

## NOTES

## DIATOMS (BACILLARIOPHYTA) FROM SALINE WATERS WITHIN QUIVIRA NATIONAL WILDLIFE REFUGE, STAFFORD COUNTY, KANSAS

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Few studies have been published on the diatom floras of saline environments in Kansas or the adjacent plains states of Oklahoma, Nebraska, and eastern Colorado (Koch, 1975; Czarnecki and Reinke, 1981; Wenke and Eberle, 1986). Blinn (1993) commented on the general paucity of information on the diatom flora of saline lakes in North America relative to studies of these communities in Africa, Australia, and South America. In his study of the structure of diatom communities in saline lakes in western North America, Blinn (1993) noted that the dominant anion in Canada and the northern United States is sulfate ( $\text{SO}_4^-$ ), and the dominant anions are  $\text{CO}_3^-$  and  $\text{Cl}^-$  in the southern Great Plains and southwestern United States, although waters of both types occur throughout the region.

Although work has been conducted in saline lakes, less is known about the diatom communities of saline marshes and associated streams in the southern Great Plains and the southwestern United States (Czarnecki et al., 1981). We sampled diatoms living in the chloride-dominated waters of Little Salt Marsh, Rattlesnake Creek, and Big Salt Marsh within Quivira National Wildlife Refuge (Quivira NWR) in Stafford Co., Kansas (Fig. 1). Our purpose was to further document species richness of the poorly known diatom flora of these inland habitats.

Our study area is underlain by Paleozoic halite deposits, and the primary source of mineralized water in the unconsolidated aquifers of this region is the dissolution of Permian evaporites, primarily halite; dominant ions are  $\text{Na}^+$  and  $\text{Cl}^-$  (Whittemore, 1993). The greatest intrusion of saline water into shallow aquifers underlying streams and wetlands is in the area

around Quivira NWR. Evaporation of water from the marshes at Quivira NWR increases concentrations of dissolved salts in these surface waters.

Little Salt Marsh and Big Salt Marsh generally range in depth from 1.0 to 1.5 m (D. Hilley, Quivira NWR Manager, pers. comm.). Surface area of Little Salt Marsh is ca. 344 ha, and Big Salt Marsh covers ca. 608 ha (D. Hilley, pers. comm.). Thus, the marshes have a relatively large surface area to depth ratio. The depth of Rattlesnake Creek within the refuge typically varies from 5 to 31 cm (D. Hilley, pers. comm.).

We collected diatom samples at intervals of 4 to 8 weeks from September 1996 through June 1997. Micropipettes were used to collect benthic samples from submerged rocks along the shores of the marshes and from sand and silt in the creek. We also used a plankton net to collect samples from open water, primarily from the Little Salt Marsh. We used silver-nitrate titrations to measure chloride concentrations at each site (Table 1); however, ice cover on the Big Salt Marsh prevented us from obtaining appropriate water samples for chloride analysis during the winter.

In the lab, we suspended each diatom sample in water and placed 1 drop on each glass slide. Slides were slowly heated to attach diatoms to the slides. These samples were mounted permanently with Hyrax or Naphrax for examination with a light microscope. To facilitate identification of taxa, we cleaned portions of each sample with sulfuric acid to remove organic material and expose features of the diatom frustules (Lind, 1985). A drop of each cleaned sample was mounted as described for the uncleaned samples. Samples and slides are

