

DISTINGUISHING CHARACTERISTICS OF TEMPORARY POND HABITAT OF ENDANGERED NORTHEASTERN BULRUSH, *SCIRPUS ANCISTROCHAETUS*

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Abstract: Habitat characteristics of wetlands that contain the federally endangered sedge, *Scirpus ancistrochaetus*, were investigated in a one-point-in-time field survey. Sixteen adjacent seasonal ponds, four of which supported populations of *S. ancistrochaetus*, were sampled for 26 habitat variables. Using only five of these variables, we were able to separate ponds with and without *S. ancistrochaetus* in a linear discriminant analysis. These five variables are wetland area, percent cover of overlying forest canopy, soil percent organic matter, soil exchangeable [Na], and water [H⁻]. Ponds containing *S. ancistrochaetus* had higher soil organic matter content, higher soil [Na], greater area, lower water [H⁺], and lower percent forest canopy cover compared to ponds that did not support this species. This information can be used toward understanding factors that control the distribution of this species and also toward evaluating possible habitat for reintroduction of this endangered species.

Key Words: conservation biology, emergent vegetation, ephemeral pond, pH, sodium, vernal pond, water chemistry

INTRODUCTION

Northeastern bulrush, *S. ancistrochaetus* Schuyler, is limited to approximately 60 populations in the northeastern United States (K. McKenna, personal communication) and is currently listed as endangered by the U. S. Fish and Wildlife Service (1991). The habitat of this perennial emergent sedge in Pennsylvania typically consists of small depressional palustrine wetlands. The ponds are usually seasonal or temporary in nature and have no standing water for 1–4 months per year, depending on yearly precipitation. While some ground-water input is important, most ponds receive water primarily from precipitation-related sources (Lentz 1998). Major threats to populations on public lands include disturbance due to logging, roads, and deer browsing/trampling, while trash dumping, agricultural activities, and development threaten

private lands (USFWS 1993). In addition to anthropogenic causes of endangerment and rarity, it has been hypothesized that *S. ancistrochaetus* may require a very specific and unusual habitat type (USFWS 1993).

Some authors suggest that basic ecological information is essential for effective management and conservation of endangered species (Brussard 1991, Lesica 1992). In contrast, Schemske et al. (1994) suggest that a demographic approach to conservation is more valuable than ecological studies. In *S. ancistrochaetus*, demographic approaches to management are difficult because of extensive vegetative reproduction in established populations, prolific seed production, and the inability to readily identify non-flowering individuals. Therefore, we have employed an ecological approach to conservation management of *S. ancistrochaetus*. To date, there is very little basic autecological information

on *S. ancistrochaetus* (but see Bartgis 1992, Lentz 1998, Lentz and Cipollini 1998, Lentz and Dunson 1998, Lentz and Johnson 1998). Most information on this species is largely anecdotal, observational, and/or non-rigorous in nature (see USFWS 1993). In fact, no systematic and thorough field survey of the wetland habitat of *S. ancistrochaetus* has ever been conducted. Since water and soil chemistry can be very important in determining species abundance and distribution in wetland plant species (e.g., Shay and Shay 1986, Chee and Vitt 1989, Lesica 1992, Cooper 1995), we hypothesized that such variables might also be important in determining the local distribution of *S. ancistrochaetus*.

In order to determine the potential important habitat characteristics of this endangered species, a series of wetlands that either contained *S. ancistrochaetus* or did not were sampled on one date for water and soil chemistry, along with other possible important variables such as percent forest canopy cover and wetland area. The site used in this study contained approximately 25 seasonal ponds, only four of which contained *S. ancistrochaetus*. Ponds that support *S. ancistrochaetus* in central Pennsylvania are usually geographically isolated from other such ponds (Lentz, personal observation). The site offered a unique opportunity for a study of this nature because the ponds within it are all in close proximity. The presence of *S. ancistrochaetus* in a given pond was probably not limited by dispersal of seeds but rather by slight differences in habitat, which prevented establishment by *S. ancistrochaetus* either through lack of appropriate conditions for seed germination or inability of seedlings to survive in a given habitat. After the ponds were intensively sampled, a linear discriminant function was created using a small number of variables. This function could be used in future studies to aid in evaluation of possible seasonal pond habitat for *S. ancistrochaetus*, perhaps for reintroduction purposes. Reciprocal transplants, which could test the results of this study, could not be performed due to restrictions on the transplantation of this endangered species.

