USE OF DIATOMS AND SOFT ALGAE AS INDICATORS OF ENVIRONMENTAL DETERMINANTS IN THE LAHONTAN BASIN, USA.

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ABSTRACT

This study represents a preliminary report of a much larger study on the efficacy of diatoms and soft algae (non-diatoms) as indicators of environmental conditions in streams located throughout the Lahontan Basin, USA. An additional 27 stream communities with abiotic parameters, including nutrients, will be added to the following data set to more fully analyze the use of diatoms and soft algae as monitors of abiotic determinants in the Lahontan Basin.

Diatom and soft algal communities were analyzed in 38 stream habitats in the Lahontan Basin during 1996 through 1999. In addition to elevation, thirteen abiotic parameters were measured at each site and tested as determinants of diatom and soft algal distributions. Stream sites ranged from 5340 to 9340 ft asl and had a wide gradient of discharge, substratum, canopy cover, and water quality conditions.

Two hundred and five diatom taxa and over 30 soft algal taxa were identified in the stream habitats, with indications that algal assemblages were closely correlated with stream abiotic determinants. Diatoms were better indicators of stream conditions than soft algal communities, although species of the filamentous green alga, *Stigeoclonium* were abundant in habitats considered to have low ecological integrity.

Several metrics were used to the test the efficacy of diatom assemblages and individual species as determinants of stream conditions. A multidimensional ordination showed dissolved oxygen, alkalinity, conductivity, and substratum conditions to be significantly correlated with diatom community structure. Diatom communities ordinated stream habitats into high elevation systems with coarse substrata, high gradients, high discharge, high canopy cover, and low conductance from low elevation systems with fine substrata, low gradients, low discharge, low canopy cover, and high conductance. The latter systems were considered to have low ecological integrity.

An ANOSIM analysis of *a priori* grouping designations based on general stream conditions showed that diatom communities in habitats with abiotic conditions that

correlated with high ecosystem integrity had significantly different diatom community compositions than those with low ecosystem integrity. The diatom species of *Achnanthidium minutissima*, *Aulacoseira islandica*, *Aulacoseira italica*, *Eunotia bilunaris*, *Fragilaria arcus*, *Opephora olsenii*, *Tabellaria fenestrata*, and *Tetracyclus rupestris* formed assemblages at higher elevations in habitats with high gradients, high discharges, coarse substrata, high canopy cover, and low conductance. These taxa are considered to represent stream habitats with high ecological integrity in the Lahontan Basin which concurs with other findings in the literature. In contrast, diatom species such as *Ctenophora pulchella*, *Cyclotella meneghiana*, *Epithemia sorex*, *Gomphonema truncatum*, *Hantzschia amphibia*, *Nitzschia acicularis*, *Nitzschia palea*, *Nitzschia frustulum*, and *Rhopalodia gibba* formed assemblages at lower elevations in habitats with low gradients, low discharges, fine substrata, low canopy cover, and high conductance. These species are considered to represent stream habitats in the Lahontan Basin with lower ecological integrity. Principal component analysis also showed a strong relationship between diatom species and selected abiotic determinants with strong loadings for elevation, canopy cover, water temperature, conductivity and substratum conditions.

Similar patterns to those of community ordinations and principal component analysis were also found for indices based on the relative abundance of motile diatom taxa. Species of *Hantzschia*, *Navicula*, *Nitzschia*, and *Surirella* were most abundant in low elevation assemblages, with fine substrata, reduced canopy, low gradients, low discharges, and high conductance and lowest in habitats with high ecological integrity. Also, based on indices of % fines and sands and % embeddedness, species such as *Cocconeis placentula* var. *euglypta*, *Cyclotella meneghiniana*, *Fragilaria ulna*, *Gyrosigma accuminatum*, *Nitzschia frustulum*, *Nitzschia palea*, *Nitzschia dissipata*, and *Rhopalodia gibba* were considered to be most tolerant of disturbed sites with substrata composed of a high percentage of fines and sand and a high degree of embeddedness.

INTRODUCTION

Benthic algae are critical components in most stream food webs (Stevenson 1996, Wehr and Sheath 2003). These organisms help stabilize substrata and provide food and habitat for many other organisms, especially invertebrates. Because benthic algal assemblages are attached to substrata, they serve as “micro environmental-loggers” for physical, chemical, and biological disturbances that occur in stream reaches during the time in which the assemblages develop.

Diatoms are especially good indicators of the environmental integrity of lotic ecosystems because they are common in most streams and provide the primary food source for many invertebrates and some juvenile fishes that reside in these systems (Dixit *et al*. 1992, Lowe and Pan 1996, Stevenson and Pan 1999). In addition, diatoms are useful monitors of change because: 1) they are readily dispersed and can invade a variety of habitats; 2) they are relatively easy to sample and create minimal impact to resident biota during collections; 3) their response time (generation time) lies between bacteria (hourly) and macroinvertebrates (triannual), and 4) diatoms are sensitive to subtle changes in environmental conditions and/or disturbances that may not visibly affect other communities, or may only affect other communities at greater levels of disturbance (Bahls 1993, Stevenson and Pan 1999, Stevenson and Bahls 1999).

In addition, the identification of diatoms is based on morphological features of their rigid walls (frustules) made of silicon dioxide (glass). This provides an opportunity to prepare permanent reference slides of diatom assemblages under different environmental regimes for use in assessing water conditions. Many investigators have used various diatom metrics to determine environmental conditions in streams including discharge and hydraulic fluctuations (Duncan and Blinn 1989, Biggs and Hicky 1994, Benenati *et al*. 1998), light (Duncan and Blinn 1989, Hardwick *et al*. 1992), temperature (Squires *et al*. 1979, Blinn *et al*. 1989), salinity (Blinn and Bailey 2001), nutrients (Patrick, 1977, Bahls *et al*. 1992, van Dam *et al*. 1994, Hill *et al*. 2000, Blinn and Bailey 2001), and herbivory (Colletti *et al*. 1987, Steinman *et al*. 1987).

Soft algae (non-diatoms) have also been used as indicators of biological integrity (Palmer 1962, Fjerdingstadt 1965, Palmer 1979, Hill *et al*. 2000), but may have less efficacy than diatoms in this respect due to their highly variable morphology. In contrast to diatoms, the complete identification of many species of soft algae requires reproductive structures and material may need to be cultured in the laboratory for full identification (Stevenson and Pan 1999). Also, soft algal material must be chemically preserved and therefore requires more space than diatom reference slides and needs continual maintenance.

The objectives of this study were to: 1) determine the utility of diatoms and soft algae as predictors of environmental conditions and ecosystem integrity for streams in the Lahontan Basin, and 2) identify those species which best serve as indicators of these environmental determinants and develop monitoring indices with diatoms and soft algae to assess the environmental health of streams throughout the basin.

METHODS

Algal samples were collected on submerged substrata from 38 stream habitats throughout the Lahontan Basin during 1996 through 1999 (SEE Table 1). Replicate collections (n = 3) were made in each stream habitat. Each collection (25 ml) was split equally for diatom and soft algal analyses. Samples for diatoms were digested following the procedures of Van der Werff (1955) and permanent Hyrax® slide mounts were prepared for each collection; i.e., one slide per sample. A minimum of 300 diatom valves was counted from each slide preparation. Density and relative abundance values for each diatom species were averaged from the set of three collections at each site in the final analyses. Diatom nomenclature followed that of Fourtanier and Kociolek (1999).

