

1975

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### Recommended Citation

Van Der Valk, A. G. (1975) "Floristic Composition and Structure of Fen Communities in Northwest Iowa," *Proceedings of the Iowa Academy of Science*, 82(2), 113-118.

Available at: <https://scholarworks.uni.edu/pias/vol82/iss2/10>

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## Floristic Composition and Structure of Fen Communities in Northwest Iowa

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Iowa fens have three distinct, concentric vegetation zones: a border zone, a sedge mat zone, and a discharge zone where ground water supplying the fens comes to the surface. *Calamagrostis inexpansa* Gray, *Viola nephrophylla* Greene, *Scirpus americanus* Pers. and *Carex* spp. are the dominants in the border zone. The composition of this zone is quite variable both within and between fens. The sedge mat is composed primarily of *Rhynchospora capillacea* Torr. Other species normally found in this zone are *Lobelia kalmii* L., *Muhlenbergia racemosa* (Michx.) BSP, *Parnassia glauca* Raf.,

*Triglochin maritima* L. and *Scirpus americanus*. Although all of the species in this zone are also found in the other zones, this zone is readily distinguishable because of the low stature of the vegetation. The discharge zone is dominated usually by *Carex* spp. or *Calamagrostis inexpansa*, except at one fen where *Phragmites communis* Trin. and *Helianthus grosseserratus* Martens are the dominants. The sedge mat zone on the average has fewer species per quadrat (5.8 versus 6.0 and 8.6), lower Shannon-Weaver index (0.8 versus 1.15 and 1.40) and higher Simpson's index (0.58 versus 0.42 and 0.32) than the discharge and border zones, respectively.

INDEX DESCRIPTORS: Fen, Floristic Composition, Shannon-Weaver Index, Simpson's Index, Vegetation, Zonation.

In the British Isles, a fen is defined as wetland vegetation with alkaline or neutral organic soils whose summer water level is usually just below the soil surface. The alkaline nature of the substrate is a result of the ground water passing through calcareous geologic strata. The vegetation of British fens is generally similar to that of other wetlands except for the presence of a few calcicolous species (Tansley, 1968).

In northwestern Iowa, there are a number of small areas of wetland vegetation which are referred to locally as fens (Anderson, 1943; Hayden, 1943; Holte and Thorne, 1962). These fens have much in common with their British counterparts and fit Tansley's definition of a fen given above. However, Iowa's fens have at least two characteristics which set them apart. First, Iowa fens are small seepage areas (only a few thousand square meters), almost always on the sides of morainic hills, while British fens cover large areas, usually in valley bottoms. Second, well-developed Iowa fens are divided into three distinct zones: a central zone associated with raised areas where calcareous groundwater reaches the surface (discharge cones); a middle zone which consists of a terraced sedge mat containing many small pools; and a border zone. This zonation is made very striking by the short stature of all the sedge mat species. In the British fens, there does not appear to be anything comparable to these terraced sedge mats. A generalized profile of an Iowa fen is given in Figure 1.

Because Iowa's fens are locally an unusual habitat, they have received a great deal of attention. There are published accounts of their protozoa (Hempstead and Jahn, 1939), algae (Gashwiler and Dodd, 1961), diatoms (Shobe et al., 1967), metazoa (Eickstaedt, 1964), vegetation (Shimek, 1915; Anderson, 1943; Conard, 1952; Holte and Thorne, 1962; Holte, 1966) and physical environment (Carter, 1939; Eickstaedt, 1964; Holte, 1966). The vegetation has received the most attention over the years, but all of these studies were primarily simple floristic surveys. As a result, very little is known about the composition and structure of the vegetation in the different zones making up an Iowa fen.

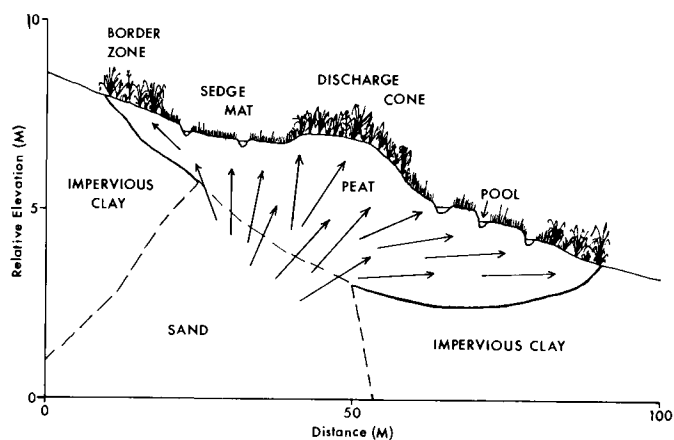


Figure 1. Generalized cross-section of an Iowa fen. The arrows indicate the general pattern of subsurface water movement (see Holte, 1966).

