant species points to the possibility of organic influence during this period. Likewise, quantitatively monitoring such a species is a potential means of noting any significant increase in organic contamination.

Vasey's Paradise (mi 32.0)

Originating as three springs flowing out of the north rim wall, this area maintained a very diverse flora throughout the year supporting 34 non-diatom algal species (Tables 1-3). This was the greatest number displayed by any site with the exception of Elves Chasm, which also had 34 species. The high algal diversity for this system results from the variety of substrates and more importantly, the variety of current regimes available. Exposed bedrock is common, as is moss and vascular plant associations, each in areas of slow, moderate and fast current. Cladophora glomerata was consistently dominant in the area of confluence with the Colorado River, as well as portions remote from the confluence. Further, it was the only species to be ranked as dominant in all three seasons. The blue-greens, Scytonema alatum and S. rivulare were very common during all seasons, inhabiting primarily the moss tufts growing on rocks marginal to pools and waterfalls. Other seasonal dominants were Vaucheria sessilis (spring and summer), Nostoc punctiforme (spring), Lyngbya perelegans (summer, and Oedogonium spp. (fall). With the exception that Vaucheria sessilis was absent during the fall, a consistent assemblage exists among the moss association e.g. Scytonema alatum,S. rivulare, and Cladophora glomerata. These species were most abundant when growing together, in moist mats near areas of flowing water. Oedogonium spp. and Lyngbya perelegans also frequently inhabit these mats. The lack of consistent occurrence of dominants and the large overall change in seasonal species composition (Tables 1-3), is likely due to the variability of flow from the springs and perhaps, incident light. No measurements of flow were made, but the amount of water visibly decreased from spring through summer to the fall, even though water temperatures varied less than 2 ^{o}C (Table 4).

Buck Farm (mi 41.0)

This north rim drainage was sampled only in the spring and summer, nevertheless, it supported a total of 30 non-diatom species (Tables 1&2). As was the case in most other sites, Cladophora glomerata was restricted to the mouth of the stream on rocks, but again was dominant in both seasons. Further upstream, away from the influence of the Colorado River, this species diminished rapidly and Nostoc hatei and Scytonema alatum became most common in the spring, while several other species (Spirogyra spp., Stigeoclonium pachydermum, Lyngbya hieronymussi and Oscillatoria rubescens) were found in fewer numbers (Tables 1-3). With an increase in water flow during the summer, N. hatei became less common, S. alatum expanded its population to become a dominant along with Gloeothece sp. and Gloeotrichia intermedia, while Mougeotia spp., Oedogonium spp., Chroococcus turgidus, Lyngbya nordgardhii, and Merismopedia punctata also became very common (Table 2).

Unlike the majority of the other drainages, the summer flora here demonstrated a large increase over the spring from 15 to 23 species, 17 of which were blue-greens. Hence, this stream can be designated as a blue-green system, as it was dominated by these species during both seasons. Further, it supported the largest blue-green algal population of any area sampled. Even though green algal representatives were in the minority, they demonstrated a relatively high degree of seasonal stability in that four of the nine species collected were present in both spring and summer (Tables 1&2), while only three of 21 blue-green species occurred.

Comparison of the floras of Vasey's Paradise and Buck Farm reveals that they are similar in algal composition, having 14 non-diatom species in common over the study period, although some species do not demonstrate the same seasonal trends in each system. Vasey's Paradise exists as a spring seep and Buck Farm as an intermittent stream, with considerable differences in seasonal temperature (Table 4). Therefore, one might expect widely divergent floras, however that the contrary is the case, indicates some similarities resulting from their proximity to one another (9 river miles) or perhaps similarity in substrates available for colonization by the periphyton.

Little Colorado River (mi 61.5)

Although this south rim drainage is one of the largest tributaries in terms of flow, its algal flora of 10 species is among the most depauperate of any area sampled (Tables 1-3). Hence, it is similar in nature to the Paria River, even though they have only two species in common, e.g. Cladophora glomerata and Oscillatoria rubescens. Only Cladophora glomerata was present each season while Spirogyra spp. was the only species present in two seasons (spring and fall). The remaining species were restricted to a single season. Again the variability in flow and the immense sediment and dissolved salt load (Kubly and Cole, 1976 and Sommerfeld et al., 1976) in combination with the scouring capacity of the water during certain times of the year strongly inhibit any significant development in periphyton populations.

Bright Angel Creek (mi 87.5)

This system is a large north rim drainage and is subjected to relatively heavy recreational pressure. The system demonstrated a relatively stable algal flora, with Cladophora glomerata again the dominant alga at the confluence, and Nostoc verrucosum, consistently dominant in the creek bed on rocks in swift current (Tables 1-3). Oedogonium spp. were present during each sampling period and were the dominant forms in the summer and fall on vegetation and filament of Cladophora glomerata, while Oscillatoria rubescens was dominant in the fall only. The remainder of the 23 species demonstrated no seasonal trends. Fall was the most diverse period, with 16 species present, followed by spring with 12 and summer with only 7. One fall species Pediastrum boryanum, is listed by Palmer (1969) as tolerating organic pollution. The number of cells present was not quantified but its presence allows a means to note possible input of organics.

Shinumo Creek (mi 108.5)

As observed in other drainages, this north rim stream demonstrated very little stability in species composition from season to season. Of the 28 species recorded, only two, Cladophora glomerata at the mouth and Nostoc hatei on rocks in swift current in the upstream areas were collected during all seasons (Table 1-3). Nostoc hatei was never a dominant in the system. Vaucheria sp. was a summer dominant, while Lyngbya spp. were dominant in the fall. The remaining species were found sporadically with no seasonal trends evident. Water temperatures recorded in the spring and fall were at 9 ^{o}C, but a marked increase to 25 ^{o}C occurred in the summer (Table 4). This was reflected in the summer flora in that only eight species were present and six of these were present at this time only. During the spring and fall, 13 and 16 species were present respectively, four of which were common to both periods. Because flow and incident light underwent only minor seasonal variation, the algal flora of this tributary may be primarily influenced by water temperature.

Elves Chasm (mi 116.5)

One of four south rim drainages sampled, Elves Chasm supported 34 species during the year, equaling Vasey's Paradise. Such diversity is not unusual due to the variety of habitats available. In the area sampled, the stream consists of alternating pools and sloping waterfalls providing a range of current regimes. Further, the large standing crop of *Chara* sp. in the open pools and moss mats serve as additional substrates. Unlike previous sites, *Cladophora glomerata* not only dominates the confluence area, but was common in the waterfalls, although it was never a dominant there.

Probably due to temperature variation, only three species occurred consistently. Along with *C. glomerata*, *Mougeotia* spp. and *Oedogonium* spp. were common, but not dominant. Rather, seasonal dominants were the rule for the system. No particular dominant was present during spring with the exception of *Oscillatoria rubescens* forming mats on rocks in pools. Summer diversity dropped sharply and again no one species was dominant. The fall flora increased markedly, with several dominants emerging, e.g. *Mougeotia* spp., *Rhizoclonium hookeri*, *R. fontanum*, *Vaucheria sessilis*, and *Scytonema rivulare*.

Tapeats Creek (mi 135.0)

Tapeats Creek, another major north rim drainage, supported a very diverse algal flora of 30 species, and unlike the majority of other sites, demonstrated a highly stable species composition throughout the year, with seven species common during each sampling period (Tables 1-3). *Cladophora glomerata* remained dominant in the confluence area, as did *Spirogyra* spp. in the upstream portion under slow to moderate current. *Microspora pachyderma* was common in the spring and summer and became dominant in the fall, while *Nostoc verrucosum* remained common during all seasons. Other species consistently present were *Oedogonium* spp., *Lyngbya aerugino-caerulea* and *Oscillatoria amoena*. Only one species, *Oscillatoria subbrevis* tended to be a seasonal form, occurring only in the spring and fall. The lack of seasonal forms is most likely due to the relatively minor change in temperature (Table 4) and flow patterns. Even though this system is highly stable, in each sampling period, species were present that are unique to a given period (Tables 1-3). Further, the stability observed presents the creek as a system in which shifts in species composition could readily be detected.

Deer Creek (mi 136.0)

Deer Creek supports a flora markedly similar to Tapeats Creek. Of the 28 species collected in Deer Creek, 16 are common to both. Further, of the 121 total species in the Grand Canyon system, 45 occur in these two tributaries. Cladophora glomerata again dominated the confluence area, and was also found as a dominant in the spray zone of waterfalls. Spirogyra spp. and Microspora pachyderma, although present during all periods were dominant only during the summer and spring respectively while Oedogonium spp. was common throughout (Tables 1-3). Its individual character was manifested during the fall, when it was dominated by Trentapholia aurea covering the rocks in the spray zone of the waterfalls, and Ulothrix tenerrima and Vaucheria sp., forming a mat in the plunge pool of the falls. As one would expect, there was only minor variation in temperature (Table 4) and flow rates appeared essentially constant. Although species composition is not as highly stable as Tapeats, major shifts in composition could likewise be detected by monitoring dominant and common periphyton communities.

Kanab Creek (mi 143.5)

The flora supported in this north rim drainage is quite small, totalling only 10 species for the study period (Tables 1-3). Other than Cladophora glomerata, at the confluence, no species occurred in more than one season. Oedogonium spp. and Oscillatoria amphibia were present in the summer and fall, but were only moderately common. With the highly variable seasonal temperatures (Table 4), the unstable species composition is not unexpected, however, the depauperate flora is not readily explained by this feature. Due to the large load frequently carried and sediment deposited at the mouth, turbidity is a possible factor inhibiting periphyton populations.

Havasu Creek (mi 157.0)

Havasu Creek is significant as a major tributary due to its heavy use as a recreational area and also because of the presence of permanent habitations along portions of its course. The algal flora of the stream is among the most diverse, totaling 31 species. However, as is most often the case, populations vary markedly between seasons (Tables 1-3). Only two species, Cladophora glomerata and Oscillatoria amphibia occur each season, and the former is the only species to be ranked as a dominant each season. C. glomerata was also found in the upstream areas during all seasons. A second species, C. fracta, was also dominant in the fall, although, it is possible, due to the high degree of variability in morphology in this genus (Prescott, 1951) that this is merely an environmental variant of C. glomerata. In view of the fact that the genus Cladophora is a good indicator of hard water and high pH (Prescott, 1951), one would expect to find a predominance of this genus in the $CaCO_3$ rich water of this stream.

Variation in water temperature (Table 4) and flow rate are again conspicuous as major contributing factors in the observed seasonal shift in periphyton species. During the fall, two species known to tolerate organic pollution (Palmer, 1969) were collected, e.g. Oscillatoria limosa and Oscillatoria tenuis. Although quantification of cells is necessary to indicate the existence of organic input, the mere presence of these two pollution tolerant species points to the possibility of organic influence.

Diamond Creek (mi 225.0)

Situated at river mile 225, this drainage from the south rim was the last sampling area. Its 17 total species is below average but demonstrated a high degree of variation between seasons. Only Cladophora glomerata, again restricted to the confluence, was present during all seasons. Number of species was greatest during the spring and decreased into the fall to a low of three. During the spring, two species known to tolerate organic pollution (Palmer, 1969) were collected, e.g. Pediastrum boryanum and Oscillatoria limosa. Because their numbers were not quantified, it is not possible to say they are present due to organic pollution, however, their presence points to the possibility of organic input and a means to monitor it. Water temperature (Table 4) demonstrated the greatest amount of change, reaching a summer high of 30 ^{o}C. This in combination with variable flow and the heavy auto traffic in parts of the stream bed are likely to be responsible for the seasonal shifts. It is interesting to note that a species of red algae, Batrachospermum sp. was collected in stream drift during the spring period. As this genus prefers cool, flowing water and shaded conditions, the upstream reaches of this tributary must be vastly different from the somewhat impacted area sampled.

Table 1. Relative abundance and per cent occurrence for spring (April-May) algal periphyton species excluding diatoms in the Colorado River and selected tributaries of the Grand Canyon. (Relative abundance ranking: 4 = dominant, 3 = common, 2 = present, 1 = rare).

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
CHLOROPHYTA													
Chlorococcum sp.				1									8.3
Cladophora glomerata	4	4	4	4	4	4	4	4	4	4	4	4	100.0
Cosmarium spp.			1								1		16.6
Cylindrocapsa sp.		1											8.3
Gongrosira lacustris									3				8.3
Microspora loefrgenii					2								8.3
Microspora pachyderma								3	4				16.6
Mougeotia spp.		2	2				3	2	1				41.6
Oedogonium spp.					2		3	2	1				33.3
Oocystis crassa		3											8.3
Pediastrum boryanum			1									2	16.6
Pediastrum integrum					1							2	16.6
Pediastrum integrum var. *scutum*												1	8.3
Rhizoclonium hieroglyphicum						2							8.3
Rhizoclonium hookeri												2	8.3
Spirogyra spp.		3	2				2	4	2		3	3	58.3

Table 1. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
Stigeoclonium pachydermum		1	2				3						25.0
Tetraspora cylindrica							2						8.3
Tetraspora sp.												3	8.3
Trentepholia aurea								2					8.3
Ulothrix aequalis			2				2	3					25.0
Ulothrix tenerrima			2				2						16.6
Ulothrix variabilis		3											8.3
Ulothrix zonata			2				2	3					25.0
Zygnema spp.									3				8.3
CYANOPHYTA													
Anabaena oscillarioides												1	8.3
Chamaesiphon sp.			2										8.3
Katagnymene pelagica		1								1			16.6
Lyngbya aerugineo-caerulea		1			1			2	2				33.3
Lyngbya aestuarii						2							8.3
Lyngbya allorgei						2							8.3
Lyngbya cryptovaginata			1										8.3
Lyngbya digueti						1			1				16.6

Table 1. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
Lyngbya hieronymussii			1										8.3
Lyngbya martensiana			1										8.3
Lyngbya spp.						2			1				16.6
Merismopedia glauca							1	1			1		25.0
Microchaete elongata					2								8.3
Nostoc hatei			3			3							16.6
Nostoc punctiforme		4											8.3
Nostoc verrucosum					4			3					16.6
Oscillatoria acuminata							1						8.3
Oscillatoria agardhii								1					8.3
Oscillatoria amoena		4						2	1				25.0
Oscillatoria amphibia											1		8.3
Oscillatoria amphigranulata									2		2		16.6
Oscillatoria chalybea							1						8.3
Oscillatoria cortiana									1				8.3
Oscillatoria foreaiu					1	2			1				25.0
Oscillatoria jasorvensis					3	2	2		1		1		41.6
Oscillatoria lemmermannii		1											8.3

Table 1. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
Oscillatoria limnetica							2				2		16.6
Oscillatoria limosa												1	8.3
Oscillatoria mougeotii					1								8.3
Oscillatoria nigro-viridis							1						8.3
Oscillatoria obscura						2			1				16.6
Oscillatoria okeni											1		8.3
Oscillatoria proteus						1			1				16.6
Oscillatoria schultzii						1		1					16.6
Oscillatoria simplicissima	2		2			2	4	2			3		50.0
Oscillatoria subbrevis		2			2	2		2	2		3	1	58.3
Oscillatoria tenuis var. *tergestina*									1			1	16.6
Oscillatoria spp.							1			1			16.6
Phormidium ambiguum		4											8.3
Phormidium anomala		1											8.3
Phormidium retzii									1				8.3
Scytonema alatum		2	3										16.6
Scytonema rivulare		2											8.3

Table 1. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
Spirulina labyrinthiformis				1	1								16.6
Stigonema hormoides			3										8.3
Symploca sp.									1				8.3
RHODOPHYTA													
Batrachospermum sp.												1	8.3
XANTHOPHYTA													
Vaucheria geminata												2	8.3
Vaucheria sessilis		4											8.3
Vaucheria sp.									3				8.3

Table 2. Relative abundance and per cent occurrence for summer (July-August) algal periphyton species excluding diatoms of the Colorado River and selected tributaries in the Grand Canyon. (Relative abundance ranking: 4 = dominant, 3 = common, 2 = present, 1 = rare.

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
CHLOROPHYTA													
Chlorococcum sp.													
Cladophora glomerata	4	4	4	4	4	4	4	4	4	4	4	4	100.0
Closterium acerosum													
var. elongatum					1								8.3
Closterium spp.									1				8.3
Cosmarium spp.			2										8.3
Gongrosira lacustris									3		2		16.6
Microspora pachyderma								3	3				16.6
Mougeotia spp.		3	3				3		1	2		1	50.0
Oedogonium spp.			3		4	2	3	2	1	2		2	66.6
Oocystis elliptica			2										8.3
Oocystis solitaria							2				2		16.6
Pediastrum boryanum			1										8.3
Spirogyra spp.								4	3				16.6
Stigeoclonium													
pachydermum							1						8.5
Ulothrix subtilissima	3	1											16.6
Ulothrix tenuissima						1							8.3

Table 2. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
Ulothrix zonata		3											8.3
Zygnema spp.									3				8.3
CYANOPHYTA													
Aphanocapsa musicola			2										8.3
Aphanocapsa sp.		1											8.3
Chroococcus minor		2											8.3
Chroococcus turgidus		2	3										16.6
Gloeothece sp.			4										8.3
Gloeotrichia intermedia		1	4										16.6
Lyngbya aerugino-caerulea		2						2					16.6
Lyngbya allegorei						2							8.3
Lyngbya cryptovaginata										1			8.3
Lyngbya digueti									1				8.3
Lyngbya nordgardhii			3					2					16.6
Lyngbya perelegans		4	4					2			2		33.3

Table 2. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
Lyngbya stagnina			1										8.3
Lyngbya spp.			1								1		16.6
Merismopedia punctata			3										8.3
Microchaete elongata					2								8.3
Nostoc hatei			2			3							16.6
Nostoc verrucosum					4			3					16.6
Oscillatoria amoena								2	1				16.6
Oscillatoria amphibia										2	3		16.1
Oscillatoria amphigranulata			2	3					1			2	33.3
Oscillatoria angusta												2	8.5
Oscillatoria angustissima								1					8.3
Oscillatoria claricentrosa												1	8.3
Oscillatoria foreaiu								3			1		16.6
Oscillatoria fremyii							1						8.3
Oscillatoria jasorvensis			1		3								16.6

Table 2. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
Oscillatoria limnetica		3	2				2	1	1		2	2	58.3
Oscillatoria limosa		1											8.3
Oscillatoria obscura		1						1	2		1		3.3
Oscillatoria pseudogeminata			1										8.3
Oscillatoria proteus						1							8.3
Oscillatoria quadripunctulata	1		2										16.6
Oscillatoria rubescens													8.3
Oscillatoria tanganyikae	3							2					16.6
Oscillatoria tenuis	3												8.3
Oscillatoria tenuis var. tergestina	3												8.3
Oscillatoria spp.					4			1			1		25.0
Phormidium corium var. constrictum			1										8.3
Phormidium dimorphum							1						8.5
Phormidium mucosum											1		8.3

Table 2. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
Phormidium retzii								1					8.3
Phormidium tenue											3		8.3
Scytonema alatum		2	4										16.6
Scytonema rivulare		2											8.3
Spirulina subtillissima			1										8.3
XANTHOPHYTA													
Vaucheria spp.		4				4							16.6

Table 3. Relative abundance and per cent occurrence for fall (November) algal periphyton species excluding diatoms in the Colorado River and selected tributaries of the Grand Canyon. (Relative abundance ranking: 4 = dominant, 3 = common, 2 = present, 1 = rare.