METHODS

Study Species

Scirpus ancistrochaetus (Cyperaceae) is a perennial emergent sedge first described by Schuyler (1962). Although some authors do not recognize this plant as a distinct species (e.g., Gleason and Cronquist 1991), others do (e.g., Kartesz and Kartesz 1980, USFWS 1991), including an authority on the genus *Scirpus* (Schuyler 1962, 1963, 1967). Leaves and flowering culms are produced from short underground rhizomes

and can grow to approximately 80–120 cm in height. *S. ancistrochaetus* flowers from mid-June to July, and its inflorescence consists of distinctly arching rays with clusters of brown spikelets (Schuyler 1962). The 1.1–1.3 mm achenes (fruits) mature in mid- to late summer (July–September). Firmly attached to the achene are six bristles, with retrorse, thick-walled, sharply-pointed teeth densely arranged over the whole bristle length (Schuyler 1967). Vegetative reproduction seems to be the most successful mode of reproduction of *S. ancistrochaetus* in established populations (Bartgis 1992), accomplished through formation of both nodal shoots on flowering stems and basal shoots from the rhizome (Schuyler 1967). This species typically forms a dense monoculture that can often occupy an entire small pond.

Nothing is known about dispersal of this species from one isolated pond to another; however, seeds readily attach to animal fur due to the barbed bristles (Lentz, unpublished data). Seeds may therefore be dispersed to a distant pond by movement of animals such as deer and bear (see Carter 1993), which frequently use the wetlands as water sources during the summer. Dispersal within a complex of ponds may be due to either animal dispersal of seeds or dispersal of seeds and/or asexual propagules by water movement. The ability of this species to form a persistent seed bank is unknown, partly due to difficulty in identifying its small seeds. The seeds germinate readily under water or on exposed soil, usually requiring a cold stratification period and presence of light (Lentz and Johnson 1998, Lentz, personal observation). Therefore, they may require some sort of disturbance that exposes buried seeds to light to germinate. Although anthropogenic disturbance at the study site is minimal, use by deer and bear in late summer does disturb the soil enough to expose and produce germination of buried seeds (Lentz, personal observation).

Study Area

The study site is located in a mixed oak forest on the border of Union and Lycoming Counties, Pennsylvania, USA and is contained within Bald Eagle State Forest. The site is a “conservation area” subject to very few management activities except maintenance of a small hiking trail. There has been no logging in the area for at least 50 years, and therefore, the site was relatively undisturbed. About 25 small, temporary ponds were scattered throughout the 0.04 km² area in a somewhat linear formation. The four ponds that contained *S. ancistrochaetus* were distributed randomly in the wetland complex, and many of the other ponds that were sampled were found between ponds that contained this species. In addition, the ponds that con-

tained *S. ancistrochaetus* had established populations for at least five years prior to the study. Not all ponds in the wetland complex were necessarily hydrologically distinct, as several ponds overflow into others during periods of high water. However, almost none of the ponds sampled in this study were interconnected by surface-water flow, even during wet periods. Therefore, dispersal by overland flow, either by seeds or asexual propagules, between sampled ponds was unlikely. Study pond sizes ranged from 100 to 500 m², and most were within 100 m of another pond. Three-way sedge (*Dulichium arundinaceum* (L.) Britton), cinnamon fern (*Osmunda cinnamomea* L.), royal fern (*Osmunda regalis* L.), woolgrass (*Scirpus cyperinus* (L.) Kunth), manna-grass (*Glyceria acutiflora* Torr.), *Sphagnum* spp., and fringed sedge (*Carex crinita* Lam.) were frequently found in these ponds (nomenclature follows Gleason and Cronquist 1991). In early June, the ponds were sparsely vegetated, with large areas of open standing water.

Sampling Methods

On 11 June 1997, a total of 16 ponds were sampled. Four ponds contained aboveground biomass of *S. ancistrochaetus*, and 12 did not. The 12 ponds without *S. ancistrochaetus* that were chosen for sampling visually appeared to be suitable habitat for *S. ancistrochaetus* based on extensive investigator experience (Lentz 1998) yet did not contain an established population. Very small ponds or those that did not currently contain water were not sampled, since ponds that contain *S. ancistrochaetus* usually are greater than 200 m² and contain standing water until July (Lentz 1998).