A diversity index (H') was calculated for diatom assemblages for each site (Shannon and Weaver, 1949).

Soft algal analyses were performed on each collection ($n = 3$) with either a Sedgwick Rafter chamber or Palmer counting cell depending on cell densities. Protocols for cell density estimates followed that of Stevenson and Bahls (1999).

Relative abundance of motile diatoms in each stream habitat was used in two siltation indices. Total relative abundance of *Hantzschia*, *Navicula*, *Nitzschia*, and *Surirella* (HNNS) was estimated for each stream habitat as proposed by Stevenson and Bahls (1999). Species in these genera have some of the most advanced and efficient motility systems in diatoms (Lowe 2003), and are able to migrate to the surface if covered by silt. Therefore, these taxa may represent a good indicator of siltation disturbance in lotic environments. In addition, the relative abundance of all species in the Bacillariales and Surirellales (BASU) was calculated for each stream habitat. A paired Student t test was used to determine significant differences between % of fines and sand and each index.

The following indices for % fines and sand (FSI) and % embeddedness (EMI) were also used to examine the distribution of diatom taxa along substratum and embeddedness gradients:

$$\text{FSI}_x \textbf{ or } \text{EMI}_x = \frac{\sum_{i=1}^{Nx} [\log_{10} (\text{RA}_i \bullet 100)]\ (\%\text{ silt \& sand } \textbf{or } \%\text{ embeddedness}),}{N_x},$$

where RA_i = relative abundance (percent) of species x at a given site, and N = number of sites in which species x occurred. These univariate indices (FSI or EMI) provide a relative numeric scale to evaluate the response of various diatom taxa to substrate composition and embeddedness. Blinn and Bailey (2001) have used similar metrics for determining the response of diatoms to salinity and nutrients in streams.

Principal components analysis was used to determine relationships between dependent (diatom taxa) and independent abiotic variables with SYSTAT software (Version 5.1, Wilkinson, 1989). Correlations between various paired combinations of diatom taxa and determinant variables were also calculated using Pearson's product-moment correlation coefficient with SYSTAT software. Significant differences between paired measurements were obtained from Bonferroni adjusted alpha values of p <0.05.

In addition, non-metric multi-dimensional scaling ordination techniques were employed to investigate relationships between sites based on diatom community composition and to relate community composition to determinant characteristics. Ordinations were based on Bray-Curtis dissimilarity distances using relative frequencies of species occurrence for diatom communities (Minchin 1999). Fourteen determinants were fitted into the ordination space as vectors to show relationships of diatom community composition along physicochemical gradients. The environmental determinants tested were: elevation, discharge, dissolved oxygen, alkalinity, specific conductance, pH, water temperature, densiometer (canopy), slope, embeddedness, and substrate composition (% fines and sand, % gravel, % cobble, % boulder). The fit of abiotic vectors to diatom community composition was tested against 1000 random iterations of fit (Kantvilas & Minchin 1989). Significance levels for vector correlations were adjusted to experiment wide alpha levels of p <0.05 using Dunn-Sidak sequential tests (Ury 1979). During field collections, sites were judged as either degraded on undegraded depending on a holistic visual assessment of substratum conditions, canopy-cover, and discharge, i.e., general health of the system. We tested the similarity of community composition between degraded and un-degraded sites using Analysis of Similarity (ANOSIM) routine (Clark 1993), which tests *a priori* grouping designations against 1000 random group designations in ordination space. Analyses were made using DECODA software (Minchin 1999).

RESULTS

Abiotic determinants: Values for the abiotic determinants used in the analyses of diatoms and soft algae are provided in Table 1. These data represent a subset of a larger data set collected for macroinvertebrates. Bonferonni adjustments showed that temperature had a significant positive relationship with % fines and sand ($r = 0.60$) and a significant inverse relationship to % cobble ($r = -0.65$; Table 2). As expected, % fines and sand showed a significant inverse relationship to cobble ($r = -0.82$) and a significant positive relationship to embeddedness (r = 0.88). Both gravel ($r = -0.58$) and cobble ($r = -0.58$) showed a significant inverse relationship to embeddedness.

Streams ranged from 5340 to 9340 ft asl with Marble the lowest system examined and Virginia the highest in elevation. Water temperatures at the time of collection ranged from a high of 22.2°C at Clearwater (26VII96) to a low of 8.5°C at Glass, and pH was generally circumneutral except for Convict at Snarl, Marble, McGee, Nye, O'Harrel, and Lower Cottonwood on 13VIII99, which had pH values ≥8.0. The most dilute streams were Deadman, Dunderberg, Glass, Hilton, Little Walker, O'Harell, Rock, Upper Truckee Forest, Virginia, and West Walker with specific conductance values <60 µS/cm. Clearwater, Kirman, Lower Hot, Nye, and Upper Owens each had conductance values >200 µS/cm; Nye (451 µS/cm) had the highest conductance. Patterns of negative relationships emerged between elevation and the abiotic determinants of dissolved oxygen, specific conductance and % fines and sand, and a positive relationship between elevation and cobble. No relationships were apparent between elevation and the determinants of water temperature, pH, discharge, slope, and canopy cover.

Diatom distribution and ecology: Estimated diatom densities averaged 211,243 (SE ±45,763) values/cm^2 for all 38 stream sites (Table 3). Lower Cottonwood Creek had the highest diatom density (1,382,202 valves/cm^2) and Upper Truckee Forest (18,610 values /cm^2) had the lowest diatom density. There were no significant correlations between diatom H' or number of diatom taxa with any abiotic determinant (Table 2). The average number of diatom taxa for all 38 streams was 48 (SE ±4.5); x = 50 taxa (SE ±2; n = 10 streams) in streams with >50% fines and sand and 47 ±2 taxa (n = 28) in streams with <50% fines and sand. Kirman had the highest number of diatom taxa (64) and Dog had the fewest taxa (33; Table 3). H' for diatom assemblages ranged from 2.5 in Convict, McGee, and Upper Truckee Barton to 3.5 in Clearwater (10VII97) and Kirman (Table 3).

Two hundred and five diatom taxa were identified from 38 stream habitats throughout the Lahontan Basin, USA. The overall relative frequencies for the dominant taxa are presented in Table 4. These taxa represent over 85% of the mean relative frequency of diatom taxa collected in the stream habitats. Taxa that were present in at least 75% of the stream habitats included, *Achnanthidium minutissima*, *Cocconeis placentula* var. *euglypta*, *Cymbella affinis*, *Fragilaria capucina*, *Fragilaria capucina* var. *vaucheriae*, *Fragilaria ulna*, *Gomphonema parvulum*, *Meridion circulare*, *Navicula cryptocephala, Navicula veneta*, *Nitzschia dissipata*, *Nitzschia palea*, *Nitzschia frustulum*, *Planothidium lanceolata*, *Reimeria sinuata, and Rhoicosphenia abbreviata.*

Achnanthidium minutissima, Fragilaria capucina var *vaucheriae*, *Fragilaria ulna*, *Nitzschia frustulum*, and *Nitzschia palea* occurred in all sampled stream sites.

