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The Use of Short-Count Methods on Field Collected Diatom Communities to Determine Water Quality of Small Streams

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This study was undertaken to determine if short-count methods for calculation of diatom species diversity could be used to determine the water quality of small streams. Two small streams, located in North Central Iowa, were selected for study; one was chosen because it appeared to be in a relatively healthy condition and the other because it appeared to be highly polluted. Diatom samples were collected by direct field collection of the predominant diatom growths in each stream. Short-counts of 50, 100, 200, 500, and 1000 diatom valves were made and species diversity computed by 2 methods, the Shannon Index of General Diversity and the Sequential Comparison Index. A one-way analysis of variance using mean species diversity values was run on all diatom counts both within and between the samples of each stream. The results showed that short-counts could be used to determine differences in water quality of the 2 small streams studied and further suggest that such analyses might be suitable for other small streams.

INDEX DESCRIPTORS: diatoms, species diversity, short-count methods, small Iowa streams, Sequential Comparison Index, Shannon Index of General Diversity.

Many studies using diatoms as indicators of water quality have been reported in the literature (Hohn, 1959; Hohn & Hellerman, 1963; Patrick, Hohn, & Wallace, 1954; Patrick, 1963; Patrick, 1967; Patrick & Strawbridge, 1963). Most of these studies utilized artificial substrates, particularly glass slides, to obtain diatom growths. This procedure necessitates incubating the artificial substrates in a river or stream for approximately 2 weeks. For a more rapid assessment of the water quality of a river or stream, the diatom growth of a single natural habitat could be collected and examined. Large rivers often have a great diversity of habitats, making it difficult to get a representative picture of water quality when only 1 or 2 habitats are sampled. Conversely, small streams often have 1 or 2 predominant diatom growths. For example, a common habitat of diatoms in small Iowa streams is the bottom, including mud and sand.

The purpose of this study was to determine if direct field collection and subsequent analysis of the predominant diatom growth of a small stream could give information about the quality of the water flowing in that stream.

Community structure as defined here includes the kinds of diatom species that are present, including their ecology (for example, pollution tolerant and pollution sensitive species) and species diversity (number of species and the sizes of their populations). The construction of a truncated log normal curve (Patrick, Hohn, & Wallace; 1954) is a long established method for analyzing species diversity of a diatom community. This procedure requires counting about 8000, and sometimes as many as 70,000, diatom valves.

This study of Iowa streams employed two methods of computing species diversity that were thought to be practical for shorter counts (50-1000 diatom valves): the Sequential Comparison Index (Cairns *et al,* 1968) and the Shannon Index of General Diversity (Shannon and Weaver, 1949).

METHODS

In order to determine the appropriateness of analyzing the community structure of predominant diatom growths in small streams as an indicator of water quality, 2 streams in North Central Iowa were selected for study: Black Cat Creek (BCC) in Kossuth County (T96N-R29W-Sec 10), and Iowa Central Community College Creek (ICCCC) in Fort Dodge, Webster County (T89N-R28W-Sec 25). BCC was selected because it appeared to be in a relatively healthy condition. A healthy stream is defined as one which is more or less in a natural state, that is, free of disturbance by man, such as industrial and municipal discharges, feedlot and agricultural runoff, etc. ICCCC was selected because it appeared to be polluted by sewage from a housing development. The 2 streams are approximately 40 miles (64 km) apart.

One collection site was chosen per stream. Each site was chosen so that it was ecologically similar to the other. The sampling site of each stream had a sand-pebble bottom. Both streams were at the bottom of a ravine with trees lining the banks. At the sampling site, both streams had similar current rates and were approximately the same width (1 meter) and depth (20 centimeters). Two collections were made at each site, 1 collection from the right side of the stream and 1 from the left side. The 2 collections were combined. The habitat sampled at BCC contained a thin layer of diatoms covering the sand bottom. ICCCC was completely covered by a mat of filamentous algae and bacteria. The habitat sampled at ICCCC consisted of a growth of diatoms on the filamentous mat. Although different micro-habitats were collected, each sample represented the only major, visible growth of diatoms in the streams.

After the 2 samples were collected, wet mounts of the living material were examined. Most cells contained protoplasm, indicating that they were a living part of the community and not dead cells washed in from another area.

The samples were cleaned of organic matter by the hydrogen peroxide method (Werff, 1955). Permanent slides for use in analysis of community structure were prepared by the method of Patrick and Reimer (1966).