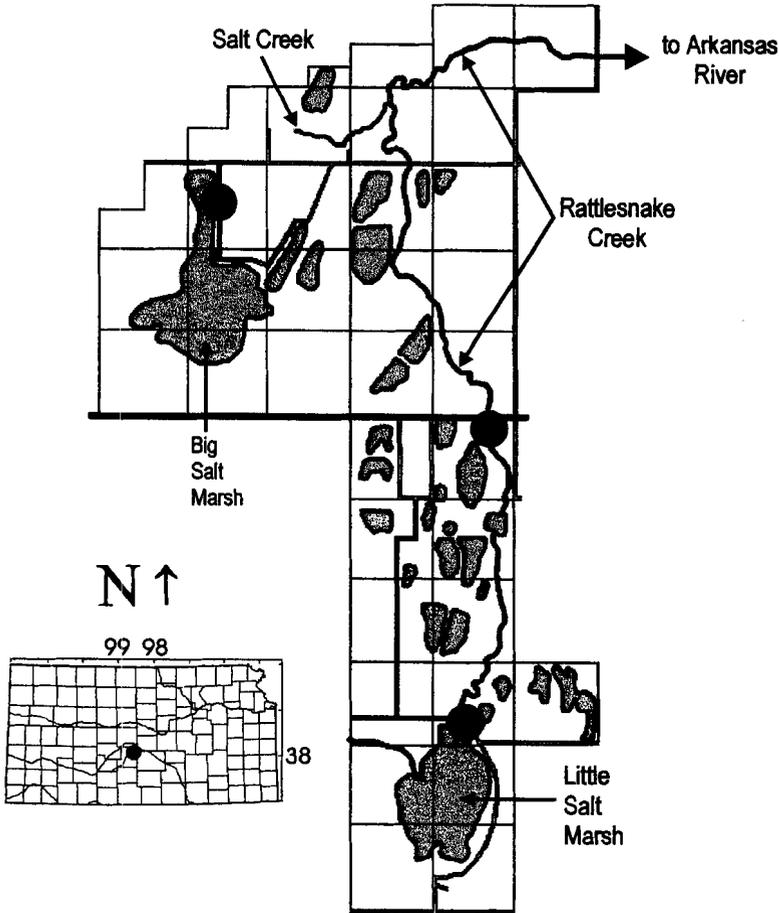


FIG. 1—Map of Quivira National Wildlife Refuge, Kansas. Marsh pools are shaded. Collection sites are marked with black circles. Square grid represents topographical survey sections ( $1 \text{ mi}^2 = 2.6 \text{ km}^2$ ). Roads are marked with double lines (sand) and a heavy line across the center (asphalt). Numbers on inset map of Kansas counties are degrees W longitude and N latitude.

housed in the Sternberg Museum of Natural History at Fort Hays State University, Hays, Kansas.

Initially, we attempted to identify as many taxa as possible on mounts of cleaned and uncleaned samples. We used references by Patrick and Reimer (1966, 1975) and Hustedt (1985) to identify most specimens. References by Schoeman and Archibald (1976–1980), Czarnecki and Blinn (1978), Czarnecki et al. (1980), and Dodd (1987) also were used. A few diatoms were notably different from the taxa described in the references. These taxa were designated “cf.” and given the scientific names of the taxa they most closely resembled. Harris (1999) summarized notes on the frustular

characteristics for the “cf.” specimens. It is possible that morphological differences in at least some of these instances simply were due to atypical depositions of cell wall components and that these might be caused by environmental variables, such as high chloride concentrations.

We identified 118 species, varieties, and forms (including “cf.” specimens), representing 44 genera (Table 2). Three additional diatoms could be identified only to genus. We identified 28 taxa, including 2 genera (*Rhizosolenia* and *Scoliopleura*), that were unreported previously from Kansas (Table 2); 19 of these taxa also have not been reported from Oklahoma, Nebraska, and eastern Colorado

TABLE 1—Collection dates (b = benthic sample; p = planktonic sample) and chloride levels (mg/l). Water samples for chloride analysis were not collected in October. Ice prevented collection of water samples from Big Salt Marsh in December and January, and the June sample from that site was lost. LSM = Little Salt Marsh. RC = Rattlesnake Creek. BSM = Big Salt Marsh.

Date	LSM	RC	BSM
14 Sep 1996	1,253 b	1,160 b	2,282 b
11 Oct 1996	— b	— b	— b
15 Nov 1996	794 b/p	771 b	2,301 b
21 Dec 1996	939 b/p	958 b	— b
20 Jan 1997	829 b/p	927 b	— b
30 Mar 1997	852 b/p	973 b	2,089 b/p
2 June 1997	980 b	1,109 b	— b/p
Mean	941	983	2,224

(Eberle, 1997). Some of these records represent taxa restricted to the poorly studied saline environments. For example, the genus *Scoliopleura* has not been reported previously from collections of Recent diatoms from Kansas, Oklahoma, Nebraska, or eastern Colorado, but it has been reported elsewhere in North America from high-chloride waters (Patrick and Reimer, 1966; Czarnecki et al., 1981). As in our study, *Scoliopleura peisonis* was reported as "rarely encountered" in the habitats with the highest salinities in Arizona (Czarnecki et al., 1981: 315).

