[The Journal of the Iowa Academy of Science: JIAS](http://scholarworks.uni.edu/jias)

Volume 99 | Number   Article 5

1992

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Recommended Citation
Main, Stephen P. and Busch, David E. (1992) "Diatoms of Northeastern Iowa Fens," *The Journal of the Iowa Academy of Science: JIAS*: Vol. 99: No. 1 , Article 5.
Available at: http://scholarworks.uni.edu/jias/vol99/iss1/5

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Jour. Iowa Acad. Sci. 99(1):15-22, 1992

Diatoms of Northeastern Iowa Fens

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Analysis of water samples from 10 fens in NE Iowa, collected 13-14 November 1987, revealed a gradient from acid, low conductivity water conditions (pH 5.6, alkalinity 30 mg/l HCO_3, conductivity 65 µmho, total hardness 30 mg/l Ca) to circumneutral, moderately conductive conditions (pH 7.2, alkalinity 390 mg/l, conductivity 705 µmho, total hardness 380 mg/l Ca). Three sites along this gradient were sampled 15 May 1988 and 3 September 1988 to evaluate seasonal variation in water conditions.

Examination of composite diatom samples collected concurrently with the water samples yielded 150 taxa, of which 14 are new Iowa distributional records and 6 remain unidentified. Previous investigators have reported 102 of these taxa from other Iowa fens, bogs, or prairie swales. Only 58 have been reported from the Cedar River basin, where most of these fens are located. This evidence suggests these scattered small wetlands resemble similar areas some distance away more than the surrounding surface waters. Distributional patterns of diatoms along the environmental gradient appear sufficiently distinct to permit delineation of species autecology.

INDEX DESCRIPTORS: diatom, fen, conductivity

This project examined the diatom flora and water characteristics of several northeastern Iowa fens. Similar descriptions of raised wetland habitats in Iowa include a swale in Cayler Prairie (Reimer 1970), a swale and related moss habitats in Cedar Hills Prairie [formerly the Mark Sand Prairie] (Dodd 1981b), Pilot Knob Bog (Christensen 1969; 1976; 1981; Dodd 1981a), Excelsior Fen (Shobe *et al.*, 1963; Reimer 1982; 1990). With the exception of Pilot Knob Bog, the fens examined for diatoms in Iowa are raised in the sense that these habitats develop on hillside drainages or as raised mounds kept wet by artesian groundwater.

Diatoms are algae which provide an excellent means of documenting water quality characteristics. The diatoms present change in response to the chemical and physical properties of the water itself. Similar diatom associations develop when ecological conditions are closely equivalent (Patrick 1968). Here we describe the diatom floras from some newly located fens in northeastern Iowa and compare them with those described previously (see above) and with those reported from other surface waters (Dodd 1971; Main 1988).

Past research has been concentrated in northwestern Iowa stimulated by the presence of Iowa Lakeside Laboratory (Reimer 1990). A controversy developed regarding the possibility that raised wetlands in northeastern and northwestern Iowa are fundamentally different. The northwestern Iowa fens described have alkaline, very hard waters; while the few northeast Iowa fens reported have acid, fairly soft waters. This report presents a more complete comparison of raised wetlands from the two areas.

METHODS AND MATERIALS

On 13 and 14 November 1987, we collected preliminary samples of water and diatom material from 11 sites in NE Iowa (see Table 1 for the site descriptions and Figure 1 for map). Busching Fen was located through local sources. Remaining sites were selected from a list provided by the Iowa Department of Natural Resources. Only one of the sites was too dry to permit sampling (Beardmore). The ten remaining fens had diatoms in sufficient abundance for further taxonomic work. All substratum types observed were sampled.

The spring and summer diatom floras were sampled from Busching, Roose and Berends Fens. Water and substratum characteristics of these fens spanned the range of conditions found; the diatoms varied floristically; and the sites were reasonably close together. Samples of diatoms and warer were obtained from these fens on 15 May 1988. When collecting more samples 3 September 1988, the *Sphagnum* area at Berends Fen was dry. Water and diatoms were collected from the stream draining the ravine adjacent to the hillside part of the fen. Benthic composite samples consisted of pipetted matter from all substrata observed at a site combined with hand collected vegetation. Additionally, longitudinal changes in diatom associations were assessed at the Busching Fen by sampling the top of the mound spring and the region around the base of the mound above the drainage into a small stream.

Non-preserved diatom collections were examined microscopically to note the presence of other algae, of protozoa and of small invertebrates and to evaluate the proportion of living to dead diatom cells. Nitric acid oxidation of the samples cleaned the diatom frustules. Rinsed suspensions of cleaned diatoms placed on coverslips were dried and mounted in Naphrax. The data reported here resulted from counts of 500 valves (250 on replicate slides by each of the two authors.) In addition, the slides were scanned for additional taxa. All counting was done using 1000X oil immersion. The slides counted are retained in the personal herbaria of the principal investigators. An additional replicate of each slide has been placed in the diatom herbarium at Iowa Lakeside Laboratory.

Chemical and physical parameters of the water samples were determined with a Hach DREL Test Kit, a Hach Portable pH Meter and a Hach Portable Conductivity Meter. Temperature, pH, conductivity and dissolved oxygen (PAO titration) were measured in the field. Water samples returned to the laboratory were refrigerated 1-2 days before determining alkalinity, hardness, total and orthophosphate, nitrate, and silica.