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
CHLOROPHYTA												
Cladophora fracta						1				4		18.2
Cladophora glomerata	4	4	4	4	4	4	4	4	4	4	4	100.0
Closterium acerosum var. elongatum				1								9.1
Closterium spp.		1			1			2		3		36.4
Cosmarium spp.		1				1			1	4		36.4
Gongrosira lacustris						3						9.1
Microspora pachyderma							4	3				18.2
Microspora sp.					1							9.1
Mougeotia spp.				2	1	4				2	1	45.5
Oedogonium spp.		4	2	4		4	2	4	2	3	2	81.8
Oocystis solitaria						1						9.1
Pediastrum boryanum				1								9.1
Pediastrum integrum				1								9.1
Rhizoclonium fontanum						3						9.1
Rhizoclonium hookeri						4						9.1
Spirogyra spp.		3	2	1		3	4	3		3		63.6
Stigeoclonium pachydermum			3	1								18.2

Table 3. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
Tetraspora cylindrica				1								9.1
Trentepholia aurea								4				9.1
Ulothrix tenerrima								4				9.1
Ulothrix zonata	3					1	2					27.3
CYANOPHYTA												
Anabaena spp.		1										9.1
Chamaesiphon sp.			1									9.1
Chroococcus minor										1		9.1
Chroococcus minutus						1						9.1
Chroococcus turgidus						2						9.1
Gloeotrichia intermedia										4		9.1
Katagnymene pelagica							1					9.1
Lyngbya aerugineo-cærulea					1		1	2	3	1		45.5
Lyngbya epiphytica						3						9.1
Lyngbya limnetica				1								9.1
Lyngbya martensiana		1										9.1
Lyngbya versicolor					3							9.1
Lyngbya spp.	1				4							18.2

Table 3. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
Merismopedia punctata										1		9.1
Nostoc hatei						3						9.1
Nostoc verrucosum				4		3	3					27.3
Oscillatoria agardhii		1										9.1
Oscillatoria amoena					2		1					18.2
Oscillatoria amphibia		3			2		1		3	1		45.5
Oscillatoria hamelii					1							9.1
Oscillatoria jasorvensis							1	1				18.2
Oscillatoria limnetica				1	1				1	1		36.4
Oscillatoria limosa			3				1			1		27.3
Oscillatoria obscura				1	1	1	1	3				45.5
Oscillatoria okeni						1						9.1
Oscillatoria Pseudogeminata										1		9.1
Oscillatoria quadripunctulata		2		1	3		2			4		45.5
Oscillatoria rubescens			3	4		3	2	2				45.5
Oscillatoria splendida										1		9.1

Table 3. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)	% Occurrence
Oscillatoria subbrevis		2		2	1		3					36.4
Scytonema alatum		2										9.1
Scytonema rivulare		2				4						18.2
XANTHOPHYTA												
Vaucheria spp.						4		4		3		27.3

Table 4. Seasonal (1975) temperatures (^{o}C) in the Colorado River and major tributaries in Grand Canyon National Park and vicinity. NS = Not sampled.

	Spring	Summer	Fall
	22 April	7 July	17 November
Colorado River	6.5	10.0	11.0
Paria River (mi 0.3)	11.0	NS	12.5
	23 April	8 July	18 November
Colorado River	9.3	10.0	10.0
Vasey's Paradise (mi 32.0)	16.8	17.0	15.0
	24 April	9 July	18 November
Colorado River	10.0	10.0	10.0
Buck Farm (mi 41.0)	NS	26.0	NS
	26 April	10 July	18 November
Colorado River	10.0	10.0	NS
Little Colorado (mi 61.5)	14.0	26.8	14.9
	28 April	12 July	19 November
Colorado River	10.5	NS	10.2
Bright Angel (mi 87.5)	13.0	17.0	10.0
	29 April	12 July	20 November
Colorado River	11.0	NS	10.5
Shinumo Creek (mi 108.5)	9.0	25.0	8.9
	29 April	15 July	20 November
Colorado River	11.0	12.0	10.8
Elves Chasm (mi 116.5)	13.0	21.0	10.0
	30 April	16 August	21 November
Colorado River	11.0	11.0	11.2
Tapeats Creek (mi 134.0)	13.0	18.0	12.0

Table 4. (Continued)

	Spring	Summer	Fall
	30 April	17 August	21 November
Colorado River	11.0	12.0	10.2
Deer Creek	14.0	17.0	14.0
(mi 136.0)			
	1 May	17 August	22 November
Colorado River	11.0	NS	NS
Kanab Creek	14.5	26.0	6.5
(mi 143.5)			
	2 May	17 August	22 November
Colorado River	11.0	12.0	NS
Havasu Creek	15.0	23.0	13.0
(mi 157.0)			
	5 May	21 August	23 November
Colorado River	11.0	NS	NS
Diamond Creek	17.0	30.0	12.0
(mi 225.0)			

Table 5. Seasonal per cent occurrences of the most common alga taxa, excluding diatoms, and their preferred substrates in Grand Canyon National Park and vicinity.

Species	Substrate	Per Cent Occurrence Sp	S	F
CHLOROPHYTA				
Cladophora glomerata	rock, slow to moderate current	100* 25.0+	100* 25.0+	100* 25.0+
Closterium spp.	planktonic and benthic in pools	0.0	8.5	36.4
Cosmarium spp.	planktonic and benthic in pools	16.6	8.5	36.4
Mougeotia spp.	rock, Cladophora glomerata, floating mats	41.6	50.0	45.5
Oedogonium spp.	wood, vegetation, Cladophora glomerata	33.0	66.0	81.8
Spirogyra spp.	rock, Cladophora glomerata, pools	58.3	16.6	63.6
CYANOPHYTA				
Lyngbya aerugino-caerulea	rock, Cladophora glomerata	33.0	16.6	45.5
Lyngbya perelegans	rock, Cladophora glomerata, mats	0.0	33.0	63.6
Oscillatoria amphibia	rock, slow current	8.5	16.6	45.5
Oscillatoria amphigranulata	tychoplanktonic in pools	16.6	33.0	0.0
Oscillatoria jasorvensis	rock, benthic	41.6	16.6	18.2
Oscillatoria limnetica	tychoplanktonic in pools	16.6	58.3	36.4

Table 5. (Continued)

Species	Substrate	Per Cent Occurrence		
		Sp	S	F
Oscillatoria obscura	rock, slow to moderate current	16.6	33.0	45.5
Oscillatoria quadripunctulata	rock, Cladophora glomerata, benthic, vegetation	0.0	16.6	45.5
Oscillatoria rubescens	rock, floating mats	50.0	8.5	45.5
Oscillatoria subbrevis	Cladophora glomerata, rock	58.3	0.0	36.4

* Confluence with Colorado River

+ Tributary bed remote from confluence

B. Periphytic Diatoms

A total of 224 taxa representing 42 genera of diatoms were observed in this study. Of the total, 96 taxa were previously unreported from Arizona, eight are tentatively considered as new species, and four tentatively considered as new varieties (Appendix Table I.). Considering that only a maximum of 200 specimens were observed from each of 129 samples of an area the magnitude (size of drainage area and diversity of habitats) of the Grand Canyon, the total number of taxa undoubtedly reflects only a partial list although probably inclusive of the common taxa. However, this large number of taxa (although underestimated) reflects an extremely diverse system and hence one which may be considered young and relatively oligotrophic (Rawson, 1956) unlike terrestrial systems where diversity reflects maturity (= eutrophic ?).

Although relative in approach, the use of system important taxa and site important taxa seems warranted for comparisons on such a large scale. Taxa with high site importance values (and low system importance values) can generally be considered good indicators of specific sites and habitat types. Taxa with high system importance values (and low site importance values) can generally be considered as having a wide range of ecological tolerances. Taxa with both high site and system importance values can be considered as characterizing the system.

In comparing the Grand Canyon system with lower Lake Powell, it becomes apparent that the major taxa from each system are quite dissimilar. (For general comparison, see Tables 6-9, after Czarnecki and Blinn, unpublished). Although not substantiated with sufficient studies,it would seem that the major difference between the two systems is current since (conceivably) the majority of water (and hence water quality) flowing through the Grand Canyon originates in Lake Powell.

One of the most obvious features of the entire Grand Canyon is high alkalinity. Coupled with varying degrees of high conductivity, this alkalinity probably is the next most single important factor determining microflora composition in the canyon system. The lower Lake Powell system is quite similar in this respect, in fact, this high conductivity-alkalinity restriction is the single most important factor for Lake Powell. Again, referring to Tables 6-9, it is evident that the Lake Powell system is dominated by taxa (notably _N. silicificata_, _N. communis_, _D. elegans_, _N. amphibia_, and _Mastogloia_) which are literally high conductivity-alkalinity indicators. While these taxa are also present in the canyon system (Appendix Table II), they are usually not in positions of system dominance, although they commonly appear as site dominant taxa (Tables 11-13).

In contrast to the Lake Powell system, the Grand Canyon is dominated by typically rheophilic (associated with current) taxa, notably Diatoma vulgare, Cocconeis pediculus (conspicuously absent from the Powell system), and Rhoicosphenia curvata (Table 17). These taxa are encountered routinely in stream and river samples of Northern Arizona (Czarnecki and Blinn, unpublished). There appears to be a gradual decline in importance values for these taxa as river distance increases. This is probably due to an increase in suspended materials which, either by abrasion or effect on light penetration, favor the replacement of these important taxa by others more capable of withstanding these effects. However, this decline does not effectively detract from the overall importance and hence characteristic nature of these taxa.

On a seasonal basis there seems to be a fluctuation in both site and system important taxa (Tables 11-13; 18-20). A probable explanation for this phenomenon is a spring period dilution due to runoff (decreasing conductivity) followed by a high temperature-evaporation increase in conductivity, increase in macrophytic substrate, and increase in organic load from recreational activity during the summer. During the fall, as macrophytic growth diminishes (and decomposes) and higher inflow resumes, conductivity is again depressed and dissolved organics increase. Seasonal fluctuations for all taxa along with environmental requirements are listed in Appendix Table II.

In general, the following statements can be made concerning the Grand Canyon system: (1) diatom diversity in this system indicates a relatively unspoiled, young environment; (2) although decidedly effected by Lake Powell, diatom taxa are markedly different than those of the Lake; (3) seasonal variation occurs throughout the system although important taxa are never completely eliminated.

Since little data is available on the ecology and taxonomy of diatoms (in the Southwest in general), it is strongly urged that ecological monitoring and taxonomic surveys be continued in an effort to realize the full recreational and biological importance and potential of the canyon, establish reliable baseline data, and predict impact preventing destruction of this unique system.

Paria River (mi 0.3)

Diversity during the spring period was low (nine taxa observed from a single mixed sample). Diatoma vulgare and D. vulgare var. breve accounted for over fifty per cent of the observed specimens. Other taxa encountered with relatively high values were

Cocconeis pediculus, Rhoicosphenia curvata, Navicula tripunctata, and Melosira varians. During this period the Paria system compares well in terms of the overall dominant system important taxa (Table 17) and spring dominant system important taxa (Table 18).

Diversity increased greatly during the summer period (twenty-six taxa observed from a single mixed sample). Again D. vulgare accounted for nearly half of the observed specimens and R. curvata had a high relative abundance value. Many attached forms belonging to the genera Cymbella, Amphora, and Achnanthes and the highly social Bacillaria paradoxa seem to indicate an increase in macrophytic substrates thereby resulting in a higher diversity.

During the fall period, two samples were obtained: the first from a psammon habitat and the second a composite. The psammon community (twelve observed taxa) consisted of over ninety per cent Achnanthes minutissima. The composite sample again had a high diversity (twenty-nine taxa) with Caloneis bacillum, Gomphonema parvulum, and Nitzschia frustulum accounting for over half of the observed specimens, seemingly indicating a higher amount of organic load.

In general, the Paria River system exhibits a seasonal diversity change in diatoms from low during the spring to high during the summer and fall periods. This change is probably attributable to higher macrophytic growth during the summer period and subsequent decomposition during the fall. Total system importance similarity with the Paria River is only 37.3% (Table 24) thereby reflecting relatively little significant input to the diatom flora of the Colorado River.

Vasey's Paradise (mi 32.0)

Six samples were taken during the spring period (mixed pool yielding 32 taxa, epilithic yielding 27 taxa, epiphytic on moss yielding 23 taxa, epipelic yielding 21 taxa, a moss seep yielding 15 taxa, and neuston yielding 13 taxa) contributing a total of 56 taxa, over one-fourth the total encountered during this period.

The pool was dominated by Navicula arvenensis, a warm water form, Achnanthes affinis, a high oxygen indicator, and A. microcephala, also a good oxygen indicator. The remaining taxa were represented by primarily epiphytic forms. The epilithic sample contained large numbers of A. affinis and Melosira varians, a common alkaliphilous form. Also important were Gomphonema parvulum and Amphora ovalis var. pediculus. Together these four taxa represented over half of the observed specimens while only about one-seventh of the observed taxa. The moss epiphytes were dominated again by N. arvenensis, A. affinis, and A. microcephala. Interestingly, Epithemia sorex, usually associated with moss in flowing water (Czarnecki and Blinn, unpublished) was absent.

The epipelic community was dominated by M. varians, A. affinis, and Nitzschia linearis, also a good oxygen indicator. The moss seep was composed of over 60% E. sorex. This is a very typical component of moss seeps throughout Northern Arizona (Czarnecki and Blinn, unpublished). The neuston community contained primarily Rhoicosphenia curvata, Diatoma vulgare, and Cocconeis pediculus, all of which are among the top six overall system important taxa (Table 17) and among the top four spring system important taxa (Table 18). Generally speaking, Vasey's Paradise contributed greatly to the taxa of the Colorado River during this period.

During the summer period, three samples were taken (a seep yielding 25 taxa, an epilithic (moist rocks in spray zone) yielding 27 taxa, and a composite with 20 taxa), again primarily a highly diverse system. The seep was dominated by Rhopalodia gibba, R. gibberula var. vanheurckii, D. vulgare, and E. turgida (these four comprising over 70% of the total). With the exception of R. gibberula var. vanheurckii, these taxa were among the top 19 in terms of summer system importance (Table 19). Epithemia sorex was also present, but in reduced numbers. The epilithic community was extremely diverse with only one taxon, Achnanthes linearis, representing more than 10% of the total observed. One notable taxon present, Denticula rainerensis, is known to require extremely high conductivity and temperature (Soverign, 1963), represented 8% of the total. This community apparently undergoes high evaporation and therefore a localized increase in conductivity.

The composite sample was taken from both pool and riffle areas and was composed primarily of Gomphonema parvulum, A. linearis, and A. microcephala. These three taxa accounted for over 65% of the total. Generally speaking, the seep community probably had the greatest impact of the three sites sampled not only in terms of the taxa present, but also in terms of flow into the Colorado River. This is reflected in the 60% similarity with the summer system important taxa (Table 22).

The fall period was represented by four samples (pool with 14 taxa, submerged moss yielding 18 taxa, epilithic yielding 25 taxa, and an epilithic-epiphytic sample yielding 25 taxa) again containing a diverse diatom flora. The pool was dominated by Synedra socia and Gomphonema olivaceum (combined representing over 65%) neither of which were important seasonally or overall as system important taxa but were in the top 14 fall site important taxa (Table 13).

The submerged moss community consisted primarily of Achnanthes linearis f. curta (over 25%), G. parvulum, Nitzschia frustulum, and Caloneis bacillum (each 10% or more). With the exception of A. linearis f. curta, a high fall site important taxon (Table 13), the other taxa were among the top 25 fall system important diatoms.

The epilithic community was dominated by A. affinis (over 25%), Navicula cryptocephala, and Cymbella affinis (both over 10%) all of which are among the top 22 overall system important taxa. The epilithic-epiphytic community was dominated by C. pediculus (20%), R. curvata (6.5%), D. vulgare (8%), Cymbella minuta (15%), and C. microcephala var. crassa (14%). All of these taxa are among the top 24 overall system important diatoms (Table 17) and except for C. minuta very important fall system taxa (Table 20). These samples resulted in a very high system similarity (over 80%) for the fall period (Table 23).

Overall, Vasey's Paradise can be considered one of the most if not the most important contributor of diatom taxa to the Colorado River. It has the highest average system similarity as well as the highest average site similarity (Table 24). It does not seem to exhibit as great a seasonal change as does the Paria River, although its highest diversity occurs during the spring period. It would therefore seem desirable to continue monitoring this system as a good general indicator of the status of water quality in the Grand Canyon.

Buck Farm (mi 41.0)

Three samples were taken from this area during the spring period (a pool epilithic yielding 18 taxa, epiphytic with 23 taxa, and seep with 13 taxa). The pool epilithic community contained over 35% A. microcephala and over 30% Navicula cryptocephala var. veneta both within the top 12 spring system important diatoms (Table 18) and top 25 overall system important taxa (Table 17). The epiphytic community consisted primarily of N. cryptocephala var. veneta (over 42%) with the remaining 22 taxa being fairly evenly distributed. The seep community was dominated by an as yet unidentified Amphora (over 40%) tentatively assigned A. adnata. Although thought to be related to A. veneta var. capitata Haw. (Dr. Charles Reimer, personal communication) we feel that this taxon is quite unique and warrants specific and not varietal status. We have previously encountered this diatom from high salt environments in Wiregrass Spring (Czarnecki and Blinn, unpublished).

Generally, although Buck Farm diatoms during this period had a 60% similarity with spring system important taxa (Table 21), this site probably contributes little to the Colorado River as the majority of similar taxa were present in low numbers.

During the summer period, four samples were collected from the area: a pool with 9 taxa; cottonwood pool yielding 10 taxa; plunge pool with 25 taxa; seep with 9 taxa. The pool was dominated by Synedra ulna (ca. 79%) normally considered an extremely important planktonic form. Other important taxa encountered in this sample were Amphora ovalis var. pediculus and Navicula pupula var. rectangularis, an indicator of high conductivity (Lowe, 1974). In the cottonwood pool over three-fourths of the observed specimens consisted of Epithemia turgida (52.5%) and R. gibba (28%), both considered almost obligate epiphytes in this area (Czarnecki and Blinn, unpublished). Both were in the top 19 summer system important taxa (Table 24), and although these taxa are obviously found in other areas of the Colorado River, the fact that this sample was from an isolated area (i.e., not in contact with the river) again indicates but a minor importance to the Colorado River proper.

The plunge pool sample contained taxa usually associated with high conductivity (none of which were represented in large numbers) notably Anoemoeoneis vitrea (12%) and Cymbella norvegica (13%). This sample area probably provides some input into the Colorado River but not to any great extent. The seep sample unexpectedly failed to contain any Amphora adnata although Denticula elegans, a taxon usually associated with water of high alkalinity and conductivity (Czarnecki and Blinn, unpublished) was the dominant (42%). Other taxa were relatively equally distributed.

No samples were collected from this area during the fall period.

In general, the Buck Farm area, although having a 60% similarity with the top 25 overall system important taxa, probably contributes very little directly to the Colorado River except possibly during periods of high runoff. This area should be considered a unique system in its own right but relatively unimportant to the rest of the Colorado River and, therefore should not be monitored further for impact on the Grand Canyon system.

Little Colorado River (mi 61.5)

No samples were taken during the spring period.

During the summer period one composite sample was taken which yielded 23 taxa. Synedra ulna was the only taxon which exceeded 10% of the total specimens observed. The remaining taxa were relatively equally distributed and indicated a system of fairly high conductivity. Notable indicators were Entomoneis alata, E. palludosa, Anoemoeoneis vitrea, Bacillaria paradoxa, and Diploneis elliptica. Summer system important taxa similarity was only 16% (Table 22) the lowest of any site for this period. Summer site important taxa similarity was also low (Table 15), those which were present, predominantly high conductivity indicators. Apparently the dilution effect of the Colorado River is enough to overcome this high conductivity inflowing system.

During the fall period, 23 taxa were encountered from a single benthic (epipelic) sample. However, this time Rhoicosphenia curvata, Cocconeis pediculus, and Diatoma vulgare accounted for over 70% of the total specimens observed. These taxa were among the top ten fall system important taxa (Table 20) and top six overall (Table 17). Although in smaller numbers, B. paradoxa, E. palludosa, and A. vitrea were still present indicating at least some residual high conductivity in the sediment.