The percentage of fines and sand (F & S) associated with stream substrata showed a highly significant positive relationship to the motile diatom indices of HNNS (t = 7.36; p <0.001) and BASU (t = 6.87; p < 0.001; Table 5). For example, stream habitats with <10% F & S had HNNS values of 0.16 (SE ±0.03), whereas those with >10% F & S had HNNS values of 0.25 (SE 0.02). Likewise, habitats with <10% F & S had BASU values of 0.1 (SE ±0.03) and those >10% F & S had BASU values of 0.2 (± 0.02). Streams with low HNNS and F & S indices include Upper Truckee Forest, Deadman, Convict, Virginia Little Walker, Green, Arastra, McGee, Deep, and West Walker (Table 5). In contrast, streams with high indices include Cottonwood Lower, Adobe, Nye, Slinkard, Bodie, Lower Hot, Marble, and O'Harrel.

The fines + sand (IFS) and embeddedness (EMI) indices identified both sensitive and tolerant diatom species that responded to substrata conditions (Table 6). *Fragilaria arcus*, *Navicula tripunctata*, *Diatoma mesodon*, *Tetracyclus rupestris*, *Tabellaria fenestrata*, *Frustulia vulgaris*, *Diatoma vulgaris*, *Aulacoseira islandica*, *Pinnularia subcapitata*, and *Eunotia bilunaris* were considered to be most sensitive to fine sediment and embeddedness based on these indices. In contrast, *Gyrosigma accuminatum*, *Achnanthidium minutissima*, *Cocconeis placentula* var. *euglypta*, *Nitzschia frustulum*, *Cyclotella meneghiniana*, *Nitzschia palea*, *Fragilaria pinnata, Rhopalodia gibba*, *Fragilaria leptostauron*, *Fragilaria ulna*, *Nitzschia dissipata*, *Fragilaria capucina* var. v*aucheriae*, and *Fragilaria capucina* were considered to be most tolerant of disturbed sites with substrata composed of a high percentage of fines and sand and a high degree of embeddedness.

Principal component analysis showed strong relationships between diatom taxa and selected abiotic determinants with strong loadings for elevation, densiometer, temperature, conductivity, % fines and sand, and embeddedness. *Aulacoseira italica* (Auit), *Eunotia bilunaris* (Eubi), *Fragilaria arcus* (Frar), *Tabellaria fenestrata* (Tafe), and *Tetracyclus rupestris* (Teru) showed strong positive loadings for elevation and canopy cover (densiometer) and strong negative loadings for temperature, conductivity, and embeddedness (Fig. 1). In contrast, species such as *Cyclotella meneghinana* (Cyme), *Melosira varians* (Meva), *Nitzschia dissipata* (Nidi), *Nitzschia frustulum* (Nifr), *Nitzschia palea* (Nipa), and *Rhopalodia gibberula* (Rhgib) showed strong positive loadings for temperature, conductivity, and embeddedness and strong negative loadings for elevation and canopy cover.

Only three taxa showed a significant relationship to abiotic determinants when adjusted to the Bonferroni test. *Tetracyclus rupestris* showed a positive correlation (r = 0.59) to elevation, *Rhopalodia gibberula* showed a positive correlation (r = 0.60) to embeddedness, and *Achnanthes exigua* showed a positive correlation (r = 0.63) to conductivity. *Achnanthes exigua* showed a positive correlation (r = 0.627) with *Caloneis silicula*. Under a less conservative matrix of probability, several patterns were apparent. *Nitzschia amphibia*, *Nitzschia palea*, and *Rhopalodia gibberula* showed a positive relationship to temperature, *Aulacoseira islandica, Fragilaria arcus*, *Tetracyclus rupestris*, and *Tabellaria fenestrata* showed a positive relationship to elevation, *Fragilaria arcus* a negative relationship to % fines and sand, and *Rhopalodia gibberula* showed a positive relationship to both % fines and sands and embeddedness. Also under similar less conservative constraints, *Pinnularia subcapitata* showed a positive relationship to *Opephora olsenii*, *Pinnularia divergens*, *Tetracyclus rupestris*, and *Tabellaria fenestrata*, *Eunotia bilunaris* showed a positive relationship to *Aulacoseira islandica* and *Aulacoseira italica*. In addition, *Tetracyclus rupestris* showed a positive correlation with *Opephora olsenii* and *Pinnularia divergens*, and *Aulacoseira islandica* showed a positive relationship with *Fragilaria arcus*. Bonferroni adjusted tests also showed a significant positive relationship between total diatom density and conductivity ($r = 0.60$) and % fines and sand ($r = 0.60$), and a significant negative relationship between diatom density and dissolved oxygen ($r = -0.60$; Table 2). There was also a significant positive relationship ($r = 0.56$) between number of diatom taxa and density of the filamentous green alga, *Cladophora*, and patterns of positive correlations between conductivity, diatom density, and *Cladophora* cell density.

A non-metric multi-dimensional ordination of stream habitats based on the relative abundance of 66 diatom taxa was completed in three dimensions with a minimum stress of 0.113. Additional dimensions did not significantly reduce stress or enhance interpretation. Differences in communities were best explained by vectors of dissolved oxygen (MAX R = 0.554, $p = 0.002$), alkalinity (MAX R = 0.601, $p = 0.002$), conductivity (MAX R = 0.535, $p = 0.008$), and substratum conditions [% boulder (MAX 0.501, $p = 0.018$), % cobble (MAX R = 0.467, $p = 0.035$), and % fines and sand (MAX R = 0.467, $p = 0.035$)].

Stream diatom communities in habitats located on the far left side of Figure 2 such as Dog, Dunderberg, Hilton, Virginia, McGee, Rock, Green, Convict (96), and Little

Walker showed strong correlations to high elevation habitats with coarse substrata, low % fines and sand and embeddedness, low conductance, and a developed canopy, with steep gradients. These conditions generally suggest high quality habitats with high ecosystem integrity and biological diversity (Platts *et al.*1983, Raven *et al.* 1998, Barbour *et al.* 1999). In contrast, stream diatom communities in habitats located on the far right of the plot such as Bodie, Clearwater, East and West Walker, Kirman, Lower Cottonwood, Upper Owens, Lower Hot, and Upper Truckee Barton showed strong positive correlations to low elevation habitats with fine substrata, high % fines and sand and embeddedness, high conductance, a more open canopy, with low gradients. These conditions generally suggest low quality habitats with low ecosystem integrity and biological diversity (Platts *et al.* 1983, Raven *et al.* 1998, Barbour *et al.* 1999).

The potential outliers on Figure 2 include Adobe Creek in the lower portion of the plot and Deep and Swauger, and possibly Poore and Deadman, in upper portion. The site at Adobe Creek is located at 6600 ft and has a low stream gradient, low discharge, high canopy cover, with 100% fines and sand (Table 1). The site at Deep Creek is located at one of the higher elevations sampled (8940 ft) and has a steep gradient, low discharge, a moderate canopy, and low % fines and sand (<15%). Swauger has a low gradient, low discharge, a high canopy cover, and is located at a moderate elevation (7880 ft.), and Deadman has a low gradient, high discharge, high canopy cover, and low % fines and sand (5.3%) at an elevation of 8265 ft. Of the stream sites sampled on two different years (Bodie, Clearwater, Lower Cottonwood, and Convict Snarl), only Convict Snarl showed a large deviation between years on the ordination plot (Fig. 2).