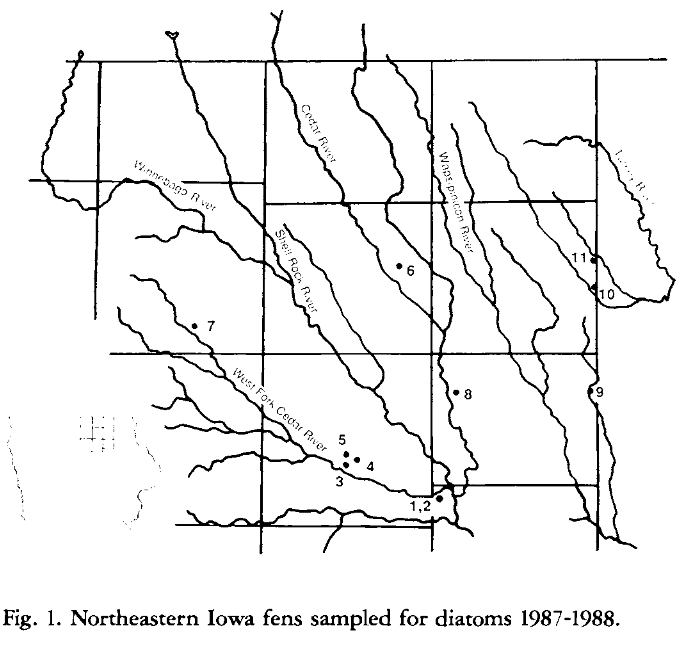

Fig. 1. Northeastern Iowa fens sampled for diatoms 1987-1988.

Table 1. Descriptions of NE Iowa Fens Sampled November 1987, May 1988, and September 1988.

Code	Site Name	County	Legal Description	Physiography
1	Cedar Hills Prairie	Blackhawk	T90N R14W S19NW	Swale with hummocks facing east
2	Miller Fen	Blackhawk	T90N R14W S19SW	Bottom of gentle N slope (cultivated) at edge of stream floodplain
3	Berends Fen	Butler	T91N R17W S10SE	Hummocks at base of east slope of high ridge; sphagnum in a channel
4	Roose Fen	Butler	T92N R16W S22NE	Hummocks at mid height of a gentle east slope
5	Seehusen Fen	Butler	T92N R17W S21E	Quaking hummocks on gentle N slope with trees
6	Beardmore Fen	Floyd	T96N R15W S36SW	Gentle NW slope with dry hummocks; not sampled
7	Park Fen	Cerro Gordo	T94N R20W S10SW	N slope with seepage in several steep channels above small stream
8	Busching Fen	Bremer	T93N R14W S36NW	Four raised quaking mounds beside stream
9	Brayton Fen	Bremer	T92N R11W S2E	Gentle E slope with trees and hummocks in clumps
10	Boeding Fen	Chickasaw	T95N R11W S22NE	Gentle NE slope with hummocks
11	Argall Fen	Chickasaw	T96N R11W S32SW	Gentle E slope with trees and hummocks in clumps

RESULTS

Study sites had an uneven, hummocky surface covered with a mixture of sedges and grasses. Water was found in shallow pools among the hummocks (Table 1). These pools had sand or silt (muck) bottoms often covered with a thin layer of plant detritus and/or carbonate precipitates. Busching, Park and Roose Fens differed from other sites in that flowing water was observed. The Busching Fen uniquely had water flowing from the top of raised quaking mounds of peat aligned from north to south. Drainage from these mound springs leads into a nearby first order stream. The three largest mound springs were 2-3 m in height by 6-10 m in diameter. A 50 m long, raised, peat mound extends to the east from these mounds. Cattle grazing on the sites was evident only at Seehusen, Roose, and Park Fens, with grazing most intense on the Seehusen Fen.

Water conditions in these fens ranged from circumneutral, hard waters of high conductivity to acid, moderately soft waters of low conductivity. The fens are listed in Table 2 beginning with the highest conductivity waters (Park Fen). Hardness varied among sites in the same way as conductivity while alkalinity displayed a somewhat different pattern. Values of pH ranged from 5.1 in the Berends Fen to 7.2 (Park Fen) and 7.3 (Busching Fen). The high pH value of 8.0 at Roose Fen in November was probably the result of diurnal photosynthesis fluctuation; the pool sampled was full of *Spirogyra sp.* Dissolved oxygen levels in this sample support this interpretation. Otherwise levels of dissolved oxygen and nutrients (nitrate, phosphate, silica) were high. Silica values were above 15 mg/l in all waters in November and were not determined in May or September.

Comparing May and September conditions at Busching, Roose, and Berends Fens revealed little change in the above patterns (Table 2). Roose Fen had more alkaline water with higher conductivity but reduced hardness in May; September levels were intermediate. Nitrate levels were generally elevated in May and low in September.

These parameters change rapidly as water flows along the surface from the outlet. In Busching Fen (Table 2) measurements taken from the top (outlet) compared to others taken from the base showed that temperature increased along with conductivity, alkalinity and hardness. However the pH descreased. Dissolved oxygen and nitrate increased downstream in May but decreased in September. The creek draining Berends Fen and the adjacent ravine had water characteristic of surface waters in NE Iowa. For this reason the diatom flora of the creek will not be discussed.