The other genus previously unreported from Kansas, *Rhizosolenia*, was reported from Tenkiller Ferry Reservoir in eastern Oklahoma (Hern et al., 1979). Round and Crawford (Round et al., 1990) transferred weakly-silicified freshwater species from the largely marine genus *Rhizosolenia* to the genus *Urosolenia*. However, the specimens that we identified as *Rhizosolenia minima* did not have the numerous copulae and the numerous plastids characteristic of *Urosolenia*. Czarnecki et al. (1981) reported *Rhizosolenia minima* from similar habitats in northeastern Arizona. We do not know whether the taxon reported from Oklahoma (Hern et al., 1979) belongs in *Rhizosolenia* or *Urosolenia* as those genera are now recognized.

*Campylodiscus clypeus* var. *bicostata* is common in coastal areas and inland saline waters (Hustedt, 1985). Our report is the first from Kansas, Oklahoma, Nebraska, or eastern Colorado, although the nominant variety was reported

once from Kansas (Czarnecki and Reinke, 1981) and once in Nebraska (Elmore, 1921). Czarnecki and Reinke (1981) stated that the frustules of *Campylodiscus clypeus* var. *bicostata* are the result of McDonald-Pfitzer size reduction in *Campylodiscus clypeus*. The specimens from Quivira NWR that we identified as *Campylodiscus clypeus* var. *bicostata* comprised small frustules (65 to 74  $\mu\text{m}$ ) compared with the larger size of the nominant variety (80 to 200  $\mu\text{m}$ ; Hustedt, 1985). Specimens assignable to the nominant variety were not found in our samples, so we retained the name of the variety in our list.

Following compilation of the initial list of taxa, we calculated relative abundances of the taxa in each sample. We counted 300 diatom frustules on random transects of one slide from each uncleaned sample. All complete frustules in the field of view at 1,000 $\times$  were counted. Diatoms in these counts were obtained from a total of 19 benthic samples: 7 samples from each marsh and 5 from the creek. We also counted diatoms from 4 planktonic samples from Little Salt Marsh. In the estimates of relative abundances for each sample, only 19 of the 90 taxa identified in our sample counts comprised 10% or more of at least 1 sample from at least 1 of the 3 water bodies (Table 2).

Although chloride levels in Little Salt Marsh and Rattlesnake Creek were lower than those from Big Salt Marsh (Table 1), comparisons of the lists of taxa indicated that there was considerable similarity among the communities in the 3 bodies of water (Table 3). Of the 90 taxa in our counted samples, 37% were found in all 3 bodies of water. Exhibiting tolerance to a wide range of chloride concentrations, *Chaetoceros muelleri*, *Cyclotella meneghiniana*, and *Nitzschia gandersheimiensis* were abundant ( $\geq 10\%$ ) at all 3 sites. Additionally, *Entomoneis paludosa* was abundant in Little Salt Marsh and Rattlesnake Creek and nearly reached this level (9%) in 1 sample from Big Salt Marsh. Other taxa seemed to be more restricted in their tolerance to chlorides and were abundant only in waters with low or high chloride levels. *Gomphonema olivaceum*, *Nitzschia acicularis*, and *Rhizosolenia minima* were abundant only in the relatively lower-chloride waters of Little Salt Marsh and Rattlesnake Creek, but *Cylindrotheca gracilis*, *Navicula gregaria*, and *Nitzschia fonticola*

TABLE 2—Alphabetical list of diatom taxa collected during 1996 and 1997 from Little Salt Marsh (LSM), Rattlesnake Creek (RC), and Big Salt Marsh (BSM) at Quivira National Wildlife Refuge, Stafford Co., Kansas. A = abundant (maximum abundance  $\geq 10\%$  of at least 1 sample); P = present (maximum abundance of 2 to 9.7%); S = scarce (maximum abundance  $< 2\%$  in all samples); x = identified from this site but not included in counted samples. New records for Kansas, Oklahoma, Nebraska, and eastern Colorado are marked with a dagger ( $\dagger$ ). Additional new records for Kansas are marked with an asterisk (\*).