An ANOSIM analysis of *a priori* grouping designations based on general stream conditions (substratum, canopy, and discharge) showed that diatom communities in habitats with abiotic conditions correlated with high ecosystem integrity and biological diversity as described above (generally on the left side of Fig. 2), and low ecosystem integrity and biological diversity (generally on the right side of Fig. 2) had significantly different diatom community compositions (ANOSIM $R = 0.269$; $p = 0.001$).

Species averages fitted into ordination space indicated that many diatom species were associated with environmental gradients (Fog. 3). Diatom taxa clustered on the left side of the plot, including *Achnanthidium minutissima* (Acmi), *Aulacoseira islandica* (Auis), *Aulacoseira italica* (Auit), *Eunotia bilunaris* (Eubi), *Fragilaria arcus* (Frar), *Opephora olsenii* (Opol), *Tabellaria fenestrata* (Tafe), and *Tetracyclus rupestris* (Teru) formed assemblages at higher elevations in habitats with steep gradients, high discharges, coarse substrata, high canopy cover, and low conductance. In contrast, species on the right side of the plot such as *Ctenophora pulchella* (Ctpu), *Epithemia sorex* (Epso), *Rhopalodia gibba* (Rhgi), *Gomphonema truncatum* (Gotr), *Nitzschia acicularis* (Niac), *Cyclotella meneghiana* (Cyme), *Hantzschia amphibia* (Haam), *Nitzschia palea* (Nipa), and *Nitzschia frustulum* (Nifr) formed assemblages at lower elevations in habitats with low gradients, low discharges, fine substrata, a more open canopy, and high conductance.

Habitats with higher conductance levels (Clearwater, Kirman, Lower Hot, and Upper Owens) were positioned along the conductance vector (Fig. 2). No diatom species showed a strong correlation to conductance, but the species cluster of *Ctenophora pulchella*, *Epithemia sorex*, *Rhopalodia gibba*, *Gomphonema truncatum*, *Nitzschia* *acicularis*, *Cyclotella meneghiana*, *Hantzschia amphibia*, and *Nitzschia palea* suggest a positive association to conductance (Fig. 3).

Soft algal distribution and ecology: Number of cyanobacterian taxa showed a significant positive relationship to conductivity (*r* = 0.71), alkalinity (*r* = 0.62), and % fines and sand (*n* = 0.59; Table 2). There was also a significant positive correlation (*r* = 0.60) between total algal density (diatoms + soft algae) and conductivity (*r* = 0.60) and % fines and sand (*r* = 0.60). There was also a significant inverse relationship (*r* = -0.57) between cobble and total number of soft and diatom taxa. No significant correlations were measured between number and density of green algae and densities of the filamentous green algae, *Cladophora* spp. and *Stigeoclonium* spp. and any of the measured abiotic determinants. *Stigeoclonium* occurred primarily in those stream habitats on the right side of Figure 2.

The estimated average density of soft algae was 599,510 cells/cm^2 for all sites and ranged from 7469 cells/cm^2 at Little Walker to over 350,000 cells/cm^2 at Marble Creek. The number of green algal taxa ranged from 0 to 5 and cyanobacterian taxa ranged from 1 to 4 in the sampled sites (Table 3). Estimated average densities of green algae and cyanobacteria for all sites was 195,299 cells/cm^2 and 403,129 cells /cm^2, respectively. Highest densities of filamentous green algae (*Cladophora* and *Stigeoclonium*) were found at Adobe, Clearwater, Mammoth, Bodie, Lower Hot, and Kirman. Other filamentous green algae included the Zygnematales (*Spirogyra* and *Mougeotia*), *Oedogonium*, and *Ulothrix*. Species of *Calothrix*, *Nostoc*, and *Phormidium* were the most common cyanobacteria. *Cladophora* spp. attained highest densities at Adobe and Clearwater, whereas *Stigeoclonium* spp. attained highest densities at Arastra, Bodie, Lower Hot, and

Kirman. No filamentous green algae were collected at Deadman, Deep, Dog, Dunderberg, McGee, Little Walker, Marble, and Swauger. Lower Cottonwood and Nye had the highest densities of cyanobacteria (Table 3).

DISCUSSION

Diatom assemblages and individual species provided reliable indicators of stream conditions throughout the Lahontan Basin. A multi-dimensional ordination showed that dissolved oxygen, alkalinity, conductivity, and substratum conditions were the most significant environmental determinants influencing diatom community structure in the region. Principal components analysis and indices for motile diatoms, % fines and sand, and % embeddedness showed similar relationships between diatom species and the four abiotic determinants. The interactions between these abiotic factors produced highly varied diatom assemblages across different stream habitats, but with distinctive and similar diatom communities in habitats with similar abiotic conditions.

An ANOSIM analysis of *a priori* grouping designations based on general stream conditions showed that those diatom communities in habitats with abiotic conditions correlated with high ecosystem integrity had significantly different diatom community compositions than those with low ecosystem integrity. Diatom communities ordinated stream habitats into high elevation streams with coarse substrata, high gradients, high discharge, high canopy cover, and low conductance from low elevation systems with fine substrata, low gradients, low discharge, low canopy cover, and high conductance. The diatom species of *Achnanthidium minutissima*, *Aulacoseira islandica*, *Aulacoseira italica*, *Eunotia bilunaris*, *Fragilaria arcus*, *Opephora olsenii*, *Tabellaria fenestrata*, and *Tetracyclus rupestris* formed assemblages at higher elevations in habitats with steep gradients, high discharges, coarse substrata, high canopy cover, and low conductance.

These taxa are considered to represent stream habitats with relatively high ecological integrity in the Lahontan Basin.

In an extensive, long-term survey of diatom communities in streams throughout Montana, USA, Bahls (1993) found that most of the above taxa were highly sensitive to pollution disturbance, including siltation and nutrient enrichment. He also reported that species that clustered on the far right side of Figure 3 such as *Amphora ovalis*, *Amphora pediculus*, *Cyclotella stelligera*, *Karayevia clevei*, and *Reimeri sinuata* are highly sensitive to pollution.

In contrast, diatom species such as *Ctenophora pulchella*, *Cyclotella meneghiana*, *Epithemia sorex*, *Gomphonema truncatum*, *Hantzschia amphibia*, *Nitzschia acicularis*, *Nitzschia palea*, *Nitzschia frustulum*, and *Rhopalodia gibba* formed assemblages at lower elevations in habitats with low gradients, low discharges, fine substrata, low canopy cover, and high conductance. Many of these species are frequently associated with lower elevation streams with a high degree of embeddedness, abundant aquatic macrophytes and/or filamentous green algae, and somewhat elevated conductivity and nutrients (Lowe, 1974, Patrick and Reimer 1976, Bahls *et al.* 1984). Bahls (1993) indicated that most of the above taxa were pollution tolerant with *G. herculeana*, *G. truncatum*, and *N. palea* highly tolerant to pollution. In fact, all taxa on the mid to far right side of the ordination plot were considered either tolerant or highly tolerant to pollution with the exception of *E. sorex* and *Meridion circulare* that Bahls considers to be highly sensitive to pollution disturbance.