As was stated earlier, 2 methods were used to calculate species diversity, the Sequential Comparison Index (Cairns *et al,* 1968; Diversity Index =

$$\frac{\text{number of runs}}{\text{number of specimens}})$$

and the Shannon Index of General Diversity (Shannon and Weaver, 1949;

$$H' = -\sum_{i=1}^{N} \left(\frac{n_i}{N}\right) \log 2 \left(\frac{n_i}{N}\right).$$

Diatom counts of varying numbers were made under oil immersion objective of the microscope (total magnification of 1000x). The starting point for each count was randomly selected. All counts for a particular sample were made from the same slide with none of the counts overlapping.

The number of diatom valves needed to yield a consistent species diversity value was determined by making a series of counts of varying sample sizes. Triplicate counts of 50, 100, 200, 500, and 1000 diatom valves were made for each stream. These data are presented in Table 1.

Measurements of several chemical parameters were made at the time of sampling. The chemical oxygen demand test was calculated by the reflux method (*Standard Methods*, 13th edition). All other chemical tests were determined by the Hach Kit Model DR.

RESULTS AND DISCUSSION

The chemical analysis indicated that both streams had a similar level of hardness (BCC, 340 ppm; ICCCC, 400 ppm), temperature (BCC, 23°C; ICCCC, 21°C) and silica (BCC, 16 ppm; ICCCC, 20 ppm). Both streams were also alkaline (BCC, pH 8.5; ICCCC, pH 7.6). The ortho-phosphate (BCC, 0.2 ppm; ICCCC, 10 ppm), nitrate (BCC, 2 ppm; ICCCC, 7 ppm), sulfate (BCC, 60 ppm; ICCCC, 170 ppm), chemical oxygen demand (BCC, 9.3 ppm; ICCCC, 56 ppm), and dissolved oxygen (BCC, 0.5; ICCCC, 11) indicate that ICCCC carried a much greater nutrient load than BCC.

The Shannon Index of Species Diversity in BCC increased from a low value of 3.52 for a 50 count to a high value of 4.27 for a 1000 count. A one-way analysis of variance (ANOVA) of mean species diversity values of all counts (50 through 1000) showed that the population means were not equal ($F = 11.19$; $F_{.05}$ (4, 10) = 3.48). A second ANOVA was run on counts of 100, 200, 500, and 1000. The results showed that the population means were equal ($F = 2.14$; $F_{.05}$ (3, 8) = 4.07).

In ICCCC, the Shannon Index varied from a low value of 1.10 for a 200 count and a high value of 1.34 for a 1000 count. An ANOVA of mean species diversity values showed these means to be equal ($F = 0.94$; $F_{.05}$ (4, 10) = 3.48). These results are consistent with the findings of McIntire and Overton (1971). In a study of diatom growths on artificial substrates in Yaquina Bay, Oregon, McIntire and Overton found that the species diversity values for the Shannon Index changed "relatively little beyond sample sizes of 300". Based on the above data, a 500 count from each stream was selected for use in computing the dominant species of each stream (Tables 2, 3).

An ANOVA of species diversity means between BCC (100 through 1000 counts) and ICCCC (50 through 1000 counts) showed that the population means were not equal ($F = 655.64$; $F_{.05}$ (8, 18) = 2.45). These results indicate that short-count methods can be used to compute species diversity values that reflect the water quality of small streams. The value of short-counts lies in the rapidity with which samples can be processed and these data analyzed.

The Sequential Comparison Index is designed to be a simplified method for a non-biologist to estimate the relative differences in biological diversity in stream pollution studies (Cairns *et al*, 1968). Cairns *et al* stated that "with increasing numbers of fish kills and greater stress on all hydrologic systems, there is need for a rapid method by which a layman can assess the biological consequences of pollution and express the results numerically."

The Sequential Comparison Index for BCC showed little variation between the 50 to 1000 counts (Table 1). For ICCCC, the Sequential Comparison Index showed slightly more variation between counts. The index seemed to fulfill its purposes in that it was easy to compute and yielded relatively consistent results.

Two points of caution must be noted when using the Sequential Comparison Index to compute species diveristy of diatom communities. The method outlined by Cairns (1968) calls for making wet mounts of living material and counting these cells under the low power or high dry objective of the microscope. Under these conditions, it is often impossible to distinguish certain diatom taxa. A case in point was the diatom growth in the ICCCC sampling. Analysis of the permanent mount revealed that there were two dominant taxa, *Nitzschia diserta* and *N. capitellata* (Table 3). Cursory inspection of the material in living condition demonstrated that it was nearly impossible to distinguish between them.