Comparing these fens with previous reports (Gashwiler and Dodd 1961; Shobe *et al.*, 1963; Dodd 1981b; Christensen 1981; Reimer 1990) reveals similarities to both hard and soft water sites. Water conditions for Berends Fen and the Cedar Hills Prairie swale in this study are similar to Dodd's previous observations from Cedar Hills Prairie and to Pilot Knob data. The alkaline waters of Park and Busching Fens resemble conditions in the Excelsior Fen-complex (Reimer 1990) with the exception that hardness is much higher in the northwestern Iowa fen. The same comparisons hold for Silver Lake Fen (Gashwiler and Dodd 1961).

The 150 diatom taxa found in this study (Table 3) include 6 unidentified taxa. Of the remaining 144 taxa, 102 have been reported from Iowa fens, bogs, or swales by previous researchers. The studies chosen for comparison are summarized in Table 3. These include a swale in Cayler Prairie (Reimer 1970) and the Excelsior Fen-complex (Shobe *et al.* 1963; Reimer 1982; 1990) which are alkaline, hard water habitats in northwestern Iowa. The acid, soft water comparisons are with the previous study of Cedar Hills Prairie (Dodd 1981b) and a series of reports on Pilot Knob Lake and Bog diatoms (Christensen 1969; 1976; 1981; Dodd 1981a). In contrast to this close similarity in floristic composition among relatively small, scattered fen and bog habitats, only 58 of the taxa found in this study have been observed in major tributaries of the Cedar River basin which drain all but 3 of the sites studied (Main 1988).

Many taxa which were abundant [1% or more of a sample count of 500 (= classes 2 and 3 in Table 3)] occurred in fens throughout the water chemistry gradient. Examples include the majority of taxa in the genus *Achnanthes*, *Caloneis bacillum*, *Cymbella microcephala*, *Gomphonema angustatum*, *G. parvulum*, *Navicula elginensis*, *N. heufleri*, *N. minima*, *N. mutica*, *N. notha*, *N. pupula*, *N. seminulum v. intermedia*,

Table 2. Water Conditions in NE Iowa Fens Sampled 13-14 November 1987 (N), 15 May 1988 (M), and 3 September 1988 (S).

Location	Date	Time	Temp.	Cond.	Hard.	Alk.	pH	D.O.	Nit.	Tot. P
			°C	μmho	Total	HCO_3		mg/l	mg/l	mg/l
Park Fen	N	1100	8.0	705	380	260	7.2	8.5	10.1	2.1
Busching Fen	N	1600	9.4	595	285	390	7.1	2.0	0.4	2.8
Top	M	1410	19.0	545	290	370	7.3	2.0	0.5	>8.0
Bottom	M	1350	24.0	640	325	405	6.5	5.0	1.0	>8.0
Top	S	1425	18.0	590	330	370	—	3.0	0.0	3.25
Bottom	S	1440	21.0	700	400	400	—	2.5	0.0	7.0
Boeding Fen	N	1500	8.5	480	270	250	6.8	2.5	0.55	1.2
Roose Fen	N	1330	7.0	445	240	230	8.0	17.0	0.3	2.6
	M	1530	24.0	575	225	280	6.9	5.0	0.6	6.0
	S	0845	16.5	520	300	250	7.1	4.0	0.2	0.4
Seehusen Fen	N	1245	8.0	420	190	80	6.6	8.5	0.6	2.6
Brayton Fen	N	1150	9.4	380	180	110	6.3	7.5	12.0	2.9
Argall Fen	N	1400	9.0	320	175	140	6.8	7.5	3.6	0.9
Miller Fen	N	1545	5.5	265	145	160	6.7	7.5	0.4	3.1
Cedar Hills Prairie	N	1615	5.0	95	90	50	6.5	7.5	0.5	3.7
Berends Fen	N	1430	5.5	65	30	30	5.6	7.5	0.25	3.25
	M	1635	24.0	60	20	10	5.1	5.0	0.6	6.0
	S	dry								
Berends Creek	S	1015	14.5	250+	180	180	7.5	10.0	0.2	2.4

Nitzschia amphibia, *N. hantzschiana*, *N. palea*, and *N. radicula*. All these frequently occur in the Cedar River and are not strictly fen taxa.

Other widespread taxa such as the genus *Hantzschia*, the *Navicula paludosa* group, *N. potzgeri* and *Nitzschia obtusa v. brevissima* are characteristic of soil floras and are often found in wetland areas, such as in this study.

A diatom distribution pattern associated with conductivity appears to characterize northeastern Iowa fens. One group of diatom taxa was found in hard waters of high conductivity; one group was in waters of low conductivity; and a third group was intermediate in this gradient.

Abundant taxa (classes 2 and 3) found only in the hard water sites included *Achnanthes lapponica*, *A. hungarica*, *Anomoeoneis vitrea*, *Cymbella amphicephala*, *C. angustata*, *C. cymbiformis v. nonpunctata*, *Denticula elegans*, *Gomphonema subclavatum v. commutatum*, *Hantzschia amphioxys v. maior*, *Meridion circulare*, *Navicula cuspidata*, *N. luzonensis*, *N. radiosa v. tenella*, *N. subhamulata v. subundulata*, *Nitzschia communis*, *N. linearis*, and *Stauroneis smithii*. Of these 17 taxa, nine were reported from either Cayler Prairie or Excelsior Fen; however two occurred in Pilot Knob Bog.