Individual diatom taxa showed subtle differences in environmental conditions. For example, *F. arcus*, *T. fenestrata*, and *T. rupestris* all prefer cold waters with relatively coarse substrata, but both *F. arcus* and *T. rupestris* showed a closer association to habitats with lower discharges than *T. fenestrata* on the community ordination plot, i.e., *F. arcus* and *T. rupestris* showed a close relationship to the cool, slower flowing habitats of Poore, Deep and Swauger creeks and *T. rupestris* aligned with the cool fast flowing habitats of Virginia, McGee, and Rock creeks (Figs. 3 and 4).

Also, individual diatom taxa suggested subtle correlations to elevated conductivity even though levels were relatively low and over a relatively narrow range (16-451µS). For example, such taxa as *Caloneis silicula*, *Ctenophora pulchella*, *Hantzschia amphioxys*, *Nitzschia frustulum*, *Nitzschia palea*, and *Rhopalodia gibberula* showed a close association on the ordination plot with streams such as Clearwater, Kirman, and Nye with higher conductivity levels (Figs. 2 and 3). Other studies have shown a similar relationships between these diatom species and higher conductance (Fritz 1990, Blinn 1993, Wilson, *et al.* 1994, Cumming and Smol 1993, Herbst and Blinn 1998, Blinn and Bailey 2001). These diatom taxa may provide early warning signals of increased salinization in semi-arid regions of the Lahontan Basin with heavy agricultural use (Williams, 1987, 1999, Blinn and Bailey 2001).

Although nutrients were not measured in this study, several diatom taxa that infer nutrient enrichment including *Achnanthes exigua*, *Hantzschia amphioxys*, *Luticola mutica*, *Melosira varians*, *Navicula veneta*, *Nitzschia frustulum*, and *Nitzschia palea* showed a close association with Dexter, Lower Cottonwood, Clearwater, Burcham, and Bodie creeks (Figs 2 and 3). All of these habitats have relatively high levels of filamentous green algae, especially *Stigeoclonium* spp. that suggest these streams receive higher nutrients from surrounding watersheds. All of these taxa have been reported to show close correlations to nutrient enrichments of phosphorus and nitrogen (Palmer 1969, Bahls 1984, Christie and Smol 1993, Hall and Smol 1995, Reavie *et al.* 1995, Blinn and Bailey 2001). The lack of filamentous green algae in Deadman, Deep, Dog, Dunderberg, McGee, Little Walker, Marble, and Swauger suggest relatively low nutrient levels in these systems (Palmer 1969). All of these streams, except Dog and Marble had specific conductance values <100 µS/cm which also suggests lower nutrients. Future collections where nutrients are included will likely show a strong nutrient vector along this axis of diatom species.

The similarities between streams with high and low ecological integrity for both number of taxa and H' diversity suggest that nutrient enrichment and/or salinity levels have not reached high enough concentrations in the sampled streams to influence these indices. A number of studies have shown that diatom species and diversity are greatly diminished under elevated organic enrichment (Nather Khan 1990, Whitton *et al*. 1991) and salinity (Fritz 1990, Blinn 1993, Blinn and Bailey 2001). The lack of change in the region demonstrates the resilience of this group of organisms to subtly (dramatically) shift assemblages under modified (disturbed) conditions, yet maintain their functional role to produce oxygen and food for the system. It further provides support as to why diatom species and assemblages are good indicators of environmental change.

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TABLE 2. Matrix of Pearson correlation coefficients of abiotic determinants and biotic indices including (Shannon-Weaver H’), diatom species richness, cyanobacteria species richness, *Stigeoclonium* cell density, and total cell density for 38 streams in the Lahontan Basin, USA.

	Elevation	Q	DO	Temp	Cond	Alka	pH	Densio	Slope	F & S	Grav	Cobble	Embed
Discharge (Q)	-0.01												
Dissolved Oxygen (DO)	-0.32	0.11											
Temperature (Temp)	-0.08	-0.08	-0.41										
Specific Conductivity (Cond)	-0.34	0.08	-0.26	0.46									
Alkalinity (Alka)	-0.38	0.03	-0.23	0.39	** 0.92								
pH	-0.23	-0.16	0.34	-0.36	-0.02	0.001							
Densiometer (Densio)	-0.13	-0.01	0.10	-0.19	-0.09	-0.17	0.33						
Slope	0.12	-0.31	-0.13	0.29	0.12	0.02	0.06	0.19					
% Fines & sand	-0.40	-0.40	-0.24	** 0.60	0.48	0.48	-0.20	0.03	0.19				
% Gravel	0.11	0.22	0.14	-0.04	-0.07	-0.01	0.01	-0.38	-0.03	-0.53			
% Cobble	0.47	0.31	0.17	**-0.65	-0.50	-0.53	0.23	0.20	-0.18	**-0.82	0.05		
% Embeddedness (Embed)	-0.23	-0.37	-0.33	0.53	0.33	0.32	-0.21	0.13	0.08	** 0.84	*-0.58	*-0.58	
Diatom H’	0.04	-0.08	-0.16	0.33	0.12	0.13	0.03	-0.23	-0.06	0.13	0.14	-0.24	0.24
No. Diatom taxa	-0.24	-0.11	-0.19	0.40	0.25	0.27	0.001	-0.32	-0.01	0.34	0.14	-0.55	0.32
No. Cyanobacteria taxa	-0.30	-0.08	-0.31	0.41	** 0.71	** 0.62	-0.06	0.06	0.30	** 0.59	-0.29	-0.48	0.46
Diatom cell density	-0.06	-0.22	**-0.60	0.55	0.37	0.35	-0.29	-0.26	0.12	** 0.52	-0.11	-0.53	0.53
Stigeoclonium cell density	0.06	-0.11	0.01	0.27	0.17	0.15	-0.13	-0.23	0.18	0.19	0.04	-0.23	-0.06
Total algal cell density	-0.35	-0.17	-0.35	0.55	** 0.60	* 0.56	-0.12	-0.02	0.32	** 0.60	-0.21	-0.53	0.50

$P < 0.05$, **$P < 0.01$

TABLE 3. Information on diatoms and soft algae in 38 streams in the Lahontan Basin, USA. Dates of collection are provided in parentheses.