Table 1. *Average values for number of diatom valves counted (N), number of taxa per count (S), and indices of species diversity for Black Cat Creek (BCC) and Iowa Central Community College Creek (ICCCC).*

Sampling Site	N	S	Shannon Index of General Diversity (practical range: 0 to 8)	Cairns Sequential Comparison Index (range: 0 to 1.0)
BCC	50	19	3.59	0.91
	100	29	3.92	0.90
	200	37	4.06	0.88
	500	47	4.16	0.89
	1000	62	4.17	0.90
ICCCC	50	4	1.24	0.54
	100	5	1.24	0.51
	200	5	1.19	0.49
	500	9	1.18	0.50
	1000	13	1.27	0.55

Secondly, it is sometimes possible to obtain misleading results, as in the case encountered with ICCCC. In this sample, there were 2 dominant taxa of approximately equal numbers (Table 3). It was theoretically possible that every other diatom valve would be different from the preceding one, thus resulting in a very high species diversity value. Because of this codominance in ICCCC, the Sequential Comparison Index shows a somewhat higher species diversity than actually exists.

A presence list of all taxa found in samples from BCC is presented in Table 2. Eighty-four taxa were identified. The predominant taxa (arbitrarily defined as greater than 4% of total population) determined from a count of 500 valves, were as follows: *Nitzschia diserta* (18.8); *N. legleri* (18.8); *N. pertica* (9.6); *Navicula lanceolata* (5.0); *Nitzschia capitellata* (4.4); and *Cymatopleura solea* (4.4). These 6 taxa accounted for 61% of the diatom community. The remaining 39% comprised 42 taxa, each contributing less than 4% of the total population. As indicated from the above data, BCC had a relatively high species diversity value (Shannon Index = 4.08; Sequential Comparison Index = 0.90).

Twenty-seven taxa in BCC were listed in Hustedt's (1957) saprobic-oxygen profile (Table 2) as follows: saproxene — 8 taxa; oligosaprobic and/or mesooxybiont — 14 taxa; and euryoxybiont — 5 taxa. Of the 6 dominant taxa in BCC, only 1 taxon was found in the saprobic system of Kolkwitz (1950). This was *Cymatopleura solea* which is listed as characteristic of oligosaprobic water.

Table 3 reports a presence list of all taxa found in ICCCC. Twenty-three taxa were found, with the dominant taxa being *Nitzschia diserta* and *N. capitellata* (Table 3). These 2 taxa comprised 98.4% of the total population. ICCCC has a relatively low species diversity value (Shannon Index = 1.22; Sequential Comparison Index = 0.52). Hustedt's saprobic-oxygen profile listed 13 of 23 taxa: saproxene — 2 taxa; oligosaprobic and/or mesooxybiont — 9 taxa; and euryoxybiont — 2 taxa (Table 3).

Thienemann (1939) stated that streams not adversely affected by pollution ("healthy" streams) have communities characterized by a large number of species with relatively small populations. Further, he stated that pollution of a stream ("unhealthy" condition) eliminates the more sensitive species which allows the more tolerant species to de-

Table 2. *Presence list of all taxa, their classification according to Hustedt's oxygen-saprobic system and their percent composition of a 500 count of a sample from BCC.*