Abundant taxa from the low conductivity sites included *Eunotia curvata*, *E. diodon*, *E. septentrionalis*, *Fragilaria virescens*, *Frustulia rhomboides v. saxonica*, *Meridion circulare v. constrictum*, *Navicula arvensis*, *N. begeri*, *N. placenta*, *N. radiosa*, *Neidium bisulcatum*, *Nitzschia hantzschiana*, *Pinnularia microstauron*, and *P. streptoraphe*. Of these 13 taxa, eleven were reported from either Pilot Knob Bog or Dodd's (1981b) Cedar Hill Prairie study; however five were also found at Cayler Prairie or Excelsior Fen.

Twenty-three taxa occurred abundantly although not at either end of the gradient. Of these, *Cymbella naviculiformis*, *C. norvegica*. *C. ventricosa v. truncatula*, *C. turgida*, *Diploneis elliptica*. *D. oblongella*, *Gomphonema angustatum v. sarcophagus*, *Navicula tridentula*, *Nitzschia denticula*, *Rhopalodia gibba*, *R. gibberula v. vanheurckii*, *Stauroneis anceps*, *S. phoenicenteron f. gracilis*, and *Surirella angusta* were previously reported from Iowa fens/bogs. *Caloneis bacillaris v. thermalis*, *Cymbella hybrida*, *C. subaequalis f. krasskeii*, *Gomphonema acuminatum v. pusilla*, *G. truncatum*, *Navicula contenta f. parallela*, *N. heufleriana v. minor*, *N. muralis*, and *Nitzschia fonticola* were not previously reported.

Widespread taxa produced a high level of floristic similarity among the fen sites sampled (Table 4). These widespread taxa included those found in nearby surface waters as well as those typifying fens. Park and Berends Fens' floras showed less similarity due to the greater abundances of taxa restricted to either end of the gradient. Increased sampling may yield more common taxa but may not change this pattern of similarity. Nevertheless, these sites showed greater similarity to each other than to sites of earlier studies referred to in Table 4.

Some evidence for seasonal variation in abundance among diatom taxa was found. Seven taxa found in May in Busching, Roose, or Berends Fens were not observed in November or September at either those sites or any other in this study. Five of the September taxa were not observed at any other time or place. At Busching Fen half as many taxa or fewer were observed in May or September as in November. Of the 48 taxa observed in November, 31 were not found in either May sample; and 35 were not found in September. Six taxa observed in May in at least one sample had not been collected at the Busching Fen in November; another six were newly observed at Busching Fen in September. Comparisons of November with May floras for Roose and Berends Fens show greater taxa changes for Roose than Berends diatom associations, even though total numbers of taxa observed were almost the same. The September flora at Roose showed similar changes from both May and November floras at that site.

Overall, the growing conditions for diatoms seem to be better in November and May than in late August. In late August vascular plants on these sites were at maximum height and foliage development. The resulting shading may be partially responsible for the presence of larger proportions of dead or senescent diatom cells in early September samples than in November or May samples.

Fourteen taxa were new Iowa distributional records — *Cymbella amphicephala*, *C. subaequalis f. krasskei*, *C. ventricosa v. paucistriata*, *Eunotia pectinalis v. ventricosa*, *Gomphonema acuminatum v. pusilla*, *Navicula begeri f. constricta*, *N. digna*, *N. heufleriana v. minor*, *N. placenta*, *N. pseudomutica*, *Pinnularia acuminata*, *P. acuminata v. bielawskii*, *P. mesogongyla*, and *P. mesolepta v. tenuis*. Most were associated

Table 3. Diatoms Observed in Iowa Fens, Bogs and Prairie Swales

[Data for locations in this study: - (absent), 1 (<1%), 2 (1-10%), 3 (>10%).
Locations in this study: Number 1-11 (see Table 1), no letter or N (November), M (May), S (Sept.), T (top), B (bottom).
Data for previous reports: +(present), - (absent), * (related variety reported), *? (apparently similar taxa).
Locations of previous reports: CP (Cayler Prairie; Reimer 1970), EF (Excelsior Fen; Shobe et al 1963; Reimer 1982, 1990), CHP (Cedar Hills Prairie; Dodd 1981b), PKB (Pilot Knob Bog; Christensen 1969, 1976, 1981, and Dodd 1981a).]