	Diatom H'	No. Diatom Taxa	Diatom Density cells/cm^2	No. Green Taxa	Green Density cells/cm^2	*Stigeoclonium* Density cells/cm^2	*Cladophora* Density cells/cm^2	No. Cyano Taxa	Cyano Density cells/cm^2	Total Soft Density cells/cm^2	Total No Algal Taxa	Total Density cells/cm^2
Convict (10VII96)	2.5	36	26871	1	1088	0	1088	2	26090	27178	39	54049
Cotton Lower (29VII96)	3.1	56	1382202	2	238621	0	0	1	2409529	2648149	59	4030351
Bodie (23VII96)	2.9	48	473317	1	31928	31928	0	3	407840	439768	52	913085
Clearwater (26VII96)	3.2	53	231125	3	247210	0	24347	4	349162	596372	60	827497
Deep (31VII96)	2.6	40	284915	1	1904	0	0	2	29543	31447	43	316362
Green (1VIII96)	2.8	44	32402	2	12056	0	861	3	35532	47588	49	79990
Adobe (2VIII96)	2.9	57	526903	4	535755	0	382045	1	57740	593495	62	1120399
O'Harrel (19VIII96)	3.0	57	159567	3	14614	0	1948	2	47329	61943	62	221510
Little Walker (10IX96)	2.7	40	22497	0	0	0	0	1	7469	7469	41	29966
Dexter (3IX96)	3.3	52	120064	3	22736	7942	13095	2	78456	101192	57	221256
East Walker (10IX96)	3.1	54	134073	2	44163	0	0	4	1027217	1071380	60	1205453
Marble (9VII97)	2.3	36	31738	1	2021162	0	0	2	1478995	3500157	39	3531895
Dog (9VII97)	2.6	33	36901	0	0	0	0	2	73214	73214	35	110115
Clearwater (10VII97)	3.5	67	326738	3	124319	19885	613671	2	952654	1076973	72	1403711
Virginia (11VII97)	3.0	43	113502	3	37875	0	35684	3	72442	110317	49	223819
Dunderberg (18VII97)	2.8	43	34715	0	0	0	0	1	3339	3339	44	38054
Glass (23VII97)	2.9	41	45539	1	589	0	0	2	9373	9962	44	55501
Slinkard (30VII97)	2.8	41	30243	1	5621	0	5621	2	18715	24336	44	54579
Poore (31VII97)	2.7	42	192962	3	10437	5151	5277	2	13532	23969	47	216931
Mammoth (18VIII97)	3.3	59	850459	5	1387551	2178	131422	3	126935	1514486	67	2364945
Burcham (25VIII97)	2.9	39	33289	1	2586	0	2 586	1	4285	6871	41	40160
Nye (15VII98)	3.0	51	326621	1	86709	0	86709	2	2303395	2390104	54	2716726
Arastra (16VII98)	2.9	51	47281	0	0	0	0	1	15419	15419	52	627000
Bodie (16VII98)	2.9	48	310329	3	1026643	819129	205104	4	1315382	2342025	55	2652354
Hilton (17VII98)	3.0	55	147068	1	124193	0	124193	2	78998	203191	58	350259
Lower Hot (17VII98)	2.6	44	586933	3	627365	459299	44138	4	1608273	2235638	51	2822571
Rock (22VI99)	2.9	54	35196	1	4905	0	4905	2	10780	15685	57	50892
Deadman (6VII99)	2.9	41	22639	0	0	0	0	2	95255	95255	43	117894
Convict (16VII99)	3.6	46	26135	2	14906	0	14278	3	144799	159705	51	185840
McGee (21VII99)	2.5	40	35835	0	0	0	0	1	36075	36075	41	71910
O'Harrel (29VII99)	3.3	62	249169	1	5720	0	5720	2	141053	146773	65	395942

TABLE 3 (Cont.)

	Diatom H'	No. Diatom Taxa	Diatom Density cells/cm^2	No. Green Taxa	Green Density cells/cm^2	*Stigeoclonium* Density cells/cm^2	*Cladophora* Density cells/cm^2	No. Cyano Taxa	Cyano Density cells/cm^2	Total Soft Density cells/cm^2	Total No Algal Taxa	Total Density cells/cm^2
Cottonwood (13VI99)	2.8	40	37491	0	0	0	0	2	213494	213494	42	250985
Kirman (18VIII99)	3.5	64	653468	5	466673	1210355	203655	4	644588	1111261	73	1764729
Swauger 17VIII99)	3.0	37	27180	0	0	0	0	2	31388	31388	39	58568
West Walker (20/VIII99)	2.9	36	25273	4	12899	3088	3307	4	17644	30543	44	55816
Upper Owens (24VIII99)	2.9	59	232704	2	152796	41398	111387	4	1058644	1252553	65	1485257
Upper Truckee Barton (29IX99)	2.5	56	155262	3	154549	66469	34452	4	362498	517047	63	672309
Upper Truckee Forest (30IX99)	2.9	57	18610	1	3800	0	0	2	11810	15610	60	34220

TABLE 4. Mean relative frequencies (% ±SE) in all sampled habitats, maximum frequency in habitat (Max), percent of streams in which taxa occurred, x % embeddedness (Embed ±SE), x % fines and sand (F & S ±SE), and x elevation (±SE) for dominant diatom taxa collected in 38 streams in the Lahontan Basin, USA. These taxa make up over 85% of the diatom assemblages in the streams. Acronyms for species are provided in parentheses.

TAXON	x Relative Frequency	Max %	% streams	x % Embed	x % F & S	x Elevation
Achnanthes exigua Grun. (Acex)	0.2 (0.06)	1.7	55.3	38.7 (5.7)	50.1 (19.2)	7094 (170)
Achnanthidium minutissima (Kütz.) Czar. (Acmi)	13.1 (1.9)	41.0	100.0	28.2 (4.0)	36.4 (5.0)	7087 (209)
Amphora coffeiformis (Ag.) Kütz. (Amco)	1.4 (0.04)	0.7	42.1	35.3 (7.7)	45.1 (8.6)	6773)435)
Amphora ovalis (Kütz.) Kütz. (Amov)	0.1 (0.05)	1.1	23.6	30.6 (7.6)	40.9 (11.4)	7167(163)
Amphora pediculus (Kütz.) Grun. (Ampe)	1.0 (0.4)	13.5	52.6	29.4 (6.3)	41.2 (7.3)	7065 (136)
Aulacoseira islandica O. Muell. (Auis)	0.2 (0.07)	1.9	28.9	25.7 (8.2)	26.1 (9.7)	7522 (273)
Aulacoseira italica (Ehr.) Simon. (Auit)	0.5 (0.2)	4.6	50.0	29.7 (6.6)	33.6 (6.8)	7202 (139)
Caloneis silicula (Ehr.) Cl. (Casi)	0.2 (0.05)	1.0	34.2	34.4 (7.8)	45.8 (9.4)	7333 (236)
Cocconeis pediculus Kütz. (Cope)	1.1 (0.8)	31.6	39.4	23.7 (7.1)	26.6 (7.8)	7274 (196)
Cocconeis placentula var. *euglypta* (Ehr.) Cl. (Cople)	7.5 (1.4)	41.9	92.1	28.5 (4.4)	38.0 (5.1)	7350 (142)
Ctenophora pulchella (Ralfs) Williams & Round (Ctpu)	0.02 (0.01)	0.3	7.9	59.1 (27.6)	69.5 (22.7)	7240 (223)
Cyclotella meneghiana Kütz. (Cyme)	0.5 (0.2)	7.4	34.2	40.4 (9.9)	60.1) (7.8)	7035 (131)
Cyclotella stelligera Cl. & Grun. (Cyst)	0.2 (0.07)	1.4	39.5	22.1 (6.3)	28.0 (7.1)	7117 (102)
Cymbella affinis Kütz. (Cyaf)	2.0 (0.9)	35.3	89.5	27.9 (4.8)	38 .0 (5.6)	7190 (120)
Cymbella minuta Hilse ex. Rabh. Cymi	0.7 (0.2)	7.5	57.8	29.8 (5.8)	38.8 (6.4)	7228 (111)
Diatoma mesodon (Ehr.) Kütz. (Dime)	0.2 (0.08)	1.8	31.6	15.2 (3.1)	20.5 (5.6)	7555 (242)
Diatoma vulgaris Bory (Divu)	0.2 (0.07)	2.1	39.5	22.5 (6.0)	35.2 (7.7)	7027 (155)
Eolimna minima (Kütz.) Lange-Bertalot (Eimi)	0.4 (0.1)	3.4	42.1	21.0 (6.1)	31.0 (7.3)	6651 (437)
Epithemia sorex Kütz. (Epso)	3.4 (1.4)	34.8	63.2	26.3 (5.8)	37.7 (6.6)	7440(150)
Eunotia bilunaris (Ehr.) Mills (Eubi)	0.5 (0.2)	5.0	50.0	25.0 (6.4)	31.0 (6.9)	7262(160)
Fragilaria arcus (Ehr.) Cl. (Frar)	0.8 (0.3)	8.7	36.8	11.6 (2.3)	9.8 (2.1)	7531(177)
Fragilaria capucina Desm. (Frca)	3.3 (0.4)	11.9	94.7	28.3 (4.4)	34.6 (5.3)	7382 (141)