Taxon	Oxygen-Saprobic Classification	Percent Composition 500 Count
1. *Achnanthes lanceolata* var. *dubia* Grun.	—	0.6
2. *Amphiprora ornata* Bailey	Saproxene	—
3. *Amphora ovalis* var. *affinis* Kütz.	—	1.0
4. *A. perpusilla* Grun.	—	0.2
5. *A. submontana* Hust.	—	0.6
6. *Caloneis bacillum* (Grun.) Cl.	Saproxene	1.0
7. *C. lewisii* Patr.	—	—
8. *C. limosa* (Kütz.) Patr.	—	0.8
9. *Cocconeis disculus* (Schum.) Cl.	—	—
10. *C. pediculus* Ehr.	Saproxene	—
11. *C. placentula* var. *euglypta* (Ehr.) Cl.	—	0.2
12. *Cyclotella meneghiniana* Kütz.	Euryoxybiont	0.6
13. *Cymatopleura cochlea* Brun.	—	—
14. *C. solea* (Breb.) W. Sm.	Oligosap. (Mesooxyb)	4.4
15. *Cymbella triangulum* (Ehr.) Cl.	—	—
16. *C. ventricosa* Kütz.	Mesooxybiont	0.2
17. *C.* sp. 1	—	0.2
18. *Diploneis subovalis* Cl.	—	3.2
19. *Epithemia turgida* (Ehr.) Kütz.	Saproxene	—
20. *Gomphonema angustatum* (Kütz.) Rabh.	—	—
21. *G. constrictum* Ehr.	Oligosaprobic	—
22. *G. parvulum* (Kütz.) Grun.	Euryoxybiont	—
23. *G.* sp. 1	—	—
24. *G.* sp. 2	—	—
25. *G.* sp. 3	—	—
26. *G.* sp. 4	—	0.2
27. *G.* sp. 5	—	—
28. *Gyrosigma acuminatum* (Kütz.) Rabh.	Oligosaprobic	0.6
29. *Hantzschia amphioxys* var. *maior* Grun.	—	—
30. *Meridion circulare* (Grev.) Agardh.	Saproxene	—
31. *Navicula capitata* Ehr.	—	0.4
32. *N. citrus* Krasske	—	0.2
33. *N. cocconeiformis* Greg. ex Grev.	Saproxene	—
34. *N. cuspidata* Kütz.	Euryoxybiont	0.2
35. *N. cuspidata* var. *ambigua* (Ehr.) Cl.	—	0.2
36. *N. elata* Gandhi	—	0.2
37. *N. heufleri* var. *leptocephala* (Breb. ex. Grun.) Patr.	—	3.0
38. *N. lanceolata* (Agardh.) Kütz.	Saproxene	5.0
39. *N. pupula* Kütz.	Mesooxybiont	2.6
40. *N. pupula* var. *mutata* (Krasske) Hust.	—	2.4
41. *N. pygmaea* Kütz.	Mesooxybiont	—
42. *N. tripunctata* (Mull.) Bory	—	—
43. *N. wittrockii* (Lagst.) A. Cl.-Euler	—	—
44. *N.* sp. 1	—	0.2
45. *N.* sp. 2	—	—
46. *N.* sp. 3	—	0.6
47. *N.* sp. 4	—	—
48. *Nitzschia acicularis* (Kütz.) W. Sm.	Mesooxybiont	2.4
49. *N. allansonii* Cholnoky	—	0.4
50. *N. amphibia* Grun.	Mesooxybiont	—
51. *N. apiculata (Greg.) Grun.*	Mesooxybiont	0.2
52. *N. bulnheimiana* var. *capitata* Reim.	—	0.6
53. *N. capitellata* Hust.	—	4.4
54. *N. capitellata* var. *mongolica* Skv.	—	1.2
55. *N. diserta* Hust.	—	18.8
56. *N. dissipata* (Kütz.) Grun.	Mesooxybiont	1.0
57. *N. gracilis* Hantz.	—	1.4
58. *N. hungarica* Grun.	Mesooxybiont	0.4
59. *N. legleri* Hust.	—	18.8
60. *N. linearis* W. Sm.	Mesooxybiont	—
61. *N. linearis* var. *tenuis* (W. Sm.) Grun.	—	1.6
62. *N. pertica* Hohn & Hellerman	—	9.6
63. *N. silicula* var. *commutata* Reim.	—	—
64. *N. thermalis* Kütz.	—	0.6
65. *N. umbilicata* Hust.	—	0.4
66. *N.* sp. 1	—	—
67. *N.* sp. 2	—	2.8
68. *N.* sp. 3	—	—
69. *N.* sp. 4	—	0.8
70. *Pinnularia biceps* Greg.	—	—
71. *P. brebissonii* (Kütz.) Rabh.	—	—
72. *Rhoicosphenia curvata* (Kütz.) Grun. ex Rabh.	Oligosaprobic	—
73. *Stauroneis smithii* Grun.	Saproxene	—
74. *Stephanodiscus* sp. 1	—	—
75. *Surirella angusta* Kütz.	Euryoxybiont	1.6
76. *S. iowensis* Lowe	—	1.6
77. *S. ovalis* Breb.	Oligosap. (Mesooxyb)	0.2
78. *S. ovata* Kütz.	Euryoxybiont	0.2
79. *S. robusta* Ehr.	—	—
80. *S. robusta* var. *splendida* (Ehr.) v. Heurck	—	—
81. *Synedra ulna* (Nitz.) Ehr.	—	2.0
82. *S. ulna* var. *contracta* Østr.	—	—
83. *S.* sp. 1	—	—
84. *S.* sp. 2	—	0.2

velop larger populations. The chemical and diatom community data obtained in this study would seem to be in agreement with Thienemann's principles.

BCC had a large number of species with relatively small populations. Although the chemical data and Hustedt's saprobic-oxygen profile indicates that there was some mineral enrichment in BCC, the diatom community structure was not adversely affected. The data thus suggests that BCC might be considered a "healthy" stream. ICCCC had a few species of large numbers. The correlation of community structure and chemical data is strongly suggestive of a polluted ("unhealthy") stream.