Diatom Taxa	Locations																			
	7	8NT	8MT	8MB	8ST	10	4N	4M	4S	5	9	11	2	1	3N	3M	CP	EF	CHP	PKB
Achnanthes																				
exigua v. heterovalva Krasske	1	2	2	-	2	-	-	1	1	1	2	1	-	1	-	-	-	-	+	-
hungarica (Grun.) Grun.	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
lanceolata (Breb.) Grun.	1	3	2	3	1	3	-	2	1	3	3	3	3	2	-	-	+	+	+	-
lanceolata v. dubia Grun.	-	2	-	-	3	2	-	-	-	-	-	-	2	2	-	-	+	-	+	+
lapponica Hust.	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
minutissima Kütz	3	-	-	-	-	2	3	3	3	1	-	3	2	-	-	-	-	+	-	+
Amphora																				
submontana Hust.	1	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Anomoeoneis																				
vitrea (Grun.) Ross	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caloneis																				
alpestris (Grun.) Cl.	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
bacillaris v. thermalis (Grun.) A. Cl.	-	-	-	-	-	1	-	-	-	-	2	-	-	-	-	-	-	-	-	-
bacillum (Grun.) Cl.	2	1	-	-	-	2	-	1	1	2	2	2	2	2	2	1	+	+	+	-
cleveii (Lagerst.) Cl.	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
lewisii v. inflata (Schultze) Patr. (form)	-	1	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	*	*
ventricosa v. truncatula (Grun.) Meist.	1	-	-	-	-	2	-	-	1	-	-	-	-	-	-	-	+	-	+	+
sp. 2	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-
sp. 3	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Cymbella																				
amphicephala Näg *ex* Kütz.	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
angustata (W. Sm.) Cl.	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-
aspera (Ehrenb.) H. Perag.	-	-	-	-	-	1	-	1	-	1	-	1	-	1	-	-	-	-	+	+
cymbiformis v. nonpunctata Font.	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
hauckii V.H.	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	+	+
hybrida Grun. *ex* Cl.	1	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-
microcephala Grun.	2	1	-	-	-	-	2	-	3	-	2	-	1	-	1	-	-	+	-	-
minuta Hilse *ex* Rabh.	-	1	-	-	-	1	-	1	-	1	1	-	1	2	-	-	-	-	-	+
minuta v. silesiaca (Bleisch *ex* Rabh.) Reim.	-	-	-	-	-	-	-	-	-	1	1	-	-	1	-	-	-	+	+	-
naviculiformis Auersw. *ex* Heib.	-	1	2	2	1	-	-	-	-	2	-	-	-	1	-	-	-	+	+	+
norvegica Grun.	1	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	+	-	-
perpusilla A. Cl.	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	+	-	-
subaequalis f. krasskei (Foged) Reim.	-	1	-	-	1	-	1	-	-	1	2	1	-	-	-	-	-	-	-	-
turgida (Greg.) Cl.	-	-	-	-	-	2	-	-	-	-	1	-	-	-	1	-	-	-	-	+
ventricosa v. paucistriata Cl.	-	-	-	-	-	1	-	-	-	-	1	1	-	1	-	-	-	-	-	-
Denticula																				
elegans Kütz.	2	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	+	-	-
Diploneis																				
elliptica (Kütz.) Cl.	-	1	-	-	-	1	-	-	-	1	1	1	-	2	-	-	-	+	-	-
oblongella (Näg *ex* Kütz.) Ross	1	-	-	-	1	-	-	1	2	1	2	1	1	1	-	-	+	+	+	-
Epithemia																				
adnata v. porcellus (Kütz.) Patr.	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Eunotia																				
curvata (Kütz.) Lagerst.	-	1	-	-	-	1	2	2	-	2	2	1	1	1	2	2	+	+	+	+
diodon Ehrenb.	-	-	-	-	-	-	-	-	-	-	2	1	-	-	1	-	-	-	-	-
maior (W. Sm.) Rabh.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	+	+
pectinalis v. ventricosa Grun.	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	*?	*?
praerupta v. bidens (Ehrenb.) Grun.	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	+	-
septentrionalis Østr.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	2	-	-	+	-
valida Hust.	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1	-	-	-	+

Table 3. (continued)