TABLE 4 (Cont.)

TAXON	x Relative Frequency	Max %	% streams	x % Embed	x % F & S	x Elevation
Fragilaria capucina var. *vaucheriae* (Kütz) Lange-Bertalot (Frcava)	4.8 (0.8)	22.5	100.0	28.2 (4.2)	36.4 (5.0)	7087 (209)
Fragilaria construens (Ehr.) Grun. (Frco)	1.7 (0.3)	8.3	73.7	27.5 (5.2)	38.1 (6.0)	7230 (132)
Fragilaria leptostauron (Ehr.) Hust. (Frle)	0.3 (0.09)	2.4	39.5	41.8 (8.8)	51.7 (9.3)	7315 (168)
Fragilaria pinnata Ehr. (Frpi)	1.9 (0.4)	9.8	73.6	31.9 (5.2)	40.1 (6.1)	7225 (137)
Fragilaria ulna (Nitzs.) Lange-Bertalot (Frul*)*	3.7 (0.7)	18.9	100.0	28.2 (4.2)	36.4 (5.0)	7087 (209)
Frustulia vulgaris (Thwaites) DeT. (Frvu)	0.1 (0.03)	0.7	57.9	33.2 (6.3)	43.0 (6.5)	7262 (163)
Gomphoneis herculeana (Ehr.) Cl. (Gohe)	0.7 (0.2)	4.7	63.2	24.5 (4.3)	32.9 (5.6)	7212 (146)
Gomphonema angustum Ag. (Goan)	0.9 (0.2)	5.9	47.4	21.8 (5.5)	28.4 (6.4)	7225 (132)
Gomphonema parvulum Kütz. (Gopa)	0.9 (0.2)	4.6	89.5	28.6 (4.7)	37.2 (5.6)	7317 (123)
Gomphonema truncatum (Cl. Ag.) Cl. Ag. (Gotr)	0.1 (0.04)	1.1	10.5	22.1 (8.0)	44.2 (10.0)	7040 (158)
Gyrosigma accuminatum (Kütz.) Rabh. (Gyac)	0.03 (0.01)	0.3	10.5	57.9 (17.6)	69.8 (15.8)	7090 (138)
Hantzschia amphioxys (Ehr.) Grun. (Haam)	0.5 (0.1)	2.6	71.1	30.4 (5.9)	43.8 (6.3)	7154 (90.6)
Karayevia clevei (Grun.) Round & Bukhtyarova (Kacl)	0.1 (0.1)	0.9	13.2	24.9 (6.2)	44.1 (6.8)	6844 (156)
Luticola mutica (Kütz.) Mann (Lumu)	0.1 (0.04)	1.1	36.8	39.9 (9.7)	49.2 (10.1)	7353 (174)
Melosira varians Ag. (Meva)	0.8 (0.3)	9.2	44.7	31.9 (6.7)	39.1 (7.3)	7075 (114)
Meridion circulare (Grev.) Ag. (Meci)	0.7 (0.1)	2.9	81.6	24.5 (4.9)	33.4 (6.0)	7367 (142)
Navicula cincta (Ehr.) Ralfs (Nacin)	0.8 (0.2)	6.4	44.7	27.6 (4.3)	40.4 (6.5)	7106 (172)
Navicula cryptocephala Kütz. (Nacr)	0.8 (0.2)	5.3	76.3	32.0 (5.2)	44.5 (6.3)	7239 (144)
Navicula indifferens Hust. (Naind)	0.1 (0.03)	0.8	15.7	53.7 (19.4)	57.7 (21.2)	7722 (335)
Navicula schroeterii Meister (Nasch)	0.1 (0.04)	0.8	26.3	30.2 (6.9)	48.4 (9.0)	6994 (270)
Navicula tripunctata (O.F. Müll) Bory (Natr)	0.1 (0.04)	1.1	31.6	17.6 (3.5)	20.4 (4.6)	7472 (255)
Navicula veneta Kütz. (Nave)	0.8 (0.1)	2.8	86.8	26.3 (4.8)	33.2 (5.2)	7287 (125)

TABLE 4 (Cont.)

TAXON	x Relative Frequency	Max %	% streams	% Embed	x % F & S	x Elevation
Nitzschia acicularis W. Sm. (Niac)	0.1 (0.07)	2.6	23.7	46.9 (11.9)	63.2 (8.9)	7157 (180)
Nitzschia amphibia Grun. (Niam)	0.7 (0.2)	4.2	65.8	34.3 (6.4)	42.5 (6.5)	7188 (92)
Nitzschia dissipata (Kütz.) Kütz. (Nidi)	3.2 (0.7)	8.3	97.4	28.7 (3.2)	38.2 (3.8)	7095 (207)
Nitzschia frustulum Kütz. (Nifr)	4.9 (0.7)	16.6	100.0	28.2 (4.2)	36.4 (5.0)	7087 (209)
Nitzschia linearis W. Sm. (Nili)	1.0 (0.2)	5.6	63.2	28.9 (4.5)	42.4 (5.9)	7033 (95)
Nitzschia palea (Kütz.) W. Sm. (Nipa)	5.0 (1.1)	30.0	100.0	28.2 (4.2)	36.4 (5.0)	7087 (209)
Nitzschia sigma (Kütz.) W. Sm. (Nisi)	0.1 (0.1)	1.1	23.7	45.2 (12.3)	54.5 (12.5)	7208 (93)
Opephora olsenii Moller (Opol)	0.5 (0.2)	8.8	44.7	24.7 (4.8)	36.4 (5.7)	7107 (149)
Pinnularia borealis Ehr. (Pibo)	0.03 (0.01)	0.3	21.1	31.7 (10.5)	47.2 (9.8)	7027 (354
Pinnularia divergens W. Sm. (Pidi)	0.2 (0.1)	1.1	50.0	41.2 (7.7)	51.9 (7.9)	7281 (217)
Pinnularia subcapitata Greg. (Pisu)	0.2 (0.04)	1.2	47.4	40.2 (7.9)	49.9 (8.2)	7338 (217)
Planothidium lanceolata (Breb.) Round & Bukhtiyarova (Plla)	8.3 (1.1)	30.7	97.4	28.5 (4.4)	38.0 (5.1)	7350 (142)
Reimeria sinuata (Greg.) Kociolek & Stoermer (Resi)	1.0 (0.2)	4.8	89.5	23.8 (3.9)	32.1 (4.9)	7038 (252)