Although no date is available from the spring period, it is apparent that the Little Colorado River is an important contributor to the flora of the Colorado River in times of higher flow, such as seen during the fall period when snow melt accounted for the reduced conductivity. During dryer periods, however, the Little Colorado is affected by a high evaporation rate resulting in a more concentrated and hence higher conductivity system which contributes rather little to the Colorado River. If monitoring of this area is to be continued, results should be evaluated cautiously and in relation to flow rate, conductivity, and suspended material.

Bright Angel Creek (mi 87.5)

During the spring period three samples were taken (psammon near the water margin yielding 13 taxa, psammon away from the margin yielding 13 taxa, and epilithic-epiphytic yielding 10 taxa). The psammon near the margin was dominated by Navicula cryptocephala var. veneta (56%) and N. secreta var. apiculata (11%). Because of this type of habitat, Bright Angel was one of the most important contributors of N. cryptocephala var. veneta to the Colorado River at this time. The psammon community sampled away from the margin exhibited a higher conductivity (as expected) and contained a large population of Cylindrotheca gracilis (31%), a very unique and interesting diatom preferring high alkalinity and conductivity. N. cryptocephala var. veneta and A. ovalis var. pediculus were also present in large numbers (19% and 14% respectively).

The epilithic-epiphytic community was composed of over 75% Epithemia sorex. Although not highly important as a spring system taxon (Table 18), it ranked 4th as a site important taxon for this period (Table 11). Generally speaking for the spring period, Bright Angel contributes significantly to the Colorado River with Navicula cryptocephala var. veneta and Epithemia sorex. Although these two taxa are the major taxa present at this site, many other spring system important taxa were present (64% similarity, Table 21), and hence Bright Angel has at least a good potential impact during this period.

One sample was collected during the summer period. This was a composite sample yielding 15 taxa. By far the dominant diatom was Cymbella affinis, an extremely common rheophilous taxon in Northern Arizona (Czarnecki and Blinn, unpublished). Comprising nearly 50% of the specimens encountered, C. affinis was a rather important summer system taxon (Table 19) as well as an overall indicator (Table 17). In addition to C. affinis, N. cryptocephala var. veneta (17%) and Nitzschia kutzingiana (10%) also have high overall importance values (Table 17). The summer period showed a lower system similarity than expected in light of the high spring similarity (Table 21) probably as a result of decreased flow into the river proper.

Three samples were collected during the fall period (slow current epilithic-epiphytic yielding 11 taxa, fast current epilithic-epiphytic with 11 taxa, and a composite yielding 17 taxa). The slow current epilithic-epiphytic community was dominated by Epithemia sorex (over 65%). Nitzschia frustulum and Diatoma vulgare var. linearis also were relatively important (14.5% and 19% respectively). This was one of the few samples that contained large amounts of D. vulgare var. linearis usually indicative of cool, flowing water (Patrick and Reimer, 1966).

The fast current epilithic-epiphytic community, although generally similar in content to the slower current sample, was dominated by N. frustulum (40%), E. sorex (29.5%), and Nitzschia dissipata (18.5%). This apparently reflects a stronger current preference by Nitzschia frustulum. All three taxa are within the top 16 overall system important diatoms (Table 17). The composite sample reflected a typical Colorado River community dominated by Rhoicosphenia curvata (49%), D. vulgare (17%), and C. pediculus (15.5%)--all in the top 6 overall system dominant taxa (Table 17).

Although Bright Angel had an overall low similarity value for system dominant taxa (53.3%) (Table 24), it is apparent that its contribution to the Colorado River in terms of specific taxa present, warrants further monitoring as an indicator of river trends.

Shinumo River (mi 108.0)

Four samples were collected during the spring period (composite with 16 taxa, epilithic with 23 taxa, epilithic-epiphytic with 19 taxa, and psammon with 13 taxa). The composite sample contained primarily Nitzschia frustulum (31%), Epithemia sorex (25%), and Cymbella affinis (12%) indicating a large amount of plant substrate (i.e., E. sorex and C. affinis are usually found attached to plant substrates). These three taxa are included in the top 19 spring system important taxa (Table 18) and top 16 overall system important diatoms (Table 17). The occurrence of Nitzschia dissipata, D. vulgare, and Navicula tripunctata in this sample indicate a high similarity with typical river microflora. The epilithic community was dominated by N. frustulum (27%) and

C. affinis (16.5%) and probably greatly influenced the composition of the mixed sample. Other important taxa found in this sample included N. tripunctata (9%), Nitzschia dissipata (5.5%) and Epithemia sorex (5.5%), again indicating a typical microflora for this system.

The epilithic-epiphytic community contained large numbers of Nitzschia frustulum(39%) and E. sorex (25%). Interestingly, Nitzschia vermicularis, an indicator of oligotrophic conditions (Lowe, 1974) represented 7% of the specimens observed. The psammon community surprisingly supported a larger growth of E. sorex (43%) and Rhopalodia gibba (23%) indicating either an abundance of plant material or their remains. During the spring period this area had the third largest similarity value (68%) (Table 21) obviously being of significant importance to the Colorado River.

Four samples were collected during the summer period (epilithic near waterfall with 14 taxa, epilithic-epiphytic in strong current with 13 taxa, a pool area with abundant vegetation yielding 10 taxa, and a composite with 15 taxa). Over 50% of the waterfall epilithics were represented by a single taxon, Nitzschia amphibia, an indicator of high alkalinity (Lowe, 1974) and probably high conductivity (Czarnecki and Blinn, unpublished). Also abundant were Achnanthes linearis var. pusilla (14%) and Rhoicosphenia curvata (9%), good current indicators. The strong current sample contained over 87% Epithemia sorex, not atypical for the more concentrated (i.e., higher conductivity) environment dominated by Cocconeis placentula var. lineata (79%). High conductivity indicators included Mastogloia elliptica var. danseii and Denticula elegans. The composite sample was dominated by Cymbella affinis (30.5%) and Gomphonema parvulum (29.5%) ranking 15th and 18th respectively in summer system important taxa. This area again ranked in the top three in system similarity for the summer period and obviously was a significant contributor of microflora.

During the fall period three samples were collected (a mossy rock with 13 taxa, epilithic with 19 taxa and a composite with 19 taxa). The mossy rock sample exhibited little diversity, containing primarily E. sorex (52.5%) and Cymbella affinis (21.5%). Nitzschia dissipata and N. frustulum were both common, each representing about 6.5% of the total specimens. Other taxa incurred minor representation. The epilithic community was slightly more diverse having Navicula cryptocephala (25%), Nitzschia dissipata (20%), Cymbella affinis (14%), and Nitzschia frustulum (13%) as the dominant taxa. The composite sample was more typical of the river proper with Diatoma vulgare (30.5%) and Cocconeis pediculus (29%), dominating. However, a somewhat higher conductivity was suggested by the presence of Cylindrotheca gracilis, Entomoneis palludosa and Anoemoeoneis vitrea. In terms of fall system importance, N. dissipata, Cocconeis pediculus, D. vulgare, N. frustulum, and C. affinis ranked 1-5 respectively. Navicula cryptocephala was (13th) and Epithemia sorex (19th), other common Shinumo taxa were also highly represented. In terms of similarity, Shinumo ranked in the top five sites with a value of 64% and overall 62.7% (in the top four sites) (Table 24).

Considering the important taxa and their numbers in the Shinumo area during all three sampling periods, further monitoring is strongly suggested as an indicator site for water quality of the Grand Canyon.

Elves Chasm (mi 116.5)

Six samples were taken during the spring period (pool with 19 taxa, moss epiphytic with 22 taxa, epiphytes on Potamogeton bercholti with 20 taxa, epilithic with 16 taxa, epilithic with large algal mat yielding 28 taxa, and mixed epilithic yielding 43 taxa). The pool sample contained large numbers of A. microcephala (55%) with other taxa being fairly equally distributed. The moss sample was dominated by C. placentula var. euglypta (26%) and A. microcephala (17%). E. sorex was conspicuously absent from this sample. The Potamogeton sample was dominated by C. pediculus (17%), A. microcephala (15%), A. linearis (12%), and Melosira varians (10%). This sample also contained a specimen of Scoliopleura peisonis, usually found only in high conductivity systems such as Great Salt Lake (Patrick and Reimer, 1966).

The epilithic community was composed primarily of Melosira varians (38%) and A. affinis (28%). The high percentage of Melosira varians was somewhat suggestive of a higher organic content, and indeed Hantzschia amphioxys and Nitzschia palea were also present in the sample although in lower numbers. The algal mat epilithics consisted primarily of C. placentula var. lineata (16%) and Navicula arvenensis (21%). Nitzschia dissipata (6%), and A. affinis (10%) were the only other taxa of major significance.

The mixed epilithic sample was the most diverse of any collected during the spring period. C. affinis and N. dissipata were the only two taxa representing 57% of the specimens. The remaining 41 taxa were fairly evenly distributed.

Although Elves Chasm had an 84% spring system similarity (Table 21), most taxa represented were in low numbers with notable exceptions being A. microcephala and Melosira varians. Biddulphia laevis, an interesting periphytic diatom restricted to waters of high conductivity was also present at this site although in relatively low numbers. It would seem that Elves Chasm probably contributes little to the Colorado River during this period but nonetheless is a quite unique system in itself based on the presence of taxa such as Scoliopleura peisonis and B. laevis.

Only one sample was collected during the summer period, a composite yielding 16 taxa. The sample was dominated by Fragilaria capucina (31.5%) and Cocconeis placentula var. euglypta (26.5%). In striking comparison to the spring period, only one high conductivity indicator was present (Denticula elegans, 4%). Summer system similarity for this area was relatively low (Table 22) as was site similarity (Table 15).

During the fall period seven samples were collected from the Elves Chasm area (pool #2 with 21 taxa, falls epilithic with 15 taxa, neuston with 9 taxa, epilithic with 11 taxa, pool composite with 25 taxa, pool #1 with 7 taxa, and standing water with 10 taxa). Pool #2 was dominated by Mastogloia smithii (30.5%), Synedra affinis (20%), Cymbella pusilla (12%), and M. smithii var. lacustris (11.5%), obviously a high conductivity system. The falls epilithic contained large amounts of Cocconeis primarily C. placentula var. euglypta (66%) and C. pediculus (22%). The neuston again contained large numbers of C. placentula var. euglyta (50%) and C. pediculus (10%) with a fair amount of Achnanthes linearis (27%). The epilithic community was dominated by M. smithii (30%), S. affinis (17%), N. kutzingiana (16%), Amphora arizonica (12%), and R. gibba (10%). The pool composite resembled both the falls epilithic and neuston communities with high amounts of C. pediculus (45%) and C. placentula var. euglyta (30.5%). B. laevis reached 4% of the specimens in this sample, a relatively high number considering the large size of this taxon. Pool #1, exhibiting very few taxa, contained over 90% A. linearis, usually considered a halophobe (Patrick and Reimer, 1966). Apparently this pool had less conductivity than the other Elves Chasm communities. The standing water sample contained taxa more typical of the Colorado River microflora with R. curvata (33.5%), Diatoma vulgare (23.5%) and C. pediculus (15.5%) dominating the system.

Like the spring period, Elves Chasm has a high fall system importance (72%) (Table 20). However during the fall period this area probably contributes greatly (C. pediculus and C. placentula var. euglypta) to the Colorado River microflora.

Overall, Elves Chasm ranks 2nd in similarity with system importance (Table 24). In terms of contribution, the fall period far outshadows both spring and summer periods. A relatively unique system exists in the Elves Chasm area and warrants further monitoring, even though its actual contribution may be seasonally minimal.

Tapeats Creek (mi 134.0)

Three samples were collected during the spring period (pool epiphytic with 28 taxa, epilithic with 30 taxa, and pool with 17 taxa). A very diverse community, the pool epiphytic was dominated by Amphora ovalis var. pediculus (12%) and Achnanthes affinis (11%) with the other 26 taxa being fairly evenly distributed. The epilithic community, also exhibiting high diversity, was composed primarily of Diatoma himale var. mesodon (12%), Nitzschia kutzingiana (13%), N. acicularis (10%), and N. frustulum (10%). The pool sample contained a large percentage of E. sorex (29%) as well as N. kutzingiana (10%) and A. affinis (9%). In terms of spring system importance similarity, Tapeats was average in comparison with the other sites (60%), however the top six taxa were not abundant at Tapeats (Tables 18 & 21).

One sample was collected from Tapeats during the summer period. This composite yielded 22 taxa strongly dominated by Diatoma vulgare (53.5%). Other taxa of medium importance were A. ovalis var. pediculus (9%), Gomphonema parvulum (4.5%), N. cryptocephala f. minuta (4.5%), and D. himale var. mesodon (4.5%). None of the taxa were indicative of high organic load or conductivity in contrast to many of the other site microflora. This is evident from comparisons in Table 19 with summer system important taxa and Table 12 with summer site important taxa.

Four samples were collected during the fall period (epilithic yielding 16 taxa, epipelic yielding 13 taxa, epiphytic yielding 20 taxa, and composite with 16 taxa). The epilithic sample was dominated by N. dissipata (34%), D. vulgare (33%) and N. frustulum (21%). These three taxa were among the top four fall system important diatoms. The epipelic community was somewhat different with N. dissipata (39.5%), Navicula tripuctata (21.5%) and N. cryptocephala var. veneta (15.5%) overshadowing the other taxa. The epiphytic community consisted primarily of Synedra socia (32%), usually preferring water of low conductivity (Patrick and Reimer, 1966), Diatoma vulgare (20%), and D. vulgare var. breve (10%). The composite sample contained a large percentage of C. pediculus (25.5%), A. ovalis var. pediculus (15.5%), R. curvata (14%) and N. cryptocephala f. minuta (11%). In general, the fall period exhibited a greater system similarity (Table 23) than any other period and probably had more impact on the Colorado River than in previous periods.

It would appear from these data that not only is Tapeats atypical during the summer period but that its greatest contribution of microflora probably occurs during the fall when most other sites tend to diminish in importance. It would therefore seem desirable to continue monitoring this area for possible system trends.

Deer Creek (mi 136.0)

Three samples were collected during the spring period (epilithic with 14 taxa, epiphytic with 18 taxa, and spray zone with 11 taxa).

The epilithic community was dominated by Cymbella minuta (34%) and Gomphonema subclavatum (16%), both common attached forms. The epiphytic community was dominated by N. tripunctata (22%), Diatoma vulgare (19%), Nitzschia dissipata (13%), and D. vulgare var. breve (12%), a more "typical" river assemblage of diatoms (Table 17). The spray zone was strongly dominated by A. linearis var. pusilla (53%) and Cymbella minuta (32%). This was the only sample encountered in which both these taxa occurred together in high proportions. During this period, Deer Creek had about average similarity for system important taxa (Table 21) and probably not much impact on the river proper.

One sample was collected during the summer period, a spray zone sample yielding 25 taxa. This sample consisted mainly of E. sorex (27.5%), D. vulgare (13%), and G. parvulum probably due to an increase in macrophytic substrates. System similarity for this period was only 52% (Table 22) but nonetheless Deer Creek probably contributed greatly to the Colorado River in light of its dominant taxa and flow.

Three samples were obtained in the fall period (neuston-epilithic yielding 30 taxa, epilithic with 19 taxa, and epiphytic with 14 taxa). The neuston-epilithic sample was dominated by N. dissipata (17.5%) and Navicula cryptocephala (12%) with other taxa being fairly evenly distributed. The epilithic community was strongly dominated by Cymbella affinis (51%), eleventh in overall system importance (Table 17). The epiphytic community was dominated by Nitzschia linearis (43.5%) and Surirella ovalis (28.5%). This was the first time in our samples that these two taxa were dominant together on plant substrates (Czarnecki and Blinn, unpublished). System importance similarity for this period was impressive (62.7%) (Table 23) and reflected primarily the importance of N. dissipata, C. affinis and N. linearis.

In terms of importance, it parallels Tapeats Creek seasonally, however its contribution of taxa is for the most part different and therefore warrants further monitoring.

Kanab Creek (mi 143.5)

During the spring period two samples were collected (epilithic yielding 21 taxa and epipelic yielding 38 taxa). The epilithic community was strongly dominated by N. dissipata (33.5%) and N. cryptocephala var. veneta (25%). Other taxa were fairly evenly distributed. One notable taxon, Coscinodiscus denarius, observed in this sample, is usually indicative of high conductivity. However, because of its relative frequency (a single specimen in 200) it remains academic as to the significance of its occurrence. The epipelic sample contained high percentages of N. dissipata (37.5%) and Surirella ovata (25%), both good indicators of flowing water and high oxygen concentrations (Lowe, 1974). Although this area has a fairly high spring system importance similarity (Table 21), it is apparent that only N. dissipata and N. cryptocephala var. veneta are of major significance to the river proper.

Only one sample was collected from the area during the summer period. This composite yielded 27 taxa of which only three were of major significance (Synedra ulna (26%), Fragilaria vaucheriae (25%), and Nitzschia kutzingiana (12.5%). It is interesting that such a highly diverse sample compares so poorly (only 40%) in similarity with system important taxa for this period (Table 22).

Two samples were collected during the fall period (benthic yielding 26 taxa and epilithic yielding 19 taxa). The benthic sample was dominated by Navicula silicificata (45%), a tentatively named taxon found in areas of high conductivity and alkalinity above and below Glen Canyon Dam (Czarnecki and Blinn, unpublished), Nitzschia palea (10%), Navicula tripunctata var. schizonemoides (10%), and Nitzschia sigma (9%). These taxa all tend to be found in areas of high concentrations of organics. The epilithic community was dominated by Achnanthes minutissima (32%), Cymbella microcephala var. crassa (16.5%), and N. cryptocephala f. minuta (13%). In terms of system importance during this period, Kanab, although having a respectable 45.4% similarity (Table 23) probably was of little significance as a contributing system.

Although having a highly diverse microflora during each of the three periods, the contributory significance of this system is very low and therefore it would seem unreasonable to continue monitoring this area as a possible indicator of Colorado River trends.

Havasu (mi 157.0)

Two samples were collected during the spring period (rock pool with 11 taxa and epilithic with 14 taxa). The rock pool was dominated by Fragilaria capucina (47%), Achnanthes affinis (16%), and Achnanthes linearis var. pusilla (10%). The epilithic community interestingly enough was dominated almost entirely by F. capucina var. mesolepta (75%) with the other taxa being relatively evenly distributed. Possibly this variety is only an ecotype of the nominate variety (rheophillic ecotype ?) since size ranges overlapped and their proximity to one another was current limited. Of the major sites sampled only Havasu contained F. capucina var. mesolepta during this period. In terms of similarity with spring system importance taxa, Havasu was eleventh (of 12) with only A. affinis playing a major role (Table 21).

One composite sample was collected during the summer period in which F. capucina was dominant (36.7%) followed by S. ulna. Interestingly diatoms were extremely sparse in this sample and the entire slide yielded only thirty cells. Diversity was also low at this time and only 9 taxa were found. Again Havasu ranked eleventh in system importance similarity during this period (Table 22).

During the fall period five samples were collected (Chara pool #1 with 12 taxa, Chara pool #2 with 4 taxa, marginal pool composite with 38 taxa, benthic with 19 taxa and epilithic with 13 taxa). Chara pool #1 was dominated by Rhopalodia gibba (38%), Nitzschia apiculata (31%), and Nitzschia recta (12%). Little, if any, current is predicted at this site, based on the dominant taxa and also other taxa (Pleurosigma delicatulum and Surirella brightwelli). Chara pool #2 apparently reflected totally different ecological conditions other than substrate since D. elegans (45%) and G. subclavatum (43%) almost completely dominated the sample. The paucity of taxa at this site is probably indicative of very restrictive conditions. The marginal pool composite was one of the most diverse samples encountered during the fall period with most taxa being fairly evenly distributed. Denticula elegans (21.5%), S. ulna (14%) and N. kutzingiana (10%) represented the major taxa. The benthic community was co-dominated by Achnanthes linearis var. pusilla and C. microcephala var. crassa with 36% each, followed by A. microcephala (12.5%). Current epilithics were almost completely dominated by D. elegans (55%) and C. microcephala var. crassa (14%) indicating a fairly high conductivity at this site.