Diatom Taxa	Locations																			
	7	8NT	8MT	8MB	8ST	10	4N	4M	4S	5	9	11	2	1	3N	3M	CP	EF	CHP	PKB
Fragilaria																				
nitzschioides Grun.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	+
virescens Ralfs	-	-	-	-	-	-	-	-	-	-	2	2	3	2	-	-	+	-	+	+
Frustulia																				
rhomboides v. saxonica Rabh.) DeT.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	3	2	-	-	+	-
vulgaris (Thwaites) DeT.	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	+	-
Gomphonema																				
acuminatum v. pusilla Grun.	-	-	-	-	-	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-
angustatum (Kütz.) Rabh.	2	-	-	2	1	-	-	-	2	-	-	2	2	2	-	-	+	+	+	+
angustatum v. citera (Hohn & Hellerm.) Patr.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
angustatum v. sarcophagus (Greg.) Grun.	-	-	-	-	-	1	-	-	-	1	1	1	2	-	-	-	+	-	-	+
dichotomum Kütz.	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	+	-	-
gracile Ehrenb. *emend* V.H.	1	-	-	-	-	-	2	-	1	-	-	-	1	-	-	-	*	+	-	-
intricatum Kütz.	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	+	+	-	-
intricatum v. pumila Grun.	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	+	-	-	-
parvulum (Kütz.) Kütz.	-	3	3	3	3	2	2	2	-	2	2	1	2	1	2	3	+	+	+	+
subclavatum v. commutatum (Grun.) A. Mayer	-	2	2	2	-	2	-	2	-	2	1	2	-	-	-	-	-	-	-	-
truncatum Ehrenb.	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Gyrosigma																				
obtusatum (Sulliv. & Wormley) Boyer	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hantzschia																				
amphioxys (Ehrenb.) Grun.	-	2	1	-	1	1	-	-	-	1	1	1	2	-	-	-	+	-	-	+
amphioxys fo. capitata O. Müll.	-	1	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	+	+	+
amphioxys v. maior Grun.	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-
Melosira																				
italica (Ehrenb.) Kütz.	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	+	-
Meridion																				
circulare (Grev.) Ag.	2	-	-	-	1	1	-	-	-	1	1	2	-	-	-	-	+	-	-	-
circulare v. constrictum (Ralfs) V.H.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	2	+	-	+	+
Navicula																				
amphibola Cl.	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	+	-
arvensis Hust.	-	-	-	-	-	-	1	-	-	-	-	-	-	2	1	1	-	+	+	-
begeri Krasske	-	1	-	-	2	2	-	-	-	-	2	1	1	2	3	2	-	-	+	+
begeri f. constricta Krasske	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
contenta v. biceps (Arnott) V.H.	-	1	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	+	-
contenta v. parallela Petersen	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
crytocephala Kütz.	1	-	-	-	1	-	-	-	3	-	-	1	-	2	-	-	-	-	+	+
crytocephala v. veneta (Kütz.) Rabh.	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	+	-	-
cuspidata (Kütz.) Kütz.	1	-	2	1	2	-	1	-	-	-	-	-	-	-	-	-	+	-	+	+
digna Hust.	-	-	-	-	-	-	-	-	-	1	1	1	-	1	-	-	-	-	-	-
elginensis (Greg.) Ralfs	2	1	2	1	2	1	1	1	-	2	2	-	2	2	-	-	*	-	+	+
hassiaca Krasske	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	+	-
heufleri Grun.	-	2	-	1	-	1	2	1	-	2	1	1	1	1	-	-	+	+	+	-
heufleri v. leptocephala (Breb. *ex* Grun.) Patr.	1	-	-	-	-	-	-	1	-	-	-	1	-	1	-	-	-	+	-	-
heufleriana v. minor Lund	-	-	-	-	-	-	-	-	-	-	1	1	1	2	-	-	-	-	-	-
insociabilis Krasske	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	+	-
lanceolata (Ag.) Kütz.	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
lapidosa Krasske	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	+	-
luzonensis Hust.	1	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
minima Grun.	-	3	2	2	-	2	2	2	-	2	2	2	2	3	2	1	-	-	-	-
muralis Grun.	1	-	-	-	-	-	-	-	-	1	2	2	2	2	-	-	-	-	-	-
mutica Kütz.	2	1	-	-	-	2	-	-	-	2	1	-	2	1	1	1	+	-	+	+
notha Wallace	2	-	-	-	-	1	1	1	-	1	-	-	2	2	-	-	-	-	-	-
paludosa Hust.	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	+	-	*?	*?
paludosa f. rhomboidea Reimer	-	1	-	-	-	2	-	-	-	-	-	-	2	1	-	-	+	-	*?	-
placenta Ehrenb.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-
potzgeri Reimer	2	-	-	-	-	-	-	-	2	-	-	-	-	2	-	-	-	+	-	-
pseudomutica Hust.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-
pupula Kütz.	-	2	2	2	3	1	-	1	-	1	1	1	1	1	-	1	-	+	+	+
pupula v. rectangularis (Greg.) Grun.	-	-	-	-	-	1	-	-	1	2	-	-	1	1	1	-	+	+	+	-
radiosa Kütz.	-	-	-	-	-	1	1	-	-	1	2	1	-	2	-	-	-	-	+	-
radiosa v. tenella (Breb. *ex* Kütz.) Grun.	2	1	-	-	-	-	2	-	-	1	-	1	1	-	-	-	-	+	-	-
seminulum Grun.	-	1	-	1	-	-	-	-	-	1	1	2	1	2	2	1	-	+	+	+
seminulum v. intermedia Hust.	-	2	2	2	2	2	1	-	-	2	-	1	1	1	-	2	-	-	-	-
simplex Krasske	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
subhamulata v. subundulata Hust.	2	-	-	-	-	-	1	-	2	-	1	-	-	-	-	-	-	-	-	-
tridentula Krasske	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	+	-	-
viridula v. argunensis Skv.	1	-	-	-	-	-	-	-	1	-	-	1	2	-	-	-	-	+	-	-
sp. 26 (? = *Stauroneis sphagnophila* Krasske)	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-

Table 3. (continued)