The direct collection of diatom growths may not be an appropriate method of water quality analysis in some pollution studies. For example, many natural habitats are ephemeral; hence, any comparative studies of the resident diatom communities over either short or long periods of time may be impossible. In addition, quantitation studies, such as biomass per area or organisms per area, are not feasible. However, the data collected in this study shows that information about the quality of water in a small stream may well be obtained by analyzing hand-collected samples.

Table 3. *Presence list of all taxa, their classification according to Hustedt's oxygen-saprobic system and their percent composition of a 500 count of a sample from ICCCC.*

Taxon	Oxygen-Saprobic Classification	Percent Composition 500 Count
1. *Achnanthes lanceolata* var. *dubia* Grun.	—	—
2. *Amphora submontana* Hust.	—	—
3. *Caloneis bacillum* var. *fontinalis* Hust.	—	—
4. *Cymbella ventricosa* Kütz.	Mesooxybiont	—
5. *Diatoma vulgare* Bory	Saproxene	—
6. *Gomphonema olivaceum* (Lyngb.) Kütz.	Oligosaprobic	0.2
7. *G. parvulum* (Kütz.) Grun.	Euryoxybiont	—
8. *G.* sp. 1	—	—
9. *Navicula cryptocephala* var, *veneta* (Kütz.) Rabh.	—	0.4
10. *N. lanceolata* (Agardh.) Kütz.	Saproxene	—
11. *N. pupula* Kütz.	Mesooxybiont	—
12. *N.* sp. 1	—	—
13. *N.* sp. 2	—	0.2
14. *Nitzschia amphibia* Grun.	Mesooxybiont	—
15. *N. apiculata* (Greg.) Grun.	Mesooxybiont	0.2
16. *N. capitellata* Hust.	—	46.4
17. *N. communis* Rabh.	Mesooxybiont	0.2
18. *N. commutata* Grun.	Mesooxybiont	—
19. *N. diserta* Hust.	—	52.0
20. *N. linearis* W. Sm.	Mesooxybiont	—
21. *N. thermalis* Kütz.	—	0.2
22. *Surirella ovalis* Breb.	Oligosap. (Mesooxyb.)	—
23. *S. ovata* Kütz.	Euryoxybiont	0.2

REFERENCES

CAIRNS, J., *et al.* 1968. The sequential comparison index — a simplified method for non-biologists to estimate relative differences in biological diversity in stream pollution studies. J. Water Poll. Control Fed. 40: 1607-1613.

HOHN, M.H. 1959. The use of diatom populations as a measure of water quality in selected areas of Galveston and Chocolate Bay, Texas. Publ. Inst. Marine Sci. 6: 206-212.

HOHN, M.H., and J. HELLERMAN. 1963. The taxonomy of diatom populations from three eastern North American rivers using three sampling methods. Trans. Am. Microsc. Soc. 82: 250-329.

HUSTEDT, F. 1957. Die diatomeenflora des flusssystems der weser im gebiet der hansestadt Bremen. Abhandl. Naturwis. Verein Bremen. 34: 181-440.

KOLKWITZ, R. 1950. Oekologie der Saprobien. Piscator-Verlag, Stuttgart. 64 pp.

MCINTIRE, C., and W. OVERTON. 1971. Distributional patterns in assemblages of attached diatoms from Yaquina Estuary, Oregon. Ecology 52: 758-777.

PATRICK, R. 1963. The structure of diatom communities under varying ecological conditions. Ann. New York Acad. Sci. 108: 359-365.

PATRICK, R. 1967. The effect of invasion rate, species pool, and size of area on the structure of the diatom community. Proc. Nat. Acad. Sci. 58: 1335-1342.

PATRICK, R., M.H. HOHN, and J.H. WALLACE. 1954. A new method for determining the pattern of the diatom flora. Notul. Naturae 259: 1-12.

PATRICK, R., and C. REIMER. 1966. The diatoms of the United States. Vol. I. Acad. Nat. Sci., Philadelphia. 688 pp.

PATRICK R., and D. STRAWBRIDGE. 1963. Variation in the structure of natural diatom communities. Am. Nat. 97:51-57.

SHANNON, D.E., and W. WEAVER. 1949. The mathematical theory of communication. Univ. Ill. Press, Urbana. 117 pp.

Standard methods for the examination of water and waste water. 1971. 13th Ed., Amer. Pub. Health Assn., New York, N.Y. 874 pp.

THIENEMANN, A. 1939. Grundzuge einer allgemeinen Okologie. Arch. Hydrobiol. 35:267-285.

WERFF, A. VAN DER. 1955. A new method for concentrating and cleaning diatoms and other organisms. Internat. Assoc. Theoret. Appl. Limnol. 12: 276-277.