Havasu again had a low system importance similarity for this period (Table 23). Of the contributing taxa only D. elegans probably had any overall importance on the river system. Since Havasu not only had one of the lowest average system importance similarities but also a scarcity of unique taxa, it would probably be of little benefit to continue monitoring this area as indicative of river trends.

Diamond Creek (mi 225.0)

Three samples were collected during the spring period (epilithic yielding 16 taxa, psammon with 15 taxa, and current sediment with 10 taxa). All three sites exhibited microflora indicative of high conductivity. The epilithic community was dominated by Amphora veneta (32%), C. pediculus (16%), Achnanthes lanceolata (11%), and A. microcephala (21%). The psammon community contained a rather different microflora dominated by Rhoicosphenia curvata (20%) and C. pediculus (16%), but containing the unique taxon Plagiotropis lepidoptera and such high conductivity indicators as A. vitrea and B. paradoxa. The current sediment sample was dominated again by Amphora veneta (50%) and D.elegans. Interestingly, the large Biddulphia laevis comprised over 8% of the total specimens. Although having a fairly low spring system importance similarity (40%) (Table 21), it is apparent that many interesting high conductivity forms are contributing to the microflora of the river at this time.

During the summer period only one sample was collected (a composite yielding 16 taxa). This sample was much like the current-sediment sample of the previous spring being dominated by A. veneta (39%), D. elegans (27%), and containing 8% B. laevis. Again, although having a low summer system importance similarity (24%) (Table 22), it seemed that this area contributed greatly to the high conductivity microflora of the river.

During the fall period, two samples were collected (fast current epilithics with 16 taxa, and moderate current epilithics with 19 taxa). The fast current was dominated by S. ulna (30%) and B. laevis (30%) and in general again was indicative of fairly high conductivity. The moderate current epilithics contained many of the same taxa but were dominated almost entirely by A. veneta (61%). We have observed A. veneta as highly epiphytic on B. laevis during culturing attempts--possibly the reason for high dominance in the absence of a scouring current.

Overall, Diamond ranked eleventh in system importance similarity (Table 24). However, the high conductivity microflora and its probable impact in downstream areas indicates a need for future monitoring of this area.

Twenty-one additional locations were periodically sampled (e.g. one or two seasons) during the study period in an effort to gain a working familiarity with the diatom taxa of the canyon system. These sites are discussed in detail below in order of their occurrence along the Colorado River system.

Lee's Ferry (mi 0.0)

A composite spring sample (containing 10 taxa) was dominated by two common and important Colorado River taxa, Diatoma vulgare (50%) and Rhoicosphenia curvata (22.4%). Achnanthes flexella present in low numbers (1%) was reminiscent of Lake Powell taxa (Czarnecki and Blinn, unpublished) and probably its presence is due to the proximity of the lake environment. Diatoma vulgare completely dominated the one summer sample (14 taxa) taken from this location, representing over 80% of the observed specimens. Only two other taxa represented more than 2%, Synedra socia (8.5%) and Rhoicosphenia curvata (3.5%). Diatoma vulgare was the number one system important taxon (Table 17) and obviously was important in the upper areas of the Grand Canyon.

Mile 5.0

A composite sample yielding 11 taxa was taken at this site. Once more Diatoma vulgare was the dominant taxon (63.3%) distantly followed by Nitzschia dissipita (11.5%). Interestingly, Asterionella formosa (1%) a very common Lake Powell phytoplankter was found at this site.

Mile 18.0

A composite sample was taken during the summer yielding 8 taxa of which Diatoma vulgare represented 92%. Rhoicosphenia curvata (4%) and Cocconeis pediculus (1.5%) were the only other taxa representing more than 1% of the total specimens. Again, Diatoma vulgare was greatly represented.

Mile 19.0

Two spring samples were collected from this area (psammon yielding 10 taxa and epilithic with 13 taxa). The psammon community was quite typical with Rhoicosphenia curvata (33.5%), Diatoma vulgare (31.5%) and Cocconeis pediculus (19%) dominating the sample. These three taxa were among the top 6 overall system important taxa (Table 17). The other taxa which were represented were present in much smaller percentages although for the most part they were also in the top 25 system important taxa (Table 17). The epilithic community was also fairly typical of the river microflora, Diatoma vulgare (48%), Navicula tripunctata (13%), Cocconeis pediculus (11%), and Rhoicosphenia curvata (9%) typified this community.

Mile 29.8

Two spring samples were collected from this area (seep with 13 taxa and pool with 10 taxa). The seep sample by virtue of the taxa present apparently is a high conductivity system. Nitzschia scalpelliforma (33%) (tentative nomenclatural assignment to a unique diatom found previously in lower Lake Powell under high conductivity (Czarnecki and Blinn, unpublished), Navicula mutica (17%), Synedra ulna (17%), and Nitzschia dissipata (12%) were the dominants at this site. The pool sample was again typical of river microflora Rhoicosphenia curvata (28%) and Diatoma vulgare (43%) tending to overshadow the other taxa.

Nautiloid (mi 36.0)

Two summer samples were collected from this area (composite with 19 taxa and seep with 2 taxa). The composite sample was more typical of the river system with Diatoma vulgare again making up 58%. With the exception of Amphora ovalis (10%0, all the other taxa represented 6% or less. The seep sample was quite unique in that only two taxa were represented, (Rhopalodia gibba (61%) and Epithemia argus var. longicornis (39%), a taxon requiring high conductivity (Patrick and Reimer, 1975) and apparently able to outcompete other diatoms in this area.

Shower Stall Seep (mi 35.5)

One spring sample was collected from this area during the spring period yielding 24 taxa. Although a fairly diverse system, only three taxa were of significant percentage: Diatoma vulgare (10%), Cymbella microcephala var. crassa (10%) and Cocconeis pediculus (9.5%). These are of major importance to the Colorado River. Other interesting taxa usually associated with high conductivity that were found in the sample included Denticula rainierensis (1.5%) and Amphipleura pellucida (7.5%).

Mile 48.9

One spring sample of epiphytes was taken at this location yielding 14 taxa, Rhoicosphenia curvata (47%) and Cocconeis pediculus (19%), typically found associated with Cladophora glomerata in the Colorado River system proper.

Nankoweap (mi 52.5)

One epilithic summer sample was taken from this site yielding 12 taxa. Once more Diatoma vulgare (45.5%) and Rhoicosphenia curvata (27.5%) and Cocconeis pediculus (7%) were the dominant taxa.

Chuar Creek (mi 65.5)

One composite summer sample was taken at this site yielding 14 taxa. Achnanthes microcephala (46%) and Diatoma vulgare (40%) dominated this system, again indicating the importance of Diatoma vulgare to the Colorado River.

Cardenas Creek (mi 71.0)

Three spring samples were collected from this area (epilithic with 15 taxa, epipelic with 15 taxa and psammon with 29 taxa). The epilithic community was dominated by Nitzschia amphibia (49%) and Achnanthes microcephala (13%) probably indicating a high conductivity, organically enriched community. The epipelic community was typically rheophilic with Rhoicosphenia curvata (57%) and Cocconeis pediculus (16%) tending to dominate the remaining 13 taxa. The psammon community proved to be one of the most diverse sites during the spring period. Although weakly dominated by Achnanthes microcephala (16.5%) and Rhoicosphenia curvata (15%) the remaining taxa were relatively evenly distributed and although many were within the top 25 system important taxa no one taxon exceeded 10%.

Unkar Creek (mi 72.5)

One composite summer sample was collected yielding 18 taxa. Only Epithemia adnata (27%) and Mastogloia smithii var. lacustris (20%) were present in significant numbers. The remaining taxa were somewhat indicative of high conductivity notably Mastogloia elliptica var. danseii (7%), Mastogloia smithii (3%), Denticula elegans (3%) and Anoemoeoneis vitrea (3%).

Clear Creek (mi 84.0)

One benthic-neuston sample was collected during the spring period yielding 21 taxa. Major taxa associated with this sample were common system important taxa including Cymbella affinis (23.5%), Navicula tripunctata (21.5%), Nitzschia frustulum (8.5%), Diatoma vulgare (8.5%) and Navicula cryptocephala (8.0%). Two samples were collected at this site during the summer (backwater pool with 25 taxa and composite with 20 taxa). The backwater pool was slightly dominated by Achnanthes affinis (17%), Achnanthes microcephala (12%), Achnanthes minutissima (15%), and Denticula elegans (12%). Other taxa of high conductivity preference were also present in reduced numbers. The composite sample was dominated by Synedra mazamaensis (75.5%). The remaining taxa were never represented by more than 3.5% each and were quite diverse in their ecological requirements.

Crystal Creek (mi 98.5)

Three spring samples were collected from this area (epilithic yielding 9 taxa, epiphytic with 12 taxa, and epipelic with 13 taxa). The epilithic sample was indicative of high conductivity and alkalinity based primarily on the presence of Achnanthes microcephala (43%), Denticula elegans (27%) and Mastogloia smithii var. lacustris (16%). The epiphytic sample although composed of dissimilar taxa also was indicative of high conductivity and alkalinity, being dominated by Achnanthes affinis (50%), Denticula elegans (19%) and Synedra ulna (15%). Other indicative taxa were Mastogloia smithii (1%), Mastogloia smithii var. lacustris (2%) and Anoemoeoneis vitrea (3%). The epipelic sample also contained high conductivity indicators especially Denticula elegans (35%), Mastogloia smithii var. lacustris (10%) and Synedra ulna (25%). In general, this area represents a system of high conductivity and alkalinity and probably contributes significantly to the Colorado River proper with input of Denticula elegans and Mastogloia var. lacustris. This area should be considered as a site for further monitoring. One composite current sample (yielding 12 taxa) was collected during the summer at this site. The sample was co-dominated by Denticula elegans and Achnanthes microcephala (40%). The remaining taxa were represented in fairly even percentages and were quite diverse in their ecological preferences.

Salt seep (mi 115)

One spring sample was collected at this site yielding 5 taxa, obviously indicators of high conductivity, Navicula longirostris (75%), Nitzschia communis (12%), Nitzschia amphibia (5%), Denticula elegans (5%) and Amphora perpusilla (3%) comprised the specimens in this very restricted environment.

Mile 119

A single neuston sample was collected from this area during the spring which yielded 14 taxa quite typical of the Colorado River microflora. The dominants in this sample were primarily Rhoicosphenia curvata (37.5%), Cocconeis pediculus (25%) and Diatoma vulgare (19%).

Fossil Rapids (mi 125.0)

Two samples were collected at this site during the summer period. A seep sample yielding 14 taxa contained (characteristically of high conductivity) contained as dominant taxa Mastogloia smithii (19%), Mastogloia smithii var. lacustris (16%), and Synedra ulna (25%). A plunge pool sample (yielding only 10 taxa) also reflected a high conductivity environment with Epithemia adnata (36%), Mastogloia smithii (32%) and Mastogloia elliptica var. danseii (12%) tending to dominate the sample.

Stone Creek (mi 132.0)

One summer sample was obtained which yielded 13 taxa. This composite sample was dominated by Fragilaria capucina (61%), typically a planktonic form preferring water of high conductivity (Patrick and Reimer, 1966), and Nitzschia frustulum (14%), Synedra ulna and Achnanthes linearis each represented by 6%. The remaining taxa were of diverse ecological preferences so that no statement could be made concerning the type of system at this time.

Thunder River (upstream of Tapeats Creek, ca. 134.0 mi).

A single composite sample was collected at this site which yielded 15 taxa. The most abundant taxon was Diatoma himale var. mesodon (35%) followed by Nitzschia linearis (16%). None of the remaining taxa exceeded a value of 10%. Again these taxa were of such diverse ecological preference so that no statement could be made concerning the water quality at this site.

The Ledges (mi 152.0)

Two spring samples were collected from this area (moss with 20 taxa and epilithic with 8 taxa). The moss sample apparently was representative of a fairly high conductivity system being dominated by Denticula elegans (23.5%) followed by Mastogloia smithii var. lacustris (8.5%) and Caloneis bacillaris var. thermalis (7.5%). The epilithic sample also exhibited taxa which are indicators of relatively high conductivity, notably Mastogloia smithii var. lacustris (4%) and Surirella brightwellei (15%). However, the majority of specimens were Rhopalodia gibba (61%), Synedra ulna (11%) or other taxa not necessarily indicative of high conductivity.

Pumpkin Spring (mi 212.0)

Three spring samples were collected from this area. None exhibited a high degree of diversity with the neuston having 10 taxa followed by epilithic with 5 taxa, and psammon with 4. The neuston community was predominately Navicula cryptocephala (55%), followed by Amphora adnata (15%), and Nitzschia pseudolinearis (10%). The remaining taxa were fairly evenly distributed. The epilithic community was composed of primarily three taxa: Amphora coffeiformis (48%), Navicula cryptocephala var. veneta (28%), and Pinnularia appendiculata (20%). The remaining taxa were Navicula pupula (3%) and Cylindrothece gracilis (1%). The psammon commonly consisted of Amphora adnata (44%), Navicula silicificata (39%), Nitzschia communis (16%) and Navicula pupula var. rectangularis (1%). All three sites seemed to be associated with high conductivity and alkalinity.

Table 6. Spring (1975) per cent occurrence and relative importance values (Im) for selected diatom periphyton at selected sites in lower Lake Powell. (6) = >50%; Dominant (5) = 25-50%; Abundant (4) = 10-24%; Common (3) = 5-9%; Present (2) = 1-4%; Rare (1) = <1%.

Species	% Occurrence	Total Im	$\bar{x}$ Im Sites	$\bar{x}$ Im System
Achnanthes microcephala	81.8	30	3.33	2.73
Cymbella ventricosa	81.8	24	2.67	2.18
Navicula silicificata	72.7	18	2.25	1.64
Nitzschia communis	54.5	22	3.67	2.00
Nitzschia microcephala	54.5	16	2.67	1.45
Denticula elegans	54.5	23	3.83	2.09
Nitzschia amphibia	45.5	12	2.40	1.09
Mastogloia elliptica var. danseii	45.5	19	3.90	1.72
Achnanthes sublaevis	36.4	10	2.50	0.91
Achnanthes linearis	36.4	11	2.75	1.00
Cymbella microcephala var. crassa	36.4	9	2.25	0.82
Nitzschia kutzingiana	36.4	16	4.00	1.45
Pleurosigma delicatulum	36.4	7	1.75	0.64
Mastogloia smithii	36.4	19	4.75	1.72
Rhopalodia gibberula var. vanheurckii	36.4	8	2.00	0.72
Caloneis ventricosa var. truncatula	27.3	8	2.66	0.73
Cymbella cistula	27.3	6	2.00	0.54

Table 7. Summer (1975) per cent occurrence and relative importance values (Im) for selected diatom periphyton at selected sites in lower Lake Powell. (6) = >50%; Dominant (5) = 25-50%; Abundant (4) = 10-24%; Common (3) = 5-9%; Present (2) = 1-4%; Rare (1) = <1%.

Species	% Occurrence	Total Im	$\bar{x}$ Im Sites	$\bar{x}$ Im System
Nitzschia kutzingiana	76.9	26	2.60	2.00
Nitzschia communis	69.2	22	2.44	1.69
Nitzschia fonticola	38.5	11	2.20	0.85
Navicula lanceolata	38.5	15	3.00	1.15
Cymbella pusilla	38.5	15	3.00	1.15
Nitzschia apiculata	30.8	8	2.00	0.62
Mastogloia smithii	30.8	9	2.25	0.69
Navicula denestriata	30.8	7	1.75	0.54
Navicula cuspidata	30.8	5	1.25	0.38
Navicula cryptocephala	30.8	6	1.50	0.46
Denticula elegans	30.8	11	2.75	0.85
Rhopalodia gibberula var. vanheurckii	23.1	8	2.67	0.62
Rhopalodia gibba	23.1	6	2.00	0.46
Navicula viridula	23.1	6	2.00	0.46
Navicula radiosa var. tenella	23.1	7	2.33	0.54
Mastogloia elliptica var. danseii	23.1	8	2.67	0.62

Table 8. Spring (1975) per cent occurrence and relative importance values (Im) for selected diatom periphyton at selected sites between Lee's Ferry and Diamond Creek in Grand Canyon National Park and vicinity. (6) = >50%; Dominant (5) = 25-50%; Abundant (4) = 10-24%; Common (3) = 5-9%; Present (2) = 1-4%; Rare (1) = <1%.

Species	% Occurrence	Total Im	$\bar{x}$ Im Sites	$\bar{x}$ Im System
Cocconeis pediculus	64.9	102	2.76	1.79
Navicula tripunctata	64.9	92	2.49	1.61
Diatoma vulgare	54.4	91	2.94	1.60
Nitzschia dissipata	52.6	78	2.60	1.37
Synedra ulna	45.6	62	2.38	1.08
Rhoicosphenia curvata	43.8	77	3.08	1.35
Nitzschia frustulum	40.4	58	2.52	1.02
Nitzschia linearis	36.8	52	2.48	0.91
Melosira varians	35.1	52	2.60	0.91
Cymbella microcephala var. crassa	35.1	39	1.95	0.91
Nitzschia kutzingiana	31.6	44	2.44	0.77
Frustulia vulgaris	29.8	33	1.94	0.58
Nitzschia apiculata	28.1	32	2.00	0.56
Achnanthes lanceolata	28.1	35	2.18	0.61
Achnanthes microcephala	28.1	56	3.50	0.98
Rhopalodia gibba	24.6	38	2.71	0.67
Epithemia sorex	15.8	39	4.33	0.68

Table 9. Summer (1975) per cent occurrence and relative importance values (Im) for selected diatom periphyton at selected sites between Lee's Ferry and Diamond Creek in Grand Canyon National Park and vicinity. (6) = 50%; Dominant (5) = 25-50%; Abundant (4) = 10-24%; Common (3) = 5-9%; Present (2) = 1-4%; Rare (1) = 1%.

Species	% Occurrence	Total Im	$\bar{x}$ Im Sites	$\bar{x}$ Im System
Synedra ulna	65.7	61	2.65	1.74
Diatoma vulgare	57.1	77	3.85	2.20
Cymbella microcephala var. *crassa*	57.1	38	1.90	1.09
Cocconeis pediculus	51.4	37	1.95	1.06
Navicula tripunctata	48.6	28	1.65	0.80
Nitzschia frustulum	42.9	31	2.07	0.89
Nitzschia kutzingiana	42.9	37	2.47	1.06
Rhoicosphenia curvata	40.0	35	2.50	1.00
Nitzschia dissipata	40.0	27	1.93	0.77
Amphora ovalis var. *pediculus*	40.0	33	2.35	0.94
Denticula elegans	34.3	32	2.67	0.91
Rhopalodia gibba	34.3	39	3.25	1.11
Achnanthes microcephala	31.4	32	2.30	0.91
Nitzschia linearis	28.6	23	2.50	0.66
Epithemia sorex	25.7	23	2.50	0.66
Cymbella affinis	25.7	23	2.50	0.66
Cymbella ventricosa	25.7	19	2.10	0.54

Table 10. Ranking in order of overall site importance (sIV) for periphytic diatoms at the confluence of major tributaries and the Colorado River in Grand Canyon National Park and vicinity.

Species	Site (sIV)
Epithemia sorex	3.34
Fragilaria capucina var. mesolepta	3.33
Diatoma vulgare	3.18
Achnanthes affinis	3.03
Mastogloia smithii	2.94
Navicula cryptocephala var. veneta	2.94
Achnanthes linearis	2.88
Achnanthes microcephala	2.84
Rhopalodia gibba	2.84
Amphora veneta	2.80
Cocconeis placentula var. euglypta	2.78
Denticula elegans	2.77
Rhoicosphenia curvata	2.77
Cocconeis pediculus	2.73
Gomphonema parvulum	2.73
Achnanthes linearis var. pusilla	2.65
Cymbella affinis	2.65
Diatoma vulgare var. breve	2.60
Diatoma himale var. mesodon	2.58
Fragilaria capucina	2.56
Biddulphia laevis	2.53
Nitzschia frustulum	2.51
Navicula longirostris	2.50
Amphora ovalis var. pediculus	2.48
Nitzschia kutzingiana	2.41
Nitzschia linearis	2.41

Table 11. Ranking in order of site importance (sIV) for periphytic diatoms collected during the spring (April-May, 1975) at the confluence of major tributaries and the Colorado River in Grand Canyon National Park and vicinity.