Diatom Taxa	7	8NT	8MT	8MB	8ST	10	4N	4M	4S	5	9	11	2	1	3N	3M	CP	EF	CHP	PKB
	Locations																			
Neidium																				
affine (Ehr.) Pfitz.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	+
affine v. undulatum (Grun.) Cl.	-	1	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	+	+	-
binode (Ehr.) Hust.	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
bisulcatum (Lagerst.) Cl.	1	-	-	-	-	-	-	-	1	-	-	-	-	-	2	1	-	-	+	+
Nitzschia																				
amphibia Grun.	-	2	-	-	-	3	1	1	-	2	2	2	2	2	-	-	+	+	+	+
communis Rabh.	-	2	2	2	2	-	1	1	-	-	-	1	1	-	-	-	*	+	-	-
denticula Grun.	-	-	-	-	-	-	-	-	3	-	-	-	2	-	-	-	-	+	+	-
fonticola Grun. in V.H.	-	1	-	-	-	-	-	-	3	2	-	-	1	-	-	-	-	-	-	-
frustulum (Kütz.) Grun.	-	-	-	-	-	1	-	1	-	-	-	2	2	-	-	-	+	-	-	-
hantzschiana Rabh.	-	1	-	1	2	1	2	1	2	2	1	2	1	2	3	1	-	-	-	-
linearis (Ag. *ex* W. Sm.) W. Sm.	2	1	-	-	-	-	1	2	2	-	1	1	1	-	-	-	-	+	-	-
linearis v. tenuis (W. Sm.) Grun.	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	+	-	-
obtusa v. brevissima Grun.	-	2	-	-	-	2	-	-	-	2	2	-	1	1	1	1	-	-	+	+
palea (Kütz.) W. Sm.	-	2	2	1	3	1	-	1	-	-	-	-	-	-	-	2	+	+	+	+
radicula Hust.	1	2	2	1	-	3	2	-	-	2	1	1	2	2	3	2	-	-	-	-
umbonata (Ehrenb.) Lange-Bertalot	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
sp. 14	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pinnularia																				
abaujensis v. rostrata (Patr.) Patr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	*	-	-	+
abaujensis v. subundulata (A. Mayer *ex* Hust.) Patr.	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	*	-	+	+
acrosphaeria W. Sm.	1	1	-	-	-	-	1	-	-	1	1	1	1	1	-	-	-	-	+	+
acuminata W. Sm.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
acuminata v. bielawskii (Hēib. & Perag.) Patr.	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
appendiculata (Ag.) Cl.	-	-	-	-	-	-	1	-	-	1	1	1	1	-	1	-	-	-	-	+
brebissonii v. diminuta (Grun.) Cl.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	+	-	-	-
instita Hohn & Hellerm.	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	+	-
mesolepta v. tenuis Cl.-Euler	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
mesolepta v. turbulenta Cl.-Euler	-	-	-	-	-	1	-	1	-	1	-	-	-	-	-	-	-	-	-	+
mesogongyla Ehrenb.	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-
microstauron (Ehrenb.) Cl.	-	1	-	-	-	1	-	-	-	-	1	-	1	1	1	2	+	+	-	+
nodosa (Ehrenb.) W. Sm.	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
obscura Krasske	-	-	-	-	-	1	-	-	-	-	1	-	1	-	1	1	-	-	-	+
stomatophora (Grun.) Cl.	-	-	-	-	-	1	1	-	-	1	-	-	-	-	-	-	-	+	+	+
streptoraphe Cl.	1	-	-	-	-	1	1	-	-	1	1	-	-	1	2	2	-	-	+	+
subcapitata Greg.	-	1	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	+	+	+
viridis v. intermedia Cl.	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	*	*	*	+
sp. 1	-	2	-	-	-	-	-	-	-	-	1	-	-	2	-	-	-	-	-	-
sp. 2	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Rhopalodia																				
gibba (Ehrenb.) O. Müll.	-	-	-	-	-	2	1	1	1	2	1	-	1	1	-	-	*	+	+	+
gibberula v. vanheurckii O. Müll.	-	1	-	-	-	2	-	-	-	2	2	2	1	-	-	-	-	+	-	-
Stauroneis																				
anceps Ehr.	-	1	-	-	-	1	-	-	-	2	-	-	-	2	1	-	+	+	+	+
phoenicenteron f. gracilis (Ehrenb.) Hust.	-	1	1	2	-	1	-	-	1	2	1	-	-	1	-	-	-	+	+	+
smithii Grun.	2	-	-	-	-	-	-	2	1	1	-	-	-	-	-	-	-	-	-	-
Surirella																				
angusta Kütz.	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	+	+
robusta v. splendida (Ehrenb.) V.H.	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
spiralis Kütz.	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Synedra																				
parasitica v. subconstricta (Grun.) Hust.	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
ulna (Nitz.) Ehrenb.	1	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	+	-	+
Total Taxa Observed	45	48	18	18	24	47	30	32	28	54	55	49	56	57	30	28	35/63	49/133	60/107	52/90

Table 4. Percentages of taxa common to fen sites in Iowa, including studies cited in Table 3. Percent common to both sites = (number of taxa common to both sites/number of taxa at one or both sites) X 100.

Location	Total Taxa	7	8	10	4	5	9	11	2	1	3
7. Park	44										
8. Busching	61	19									
10. Boeding	47	14	38								
4. Roose	63	35	31	34							
5. Seehusen	54	21	40	46	39						
9. Brayton	55	16	40	42	27	45					
11. Argall	49	18	31	32	35	41	46				
2. Miller	56	25	39	37	34	39	42	38			
1. Cedar Hills Prairie	57	17	37	39	32	42	42	36	38		
3. Behrends	39	8	20	25	19	21	25	21	25	23	
Caylor Prairie	63	9	17	21	12	13	13	15	20	14	10
Excelsior Fen	133	12	15	11	18	13	13	10	15	14	6
Cedar Hills Prairie	107	9	20	17	19	21	18	13	19	26	14
Pilot Knob	90	9	21	22	18	22	19	14	19	19	16

with circumneutral or slightly acid conditions. *N. placenta* is a *Sphagnum* epiphyte; *G. acuminatum v. pusilla* was abundant in a *Spirogyra* bloom at Roose Fen. In addition an atypical form of *Caloneis lewisii v. inflata* was found.

DISCUSSION

The controversy about whether or not raised wetlands in northwestern and northeastern Iowa are fundamentally different reflects the habitats sampled earlier. The areas studied in northwestern Iowa are alkaline, hard water sites described as fens or swales. The areas previously studied in northeastern Iowa are acid, moderately soft water sites described as bogs or moss polsters. The present study shows that raised wetlands with alkaline waters, moderate conductivity and circumneutral pH extend across the state. Iowa fen waters show a gradual gradient of increase from east to west in conductivity, alkalinity and hardness while remaining circumneutral. The three centrally located sites with acid, soft waters are exceptions.