Scientific name	LSM		BSM		
	Benthic	Plank- tonic	RC Benthic	Benthic	Plank- tonic
<i>Amphora acutiuscula</i> Kütz.	S		S	P	x
<i>A. cf. acutiuscula</i> Kütz.	S		P	P	x
<i>A. coffeiformis</i> (Ag.) Kütz.				S	x
$\dagger$ <i>A. commutata</i> Grun. in Olive				S	
<i>A. copulata</i> (Kütz.) Schoem. & Arch.	x		S		
<i>A. ovalis</i> (Kütz.) Kütz.		S			
<i>A. veneta</i> Kütz.				x	x
<i>Anomoeoneis costata</i> (Kütz.) Hust.				S	
<i>A. sphaerophora</i> (Ehr.) Pfütz.	x		S	S	x
<i>Aulacoseira</i> sp.	A	P	P		x
<i>Bacillaria paradoxa</i> Gmel.	S	P	S	S	
<i>Caloneis amphibiaena</i> (Bory) Cl.	S		x		
* <i>Caloneis amphibiaena</i> var. <i>subsalina</i> (Donk.) Cl.	x				
<i>C. lewisii</i> Patr.	x		x		
<i>C. ventricosa</i> var. <i>minuta</i> (Grun.) Patr.				x	
$\dagger$ <i>Campylodiscus clypeus</i> var. <i>bicostata</i> W. Sm.	x		S	x	
<i>Chaetoceros muelleri</i> Lemm.	S	A	A	A	x
<i>Cocconeis placentula</i> var. <i>euglypta</i> (Ehr.) Cl.	S	S		P	x
<i>Craticula accomoda</i> (Hust.) D. Mann	S	S		S	
<i>C. cuspidata</i> (Kütz.) D. Mann	S			x	
<i>C. halophila</i> (Grun.) D. Mann	x				
<i>Ctenophora pulchella</i> (Ralfs ex Kütz.) Will. & Round	S	S		P	x
<i>Cyclotella meneghiniana</i> Kütz.	A	A	A	A	x
<i>Cylindrotheca gracilis</i> (Bréb. ex Kütz.) Grun.	S		S	P	x
<i>Cymatopleura elliptica</i> (Bréb.) W. Sm.	x				
<i>Cymbella pusilla</i> Grun.	P	S	x	P	x
<i>C. tumida</i> (Bréb. ex Kütz.) V.H.	x				
<i>Denticula elegans</i> Kütz.				S	
<i>Diatoma vulgare</i> Bory	x				
<i>Diploneis interrupta</i> (Kütz.) Cl.				x	x
<i>D. oblongella</i> (Naeg. ex Kütz.) Ross			x	x	
<i>Encyonema triangulum</i> (Ehr.) Kütz.	x				
<i>Entomoneis alata</i> (Ehr.) Ehr.	S	P	S	P	x
<i>E. paludosa</i> (W. Sm.) Reim.	A	A	A	P	x
* <i>E. robusta</i> (McCall) Reim.	P	S	S	x	
$\dagger$ <i>Epithemia argus</i> var. <i>longicornis</i> (Ehr.) Grun.				x	
<i>E. turgida</i> (Ehr.) Kütz.	x				
<i>Fallacia pygmaea</i> (Kütz.) Stickle & D. Mann	P	P	P	P	x
<i>Fragilaria vaucheriae</i> (Kütz.) Peters.	S	A	P	S	
<i>Gomphonema affine</i> Kütz.	P	P	S	P	x
<i>G. angustatum</i> (Kütz.) Rab.			x		
<i>G. olivaceum</i> (Lyngb.) Kütz.	A	A	A	x	
* <i>G. olivaceum</i> var. <i>calcareum</i> (Cl.) Cl.			S		
<i>G. parvulum</i> (Kütz.) Kütz.		x	S		
<i>Gyrosigma acuminatum</i> (Kütz.) Rab.	S	S	S	S	x
<i>Hantzchia amphioxys</i> (Ehr.) Grun.	x			S	

TABLE 2—Continued.