Species	Site (sIV)
Fragilaria capucina var. *mesolepta*	6.00
Navicula longirostris	4.50
Navicula mutica	4.00
Epithemia sorex	3.90
Fragilaria capucina	3.67
Navicula cryptocephala var. *veneta*	3.61
Achnanthes microcephala	3.50
Nitzschia scalpelliforma	3.50
Achnanthes affinis	3.35
Amphora adnata	3.14
Denticula elegans	3.07
Rhoicosphenia curvata	3.04
Achnanthes linearis	3.00
Amphora coffeiformis	3.00
Amphora veneta	3.00
Caloneis bacillaris var. *thermalis*	3.00
Diatoma vulgare var. *breve*	3.00
Navicula arvensis	3.00
Navicula silicificata	3.00
Nitzschia vermicularis	3.00
Synedra delicatissima var. *angustissima*	3.00
Diatoma vulgare	2.93
Cocconeis pediculus	2.76
Achnanthes linearis var. *pusilla*	2.75
Diatoma himale var. *mesodon*	2.75
Synedra acus	2.75

Table 12. Ranking in order of site importance (sIV) for periphytic diatoms collected during the summer (July-August, 1975) at the confluence of major tributaries and the Colorado River in Grand Canyon National Park and vicinity.

Species	Site (sIV)
Synedra mazamaensis	6.00
Fragilaria capucina	4.00
Diatoma vulgare	3.85
Gomphonema parvulum	3.50
Rhopalodia gibba	3.25
Biddulphia laevis	3.00
Cocconeis placentula var. lineata	3.00
Cymbella laevis	3.00
Cymbella norvegica	3.00
Diatoma himale var. mesodon	3.00
Entomoneis alata	3.00
Entomoneis palludosa	3.00
Epithemia adnata	3.00
Mastogloia smithii var. lacustris	3.00
Navicula longirostris	3.00
Nitzschia amphibia	3.00
Nitzschia angustata	3.00
Amphora ovalis var. pediculus	2.91
Achnanthes microcephala	2.90
Navicula cryptocephala var. veneta	2.80
Mastogloia smithii	2.83
Achnanthes linearis	2.77
Achnanthes affinis	2.75
Cocconeis placentula var. euglypta	2.75
Denticula elegans	2.75
Epithemia turgida	2.75
Mastogloia elliptica var. danseii	2.75

Table 13. Ranking in order of site importance (sIV) for periphytic diatoms collected during the fall (November, 1975) at the confluence of major tributaries and the Colorado River in Grand Canyon National Park and vicinity.

Species	Site (sIV)
Diatoma vulgare var. *breve*	4.00
Mastogloia smithii	4.00
Nitzschia recta	4.00
Epithemia sorex	3.57
Mastogloia smithii var. *lacustris*	3.50
Cocconeis pediculus	3.47
Synedra affinis	3.33
Synedra socia	3.20
Achnanthes affinis	3.00
Achnanthes linearis f. *curta*	3.00
Achnanthes linearis var. *pusilla*	3.00
Cocconeis placentula var. *euglypta*	3.00
Cymbella microcephala var. *crassa*	3.00
Gomphonema olivaceum	3.00
Gomphonema subclavatum	3.00
Navicula silicificata	3.00
Surirella ovalis	3.00
Nitzschia frustulum	2.94
Achnanthes linearis	2.88
Amphora veneta	2.83
Cymbella affinis	2.82
Diatoma vulgare	2.77
Rhoicosphenia curvata	2.76
Amphora arizonica	2.67
Nitzschia palea	2.67

Table 14. Spring (April-May, 1975) occurrence for site important periphytic diatoms collected at the confluence of selected tributaries and the Colorado River in Grand Canyon National Park and vicinity.

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)
Fragilaria capucina var. mesolepta											x	
Navicula longirostris												
Navicula mutica												
Epithemia sorex		x			x	x		x	x			
Fragilaria capucina							x				x	
Navicula cryptocephala var. veneta			x		x	x		x		x		x
Achnanthes microcephala		x	x				x		x	x		
Nitzschia scalpelliforma												
Achnanthes affinis		x					x	x	x	x	x	x
Amphora adnata												
Denticula elegans							x				x	x
Rhoicosphenia curvata	x	x	x		x		x			x		x
Achnanthes linearis												x
Amphora coffeiformis										x		
Amphora veneta							x		x			x
Caloneis bacillaris var. thermalis												

Table 14. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)
Diatoma vulgare var. *breve*	x								x			
Navicula arvenensis		x				x		x				
Navicula silicificata							x					x
Nitzschia vermicularis						x						
Synedra delicatissima var. *angustissima*												
Diatoma vulgare	x	x			x	x		x	x	x		x
Cocconeis pediculus	x	x			x		x	x	x	x		x
Achnanthes linearis var. *pusilla*							x	x	x		x	
Diatoma himale var. *mesodon*						x		x				
Synedra acus											x	
Total % Similarity	16	28	16	-	20	24	36	32	32	28	24	36

Table 15. Summer (July-August, 1975) occurrence for site important periphytic diatoms collected at the confluence of selected tributaries and the Colorado River in Grand Canyon National Park and vicinity.

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)
Synedra mazamaensis												
Fragilaria capucina			X				X				X	
Diatoma vulgare	X	X			X	X	X	X	X		X	X
Gomphonema parvulum		X			X	X		X	X			
Rhopalodia gibba		X	X						X			
Biddulphia laevis												X
Cocconeis placentula												
var. lineata						X						
Cymbella laevis											X	
Cymbella norvegica			X									
Diatoma himale												
var. mesodon								X				
Entomoneis alata				X								
Entomoneis palludosa				X								
Epithemia adnata		X										
Mastogloia smithii												
var. lacustris				X								
Navicula longirostris			X									
Nitzschia amphibia						X		X				

Table 15 (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)
Nitzschia angustata				x								
Amphora ovalis												
var. *pediculus*	x		x			x	x	x	x			
Achnanthes microcephala		x	x			x				x		
Navicula cryptocephala												
var. *veneta*					x							
Mastogloia smithii			x									
Achnanthes linearis	x	x					x		x			
Achnanthes affinis		x										x
Cocconeis placentula												
var. *euglypta*					x	x	x	x				
Denticula elegans		x	x			x	x				x	x
Epithemia turgida		x	x									
Mastogloia elliptica												
var. *danseii*			x			x						
Total % Similarity	12	36	40	16	16	36	24	24	20	4	16	16

Table 16. Fall (November, 1975) occurrence for site important values for periphytic diatoms at the confluence of selected tributaries and the Colorado River in Grand Canyon National Park and vicinity.

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)
Diatoma vulgare var. breve								x	x			
Mastogloia smithii							x				x	
Nitzschia recta											x	
Epithemia sorex		x			x	x		x	x			
Mastogloia smithii var. lacustris							x					
Cocconeis pediculus		x		x	x	x	x	x	x			
Synedra affinis							x					
Synedra socia	x	x						x	x			
Achnanthes affinis	x	x									x	
Achnanthes linearis f. curta	x	x									x	
Achnanthes linearis var. pusilla								x	x		x	
Cocconeis placentula var. euglypta		x			x	x	x	x	x			
Cymbella microcephala var. crassa	x			x		x	x			x	x	

Table 16. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)
Gomphonema olivaceum	x				x							
Gomphonema subclavatum										x	x	
Navicula silicificata										x		x
Surirella ovalis				x				x	x			
Nitzschia frustulum	x	x			x	x		x		x		x
Achnanthes linearis		x				x	x					
Amphora veneta								x	x		x	x
Cymbella affinis		x		x	x	x		x	x		x	x
Diatoma vulgare	x	x		x	x	x	x	x	x			
Rhoicosphenia curvata				x	x	x	x		x	x		x
Amphora arizonica							x					x
Nitzschia palea		x								x	x	
Total % Similarity	24	48	-	24	28	40	40	44	44	24	40	24

Table 17. Ranking in order of overall system importance (SIV) for periphytic diatoms at the confluence of major tributaries and the Colorado River in Grand Canyon National Park and vicinity.

Species	System (SIV)
Diatoma vulgare	1.72
Cocconeis pediculus	1.42
Synedra ulna	1.31
Nitzschia dissipata	1.17
Navicula tripunctata	1.13
Rhoicosphenia curvata	1.10
Nitzschia frustulum	1.09
Nitzschia kutzingiana	0.93
Denticula elegans	0.92
Cymbella microcephala var. crassa	0.90
Cymbella affinis	0.87
Nitzschia linearis	0.81
Rhopalodia gibba	0.80
Achnanthes microcephala	0.78
Amphora ovalis var. pediculus	0.70
Epithemia sorex	0.65
Gomphonema parvulum	0.61
Achnanthes lanceolata	0.56
Navicula cryptocephala f. minuta	0.56
Cocconeis placentula var. euglypta	0.55
Navicula cryptocephala	0.55
Achnanthes affinis	0.54
Achnanthes linearis	0.54
Cymbella minuta	0.51
Navicula cryptocephala var. veneta	0.51

Table 18. Ranking in order of system importance (SIV) for periphytic diatoms collected during the spring (April-May, 1975) at the confluence of major tributaries and the Colorado River in Grand Canyon National Park and vicinity.

Species	System (SIV)
Cocconeis pediculus	1.79
Diatoma vulgare	1.60
Navicula tripunctata	1.47
Rhoicosphenia curvata	0.67
Nitzschia dissipata	1.31
Synedra ulna	1.09
Nitzschia frustulum	1.02
Achnanthes affinis	1.00
Achnanthes microcephala	0.98
Melosira varians	0.91
Nitzschia linearis	0.91
Navicula cryptocephala var. veneta	0.82
Nitzschia kutzingiana	0.77
Denticula elegans	0.75
Achnanthes lanceolata	0.68
Cymbella microcephala var. crassa	0.68
Epithemia sorex	0.68
Rhopalodia gibba	0.67
Cymbella affinis	0.64
Amphora ovalis var. pediculus	0.61
Cymbella minuta	0.58
Frustulia vulgaris	0.58
Nitzschia apiculata	0.56
Navicula arvensis	0.53
Navicula cryptocephala	0.53

Table 19. Ranking in order of system importance (SIV) for periphytic diatoms collected during the summer (July-August, 1975) at the confluence of major tributaries and the Colorado River in Grand Canyon National Park and vicinity.

Species	System (SIV)
Diatoma vulgare	2.20
Synedra ulna	1.74
Rhopalodia gibba	1.11
Cymbella microcephala var. crassa	1.08
Cocconeis pediculus	1.06
Nitzschia kutzingiana	1.06
Rhoicosphenia curvata	1.00
Denticula elegans	0.94
Achnanthes microcephala	0.91
Amphora ovalis var. pediculus	0.91
Nitzschia frustulum	0.89
Navicula tripunctata	0.80
Nitzschia dissipata	0.77
Achnanthes linearis	0.71
Cymbella affinis	0.66
Epithemia sorex	0.66
Nitzschia linearis	0.66
Gomphonema parvulum	0.60
Epithemia turgida	0.59
Fragilaria capucina	0.57
Cymbella minuta	0.54
Epithemia argus var. longicornis	0.54
Amphora veneta	0.51
Epithemia adnata	0.51
Mastogloia smithii	0.49

Table 20. Ranking in order of system importance (SIV) for periphytic diatoms collected during the fall (November, 1975) at the confluence of major tributaries and the Colorado River in Grand Canyon National Park and vicinity.

Species	System (SIV)
Nitzschia dissipata	1.43
Cocconeis pediculus	1.41
Diatoma vulgare	1.35
Nitzschia frustulum	1.35
Cymbella affinis	1.30
Navicula tripunctata	1.11
Synedra ulna	1.11
Denticula elegans	1.08
Cocconeis placentula var. euglypta	1.05
Rhoicosphenia curvata	0.97
Nitzschia kutzingiana	0.95
Cymbella microcephala var. crassa	0.94
Navicula cryptocephala	0.86
Nitzschia linearis	0.86
Gomphonema parvulum	0.81
Navicula cryptocephala f. minuta	0.81
Achnanthes linearis	0.70
Achnanthes lanceolata	0.65
Epithemia sorex	0.62
Rhopalodia gibba	0.62
Amphora ovalis var. pediculus	0.59
Achnanthes minutissima	0.57
Achnanthes microcephala	0.46
Amphora veneta	0.46
Caloneis bacillum	0.46
Nitzschia microcephala	0.46

Table 21. Spring (April-May, 1975) occurrence for system important periphytic diatoms collected at the confluence of selected tributaries and the Colorado River in Grand Canyon National Park and vicinity.

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)
Cocconeis pediculus	x	x			x		x	x	x	x		x
Diatoma vulgare	x	x			x	x	x	x	x	x		x
Navicula tripunctata	x	x	x		x	x	x	x	x	x	x	x
Rhoicosphenia curvata	x	x	x		x		x			x		x
Nitzschia dissipata		x	x		x	x	x	x	x	x		x
Synedra ulna		x	x			x	x	x	x			x
Nitzschia frustulum		x	x		x	x	x	x	x			
Achnanthes affinis		x					x	x	x	x	x	x
Achnanthes microcephala		x	x				x		x	x		
Melosira varians	x	x			x	x	x		x			
Nitzschia linearis		x	x			x	x	x	x			
Navicula cryptocephala var. veneta		x	x		x	x		x		x		x
Nitzschia kutzingiana		x	x		x		x	x	x	x	x	
Denticula elegans							x				x	x
Achnanthes lanceolata		x				x	x	x	x			x
Cymbella microcephala var. crassa		x	x		x	x	x			x	x	
Epithemia sorex		x			x	x		x	x			

Table 21. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)
Rhopalodia gibba		x	x			x	x					
Cymbella affinis		x	x		x	x	x	x	x		x	
Amphora ovalis var. pediculus		x	x		x	x	x	x				
Cymbella minuta			x						x	x	x	
Frustulia vulgaris		x	x		x	x	x			x		
Nitzschia apiculata		x			x		x					
Navicula arvenensis		x				x	x	x				
Navicula cryptocephala		x			x	x				x	x	
Total % Similarity	20	92	60	-	64	68	84	60	60	52	32	40

Table 22. Summer (July-August, 1975) occurrence for system important periphytic diatoms collected at the confluence of selected tributaries and the Colorado River in Grand Canyon National Park and vicinity.

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)
Diatoma vulgare	x				x	x	x	x	x		x	x
Synedra ulna	x		x	x		x	x	x		x	x	x
Rhopalodia gibba		x	x						x			
Cymbella microcephala												
var. *crassa*	x	x	x		x		x			x		
Cocconeis pediculus	x	x			x	x	x			x	x	x
Nitzschia kutzingiana		x	x		x	x			x	x		x
Rhoicosphenia curvata	x	x				x			x	x		
Denticula elegans		x	x			x	x				x	x
Achnanthes microcephala		x	x			x				x		
Amphora ovalis												
var. *pediculus*	x	x	x			x	x	x	x			
Nitzschia frustulum	x	x			x	x	x	x	x	x		
Navicula tripunctata		x	x	x	x	x		x	x	x		
Nitzschia dissipata		x			x		x	x	x	x		
Achnanthes linearis		x					x		x	x		
Cymbella affinis	x				x	x		x				
Epithemia sorex		x		x		x			x			
Nitzschia linearis			x				x					

Table 22. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)
Gomphonema parvulum		x			x	x		x	x			
Epithemia turgida			x									
Fragilaria capucina			x				x				x	
Cymbella minuta	x					x			x			
Epithemia argus var. _longicornis_			x									
Amphora veneta			x	x					x			x
Epithemia adnata		x	x									
Mastogloia smithii		x										
Total % Similarity	36	60	60	16	36	56	44	32	52	40	20	24

Table 23. Fall (November, 1975) occurrence for system important periphytic diatoms collected at the confluence of selected tributaries and the Colorado River in Grand Canyon National Park and vicinity.

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)
Nitzschia dissipata	x	x		x	x	x	x	x	x	x		
Cocconeis pediculus		x		x	x	x	x	x	x			
Diatoma vulgare	x	x		x	x	x	x	x	x			
Nitzschia frustulum	x	x		x	x	x		x	x	x		x
Cymbella affinis	x	x		x	x	x		x	x		x	x
Navicula tripunctata	x	x		x	x	x	x	x			x	
Synedra ulna		x		x	x	x	x		x	x	x	x
Denticula elegans	x						x			x	x	x
Cocconeis placentula var. *euglypta*		x			x		x	x	x			
Rhoicosphenia curvata		x		x	x	x	x	x	x	x		x
Nitzschia kutzingiana	x				x	x	x	x	x		x	x
Cymbella microcephala var. *crassa*		x		x	x	x	x			x	x	
Navicula cryptocephala	x	x		x	x	x		x	x			
Nitzschia linearis		x				x	x	x	x			x
Gomphonema parvulum	x	x						x	x		x	
Navicula cryptocephala f. *minuta*	x	x		x	x		x	x	x	x	x	

Table 23. (Continued)

SPECIES	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)
Achnanthes linearis		x				x	x	x	x			
Achnanthes lanceolata		x		x		x		x	x			
Epithemia sorex					x	x		x	x			
Rhopalodia gibba	x	x					x				x	
Amphora ovalis var. pediculus	x				x	x	x		x		x	
Achnanthes minutissima	x	x					x		x	x	x	
Achnanthes microcephala		x					x			x	x	
Amphora veneta								x	x		x	x
Caloneis bacillum	x	x								x	x	
Nitzschia microcephala		x					x			x	x	x
Total % Similarity	56	84	-	48	60	64	72	68	76	44	60	36

Table 24. Composite site and system importance similarities based on spring, summer and fall (1975) occurrences of major periphytic diatoms collected at the confluence of selected tributaries and the Colorado River in Grand Canyon National Park and vicinity.

	Paria River (mi 0.3)	Vasey's Paradise (mi 32.0)	Buck Farm (mi 41.0)	Little Colorado (mi 61.5)	Bright Angel Cr. (mi 87.5)	Shinumo Creek (mi 108.5)	Elves Chasm (mi 116.5)	Tapeats Creek (mi 134.0)	Deer Creek (mi 136.0)	Kanab Creek (mi 143.5)	Havasu Creek (mi 157.0)	Diamond Creek (mi 225.0)
Site Composite % Similarity	17.3	37.3	28.0	20.0	21.3	33.3	33.3	33.3	32.0	18.6	26.7	25.3
System Composite % Similarity	37.3	78.7	60.0	32.0	53.3	62.7	66.7	53.3	62.7	45.3	37.3	33.3

CONCLUSIONS

Seasonal (spring, summer, fall) collections of algal
periphyton were taken from 33 north and south rim drainages
in Grand Canyon National Park. A total of 345 taxa were observed
with diatoms (224 taxa) numerically most important followed by
blue-greens (83 taxa), greens (34 taxa), yellow-greens (3 taxa)
and reds (a single taxon). The high diversity of the Colorado
River in the vicinity of the Grand Canyon indicates a relatively
young and unspoiled environment with the taxonomic significance
of this area of unprecedented magnitude in the Southwest, based 31
on total number of taxa encountered. Major differences in taxa
exist above and below Glen Canyon Dam. These differences are 31-32,
attributed to the lentic nature of the system above the dam, 52-55
variable flow characteristics below the dam, and increasing levels
of suspended materials downstream.