The terminology used to describe raised wetlands with some peat development is entangled in the complex and sometimes ambiguous terminology of mires, bogs, fens, and moors as described by Gore (1983). A distinction between acid, mineral-poor bogs and alkaline, mineral-rich fens has been made, but Gore differentiates between fens and bogs based on the source of water to the fen/bog. The water in fens comes predominantly from outside the area of the fen through the ground. The water in bogs has fallen into that area from the atmosphere. Fen waters can be expected to relate to the chemical composition of the soils and bedrock formations through which those waters have moved.

This distinction between fens and bogs is useful in the present study because all of these sites, acid or alkaline, can now be termed fens. The amount of water in these relatively small areas indicates a source outside the area of hummocks and pools. Even finding quantities of water sufficient for sampling in these upland sites was surprising considering that near drought conditions prevailed in NE Iowa throughout 1987 and 1988. The variation in water conditions from acid, low conductivity waters to circumneutral, moderately conductive waters found among the 10 sites must be due to the soil and bedrock the water passed through before emerging at each fen. Finding such a variety of fens within such a short distance was also surprising.

The diatoms found in these fens reflect the water conditions and substrata available. The distribution of many taxa appears to be related to conductivity and correlated parameters. In northeast Iowa fens, pH does not appear to be correlated to diatom distribution, since most fens were circumneutral. The substances producing alkalinity and hardness in these waters may be more critical influences than pH on the diatom distribution.

The variety of substrata for diatom growth was limited. Substratum was primarily silt (muck) or sand favoring epipelic and epipsammic diatom growths. A few epiphytes were associated with *Sphagnum* and other mosses and with filamentous algae. The pools sampled were too small and shallow for plankton to develop. The absence of planktonic and most epiphytic diatoms restricts the number of taxa expected. Finding 50 or 60 taxa in a site with limited substrata suggests some of these fens have a relatively rich flora (Table 3).

The mounds of peat beneath the springs at Busching Fen represent the thickest layer of peat from which diatoms were sampled in this study. This fibrous organic matrix of the silt in the pools no doubt influences microtexture for motile diatoms as well as contributing to the humic physico-chemistry of the water. The pools at Busching Fen often have blooms of *Closterium sp.;* this was the only observation of large numbers of any desmid.

The Iowa fens studied so far occur on glacial moraine slopes where water seeps or flows from beneath the surface. Dead Man's Lake, a kettlehole fen, is the only exception. Iowa fens are located south and west of Transeau's line (Transeau 1903), the climatically predicted limit for the distribution of true bogs in eastern North America. In this drier climate, groundwater becomes the major source of moisture needed to permit peat formation. Insufficient atmospheric precipitation during the growing sason over many years prevents the development of ombrotrophic bogs on top of the minerotrophic layer. As a result, Iowa fens exhibit much less spatial heterogeneity among microhabitats when compared to studies from northern Europe, Canada, the northeastern U.S., and even northern Minnesota (DuRietz 1950a; 1950b; 1950c; Niessen 1956; Bruno and Lowe 1980; Kingston 1982; Cochran-Stafira and Andersen 1984; Foged 1984; Pienkowski and Wujek 1987/88). The greatest similarity is to certain Danish fens developed on glacial moraines overlying limestone (Foged 1984).

The variations in diatom flora and in water physico-chemistry found in this study reflect the response of each fen to local aquifers. An example is the amount of difference between Roose and Berends Fens which are located about 10 km apart. Their diatom floras vary significantly from each other and from those of nearby surface waters.

The unique nature of northeast Iowa fen habitats contributes to the distinct composition of their diatom flora. One indication is the discovery of 14 taxa not previously reported from Iowa. Another aspect is the floristic difference between these sites and the larger streams in the area. In a sense these scattered fens seem discontinuous with their immediate surroundings. The taxa identified in this study as characteristic of the northeastern Iowa fens may occur elsewhere but seldom as abundantly or in this combination. From one fen to another a continuum of water conditions extends almost to the extremely hard waters prevailing in the northwestern Iowa fens described so far. This continuity with change is reflected in the taxonomic pattern as well.

This study suggests several new lines of investigation for diatom taxonomy and ecology in Iowa. The distribution of diatom taxa along gradients from these upland water sources into local streams remains unknown. The seasonal distribution of taxa is incompletely described. Morphological variation within a taxon among different fens exists and should be evaluated. The completeness of the gradient in hardwater fens can be described by further sampling of fens between northeast and northwest Iowa. The occurrence of softwater fens and their relation to the hardwater fens along this gradient also needs more study. The glacial history of northern Iowa and known soil differences among the glacial lobes could provide an explanation for water chemistry and the related diatom floras of the Iowa fens.

ACKNOWLEDGEMENTS

Financial support for travel, materials, and technical assistance was provided by the Iowa Department of Natural Resources. We thank Iowa Lakeside Laboratory and Dr. Charles Reimer for the use of the Iowa Diatom Herbarium in checking the identifications of our specimens. Brian Robinson and David Marx were our student associates. The constructive criticism of our anonymous reviewers is gratefully acknowledged.

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