The main purpose of this study was to examine the floristic composition, species richness and floristic structure of the three vegetation zones in as many fens as possible. Species richness is defined as the number of species per unit area (Peet, 1974). Floristic structure refers to the relative abundance of different species in the community. Two indices were used to examine floristic structure: the Simpson's index (C), which is a measure of dominance, and the Shannon-Weaver index (H'), which is a measure of complexity and diversity (Whittaker, 1972; Peet, 1974).

The nomenclature follows Gleason and Cronquist (1963).

### STUDY SITES

Attempts were made to relocate all previously reported fen

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sites. It proved to be impossible to relocate some fen areas, while others had been damaged or destroyed.

Two study sites were used in the study; both were in Dickinson County, northwest Iowa. One site was the Silver Lake fen complex located in the northwestern corner of Section 32, Silver Lake Township. This site is a state preserve and the fens are protected from disturbance. Only the main fen was studied (Eickstaedt, 1964). The second site was the Excelsior fen complex located in the southwest corner of Section 10 and the northwest corner of Section 15, Excelsior Township. All the well-developed fen areas in the complex were sampled, i.e., fens 2, 3, 4, 7, 9, 10 and 11 (Holte, 1966). The Excelsior fens are located in a pasture and, as a result, are subject to grazing. This grazing is only significant around the border of the fens most years, because the cattle will not venture onto the unstable fen surface. In dry years, grazing becomes a problem over the entire fen. During the study no cattle were seen on the fens and there were no signs that the fens were being grazed except around the edges.

Dickinson County has a continental climate with the coldest month (January) having an average temperature of -9 C and the warmest month (July) one of 23 C. The average annual precipitation is around 686 mm (Shaw and Waite, 1964).

METHODS

At the Excelsior fen complex, each fen was sampled using 11 quadrats (20 cm x 50 cm) spaced evenly along a transect line. The transect was positioned so that it started and ended in border areas as little disturbed by cattle as possible and so that it passed through all three zones in a fen. At the Silver Lake fen two random transects passing through the discharge zone were used to sample the fen.

In each quadrat, a list of all the species present was made and the cover of each species was then estimated using a cover-abundance scale modified from Braun-Blanquet (1932) and previously used by van der Valk and Bliss (1971) (see Table 3). All vegetation sampling was done from July 19 to August 9, 1974.

The Simpson's index was calculated from the data for each quadrat using the following formula:

$$C = \frac{\sum_{i=1}^n P_i^2}{n}$$

where

$$P_i = \frac{c_i}{C}$$

$c_i$  = cover of the  $i$  th species in a quadrat.

$C$  = total cover of all the species in the quadrat.

$n$  = total number of species in the quadrat.

The Shannon-Weaver index was calculated using:

$$H' = -\sum_{i=1}^n P_i \cdot \ln P_i$$

where  $P_i$  and  $n$  are the same as above.

A nested analysis of variance was used to analyze the floristic structural indices (Service, 1972). A logarithmic transformation was used on the Simpson's index. All tests of significance were made at the 95% confidence level.

For each fen, a composite water sample was collected from five or six pools on the sedge mat. These samples were analyzed for calcium and total hardness, conductivity and pH using Hach water analysis equipment.

TABLE 1. FEN POOL WATER CHEMISTRY DATA

Fen	Hardness (ppm)		Conductivity (micromhos)	pH
	CaCO <sub>4</sub>	Total		
E-2 <sup>1</sup>	390	680	1,140	7.2
E-3	380	800	1,380	7.1
E-4	440	900	1,550	7.0
E-7	460	940	1,560	7.0
E-9	350	800	1,330	7.5
E-10	430	920	1,400	7.4
E-11	405	740	1,330	7.0
SLF	650	1,580	2,600	7.1

<sup>1</sup>E—Excelsior fen complex; SLF—Silver Lake fen.