Pollution tolerant species (Palmer, 1969) were only casually
encountered during the year long study at relatively low levels 7,9,12
with little or not detectable trends in unnatural organic en-
richment. However, with improved methodology in quantitative
sampling over a longer time period, estimates of pollution
tolerant periphytic species (e.g. *Oscillatoria tenuis* and
Oscillatoria limosa) encountered within the system may provide
more precise information on the environmental future of the
Colorado River system. The occasional appearance of such species
in the Paria River (mi 0.3), Bright Angel Creek (mi 87.5), 7,9,12
Shinumo Creek (mi 108.5), Havasu Creek (mi 157.0) and Diamond
Creek (mi 225.0) provides a feasible means for future monitoring
whereby, quantitative periphyton estimates could be supplemented
with information on recreational utilization and bacteriological
data to help predict unnatural enrichment within the system.
This information could then be used in decision making policies
relating to management of recreational activities in the Grand
Canyon.

A relative ranking scheme was designed to characterize site 31
important and system important periphytic diatoms. Taxa with high
site importance values (e.g. *Epithemia sorex*, *Mastogloia smithii*, 37,41,
Fragilaria capucina var. *mesolepta*) were generally considered to 44
be good indicators of specific sites and habitat types. Taxa with
high system and low site importance values (e.g. *Synedra ulna*, 42,43,
Nitzschia dissipata, *Navicula tripunctata*) were essentially con- 46
sidered to have wide ranges of ecological tolerance while taxa
with both high site and system importance values (e.g. *Diatoma
vulgare*, *Cocconeis pediculus*, *Rhoicosphenia curvata*) were con- 32,41
sidered to be representative of the overall system. Based on
ecological preferences of major taxa, the Colorado River can be

considered to be a high alkalinity and conductivity system.
An overall system importance index was calculated for 76
each major tributary to determine those most important in
contributing to the present diatom microflora of the Colorado
River. Those determined to be of greatest significance include:
Vasey's Paradise (mi 32.0), Bright Angel Creek (mi 87.5), 33,37
Shinumo Creek (mi 108.0), Elves Chasm (mi 116.5), Tapeats 38,40
Creek (mi 134.0), and Deer Creek (mi 136.0). Due to the im- 42
portance of these systems in contributing to the microflora of
the Colorado River, it is recommended that a biannual moni-
toring program be initiated on at least three of these major
systems as a good general indicator of the status of water
quality in the Grand Canyon.

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

APPENDIX TABLES

Appendix Table I. List of algal species collected at the confluence of major tributaries and the Colorado River between Lee's Ferry and Diamond Creek in Grand Canyon National Park and vicinity, 1975-1976. (* indicates new distribution record for Arizona).

BACILLARIOPHYTA (Diatoms)
Achnanthes affinis Grun.
*Achnanthes clevei Grun.
Achnanthes coarctata Breb.
*Achnanthes deflexa Reim.
Achnanthes exigua var. heterovalva Krasske
Achnanthes flexella (Kutz.) Brun.
Achnanthes lanceolata Breb.
Achnanthes lanceolata var. dubia Grun.
*Achnanthes var. omissa Reim.
Achnanthes linearis (W. Sm.) Grun.
*Achnanthes linearis f. curta H. L. Sm.
*Achnanthes linearis var. pusilla Grun.
Achnanthes microcephala Kutz.
Achnanthes minutissima Kutz.
Achnanthes sublaevis var. crassa Reim.
*Achnanthes wellsiae Reim.
Amphipleura pellucida Kutz.
Amphora adnata (tentative) Czar. & Blinn sp. nov.
Amphora arizonica (tentative) Czar. & Blinn sp. nov.
Amphora coffeiformis (Ag.) Kutz.
Amphora ovalis (Ehr.) Kutz.
Amphora ovalis var. pediculus (Kutz.) V.H. ex DeT.
*Amphora perpusilla (Grun.) Grun.
Amphora veneta Kutz.
Anomoeoneis vitrea (Grun.) Ross
Asterionella formosa Hass.
Bacillaria paradoxa Gmelin
Biddulphia laevis (Ehr.) Hust.
Caloneis amphisbaena (Bory) Cl.
*Caloneis bacillaris var. thermalis (Grun.) A. Cl.
*Caloneis bacillum (Grun.) Cl.
*Caloneis backmanii A. Cl.
*Caloneis hyalina Hust.
*Caloneis pulchra var. brevistriata O. Mull.
Caloneis ventricosa var. truncatula (Grun.) Meist.
*Campylodiscus noricus var. hibernica (Ehr.) Grun.
*Cocconeis diminuta Pant.
Cocconeis placentula var. euglypta (Ehr.) Cl.
Cocconeis placentula var. lineata (Ehr.) V.H.

Cocconeis pediculus Ehr.
*Coscinodiscus denarius A. S.
Cyclotella atomus Hust.
Cyclotella meneghiniana Kutz.
Cyclotella michiganiana Skv.
*Cylindrotheca gracilis (Breb.) W. Sm.
Cymatopleura solea (Breb.) W. Sm.
Cymbella affinis Kutz.
Cymbella affinis var. bipunctata (tentative) Czar. & Blinn var. nov.
Cymbella amphicephala Naeg. ex. Kutz.
Cymbella cistula (Hemp.) Grun.
Cymbella laevis Naeg.
Cymbella leptoceros (Ehr.) Kutz.
Cymbella magnapunctata (tentative) Czar. & Blinn sp. nov.
Cymbella mexicana (Ehr.) Cl.
Cymbella microcephala Grun.
*Cymbella microcephala var. crassa Reim.
Cymbella minuta Hilse ex Rabh.
*Cymbella norvegica Grun.
*Cymbella parva (W. Sm.) Cl.
Cymbella prostrata (Berk.) Cl.
*Cymbella pusilla Grun.
*Cymbella sinuata Greg.
Cymbella tumida (Breb.) V.H.
Cymbella tumidula Grun.
Denticula elegans Kutz.
*Denticula rainerensis Sov.
*Diatoma himale var. mesodon (Ehr.) Grun.
Diatoma vulgare Bory
*Diatoma vulgare var. breve Grun.
*Diatoma vulgare var. linearis V.H.
*Diploneis elliptica (Kutz.) Cl.
*Diploneis oblongella (Naeg. ex Kutz.) Ross
*Diploneis oculata (Breb.) Cl.
Diploneis puella (Schum.) Cl.
*Diploneis smithii var. dilatata (M. Perag.) Boyer
Entomoneis alata (Ehr.) Ehr.
Entomoneis palludosa (W. Sm.) Reim.
Epithemia adnata (Kutz.) Breb.
*Epithemia argus var. alpestris Grun.
*Epithemia argus var. longicornis (Ehr.) Grun.
Epithemia sorex Kutz.
Epithemia turgida (Ehr.) Kutz.
Fragilaria brevistriata var. inflata (Pant.) Hust.
Fragilaria capucina Desm.
Fragilaria capucina var. mesolepta Rabh.
Fragilaria crotonensis Kitton

Fragilaria construens var. venter (Ehr.) Grun.
*Fragilaria leptostauron (Ehr.) Hust.
Fragilaria leptostauron var. dubia (Grun.) Hust.
Fragilaria vaucheriae (Kutz.) Peters
*Frustulia vulgaris Thwaites
*Gomphoneis herculeana (Ehr.) Cl.
Gomphonema acuminatus Ehr.
*Gomphonema affine var. insigne (Greg.) Andrews
Gomphonema intracatum Kutz.
*Gomphonema intracatum var. vibrio (Ehr.) Cl.
*Gomphonema grunowii Patr.
Gomphonema olivaceum (Lyng.) Kutz.
Gomphonema parvulum Kutz.
Gomphonema subclavatum (Grun.) Grun.
Gomphonema truncatum Ehr.
Gyrosigma spencerii (Quek.) Griff. & Henfr.
*Gyrosigma spencerii var. curvula (Grun.) Reim.
Hantzschia amphioxys (Ehr.) Grun.
*Hantzschia amphioxys f. capitata Mull.
*Mastogloia elliptica var. danseii (Thwaites) Cl.
*Mastogloia grevillei W. Sm.
*Mastogloia smithii Thwaites
*Mastogloia smithii var. amphicephala Grun.
Mastogloia smithii var. lacustris Grun.
Melosira varians Ag.
Meridion circulare (Grev.) Ag.
*Navicula accomoda Hust.
Navicula anglica var. subsalsa Grun.
*Navicula arvenensis Hust.
Navicula bacillum Ehr.
Navicula cincta (Ehr.) Kutz.
*Navicula cocconeiformis Greg. ex Grev.
Navicula cryptocephala Kutz.
*Navicula cryptocephala f. minuta Boye P.
Navicula cryptocephala var. veneta (Kutz.) Grun.
Navicula cuspidata Kutz.
*Navicula cuspidata var. major Meist.
Navicula decussis Ostr.
*Navicula densestriata Hust.
Navicula eulineata (tentative) Czar. & Blinn sp. nov.
*Navicula gregaria Donkin
*Navicula grimmei Krass.
*Navicula lanceolata (Ag.) Kutz.
*Navicula longirostris Hust.
Navicula minima Grun.
Navicula miniradiata (tentative) Czar. & Blinn sp. nov.
*Navicula minuscula Grun.

*Navicula mutica Kutz.
*Navicula mutica var. cohnii (Hilse) Grun.
*Navicula mutica var. stigma Patr.
*Navicula mutica var. undulata (Hilse) Grun.
*Navicula notha Wallace
Navicula pelliculosa (Breb.) Hilse
*Navicula pseudoreinhardtii Patr.
Navicula pupula Kutz.
Navicula pupula var. rectangularis (Greg.) Grun.
Navicula radiosa Kutz.
Navicula radiosa var. tenella (Breb.) Grun.
Navicula secreta var. apiculata Patr.
Navicula silicificata (tentative) Czar. & Blinn sp. nov.
*Navicula subtilissima Cl.
*Navicula tridentula Krasske
Navicula tripunctata (Mull.) Bory
Navicula tripunctata var. schizonemoides (V.H.) Patr.
*Navicula tuscula Ehr.
Navicula viridula (Kutz.) Kutz. emend. V.H.
Navicula viridula var. rostellata (Kutz.) Cl.
Navicula zanoni Hust.
*Neidium binode (Ehr.) Hust.
*Neidium dubium f. constrictum Hust.
Nitzschia acicularis W. Sm.
*Nitzschia acuta Hantzsch
Nitzschia amphibia Grun.
Nitzschia angustata (W. Sm.) Grun.
*Nitzschia angustata var. acuta Grun.
Nitzschia apiculata (Greg.) Grun.
*Nitzschia bicrena Hohn & Hell.
*Nitzschia bita Hohn & Hell.
Nitzschia capitellata Hust.
Nitzschia communis Rabh.
Nitzschia denticula Grun.
Nitzschia dissipata (Kutz.) Grun.
Nitzschia fonticola Grun.
Nitzschia frustulum Kutz.
*Nitzschia frustulum var. perpusilla (Rabh.) Grun.
Nitzschia gracilis Hantzsch
Nitzschia hungarica Grun.
*Nitzschia hybrida Grun.
Nitzschia kutzingiana Hilse
*Nitzschia lacunarum Hust.
Nitzschia linearis W. Sm.
*Nitzschia littoralis var. tergestina Grun.
Nitzschia microcephala Grun.
Nitzschia palea (Kutz.) W. Sm.
Nitzschia pseudolinearis (tentative) Czar. & Blinn sp. nov.

*Nitzschia recta Hantzsch
Nitzschia scalpelliforma (tentative) Czar. & Blinn sp. nov.
*Nitzschia sigma (Kutz.) W. Sm.
Nitzschia sinuata var. tabellaria Grun.
*Nitzschia tryblionella var. calida (Grun.) V.H.
Nitzschia vermicularis (Kutz.) Grun.
*Opephora ansata Hohn & Hell.
*Plagiotropis lepidoptera (Greg.) Czar. & Blinn comb. nov. (tentative comb.)
*Pinnularia appendiculata (Ag.) Cl.
*Pinnularia borealis var. rectangularis Carlson
*Pinnularia brebissoni (Kutz.) Rabh.
*Pinnularia divergentissima (Grun.) Cl.
Pinnularia prescottii (tentative) Czar. & Blinn sp. nov.
Pleurosigma delicatulum W. Sm.
Rhoicosphenia curvata (Kutz.) Grun.
Rhopalodia gibba (Ehr.) Mull.
Rhopalodia gibba var. ventricosa (Kutz.) H. & M. Perag.
*Rhopalodia gibberula var. vanheirckii Mull.
*Scoliopleura peisonis Grun.
Stauroneis anceps Ehr.
Stauroneis amphioxys var. rostrata (tentative) Czar. & Blinn var. nov.
*Stauroneis smithii Grun.
Surirella angustata Kutz.
Surirella brightwellei W. Sm.
Surirella ovalis Breb.
Surirella ovata Kutz.
*Surirella ovata var. africana Choln.
*Surirella ovata var. pinnata W. Sm.
*Surirella patella Ehr.
Surirella striatula Turp.
Surirella striatula var. parva (tentative) Czar. & Blinn var. nov.
Synedra acus Kutz.
*Synedra affinis Kutz. (in sensu stricto Hust. 1930, p. 166)
Synedra delicatissima var. angustissima Grun.
*Synedra goulardii Breb.
*Synedra incisa Boyer
*Synedra mazamaensis Sov.
Synedra miniscula var. longa (tentative) Czar. & Blinn var nov.
*Synedra pulchella var. lacerata Hust.
*Synedra rumpens Kutz.
*Synedra socia Wall.
Synedra ulna (Nitz.) Ehr.
*Synedra ulna var. contracta Ostr.

CHLOROPHYTA (Green algae)
Chlorococcum spp.
Cladophora fracta (Dillw.) Kuetzing
Cladophora glomerata (L.) Kuetzing
Closterium acerosum var. elongatum de Breb.
Closterium spp.
Cosmarium spp.
Cylindrocapsa sp.
*Gongrosira lacustris Brand
*Microspora loefrgenii (Nordst.) Lagerheim
Microspora pachyderma (Wille) Lagerheim
Microspora sp.
Mougeotia spp.
Oedogonium spp.
Oocystis crassa Wittrock
*Oocystis elliptica W. West.
*Oocystis solitaria Wittrock
Pediastrum boryanum (Turp.) Meneghini
Pediastrum integrum Naegeli
Pediastrum integrum var. scutum Raciborski
Rhizoclonium hieroglyphicum (C.A. Ag.) Kuetzing
Rhizoclonium hookeri Kuetzing
Spirogyra spp.
Stigeoclonium pachydermum Prescott
Tetraspora cylindrica (Wahl.) C.A. Agardh.
Tetraspora sp.
*Trentepholia aurea (L.) Martius
*Ulothrix aequalis Kuetzing
*Ulothrix cylindricum Prescott
Ulothrix subtilissima Rabenhorst
Ulothrix tenerrima Kuetzing
*Ulothrix tenuissima Kuetzing
*Ulothrix variabilis Kuetzing
Ulothrix zonata (Weber & Mohr) Kuetzing
Zygnema spp.

CYANOPHYTA (Blue-green algae)
Anabaena oscillarioides Bory
Anabaena spp.
*Aphanocapsa musicola (Menegh.) Wille
Aphanocapsa sp.
Chamaesiphon sp.
*Chroococcus minor (Kuetz.) Naegeli
Chroococcus minutus (Kuetz.) Naegeli
Chroococcus turgidus (Kuetz.) Naegeli
*Gloeocapsa polydermatica Kuetzing
Gloeothece sp.

*Gloeotrichia intermedia (Lemm.) Geitler
*Katagnymene pelagica Lemmermann
Lyngbya aerugineo-caerulea (Kuetz.) Gomont
Lyngbya aestaurii (Mert.) Liebmann
Lyngbya allegori Fremy
*Lyngbya cryptovaginata Schkorbatow
Lyngbya digueti Gomont
*Lyngbya epiphytica Hieronymus
*Lyngbya hieronymusii Lemmermann
Lyngbya limnetica Lemmermann
*Lyngbya major Meneghini
Lyngbya martensiana Meneghini
*Lyngbya mesotrichia Ruja
*Lyngbya nordgardhii Wille
*Lyngbya perelegans Lemmermann
*Lyngbya statina Kuetzing
Lyngbya versicolor (Wartmann) Gomont
Lyngbya spp.
Merismopedia glauca (Ehrenb.) Naegeli
Merismopedia punctata Meyent
*Microchaete elongata Fremy
*Nostoc hatei Dixit
Nostoc paludosum Kuetzing
*Nostoc punctiforme (Kuetz.) Hariot
*Nostoc verrucosum vaucher
Nostoc spp.
*Oscillatoria acuminata Gomont
Oscillatoria agardhii Gomont
*Oscillatoria amoena (Kuetz.) Gomont
Oscillatoria amphibia Agardh
*Oscillatoria amphigranulata Van Goor
*Oscillatoria angusta Kappe
*Oscillatoria angustissima West & West
Oscillatoria chalybea Mertens
*Oscillatoria claricentrosa Gardner
Oscillatoria cortiana Meneghini
*Oscillatoria foreaiu Fremy
*Oscillatoria fremyii De Toni
*Oscillatoria hamelii Fremy
*Oscillatoria jasorvensis Vouk
*Oscillatoria lemmermannii Walosz
Oscillatoria limnetica Lemmermann
Oscillatoria limosa (Roth) C.A. Agardh
*Oscillatoria mougeotii Kuetzing
*Oscillatoria migro-viridis Thwaites
*Oscillatoria obscura Bruhl
Oscillatoria okeni Agardh

*Oscillatoria pseudogeminata G. Schmid
*Oscillatoria proteus Skuja
Oscillatoria quadripunctulata Bruhl & Biswas
*Oscillatoria rubescens De Candolle
*Oscillatoria schultzii Lemmermann
*Oscillatoria simplicissima Gomont
Oscillatoria splendida Grev
Oscillatoria subbrevis Schmidle
*Oscillatoria tanganyikae West
Oscillatoria tenuis C.A. Agardh
*Oscillatoria tenuis var. tergestina Rabenhorst
*Oscillatoria trichoides Szafer
Oscillatoria spp.
*Phormidium anomala Rao
Phormidium ambiguum Gomont
*Phormidium corium var. constrictum Playfair
*Phormidium dimorphum Lemmermann
*Phormidium mucosum Gardner
Phormidium retzii (Ag.) Gomont
Phormidium tenue (Menegh.) Gomont
*Scytonema alatum (Carm.) Borzi
*Scytonema rivulare Borzi
Spirulina labyrinthiformis (Menegh.) Gomont
*Spirulina subtilissima Kuetz
*Stigonema hormoides Kuetzing
Symploca sp.

RHODOPHYTA (Red algae)
Batrachospermum sp.

XANTHOPHYTA (Yellow-green algae)
Vaucheria geminata (Vauch.) De Candolle
Vaucheria sessilis (Vauch.) De Candolle
Vaucheria spp.

Appendix Table II. Site and system importance values for periphytic diatoms collected at the confluence of major tributaries and the Colorado River in Grand Canyon National Park and vicinity.

Eight numbers follow each taxon: spring, summer, fall, and average site importance values (sIV); spring, summer, fall, and average system importance values (SIV). Additional comments are made concerning each taxon where appropriate.