Scientific name	LSM			BSM	
	Benthic	Plank- tonic	RC Benthic	Benthic	Plank- tonic
<i>Martyana martyi</i> (Hèrib.) Round	S		S		
† <i>Mastogloia braunii</i> Grun.	x			x	
<i>M. danseii</i> Thw. ex W. Sm.			S	P	x
<i>M. pumila</i> (Grun.) Cl.	x				
<i>Navicula capitata</i> var. <i>hungarica</i> (Grun.) Ross	P	P	A	S	
<i>N. circumtexta</i> Meist. ex Hust.	S	P	S		
<i>N. cryptocephala</i> var. <i>veneta</i> (Kütz.) Rab.	S	P			
<i>N. graciloides</i> A. Mayer	A	A	P	P	x
<i>N. gregaria</i> Donk.	S		P	A	
<i>N. integra</i> (W. Sm.) Ralfs	S		A		
<i>N. lanceolata</i> (Ag.) Kütz.	S	P	P	P	x
<i>N. peregrina</i> (Ehr.) Kütz.	S	S	S	x	x
* <i>N. cf. secreta</i> var. <i>apiculata</i> Patr.	P	P	A	A	x
<i>Neidium affine</i> (Ehr.) Pfitz.				x	
* <i>N. ampliatum</i> (Ehr.) Kramm.	x				
† <i>N. iridis</i> var. <i>iridis</i> f. <i>vernalis</i> Reichelt				x	
<i>Nitzschia</i> sp.	x		P	P	x
<i>Nitzschia acicularis</i> (Kütz.) W. Sm.	A	A	A		
† <i>N. adapta</i> Hust.	S	P	S	S	
† <i>N. agnewii</i> Choln.	x				
<i>N. amphibia</i> Grun.	S	S	S	S	
† <i>N. caledonensis</i> Schoem.		S	x	S	
<i>N. cf. communis</i> Rab. #1	A		S	P	x
<i>N. cf. communis</i> Rab. #2	S	S		P	x
† <i>N. confinis</i> Hust.			x		
<i>N. cf. dissipata</i> (Kütz.) Grun.			S	P	
<i>N. filiformis</i> (W. Sm.) V.H.	x	S	x		x
* <i>N. fonticola</i> Grun.	P	P	P	A	x
<i>N. frustulum</i> (Kütz.) Grun.	P	S	S	P	x
† <i>N. gandersheimiensis</i> Krasske	A	A	A	A	x
† <i>N. cf. geitleri</i> Hust.	x	S	S		
<i>N. gracilis</i> Hantz.		S	S	S	
<i>N. microcephala</i> Grun.	S		S	P	x
<i>N. palea</i> (Kütz.) W. Sm.	P	P	A	P	x
<i>N. cf. palea</i> (Kütz.) W. Sm.		S	x		
* <i>N. paleacea</i> (Grun.) Grun.	P	P	P	P	x
† <i>N. rautenbachiae</i> Choln.	S		S	x	
<i>N. reversa</i> W. Sm.	P	S	P		
<i>N. sigma</i> (Kütz.) W. Sm.		S	S		
<i>N. cf. signoidea</i> (Nitz.) W. Sm.				x	
† <i>N. spiculoides</i> Hust.	S				
† <i>N. cf. subvitreata</i> Hust.	x			S	x
<i>N. vermicularis</i> (Kütz.) Hantz.				P	x
<i>N. vitrea</i> var. <i>salinarum</i> Grun.			x		
† <i>N. cf. vitrea</i> var. <i>scaphiformis</i> Wisl. & Poretz.				x	
<i>Pinnularia brebissonii</i> (Kütz.) Rab.	S			x	
† <i>P. brebissonii</i> var. <i>diminuta</i> (Grun.) Cl.	x				
<i>P. viridis</i> (Nitz.) Ehr.	x				
<i>Placoneis elginensis</i> (Greg.) Cox	x				
<i>Plagiotropis arizonica</i> Czarn. & Blinn	P	S	S	S	
<i>P. cf. arizonica</i> Czarn. & Blinn	x			x	

TABLE 2—Continued.