RESULTS AND DISCUSSION

Water Chemistry

The water chemistry data (Table 1) for all seven of the Excelsior fens are very similar. Their total hardness ranges from 680 to 940 ppm, about half of which is CaCO<sub>4</sub>. They have a conductivity of about 1,300 to 1,500 micromhos and a pH which ranges from 7.0 to 7.5. The differences in hardness and pH between the seven fens in Table 1 are smaller than those reported for a transect across a single fen by Holte (1966). The data in Table 1 support Holte's (1966) hypothesis, based on other evidence, that all of the fens in the complex are supplied water by the same aquifer. The hardness and pH values in Table 1 are similar to those previously reported for several Excelsior fens by Holte (1966). However, the CaCO<sub>4</sub> percentage of the total hardness values is always higher in Holte's data. This is probably the result of differences in determining the end points of titration.

The Silver Lake fen water has a much higher dissolved mineral content (Table 1). The total hardness and conductivity are both considerably higher, sometimes twice as high. However, the pH values are the same. Eickstaedt (1964) made detailed measurements of the pH of Silver Lake fen pool water. His data indicate that the total hardness and pH values in Table 1 are typical for this fen.

A comparison of the data in Table 1, Eickstaedt (1964), and Holte (1966) for Iowa fens and Bachman's (1965) data on Iowa lakes and reservoirs of the same region clearly demonstrates the unique water chemistry of these fens. On the average, lakes and reservoirs have a conductivity of only 409 micromhos and a total hardness of 199 ppm, while the lowest fen readings are 1,330 micromhos and 680 ppm, respectively (Table 1).

Floristic Composition of Fen Communities

The average cover of all species which were found in any one zone in three or more fens or which had a cover of 5% or more in at least one quadrat in a zone is listed in Table 2.

The border vegetation always has two layers of plants: a tall layer, 50 cm or more in height, usually composed of *Calamagrostis inexpansa*, *Eupatorium* spp., *Lycopus asper*, and *Scirpus americanus*, plus many other species, and a shorter layer of plants which includes *Parnassia glauca*, *Viola nephrophylla* and *Eleocharis erythropoda* (*E. calva* Torr.). Because of disturbance at the Excelsior fens, the border zone often contains a few individuals of some weedy species from

FEN COMMUNITIES IN NORTHWEST IOWA

TABLE 2. ALL SPECIES FOUND AT THREE OR MORE FENS OR HAVING A COVER OF FIVE PERCENT OR HIGHER IN A QUADRAT IN EITHER THE BORDER, SEDGE MAT, OR DISCHARGE ZONE

SPECIES	FEN							
	E-2 <sup>1</sup>	E-3	E-4	E-7	E-9	E-10	E-11	SLF
BORDER ZONE								
<i>Calamagrostis inexpansa</i>	+ <sup>2</sup>	+	1	2	+	+		R
<i>Carex aquatilis</i>	+				+			+
<i>Carex hystericina</i>				+	1			P
<i>Eleocharis erythropoda</i>		P		P	P	+	R	
<i>Eupatorium maculatum</i>			1	1	P	1	+	+
<i>Eupatorium perfoliatum</i>	+					+	R	R
<i>Juncus nodosus</i>	+		R	R	P	+	R	P
<i>Lobelia kalmii</i>				P	R	P		P
<i>Lycopus asper</i>	1	+	+	R	R	+	R	
<i>Muhlenbergia racemosa</i>		+	+	R	R		P	R
<i>Parnassia glauca</i>	R		+	1	+	+	P	2
<i>Rhynchospora capillacea</i>				P		P	P	P
<i>Scirpus acutus</i>	R	P			1			+
<i>Scirpus americanus</i>	R	+	+	+	R	+	+	+
<i>Scutellaria gericulata</i>				P	R			P
<i>Triglochin maritima</i>				R		R		+
<i>Viola nephrophylla</i>	1	+	1	1	R	+	1	R
SEEDGE MAT ZONE								
<i>Eupatorium maculatum</i>	P	R		R	R	P		P
<i>Eupatorium perfoliatum</i>				P		+	P	P
<i>Lobelia kalmii</i>	+	+	+	R	+	R	R	R
<i>Lycopus asper</i>		P		P			P	P
<i>Muhlenbergia racemosa</i>	R	P	P	P	R	R		R
<i>Parnassia glauca</i>	+	R	R	+	+	1	1	+