Genus Achnanthes

1. affinis: 3.35, 2.75, 3.0, 3.03; 1.0,0.31, 0.32, 0.54. Alkaliphilous, euryhalobous, preferring high oxygen. Usually epiphytic or epilithic.
2. clevei: 2.0, 0, 1.0, 1.0; 0.04, 0, 0.03, 0.02. Alkaliphilous, preferring high conductivity. Common in Montezuma Well (Czarnecki & Blinn, unpublished).
3. coarctata: 1.66, 2.0, 0, 1.22; 0.08, 0.06, 0, 0.05. Commonly a moss epiphyte. Also routinely encountered in Oak Creek (Czarnecki & Blinn, unpublished).
4. deflexa: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01.
5. exigua var. heterovalva: 2.2, 2.0, 2.0, 2.06; 0.19, 0.06, 0.05, 0.1. Probably indicative of warm water.
6. flexella: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Supposedly indicative of low conductivity (Lowe, 1974). This is definitely not the case in our collections.
7. lanceolata: 2.44, 1.75, 2.0, 2.06; 0.68, 0.4, 0.65, 0.56. Alkaliphilous, preferring high oxygen concentrations. An extremely common taxon found in almost all collections in Northern Arizona (Czarnecki & Blinn, unpublished).
8. lanceolata var. dubia: 2.0, 2.0, 1.0, 1.67; 0.28, 0.06, 0.05, 0.13. Alkaliphilous, usually preferring water of lower conductivity than the nominate variety (in our collections). Intolerant of organic enrichment (Lowe, 1974).
9. lanceolata var. omissa: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Probably alkaliphilous. This taxon is commonly found in Oak Creek (Czarnecki & Blinn, unpublished).
10. linearis: 3.0, 2.77, 2.88, 2.88; 0.21, 0.71, 0.70, 0.54. Alkaliphilous, preferring high oxygen. Usually epiphytic or epilithic.
11. linearis f. curta: 2.0, 0, 3.0, 1.67; 0.28, 0, 0.32, 0.20. Probably alkaliphilous, preferring high oxygen. This taxon has also been found in Southern Lake Powell (Czarnecki & Blinn, Unpublished).

12. _linearis_ var. _pusilla_: 2.75, 2.2, 3.0, 2.65; 0.39, 0.31, 0.32, 0.34. According to Patrick & Reimer (1966), this taxon prefers fast flowing streams (in Pennsylvania). Probably alkaliphilous, preferring high concentrations of oxygen.
13. _microcephala_: 3.5, 2.9, 2.13, 2.84; 0.98, 0.91, 0.46, 0.78. Supposedly indicative of high oxygen in weakly acidic waters (Lowe, 1974). This is definitely not the case in our collections. This taxon is widespread in Northern Arizona, and has been particularly abundant in areas of Southern Lake Powell (Czarnecki & Blinn, unpublished).
14. _minutissima_: 2.0, 2.5, 2.3, 2.26; 0.04, 0.29, 0.57, 0.29. Alkaliphilous, preferring high concentrations of oxygen.
15. _sublaevis_ var. _crassa_: 2.0, 2.0, 2.0, 2.0; 0.04, 0.06, 0.05, 0.05. Probably alkaliphilous, preferring high conductivity. Consistently found in areas of Southern Lake Powell (Czarnecki & Blinn, unpublished).
16. _wellsiae_: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.1. Only reported from waters of high conductivity (Patrick & Reimer, 1966). This is no exception in our collections.

Genus _Amphipleura_

1. _pellucida_: 2.33, 2.0, 2.0, 2.11; 0.12, 0.06, 0.05, 0.08. Strongly alkaliphilous. Usually associated with epipelic collections (high organic concentrations) in our studies.

Genus Amphora

1. _adnata_: 3.14, 0, 0, 1.05; 0.39, 0, 0, 0.13. This tentatively assigned taxon seems to prefer high conductivity, alkalinity, and temperature. It is also quite common under these ecological regimes in the Warm Creek and Wiregrass Springs area of Lake Powell (Czarnecki & Blinn, unpublished).
2. _arizonica_: 0, 0, 2.67, 0.89; 0, 0, 0.21, 0.07. This tentatively assigned taxon seems to prefer high alkalinity and moderate conductivity.
3. _coffeiformis_: 3.0, 0, 1.0, 1.33; 0.11, 0, 0.02, 0.04. A good indicator of high conductivity and alkalinity.
4. _ovalis_: 2.33, 2.4, 0, 1.58; 0.12, 0.34, 0, 0.15. Alkaliphilous and calciphilous.
5. _ovalis_ var. _pediculus_: 2.33, 2.91, 2.2, 2.48; 0.61, 0.91, 0.59, 0.70. Alkaliphilous, preferring high oxygen concentrations.
6. _perpusilla_: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Alkaliphilous and by association with other taxa undoubtedly preferring high conductivity.

7. _veneta_: 3.0, 2.57, 2.83, 2.8; 0.42, 0.51, 0.46, 0.46. Supposedly found commonly with _Epithemia sorex_ (Lowe, 1974), this has not been the case in our collections. Alkaliphilous and probably preferring water of high conductivity. This taxon is also commonly found in Warm Creek and Wiregrass Springs areas of Lake Powell (Czarnecki & Blinn, unpublished).

Genus _Anomoeoneis_

1. _vitrea_: 2.0, 2.0, 1.67, 1.89; 0.11, 0.45, 0.27, 0.28. Alkaliphilous and a good indicator of high conductivity (in our collections).

Genus _Asterionella_

1. _formosa_: 2.0, 1.5, 0, 1.17; 0.04, 0.09, 0, 0.04. One of the commonest phytoplankters in Lake Powell. This taxon is probably transient and not a true component of the periphyton of the canyon.

Genus _Bacillaria_

1. _paradoxa_: 2.0, 1.67, 1.0, 1.56; 0.04, 0.14, 0.05, 0.08. Definitely associated with high conductivity. This taxon is common in Cholla Lake and Verde River usually associated with epiphytic or psammonic communities (Czarnecki & Blinn, unpublished).

Genus _Biddulphia_

1. _laevis_: 2.25, 3.0, 2.33, 2.53; 0.16, 0.09, 0.38, 0.21. Alkaliphilous, preferring water of high conductivity. In our collections this taxon occurred only at Elves Chasm and Diamond Creek.

Genus _Caloneis_

1. _amphisbaena_: 2.0, 2.0, 0, 1.33; 0.04, 0.16, 0, 0.07. Alkaliphilous, usually found in high organic sediments (in our collections).
2. _bacillaris_ var. _thermalis_: 3.0, 2.33, 0, 1.78; 0.05, 0.2, 0, 0.08. Found in water of high conductivity. One specimen depressed frustule length to 21 µm, width to 5 µm, and extended the strial range to 28 in 10 µm.
3. _bacillum_: 2.0, 1.5, 2.42, 1.97; 0.24, 0.09, 0.46, 0.26. Alkaliphilous. Quite common in Northern Arizona (Czarnecki & Blinn, unpublished).

4. backmanii: 1.0, 0, 0, 0.33; 0.02, 0, 0, 0.01. Little is known regarding the ecological requirements of this taxon. It would appear to be alkaliphilous and epilithic. This is possibly the first report of its occurrence in the United States.
5. hyalina: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Probably alkaliphilous.
6. pulchra var. brevistriata: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Probably alkaliphilous preferring water of high conductivity. This is possibly the first report of its occurrence in the United States.
7. ventricosa var. truncatula: 2.0, 1.0, 2.0, 1.67; 0.07, 0.03, 0.05, 0.05. Alkaliphilous, This taxon is commonly found in Wahweap Bay, Lake Powell (Czarnecki & Blinn, unpublished).

Genus Campylodiscus

1. noricus var. hibernica: 0, 0, 2.0, 0.67; 0, 0, 0.05, 0.02. Alkaliphilous, probably preferring moderate conductivity. Common in Oak Creek and Cholla Lake, Arizona (Czarnecki & Blinn, unpublished)

Genus Cocconeis

1. diminuta: 2.27, 0, 2.0, 1.42; 0.44, 0, 0.11, 0.18. Alkalibiontic, usually associated with flowing systems (in our collections).
2. placentula var. euglypta: 2.33, 2.75, 3.25, 2.78; 0.3, 0.31 1.05, 0.55. Alkaliphilous. This taxon is widespread in Northern Arizona (Czarnecki & Blinn, unpublished).
3. placentula var. lineata: 2.33, 3.0, 1.83, 2.39; 0.24, 0.26, 0.3, 0.27. Alkaliphilous. This taxon is widespread in Northern Arizona (Czarnecki & Blinn, unpublished).
4. pediculus: 2.76, 1.95, 3.47, 2.73; 1.79, 1.06, 1.41, 1.42. Alkaliphilous, probably preferring moderate conductivity (in our collections). This taxon is especially widespread in flowing water systems in Northern Arizona (Czarnecki & Blinn, unpublished). This is one of the most common taxa in the canyon.

Genus Coscinodiscus

1. denarius: 1.0, 0, 0, 0.33; 0.02, 0, 0, 0.01. Alkaliphilous probably preferring water of high conductivity. This is the first encounter we have had with this taxon in Northern Arizona.

Genus _Cyclotella_

1. _atomus_: 1.0, 0, 0, 0.33; 0.02, 0, 0, 0.01. Prefers water of high conductivity.
2. _meneghiniana_: 1.86, 2.25, 1.5, 1.87; 0.23, 0.26, 0.08, 0.19. Alkaliphilous, preferring water of moderate conductivity. Very common especially in Oak Creek and Beaver Creek (Czarnecki & Blinn, unpublished).
3. _michiganiana_: 1.0, 1.0, 1.6, 1.2; 0.02, 0.03, 0.22, 0.09. According to Lowe (1974), this taxon is indicative of oligotrophic systems. This is a very common phytoplankter in Wahweap Bay, Lake Powell (Czarnecki & Blinn, unpublished).

Genus _Cylindrotheca_

1. _gracilis_: 2.2, 0, 2.0, 1.4; 0.19, 0, 0.11, 0.1. Unquestionably a good indicator of high conductivity.

Genus _Cymatopleura_

1. _solea_: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Alkaliphilous. This taxon is extremely common in mats of _Vaucheria geminata_ in West Fork (Oak Creek Canyon) but not too common in the Colorado River (Czarnecki & Blinn, unpublished).

Genus _Cymbella_

1. _affinis_: 2.57, 2.56, 2.82, 2.65; 0.64, 0.66, 1.3, 0.87. Strongly alkaliphilous and preferring water with high oxygen concentrations (in our collections). We have also seen this taxon forming extensive mats up to approximately 10 m^2 in areas of Oak Creek, however this has not been the case in the canyon. This taxon is extremely common, especially in flowing systems in Northern Arizona (Czarnecki & Blinn, unpublished).
2. _affinis_ var. _bipunctata_: 0, 2.0, 2.0, 1.33; 0, 0.11, 0.22, 0.11. This tentatively assigned taxon is probably by association strongly alkaliphilous.
3. _amphicephala_: 2.0, 2.0, 1.5, 1.83; 0.18, 0.06, 0.16, 0.13. Alkaliphilous, preferring water of moderate conductivity (in our collections). This taxon was found to occur quite commonly with _C. microcephala_ var. _crassa_ in the Lower Lake Powell area but not in great abundance.
4. _cistula_: 2.0, 1.0, 0, 1.0; 0.14, 0.06, 0, 0.07. Alkaliphilous, preferring high concentrations of oxygen.

5. laevis: 1.83, 3.0, 1.0, 1.94; 0.19, 0.09, 0.05, 0.11. Commonly found in or near seeps with high conductivity (in our observations).
6. leptoceros: 0, 0, 1.0, 0.33; 0, 0, 0.03, 0.01. Probably alkaliphilous.
7. magnapunctata: 0, 1.5, 1.0, 0.83; 0, 0.09, 0.03, 0.04. This tentatively assigned taxon seems to prefer flowing water of high alkalinity and moderate conductivity. We have also found this diatom in Beaver Creek (Czarnecki & Blinn, unpublished).
8. mexicana: 0, 1.0, 0, 0.33; 0, 0.06, 0, 0.02. Alkaliphilous.
9. microcephala: 0, 2.0, 2.0, 1.33; 0, 0.06, 0.05, 0.04. Alkaliphilous.
10. microcephala var. crassa: 1.95, 1.9, 3.0, 2.28; 0.68, 1.08, 0.94, 0.90. Alkaliphilous, preferring water of moderate to high conductivity (in our collections). Very common in the Warm Creek and Wahweap areas of Lake Powell (Czarnecki & Blinn, unpublished).
11. minuta: 2.54, 2.11, 2.14, 2.26; 0.58, 0.54, 0.41, 0.51. Alkaliphilous, preferring high concentrations of oxygen. This diatom is of widespread occurrence in Northern Arizona especially in Lower Lake Powell during the spring (Czarnecki & Blinn, unpublished).
12. norvegica: 0, 3.0, 0, 1.0; 0, 0.17, 0, 0.06. According to Patrick & Reimer (1975), this taxon appears to be associated with lakes, lake sediments, and springs, is a possible cold water form and is pH indifferent. In our collections, this diatom is usually in warm water of high alkalinity and conductivity. It is quite common in Lake Powell during the summer (Czarnecki & Blinn, unpublished).
13. parva: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Probably alkaliphilous.
14. prostrata: 2.0, 1.0, 1.5, 1.5; 0.28, 0.3, 0.08, 0.22. Alkaliphilous, preferring water with high oxygen concentrations, and in our collections, preferring moderate conductivity.
15. pusilla: 2.0, 2.0, 2.25, 2.08; 0.07, 0.06, 0.24, 0.12. Probably alkaliphilous.
16. sinuata: 1.33, 1.5, 1.0, 1.29; 0.07, 0.09, 0.02, 0.06. Tolerant of a wide range of ecological conditions. In our collections this diatom is alkaliphilous.
17. tumida: 2.33, 1.0, 0, 1.11; 0.49, 0.06, 0, 0.18. Alkaliphilous.
18. tumidula: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Probably alkaliphilous.

Genus *Denticula*

1. *elegans*: 3.07, 2.75, 2.5, 2.77; 0.75, 0.94, 1.08, 0.92. Alkaliphilous and in our collections preferring water of high conductivity.
2. *rainierensis*: 2.0, 2.0, 0, 1.33; 0.14, 0.06, 0, 0.07. Undoubtedly a good indicator of high alkalinity and conductivity. The highest concentrations of this taxon have occurred on salt cakes ($MgSO_4$?) adjacent to Wiregrass Spring (Czarnecki & Blinn, unpublished).

Genus *Diatoma*

1. *himale* var. *mesodon*: 2.75, 3.0, 2.0, 2.58; 0.19, 0.26, 0.16, 0.2. Alkaliphilous (?).
2. *vulgare*: 2.93, 3.85, 2.77, 3.18; 1.6, 2.2, 1.35, 1.72. Alkaliphilous, preferring water of moderate conductivity (in our collections). This taxon is usually found associated with *Cladophora* in moderate to strong current (in our collections).
3. *vulgare* var. *breve*: 3.0, 1.0, 4.0, 2.6; 0.21, 0.03, 0.11, 0.12. Alkaliphilous.
4. *vulgare* var. *linearis*: 0, 1.0, 1.67, 0.89; 0, 0.03, 0.14, 0.06. Alkaliphilous (?).

Genus *Diploneis*

1. *elliptica*: 2.0, 2.0, 0, 1.33; 0.07, 0.11, 0, 0.06. Alkaliphilous, preferring water of high conductivity (in our collections).
2. *oblongella*: 2.0, 1.5, 0, 1.16; 0.04, 0.09, 0, 0.04. Alkaliphilous, probably preferring water of high conductivity. One specimen extended the alveolar range to 21 in 10 μm.
3. *oculata*: 0, 2.0, 2.0, 1.33; 0, 0.11, 0.05, 0.05. Alkaliphilous, preferring water of high conductivity (in our collections).
4. *puella*: 1.67, 2.0, 0, 1.22; 0.09, 0.05, 0, 0.05. Alkaliphilous, preferring water of moderate to high conductivity.
5. *smithii* var. *dilatata*: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Probably alkaliphilous, preferring water of high conductivity.

Genus *Entomoneis* (Previously *Amphiprora*)

1. *alata*: 0, 3.0, 0, 1.0; 0, 0.08, 0, 0.03. Alkaliphilous, preferring water of extremely high conductivity. This taxon is commonly found in Cholla Lake and is presently in the culture collection of Northern Arizona University (Czarnecki & Blinn, unpublished).

2. palludosa: 2.0, 3.0, 2.0, 2.33; 0.04, 0.08, 0.16, 0.09. Alkaliphilous, preferring water of high conductivity.

Genus Epithemia

1. adnata: 2.5, 3.0, 1.5, 2.33; 0.09, 0.51, 0.08, 0.23. (Previously E. zebra) Alkaliphilous, but able to tolerate a wide range of ecological conditions.
2. argus var. alpestris: 0, 2.0, 2.0, 1.33; 0, 0.06, 0.05, 0.04. Probably alkaliphilous.
3. argus var. longicornis: 2.0, 2.71, 2.0, 2.24; 0.18, 0.54, 0.05, 0.26. Probably alkaliphilous preferring moderate conductivity.
4. sorex: 3.9, 2.56, 3.57, 3.34; 0.68, 0.66, 0.62, 0.65. Alkaliphilous, usually associated with moss seeps or entanglements of vegetation.
5. turgida: 2.0, 2.75, 0, 1.58; 0.07, 0.59, 0, 0.22. Alkaliphilous, calciphilous (?).

Genus Fragilaria

1. brevistriata var. inflata: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Alkaliphilous, preferring high conductivity.
2. capucina: 3.67, 4.0, 0, 2.56; 0.19, 0.57, 0, 0.25. Alkaliphilous, a common plankter.
3. capucina var. mesolepta: 6.0, 2.0, 2.0, 3.33; 0.11, 0.05, 0.09. Alkaliphilous, able to tolerate higher conductivity than the nominate variety.
4. crotonensis: 2.0, 2.0, 0, 1.33; 0.11, 0.06, 0, 0.06. Alkaliphilous, a common plankter.
5. construens var. venter: 2.0, 2.0, 2.0, 2.0; 0.04, 0.06, 0.05, 0.05. Alkaliphilous. This taxon is quite common in Montezuma Well (Czarnecki & Blinn, unpublished).
6. leptostauron: 2.0, 0, 2.0, 1.33; 0.07, 0, 0.05, 0.04. Alkaliphilous.
7. leptostauron var. dubia: 2.0, 1.0, 2.0, 1.67; 0.04, 0.03, 0.11, 0.06. Alkaliphilous.
8. vaucheriae: 2.0, 2.6, 0, 1.53; 0.28, 0.37, 0, 0.22. Alkaliphilous. Common in lower Lake Powell (Czarnecki & Blinn, unpublished).

Genus Frustulia

1. vulgaris: 1.94, 1.2, 1.6, 1.58; 0.58, 0.17 0.22, 0.32. Alkaliphilous. Probably requiring high organic content (in our collections).

Genus Gomphoneis

1. herculeana: 2.0, 0, 0, 0.67; 0.07, 0, 0, 0.02. Alkaliphilous. Common in Oak Creek and Beaver Creek, probably indicative of a current requirement (Czarnecki & Blinn, unpublished).

Genus Gomphonema

1. acuminatum: 0, 1.0, 1.0, 0.67; 0, 0.03, 0.03, 0.02. Alkaliphilous. Usually considered a lake form, however this is not the case in our collections.
2. affine var. insigne: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Alkaliphilous.
3. intricatum: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Alkaliphilous.
4. intricatum var. vibrio: 0, 1.0, 0, 0.33; 0, 0.03, 9, 0.01. Alkaliphilous.
5. grunowii: 0, 0, 1.0, 0.33; 0, 0, 0.03, 0.01. (Previously G. lanceolatum). Alkaliphilous.
6. parvulum: 2.18, 3.5, 2.5, 2.73; 0.42, 0.60, 0.81, 0.61. Alkaliphilous (?), possibly an indicator of organic enrichment. Very common in Northern Arizona (Czarnecki & Blinn, unpublished)..
7. subclavatum: 2.0, 1.63, 3.0, 2.21; 0.11, 0.37, 0.16, 0.21. (Previously G. longiceps var. subclavatum and var. subclavatum f. gracilis). Probably alkaliphilous and preferring moderate conductivity.
8. truncatum: 2.0, 0, 0, 0.67; 0.11, 0, 0, 0.04. (Previously G. constrictum). Alkaliphilous and calciphilous (?).