Scientific name	LSM		RC	BSM	
	Benthic	Plank- tonic	Benthic	Benthic	Plank- tonic
<i>P. lepidoptera</i> var. <i>proboscidea</i> (Cl.) Reim.			S		
<i>Pleurosira laevis</i> (Ehr.) Compère	x	x			
† <i>Rhizosolenia minima</i> Leav.	A	A	A		
<i>Rhopalodia gibba</i> (Ehr.) O. Müll.			x	S	
<i>R. gibberula</i> (Ehr.) O. Müll.				S	
<i>R. musculus</i> (Kütz.) O. Müll.	x		S	x	
† <i>Scolioptera peisonis</i> Grun.	x			S	x
<i>Sellaphora pupula</i> (Kütz.) Meresch.	x	P			
<i>S. pupula</i> var. <i>rectangularis</i> (Greg.) Meresch.	S		S		
<i>Staurosira construens</i> var. <i>venter</i> (Ehr.) Ham.	S			P	x
<i>Stephanodiscus</i> sp.	S		S		x
<i>Surirella angusta</i> Kütz.	S		S		
<i>S. crumena</i> Bréb.	x				
<i>S. cf. ovalis</i> Bréb.	S	S	S		
<i>S. cf. striatula</i> Turp.	S	S	S	S	x
<i>Synedra</i> cf. <i>delicatissima</i> W. Sm.	A	S			
<i>S. ulna</i> (Nitz.) Ehr.	P	P	A		
<i>S. ulna</i> var. <i>danica</i> (Kütz.) V.H.			x		
<i>Tabularia fasciculata</i> (Ag.) Will. & Round	S	S		S	
* <i>T. tabulata</i> (Ag.) Snoeijs	x		S	P	x
† <i>Tryblionella calida</i> (Grun. in Cl. & Grun.) D.G. Mann	S		S		
<i>T. hungarica</i> (Grun.) D. Mann	S	P	P	P	x
* <i>T. levidensis</i> W. Sm.	S	S	S	S	x
<i>T. tryblionella</i> (Hantz.) Proch.	P	P	P	S	x
Number of abundant taxa (19 total)	10	9	12	6	0
Number of taxa in counted samples (90 total)	61	51	62	55	0
Number of taxa identified (121 total)	91	53	74	74	43

TABLE 3—Percent taxa included in counts that were shared between samples. Percentages represent portion of the total number of taxa from the site in the left column shared with the site given in the top row. For example, 84% of the taxa from LSM-p also were present in samples from LSM-b. LSM-b = Little Salt Marsh, benthic. LSM-p = Little Salt Marsh, planktonic. RC = Rattlesnake Creek, benthic. BSM = Big Salt Marsh, benthic. Number of taxa in parentheses.

	LSM-b	LSM-p	RC	BSM
LSM-b (61)		70%	79%	62%
LSM-p (51)	84%		74%	65%
RC (62)	77%	61%		60%
BSM (55)	69%	60%	67%	

were abundant only in the higher-chloride waters of Big Salt Marsh.

There was a similar level of overlap among taxa present in benthic and planktonic samples (Table 3), which has been noted in other types of lentic habitats (Brown and Austin, 1973; Moss, 1981; Hoagland et al., 1986). *Fragilaria vaucheriae* was the lone taxon that was abundant only in planktonic samples. In a reservoir in western Nebraska, Hoagland et al. (1986) noted that *Fragilaria vaucheriae* was the dominant planktonic diatom, although it also forms colonial rosettes attached to substrates (Hoagland et al., 1982). Of our other 18 abundant taxa, 10 were abundant only in benthic samples, and 8 were abundant in both benthic and planktonic samples.

Results of this study (121 taxa) and the study by Czarnecki et al. (1981; 186 taxa) suggest that diatom communities of saline marshes

and associated streams in the southwestern United States are reasonably rich in taxa. Potential interactions among various diatom taxa and chlorides or other limnological features, either in an ecological context or with regard to cellular morphology, remain to be explored in more detail in these interior wetlands.

*Resumen*—Colectamos 121 diatomeas (Bacillariophyta) de dos pantanos salinos y de un arroyo salino en el municipio de Stafford en Kansas, E. U., durante 1996–1997. El anión dominante fue cloruro (771–2301 mg/l). Solamente 19 taxones lograron una relativa abundancia del 10% o más en una muestra. Muestras bentónicas de los 3 lugares y muestras plantónicas de un pantano salino compartieron el 60–84% de sus taxones.

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