SPECIES	FEN							
	E-2 <sup>1</sup>	E-3	E-4	E-7	E-9	E-10	E-11	SLF
<i>Rhynchospora capillacea</i>	2	2	3	2	3	2	2	3
<i>Scirpus acutus</i>			R			P	1	
<i>Scirpus americanus</i>	+	+	+		+	P	R	R
<i>Triglochin maritima</i>	+	1	1	1	1	1	1	1
<i>Viola nephrophylla</i>		P	P				R	
DISCHARGE ZONE								
<i>Calamagrostis inexpansa</i>	R		2		P	+		
<i>Carex aquatilis</i>					3	R	1	
<i>Carex hystericina</i>			1				1	
<i>Carex rostrata</i>	3	1	1	1				
<i>Eupatorium maculatum</i>	1	R		1	1	1		
<i>Helianthus grosseserratus</i>								3
<i>Impatiens biflora</i>				1				
<i>Lycopus asper</i>				1		R	+	2
<i>Mentha arvensis</i>			R	1	+			2
<i>Muhlenbergia racemosa</i>	+				R	R		
<i>Parnassia glauca</i>	R	+		P	P	+	+	
<i>Phragmites communis</i>								4
<i>Scirpus acutus</i>							2	
<i>Scirpus americanus</i>	+	R		P	R	R		
<i>Triglochin maritima</i>						1	1	
<i>Viola nephrophylla</i>		1		R	+	1		

<sup>1</sup> E—Excelsior Fen complex (Holte 1966).  
SLF—Silver Lake Fen.

<sup>2</sup> P—Present, one individual  
R—Rare, several individuals, ca. 0.1% cover.  
+—Uncommon, ca. 0.5% cover.  
1—1 to 5% cover.  
2—5 to 15% cover.  
3—15 to 25% cover.

the surrounding pasture, e.g., *Lactuca canadensis*, *Ambrosia artemisiifolia* and *Hordeum jubatum*. However, grazing at the Excelsior fens does not appear to have produced any major shift in the composition of the border zone (Table 2).

In the border zone, most of the species are widespread wetland species (Table 2), e.g., *Lycopus asper*, *Carex aquatilis*, *Eupatorium maculatum*, *E. perfoliatum*, *Scirpus acutus* and *S. americanus* (Muenscher, 1944). Four of the species in

the border zone are considered to be characteristic of Iowa fens: *Lobelia kalmii*, *Parnassia glauca*, *Rhynchospora capillacea* and *Triglochin maritima* (Holte, 1966). Although they are restricted to this habitat in Iowa (Beal and Monson, 1954), all four species are quite widespread in wetlands throughout boreal North America (Gleason and Cronquist, 1963).

There is a great deal of variety in the composition of the

border zone from fen to fen (Table 2). Field observations indicate that there is a great deal of variability even around a particular fen border. Only two species (*Scirpus americanus* and *Viola nephrophylla*) were present in the border zones of all the fens (Table 2).

The sedge mat zone, which is dominated by *Rhynchospora capillacea*, was very similar in its floristic composition from fen to fen (Table 2). Four of the eleven most common species are found at all the fens (*Rhynchospora capillacea*, *Parnassia glauca*, *Triglochin maritima* and *Lobelia kalmii*). The plants growing in this zone are all about the same height, 25 to 35 cm, except *Scirpus americanus*, which is sometimes 75 to 85 cm tall. All of the species making up the sedge mat were also found as minor species in the border zone (Table 2). However, when these species grew on the mat, their stature was greatly reduced.