Rhopalodia gibba (Ehr.) O. Müll. (Rhgi)	0.3 (0.1)	3.0	39.5	38.6 (9.3)	55.8 (8.9)	7090 (116)
Rhopalodia gibberula (Ehr.) O. Müll. (Rhgib)	0.4 (0.1)	2.1	55.3	39.7 (6.4)	50.9 (6.8)	7038 (117)
Rhoicosphenia abbreviata (Ag.) Lange-Bertalort (Rhab)	3.0 (0.6)	14.7	97.4	25.6 (4.3)	25.9 (5.0)	7243 (119)
Sellophora pupula (Kütz.) Mereschkowsky (Sepu)	0.2 (0.05)	1.1	39.5	34.6 (8.2)	45.6 (8.5)	7205 (143)
Surirella angustata Kütz. (Syan)	0.1 (0.04)	0.9	29.0	32.5 (11.2)	41.1 (12.3)	7344 (214)
Surirella ovalis Breb. (Suov)	0.1 (0.03)	0.7	15.8	49.7 (20.9)	47.9 (21.8)	7620 (356)
Tabellaria fenestrata (Lyngb.) Grun. (Tafe)	0.3 (0.1)	3.8	23.7	16.6 (3.2)	28.1 (6.3)	7265 (287)
Tetracyclus rupestris (Braun.) Grun. (Teru)	0.2 (0.1)	2.8	21.1	16.2 (0.5)	24.7 (6.5)	8010 (280)

TABLE 5. Stream habitats in the Lahontan Basin ranked by %fines and sands (F & S) with relative abundance of *Hantzschia*, *Navicula*, *Nitzschia*, and *Surirella* species index (HNNS) and the relative abundance of Bacillariales and Surirelliales species index (BASU).

STREAM	F & S	HNNS	BASU
Upper Truckee Forest (30IX99)	5.0	0.20	0.09
Deadman (6VII99)	5.3	0.21	0.20
Convict (16VII99)	5.3	0.11	0.10
Virginia (11VII97)	6.7	0.02	0.01
Little Walker (10IX96)	7.0	0.21	0.08
Green (1VIII96)	8.0	0.07	0.06
Arastra (16VII98)	8.0	0.31	0.26
Convict (10VII96)	9.0	0.07	0.03
McGee (21VII99)	9.3	0.07	0.04
Deep (31VII96)	10.0	0.14	0.10
West Walker (20/VIII99)	12.0	0.22	0.10
Glass (23VII97)	13.3	0.24	0.20
Mammoth (18VIII97)	14.0	0.30	0.27
Swauger 17VIII99)	14.7	0.31	0.17
Dunderberg (18VII97)	16.0	0.19	0.10

Cottonwood (13VI99)	17.3	0.47	0.38
Poore (31VII97)	21.3	0.20	0.10
Upper Owens (24VIII99)	25.3	0.22	0.20
Rock (22VI99)	29.3	0.05	0.03
Dog (9VII97)	29.3	0.13	0.05
Clearwater (10VII97)	36.6	0.32	0.28
Upper Truckee Barton (29IX99)	32.0	0.18	0.15
Burcham (25VIII97)	36.7	0.41	0.37
Kirman (18VIII99)	42.7	0.22	0.18
Hilton (17VII98)	45.0	0.09	0.06
East Walker (10IX96)	49.0	0.31	0.26
O'Harrel (29VII99)	49.3	0.19	0.12
Dexter (3IX96)	50.0	0.44	0.28
Bodie (16VII98)	55.0	0.45	0.41
Clearwater (26VII96)	67.0	0.30	0.19
O'Harrel (19VIII96)	67.0	0.25	0.21
Marble (9VII97)	68.3	0.11	0.04
Lower Hot (17VII98)	72.0	0.20	0.18
Bodie (23VII96)	72.0	0.49	0.42
Slinkard (30VII97)	73.3	0.20	0.15
Nye (15VII98)	93.3	0.18	0.13
Adobe (2VIII96)	100.0	0.25	0.22
Cotton Lower (29VII96)	100.0	0.27	0.18

TABLE 6. Ranking of fines + sand (IFS) and embeddedeness (EMI) indices for domimant diatom taxa in streams in the Lahontan basin, USA. Species are ranked from most sensitive to most tolerant.

TAXON	IFS	EMI
Fragilaria arcus	28	23
Navicula tripunctata	34	26
Diatoma mesodon	35	25
Tetracyclus rupestris	37	32
Tabellaria fenestrata	42	31
Frustulia vulgaris	47	36
Diatoma vulgaris	48	35
Aulacoseira islandica	48	41
Pinnularia subcapitata	50	43
Eunotia bilunaris	52	38
Reimeria sinuata	52	41

Rhoicosphenia abbreviata	53	45
Eolimna minima	54	33
Cyclotella stelligera	55	38
Surirella angustata	55	45
Gomphoneis herculeana	58	44
Navicula indifferens	58	51
Gomphonema angustum	59	48
Amphora coffeiformis	60	40
Navicula veneta	***61***	***49***
Cymbella minuta	64	53
Aulacoseira italica	65	50
Karayevia clevei	65	44
Cymbella affinis	67	50
Caloneis silicula	68	37
Luticola mutica	68	49
Navicula schroeterii	68	43
Opephora olsenii	68	52
Surirella ovalis	68	64
Gomphonema truncatum	69	42
Gomphonema parvulum	69	52
Amphora ovalis	70	48
Planothidium lanceolata	70	50
Achnanthes exigua	70	52
Sellophora pupula	71	53
Pinnularia divergens	71	55
Navicula cryptocephala	72	53
Meridion circulare	73	52
Hantzschia amphioxys	73	54
Nitzschia amphibia	***78***	***56***
Navicula cincta	82	57

TABLE 6 (Cont.)

TAXON	IFS	EMI
Rhoicosphenia abbreviata	82	61
Melosira varians	82	67
Rhopalodia gibberula	83	68
Ctenophora pulchella	83	47
Fragilaria construens	83	58
Epithemia sorex	84	54
Nitzschia linearis	86	60
Amphora pediculus	87	59
Nitzschia acicularis	88	61
Fragilaria capucina	88	64
Fragilaria capucina var. *vaucheriae*	88	65
Nitzschia dissipata	89	66
Fragilaria ulna	89	67
Fragilaria leptostauron	89	69
Rhopalodia gibba	90	58
Fragilaria pinnata	91	70
Nitzschia palea	92	67
Cyclotella meneghiana	94	75
Nitzschia frustulum	97	72
Cocconeis placentula var. *euglypta*	100	72
Achnanthidium minutissima	104	77
Gyrosigma accuminatum	120	109