Water pH was measured *in situ* with a pH meter at three haphazardly chosen locations within each pond. Measurements of pH were converted to [H⁺] and multiplied by 10000 to facilitate handling of data. Approximate width and length of each wetland were measured using a measuring tape. Wetlands were assumed to be roughly rectangular in shape, and thus, area was calculated by simply multiplying width by length. Percent forest canopy cover was measured in each cardinal direction from a single point in the center of each pond using a spherical densiometer. Percent cover average of the four directions was used in statistical analyses. Water and soil samples were collected from three haphazardly chosen areas in each wetland and transported back to the lab on ice for analysis. The three samples were pooled before analysis. Water samples were filtered through a 0.45 µm nitrocellulose filter prior to chemical analyses. Soil samples were air-dried for 3 days and sent to the Penn State Agricultural Analytical Services Laboratory (University Park, PA)

Table 1. Summary of habitat variables that were measured from 16 seasonal ponds but not included in final discriminant function and the methods used to measure them.

Soil Variables	Method Used
pH	in water (Eckert and Sims 1991)
available P, K, Ca, and Mg	Mehlich 3 (Wolf and Beegle 1991)
NH ₄ -N	specific ion electrode (Keeney and Nelson 1982)
NO ₃ -N	specific ion electrode (Griffin 1991)
total N	Kjeldahl (Bremner and Mulvaney 1982)
SO ₄ -S	Acetate-Extractable (Tabatabai 1982)
acidity	SMP buffer (Eckert and Sims 1991)
Water Variables	
specific conductance	specific conductance meter <i>in situ</i>
K, Ca, Na, and Mg	atomic absorption spectrophotometry
NH ₃ -N	Nessler's (Hach Company 1992)
NO ₃ -N	cadmium reduction (Hach Company 1992)
SO ₄	barium precipitate (Hach Company 1992)
PO ₄	ascorbic acid (Hach Company 1992)
temperature	sensor on pH meter
maximum depth of standing water	measuring stick in deepest part of pond

for analysis. Percent organic matter was measured by the loss on ignition method (Schulte 1991), while exchangeable [Na] was measured using the diagnostic soil test method (ASTM 1995). A variety of other water and soil chemistry variables were measured and are reported in Table 1, as well as the method used to measure them.

Statistical Analyses

Different combinations of variables were investigated using a multivariate linear discriminant analysis (Minitab 1994) in order to identify the habitat factors that best separated ponds with and without *S. ancistrochaetus*. This multivariate procedure was chosen rather than a univariate procedure to discover habitat variables that may be working in combination with other variables. The function that contained the lowest number of variables and most accurately separated the two types of ponds was selected. Data were tested for normality, and none of the variables used in the model were significantly correlated. The function was cross-validated by removing one pond from the analysis, finding the new discriminant function, and then predicting the group of the removed pond. This procedure

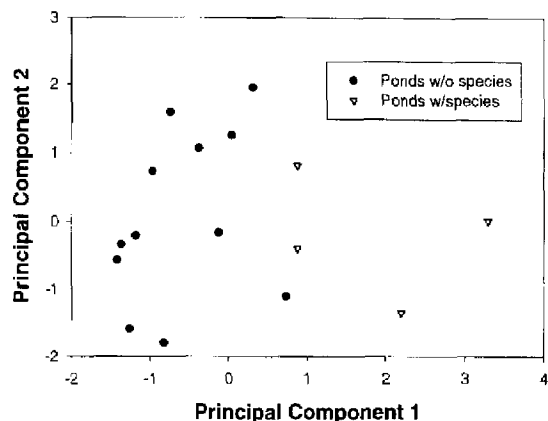


Figure 1. Principal Component 1 vs. Principal Component 2 for combination of wetland area, percent forest canopy cover, soil percent organic matter, soil exchangeable [Na], and 10000 * water [H⁺].

was performed for all 16 ponds. To display the data graphically, the first and second principal components of the same five factors that were included in the discriminant function were calculated and graphed against each other. One-way analyses of variance (ANOVAs) with the fixed factor of presence were run separately on each of the five variables included in the discriminant analysis to examine the univariate variation of these factors between the two types of ponds. To test the generality of the model created, data that were collected in an identical fashion in July 1995 from 11 seasonal ponds containing *S. ancistrochaetus* in other areas of central Pennsylvania were entered into the final discriminant function. The alpha level used to determine significance in tests of normality and ANOVAs was 0.05.