The vegetation of the discharge zone is the most variable of all three zones (Table 2). Not one species was present in all the discharge zones. *Parnassia glauca*, the most nearly ubiquitous species, was found in six of the seven Excelsior fens<sup>3</sup> discharge zones. At the Excelsior fens, the discharge zone vegetation resembled the border vegetation in composition and height. However, it had a higher total cover which was due largely to the abundance of various species of *Carex* (*C. aquatilis*, *C. hystericina* and *C. rostrata*). At the Silver Lake fen, the discharge zone is dominated by *Phragmites communis* and *Helianthus grosseserratus* and does not in the least resemble the border zone (Table 2). Stewart and Kantrud (1972) consider *Phragmites communis* to be a dominant species in fens undisturbed by grazing in North Dakota, and its absence from the Excelsior fen may reflect past grazing pressure.

Data in previous floristic studies on Iowa fens by Wolden (1926), Anderson (1943), Conard (1952), Holte and Thorne (1962), and Holte (1966) when compared to the data in Table 2 indicate that qualitatively there has been little change in the make-up of fen vegetation. It is more difficult to tell if there have been any quantitative changes in the composition of these fen communities. Holte (1966) ran transects across several fens and estimated the abundance of the species along the transects. He used an abundance measure which is not directly comparable to the cover data in Table 2. Nevertheless, Holte's (1966) data indicate that the composition of the different zones was similar to that found at the same fens in this study. Iowa fens do not appear to be undergoing rapid succession.

In North America, fen vegetation has been described from Wisconsin (Curtis, 1959), Michigan (Cain and Slater, 1948), North Dakota (Stewart and Kantrud, 1972), Missouri (Steyermark, 1938), New York (Zenkert, 1934; Muenscher, 1946), Ohio (Gordon, 1933) and Canada (Sjörs, 1959). However, there is so little quantitative information about these fens in these studies that it is impossible to relate the various studies to each other or to the present study. Iowa's fens have species in common with fens in other regions, especially those in North Dakota. However, much more field work must be done on North American fens before their floristic and ecological relations can be discerned.

*Floristic Structure*

Table 3 summarizes the floristic structural data for each zone in each fen, and Table 4 contains a summary of the nested analysis of variance done on these data.

Species richness varies significantly from fen to fen and among zones in a particular fen (Table 4). On the average

TABLE 3. AVERAGE SPECIES RICHNESS, SIMPSON'S INDEX AND SHANNON-WEAVER INDEX FOR EACH ZONE AT A FEN

Zone	Fen								Average
	E-2 <sup>1</sup>	E-3	E-4	E-7	E-9	E-10	E-11	SLF	
	Species Richness								
Border <sup>2</sup>	8.5	8.0	7.0	9.5	9.7	9.5	8.5	8.3	8.6
Sedge Mat	6.0	5.6	5.5	5.3	6.7	7.6	5.0	5.5	5.8
Discharge	6.3	6.0	7.0	7.0	6.5	7.5	6.0	2.3	6.0
	Simpson's Index								
Border	0.28	0.33	0.22	0.29	0.31	0.22	0.31	0.43	0.33
Sedge Mat	0.65	0.57	0.63	0.61	0.55	0.39	0.51	0.65	0.58
Discharge	0.43	0.32	0.58	0.42	0.62	0.24	0.43	0.52	0.42
	Shannon-Weaver Index								
Border	1.53	1.45	1.63	1.48	1.44	1.68	1.43	1.17	1.40
Sedge Mat	0.73	0.86	0.71	0.72	0.93	1.18	0.83	0.67	0.81
Discharge	1.17	1.38	0.78	1.18	0.77	1.66	1.17	0.68	1.15

<sup>1</sup> E—Excelsior fen complex; SLF—Silver Lake fen.

<sup>2</sup> There were a total of 23, 58, and 18 quadrats in the border, mat, and discharge zones respectively.

there are 8.6, 5.8 and 6.0 species/quadrat in border, sedge mat and discharge zones, respectively. Although the border zones at some of the Excelsior fens have slightly more species/quadrat than at the Silver Lake fen, there does not seem to be any marked effect of grazing or trampling on the species richness of the border zone (see Table 4).