Genus Gyrosigma

1. spencerii: 1.0, 0, 2.0, 1.0; 0.04, 0, 0.11, 0.05. Alkaliphilous, preferring moderate to high conductivity (in our collections).
2. spencerii var. curvula: 2.0, 0, 0, 0.67; 0.07, 0, 0, 0.02. As the nominate variety.

Genus Hantzschia

1. amphioxys: 2.0, 1.5, 2.0, 1.83; 0.25, 0.09, 0.05, 0.13. Alkaliphilous. Some of our specimens were quite atypical, depressing the length range to 21 μm, width to 5 μm, and extending the strial range to 28 in 10 μm.
2. amphioxys f. capitata: 1.0, 2.0, 2.0, 1.67; 0.02, 0.06, 0.05, 0.04. Alkaliphilous.

Genus Mastogloia

1. elliptica var. danseii: 2.0, 2.75, 1.0, 1.92; 0.04, 0.31, 0.03, 0.13. Alkaliphilous, preferring water of high conductivity. Common in the Warm Creek and Wiregrass Spring area of Lower Lake Powell (Czarnecki & Blinn, unpublished).
2. grevillei: 2.0, 2.0, 0, 1.33; 0.04, 0.06, 0, 0.03. Probably alkaliphilous.
3. smithii: 2.0, 2.83, 4.0, 2.94; 0.14, 0.49, 0.32, 0.32. Alkaliphilous and calciphilous.
4. smithii var. amphicephala: 0, 2.5, 0, 0.83; 0, 0.14, 0, 0.05. Probably alkaliphilous.
5. smithii var. lacustris: 2.65, 3.0, 3.5, 3.05; 0.37, 0.34, 0.19, 0.30. Alkaliphilous and calciphilous. Common in the Warm Creek area of Lake Powell (Czarnecki & Blinn, unpublished).

Genus Melosira

1. varians: 2.6, 2.0, 2.17, 2.26; 0.91, 0.17, 0.35, 0.30. Alkaliphilous. This is the commonest member of Melosira in Northern Arizona (Czarnecki & Blinn, unpublished) and is usually restricted to flowing systems.

Genus Meridion

1. circulare: 2.0, 0, 0, 0.67; 0.11, 0, 0, 0.04. Common in flowing systems.

Genus Navicula

1. accomoda: 1.5, 0, 0, 0.5; 0.05, 0, 0, 0.02. Alkaliphilous.
2. anglica var. subsalsa: 1.5, 0, 0, 0.5; 0.05, 0, 0, 0.02. Alkaliphilous preferring water of high conductivity.
3. arvenensis: 3.0, 2.2, 2.0, 2.4; 0.53, 0.31, 0.22, 0.35. A warm water alkaliphil.
4. bacillum: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Alkaliphilous.
5. cincta: 1.5, 1.5, 2.0, 1.67; 0.05, 0.09, 0.05, 0.06. Alkaliphilous preferring water of high conductivity.
6. cocconeiformis: 2.0, 0, 2.0, 1.33; 0.04, 0, 0.05, 0.03. Probably alkaliphilous.
7. cryptocephala: 2.3, 1.8, 2.46, 2.19; 0.53, 0.26, 0.86, 0.55. Alkaliphilous. Common throughout Northern Arizona (Czarnecki & Blinn, unpublished).
8. cryptocephala f. minuta: 2.0, 1.86, 2.14, 2.0; 0.49, 0.37, 0.81, 0.56. As the nominate.

9. cryptocephala var. veneta: 3.61, 2.8, 2.4, 2.94; 0.82, 0.40, 0.32, 0.51. Alkaliphilous preferring water of high conductivity.
10. cuspidata: 1.5, 1.38, 2.0, 1.63; 0.05, 0.31, 0.05, 0.14. Alkaliphilous. Common throughout Northern Arizona and usually associated with sediment (Czarnecki & Blinn, unpublished).
11. cuspidata var. major: 0, 0, 2.0, 0.67; 0, 0, 0.05, 0.02. Probably alkaliphilous.
12. decussis: 1.67, 0, 1.67, 1.11; 0.09, 0, 0.14, 0.08. Alkaliphilous preferring water of high conductivity.
13. densestriata: 0, 2.0, 0, 0.67; 0, 0.06, 0, 0.02. Probably alkaliphilous.
14. eulineata: 0, 2.0, 0, 0.67; 0, 0.06, 0, 0.02. This tentatively assigned taxon is probably alkaliphilous.
15. gregaria: 1.0, 0, 0, 0.33; 0.02, 0, 0, 0.01. Alkaliphilous preferring water of high conductivity.
16. grimmei: 0, 0, 2.0, 0.67; 0, 0, 0.05, 0.02. Alkaliphilous.
17. lanceolata: 0, 0, 2.0, 0.67; 0, 0, 0.09, 0.03. Alkaliphilous preferring water of high conductivity.
18. longirostris: 4.5, 3.0, 0, 2.5; 0.16, 0.09, 0, 0.08. Alkaliphilous and preferring water of high conductivity. Common on salt cakes ($MgSO_4$?) adjacent to Warm Creek and Wiregrass Springs (Czarnecki & Blinn, unpublished).
19. minima: 1.5, 2.5,1.75, 1.92; 0.05, 0.14, 0.19, 0.13. Alkaliphilous but tolerant of low oxygen concentrations.
20. miniradiata: 0, 0, 1.0, 0.33; 0, 0, 0.02, 0.01. This tentatively assigned taxon is probably alkaliphilous.
21. miniscula: 0, 2.0, 0, 0.67; 0, 0.06, 0, 0.02. Alkaliphilous (?).
22. mutica: 4.0, 1.57, 0, 1.86; 0.07, 0.31, 0, 0.13. Alkaliphilous preferring water of high conductivity.
23. mutica var. cohnii: 2.0, 0, 1.0, 1.0; 0.07, 0, 0.03, 0.03. As the nominate variety.
24. mutica var. stigma: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Probably alkaliphilous, preferring water of high conductivity and warmer temperatures.
25. mutica var. undulata: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Alkaliphilous preferring water of high conductivity.
26. notha: 0, 0, 2.0, 0.67; 0, 0, 0.05, 0.02. Probably alkaliphilous.
27. pelliculosa: 1.0, 0, 0, 0.33; 0.02, 0, 0, 0.01. Alkaliphilous preferring water of high conductivity.
28. pseudoreinhardtii: 0, 1.0, 0, 0.33; 0, 0.03, 0, 0.01. Probably alkaliphilous.
29. pupula: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Alkaliphilous, halophilous.

30. *pupula* var. *rectangularis*: 1.5, 2.0, 1.6, 1.7; 0.05, 0.4, 0.22, 0.22. Prefers slightly higher conductivity than *N. pupula*.
31. *radiosa*: 2.1, 1.5, 1.5, 1.7; 0.37, 0.26, 0.41, 0.35. Tolerant of many ecological conditions. Widespread in Northern Arizona but not in high abundance (Czarnecki & Blinn, unpublished).
32. *radiosa* var. *tenella*: 2.14, 1.6, 2.0, 1.91; 0.26, 0.29, 0.38, 0.31. As the nominate.
33. *secreta* var. *apiculata*: 2.25, 2.0, 2.0, 2.08; 0.32, 0.06, 0.05, 0.14. Alkaliphilous preferring water of high conductivity. One of the specimens depressed the length range to 25 um and extended the strial range to 19 in 10 um.
34. *silicificata*: 3.0, 1.0, 3.0, 2.33; 0.21, 0.03, 0.24, 0.16. This tentatively assigned taxon is probably alkaliphilous and halophilous. It is widely distributed in the lower Lake Powell system (Czarnecki & Blinn, unpublished).
35. *subtilissima*: 0, 1.5, 0, 0.5; 0, 0.09, 0, 0.03. Probably alkaliphilous.
36. *tridentula*: 2.0, 1.0, 1.67, 1.56; 0.07, 0.03, 0.14, 0.08. Probably alkaliphilous. This is probably the first report of this taxon's occurrence in the United States.
37. *tripunctata*: 2.27, 1.65, 1.86, 1.93; 1.47, 0.8, 1.11, 1.13. Alkaliphilous. One of the most common diatoms in the Grand Canyon.
38. *tripunctata* var. *schizonemoides*: 2.0, 0, 2.6, 1.53; 0.07, 0, 0.35, 0.14. Prefers water of high conductivity.
39. *tuscula*: 2.0, 0, 1.0, 1.0; 0.04, 0, 0.03, 0.02. Probably alkaliphilous.
40. *viridula*: 0, 1.5, 2.0, 1.16; 0, 0.09, 0.05, 0.05. Alkaliphilous. Common in the Oak Creek area (Czarnecki & Blinn, unpublished).
41. *viridula* var. *rostellata*: 0, 0, 2.0, 0.67; 0, 0, 0.05, 0.02. Alkaliphilous.
42. *zanoni*: 2.0, 2.0, 0, 1.33; 0.11, 0.11, 0.07. Alkaliphilous.

Genus *Neidium*

1. *binode*: 2.0, 1.0, 0, 1.0; 0.07, 0.33, 0, 0.13. We usually find this taxon associated with a neustonic community, especially in pools with high organic sediments (Czarnecki & Blinn, unpublished).
2. *dubium* f. *constrictum*: 1.67, 0, 0, 0.56; 0.09, 0, 0, 0.03. Usually epipelic and probably alkaliphilous preferring dissolved organics.

Genus Nitzschia

1. aciculaAris: 2.33, 1.5, 1.5, 1.78; 0.24, 0.09, 0.08, 0.14. Probably alkaliphilous.
2. acuta: 0, 0, 2.0, 0.67; 0, 0, 0.05, 0.02. Probably alkaliphilous.
3. amphibia: 2.6, 3.0, 0, 1.87; 0.23, 0.34, 0, 0.19. Alkaliphilous and in our collections preferring water of high conductivity.
4. angustata: 0, 3.0, 0, 1.0; 0, 0.09, 0, 0.03. Alkaliphilous.
5. angustata var. acuta: 0, 0, 1.5, 0.5; 0, 0, 0.08, 0.03. Alkaliphilous.
6. apiculata: 2.0, 2.25, 1.7, 1.98; 0.56, 0.26, 0.32, 0.38. Alkaliphilous preferring water of high conductivity.
7. bicrena: 0, 0, 2.0, 0.67; 0, 0, 0.05, 0.02. Alkaliphilous (?).
8. bita: 0, 0, 2.0, 0.67; 0, 0, 0.05, 0.02. Alkaliphilous (?).
9. capitellata: 2.0, 2.0, 1.25, 1.75; 0.04, 0.11, 0.14, 0.10. Alkaliphilous, halophilous.
10. communis: 2.5, 2.0, 1.8, 2.1; 0.35, 0.34, 0.24, 0.31. Alkaliphilous, an obligate nitrogen heterotroph, and in our collections, halophilous.
11. denticula: 1.0, 2.25, 2.0, 1.75; 0.02, 0.26, 0.05, 0.11. Alkaliphilous preferring water of high oxygen concentrations, and in our collections preferring moderate conductivity. Common in lower Lake Powell (Czarnecki & Blinn, unpublished).
12. dissipata: 2.5, 1.92, 2.52, 2.31; 1.31, 0.77, 1.43, 1.17. Alkaliphilous preferring high oxygen concentrations. Common throughout Northern Arizona (Czarnecki & Blinn, unpublished).
13. fonticola: 1.0, 0, 0, 0.33; 0.02 0, 0, 0.01. Alkaliphilous, tolerant of amino acids.
14. frustulum: 2.52, 2.06, 2.94, 2.51; 1.02, 0.89, 1.35, 1.09. Alkaliphilous, halophilous, and an obligate nitrogen heterotroph, One of the most important taxa in the canyon.
15. frustulum var. perpusilla: 1.67, 0, 2.0,1.22; 0.09, 0, 0.22, 0.10. As the nominate.
16. gracilis: 2.0, 1.0, 0, 1.0; 0.04, 0.29, 0, 0.11. Alkaliphilous (?).
17. hungarica: 2.0, 2.0, 0, 1.33; 0.04, 0.06, 0, 0.03. Alkaliphilous, halophilous, able to tolerate low oxygen concentrations.
18. hybrida: 0, 0, 2.0, 0.67; 0, 0, 0.05, 0.02. Alkaliphilous (?).
19. kutzingiana: 2.44, 2.47, 2.33, 2.41; 0.77, 1.06, 0.95, 0.93. Alkaliphilous. One of the most important taxa in the canyon.
20. lacunarum: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Halophilous, calciphilous, and alkaliphilous. One specimen extended the keel puncta range to 10 in 10 μm and depressed the length to 53 μm.

21. linearis: 2.48, 2.3, 2.46, 2.41; 0.91, 0.66, 0.86, 0.81. Alkaliphilous preferring water with high oxygen concentrations. One of the most important taxa in the canyon.
22. littoralis var. tergestina: 0, 2.0, 0, 0.67; 0, 0.06, 0, 0.02. Alkaliphilous (?).
23. microcephala: 1.89, 1.83, 2.13, 1.95; 0.3, 0.31, 0.46, 0.36. Alkaliphilous, halophilous.
24. palea: 2.0, 2.0, 2.67, 2.22; 0.07, 0.11, 0.22, 0.13. A good indicator of organic pollution.
25. pseudolinearis: 2.0, 2.0, 0, 1.33; 0.07, 0.06, 0, 0.04. This tentatively assigned taxon probably is alkaliphilous preferring water of high conductivity. Very common in the Wiregrass Spring area (Czarnecki & Blinn, unpublished).
26. recta: 0, 0, 4.0, 1.33; 0, 0, 0.11, 0.04. Alkaliphilous (?).
27. scalpelliforma: 3.5, 1.0, 2.0, 1.83; 0.12, 0.03, 0.11, 0.09. This tentatively assigned taxon is probably alkaliphilous preferring water of high conductivity. This diatom is common in the Warm Creek area of Lake Powell (Czarnecki & Blinn, Unpublished).
28. sigma: 0, 2.0, 2.5, 1.5; 0, 0.06, 0.14, 0.07. Alkaliphilous, halophilous.
29. sinuata var. tabellaria: 0, 0, 2.0, 0.67; 0, 0, 0.05, 0.02. Alkaliphilous. Very common in Oak Creek (Czarnecki & Blinn, unpublished).
30. tryblionella var. calida: 0, 0, 2.0, 0.67; 0, 0, 0.11, 0.04. Alkaliphilous (?).
31. vermicularis: 3.0, 0, 0, 1.0; 0.05, 0, 0, 0.02. Alkaliphilous and halophilous.

Genus Opephora

1. ansata: 2.0, 1.0, 2.0, 1.67; 0.04, 0.06, 0.05, 0.05. Probably alkaliphilous and halophilous.

Genus Plagiotropis (Formerly Tropodoneis)

1. lepidoptera: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Euhalobous.

Genus Pinnularia

1. appendiculata: 2.67, 2.0, 2.0, 2.22; 0.14, 0.11, 0.22, 0.16. Aerophilous.
2. borealis var. rectangularis: 0, 0, 1.0, 0.33; 0, 0, 0.02, 0.01. Alkaliphilous (?).
3. brebissonii: 0, 2.0, 2.0, 1.33; 0, 0.06, 0.05, 0.04. According to Patrick & Reimer (1966) this taxon prefers water of low mineral content. This is definitely not the case in our collections.
4. divergentissima: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Cool water form. One specimen depressed the length range to 27 μm.

5. *prescottia*: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01.
This tentatively assigned taxon is probably alkaliphilous.

Genus *Pleurosigma*

1. *delicatulum*: 2.0, 0, 1.8, 1.27; 0.04, 0, 0.24, 0.09.
Alkaliphilous and halophilous.

Genus *Rhoicosphenia*

1. *curvata*: 3.04, 2.5, 2.76, 2.77; 1.33, 1.0, 0.97, 1.1.
Alkaliphilous preferring water with high oxygen concentrations. Very common in flowing waters in Northern Arizona (Czarnecki & Blinn, unpublished). This is one of the most important taxa in the canyon.

Genus *Rhopalodia*

1. *gibba*: 2.71, 3.25, 2.56, 2.84; 0.67, 1.11, 0.62, 0.80.
Alkaliphilous. Very common throughout Northern Arizona and usually associated with epilithic or epiphytic communities (Czarnecki & Blinn, unpublished). This is one of the most important taxa in the canyon.
2. *gibba* var. *ventricosa*: 0, 0, 2.0, 0.67; 0, 0, 0.05, 0.02.
As the nominate variety.
3. *gibberula* var. *vanheurckii*: 1.83, 2.29, 2.33, 2.15; 0.19, 0.46, 0.19, 0.28. Alkaliphilous preferring somewhat higher conductivity than *R*. *gibba*.

Genus *Scoliopleura*

1. *peisonis*: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01.
Alkaliphilous and extremely halophilous.

Genus *Stauroneis*

1. *anceps*: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01.
Wide range of ecological tolerances.
2. *amphioxys* var. *rostrata*: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01.
This tentatively assigned taxon is probably alkaliphilous.
3. *smithii*: 2.0, 1.0, 1.0, 1.33; 0.04, 0.03, 0.03, 0.03.
Alkaliphilous.

Genus *Surirella*

1. *angustata*: 2.2, 2.0, 2.0, 2.06; 0.19, 0.06, 0.22, 0.16.
Alkaliphilous.

2. brightwellei: 2.0, 2.0, 1.6, 1.87; 0.14, 0.06, 0.22, 0.14. Probably alkaliphilous and halophilous.
3. ovalis: 0, 2.0, 3.0, 1.67; 0, 0.06, 0.32, 0.13. Alkaliphilous.
4. ovata: 2.38, 1.5, 1.5, 1.79; 0.33, 0.09, 0.08, 0.16. Alkaliphilous, rheophilous.
5. ovata var. africana: 0, 1.0, 0, 0.33; 0, 0.03, 0, 0.01. Alkaliphilous (?).
6. ovata var. pinnata: 1.0, 0, 0, 0.33; 0.02, 0, 0, 0.01. As the nominate variety.
7. patella: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Alkaliphilous.
8. striatula: 2.0, 0, 0, 0.67; 0.07, 0, 0, 0.02. Alkaliphilous and halophilous.
9. striatula var. parva: 0, 1.5, 0, 0.5; 0, 0.09, 0, 0.03. As the nominate variety.

Genus Synedra

1. acus: 2.75, 2.5, 1.0, 2.08; 0.19, 0.14, 0.03, 0.12. Alkaliphilous and halophilous.
2. affinis: 0, 0, 3.33, 1.11; 0, 0, 0.27, 0.09. Alkaliphilous (?).
3. delicatissima var. angustissima: 3.0, 0, 2.0, 1.67; 0.05, 0, 0.05, 0.03. Phytoplankter.
4. goulardii: 2.0, 0, 0, 0.67; 0.04, 0, 0, 0.01. Usually found in warm water.
5. incisa: 0, 1.5, 2.0, 1.16; 0, 0.09, 0.05, 0.05. Alkaliphilous (?).
6. mezamaensis: 0, 6.0, 0, 2.0; 0, 0.17, 0, 0.06. Alkaliphilous (?).
7. miniscula var. longa: 1.0, 0, 0, 0.33; 0.02, 0, 0, 0.01. This tentatively assigned taxon is probably alkaliphilous and possibly halophilous.
8. pulchella var. lacerata: 1.0, 0, 0, 0.33; 0.02, 0, 0, 0.01. Probably alkaliphilous. One specimen depressed the strial range to 15 in 10 um and length to 24 um.
9. rumpens: 1.5, 1.0, 0, 0.83; 0.05, 0.03, 0, 0.03. Widely tolerant.
10. socia: 0, 2.5, 3.2, 1.9; 0, 0.28, 0.43, 0.24. Alkaliphilous, rheophilous (?).
11. ulna: 2.38, 2.65, 2.16, 2.4; 1.09, 1.74, 1.11, 1.31. Widely tolerant. One of the most important taxa in the canyon.
12. ulna var. contracta: 2.0, 0, 1.0, 1.0; 0.04, 0, 0.03, 0.02. Alkaliphilous (?).