The Shannon-Weaver indices are slightly higher in all three zones at the Excelsior fens than those at the Silver Lake fen (Tables 3, 4). It is unknown whether this is a result of grazing at the Excelsior fens or due to differences in water chemistry between the two sites (see Table 1). As a plant community's physical environment becomes harsher, its Shannon-Weaver index value decreases (Monk, 1967; Auclair and Goff, 1971; Whittaker, 1972; van der Valk, 1975), i.e., it

TABLE 4. NESTED ANALYSIS OF VARIANCE OF THE SPECIES RICHNESS, SIMPSON'S INDEX AND SHANNON-WEAVER DATA

Source	df	Species	Simpson's	Shannon-Weaver
		Richness	Index	Index
		SS <sup>1</sup>	SS	SS
Site <sup>2</sup>	1	4.73	0.52	0.64 <sup>3</sup>
Fen (Site) <sup>4</sup>	6	43.95 <sup>3</sup>	2.67 <sup>3</sup>	2.25 <sup>3</sup>
Zone				
(Fen Site)	16	182.46 <sup>3</sup>	6.89 <sup>3</sup>	7.47 <sup>3</sup>
Error	75	187.40	11.82	10.89
Corrected				
Total	98	418.54	21.90	21.25

<sup>1</sup> SS—sum of squares.

<sup>2</sup> Site—Silver Lake fen and Excelsior fen complex.

<sup>3</sup> Significant at the 95% confidence level.

<sup>4</sup> Fen (Site)—Fen nested within site where fen refers to the seven Excelsior fens and the Silver Lake fen.

becomes a simpler community. It is possible that the greater dissolved mineral content of the Silver Lake fen water makes the Silver Lake fen physical environment harsher than that at the Excelsior fens. There is at the present time no direct experimental evidence which could be used to test this hypothesis. However, it has been established that various species of aquatic and marsh plants are found only in habitats within a limited range of water hardness (Moyle, 1945; Olsen, 1950; Seddon, 1972) and that the hardness of the water can influence the growth of aquatic plants (Moyle, 1945).

In the border, sedge mat and discharge zones, the Shan-

non-Weaver indices are 1.40, 0.81 and 1.15 respectively. This pattern is identical with that of species richness. The magnitude of the Shannon-Weaver values for all three fen zones is low compared to those reported for forests (Monk, 1967; Auclair and Goff, 1971), but it is about the same as that for coastal dune grasslands (van der Valk, 1975). This reflects the depauperate floristic condition of these environmentally stressed communities.

The Simpson's index (Tables 3, 4) averages 0.33, 0.58 and 0.42 in the border, sedge mat and discharge zones respectively. The sedge mat zone has the most unequal distribution of cover values. *Rhynchospora capillacea* (Table 2) was the overwhelming dominant in this zone and no other species approached its cover. In the two other zones, species abundance was more even, and often there were two or more equally abundant species.

The structural data show that the sedge mat community when compared with the other two zones is significantly less complex, has fewer species/quadrat and is dominated by only one species (Tables 3, 4). All three conditions indicate that the sedge mat is the zone with the harshest environment (see Monk, 1967; Auclair and Goff, 1971). What environmental differences between the sedge mat and the other two zones are responsible for these floristic structural differences? No definitive answer to this question is possible. However, from some preliminary environmental measurements along transects made by Holte (1966), it is possible to outline some of the major environmental differences among the three zones. His data indicate that, although there is a correlation between soil temperature and the distribution of certain species, e.g., *Cardamine bulbosa*, soil temperature and water chemistry are not major factors influencing the zonation of fen species. Elevation above the water table may be a factor responsible for differences between the composition of the vegetation of discharge cones and the sedge mat zones. This is supported by the results of a simple preliminary experiment done by Holte (1966) which involved changing soil surface levels artificially. Plants growing on the discharge cones probably grow in an area with better soil aeration than those growing closer to the water table on the sedge mat. Plants growing in the border zone are probably influenced by the mineral soils under the fens and, as a result, undoubtedly have a more favorable nutrient status. Cattle trampling has also influenced the Excelsior fen border zones by creating a great deal of microrelief. This has allowed certain weedy pasture species to become established in the zone on the tops of small hummocks. Holte's (1966) field measurements suggest that two important environmental factors (soil nutrients and relief) may be responsible for the zonation found in Iowa fens. These two factors should now be investigated experimentally in the field and laboratory to evaluate their significance.

#### ACKNOWLEDGMENTS

I would like to thank Craig B. Davis and David Glenn-Lewin for critically reading the manuscript and Jeff Dodd for his assistance in the field. Support for this study was in part supplied by an Iowa State Research Initiation Grant (NSF-GU-3373).

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