RESULTS AND DISCUSSION

The linear discriminant function separating the two groups of ponds (those with and without *S. ancistrochaetus*) was as follows:

$$Y = 0.018 \cdot \text{wetland area} - 0.066 \cdot \text{\%forest canopy cover} \\ + 0.146 \cdot \text{soil \%organic matter} + 0.995 \cdot \text{soil[Na]} \\ - 3.98 \cdot 10,000 \cdot \text{water[H}^+].$$

If $Y > 11.93$, then the pond has characters similar to those ponds that contain *S. ancistrochaetus*. If $Y \leq 11.93$, then the pond has similar habitat characters as those that lack *S. ancistrochaetus*. This model was able to separate all of the ponds into two completely separate groups (Figure 1). When the cross-validation was performed, 13 out of 16 ponds were placed in their proper group (81.2% success). In the cross-validation, one (25%) of the ponds that contained *S. ancistrochaetus* was placed in the incorrect group, while only two (16.7%) of the ponds that lacked this species were incorrectly categorized. When the 11 ponds from other sites that contain *S. ancistrochaetus* were evaluated using the above linear discriminant function, eight (72.7%) of them fell into the correct group, confirming that the function may be sufficient to evaluate ponds in sites other than the 16 that were sampled in this study.

Ponds containing *S. ancistrochaetus* had higher soil organic matter content, higher soil [Na], greater area, lower water [H⁺], and lower percent forest canopy cover than ponds that do not support this species (Table 2). Percent forest canopy cover showed the most variation between the two types of ponds in the one-way ANOVA (Table 2), indicating the relative importance of this factor. Soil exchangeable [Na] also varied significantly between the two types of ponds (Table 2). The other three factors used in the discriminant function were not significantly different from the two types of ponds in the univariate ANOVA (Table 2). However, it is important to note that not one of these factors could be removed from the multivariate linear discriminant function without losing the accuracy of the model, indicating the importance of these factors in combination with the other factors in the function.

High soil organic matter content could be indicative of a longer hydroperiod in these ponds, as inundation

Table 2. Mean \pm SE for each variable used in the discriminant function in ponds with and without populations of *S. ancistrochaetus*. The p-value from a one-way univariate, ANOVA for each factor is included.

Variable	Ponds w/ N = 4	Ponds w/o N = 12	One-way ANOVA
% forest canopy cover	60.1 \pm 6.7	75.8 \pm 1.84	p = 0.006
soil exchangeable [Na] (in ppm)	7.56 \pm 2.17	3.55 \pm 0.70	p = 0.033
wetland area (in m ²)	437.1 \pm 74.9	263.2 \pm 52.4	p = 0.108
water [H ⁺] * 10000 (in M)	0.287 \pm 0.163 (pH = 4.54)	0.704 \pm 0.129 (pH = 4.15)	p = 0.110
soil % organic matter	50.8 \pm 2.6	39.3 \pm 4.2	p = 0.150

inhibits the decomposition of organic matter (Mitsch and Gosselink 1993). Alternatively, a higher soil organic matter content could simply indicate a higher organic matter input into the wetland. *Scirpus ancistrochaetus* performs better in high light (Lentz and Cipollini 1998), so it would be expected to be found in ponds with low percent forest canopy cover. Wetland area may exert its influence through percent forest canopy cover, as ponds with larger areas would most likely have a lower percent forest canopy cover in the center of the pond. Percent forest canopy cover and area were not related in this study ($r = -4.49$, $p = 0.08$), although the relationship might have been significant if a larger sample size had been used. Soil [Na] is controlled mainly through physical rather than biological processes (Cole and Fisher 1979, Hem 1985), and the higher soil [Na] could be due to local soil conditions and rock underlying and adjacent to individual ponds. The differences in pH between ponds could be caused by slight differences in the balance of hydrologic inputs from precipitation versus ground water between ponds. Soil and water sodium and pH have been found in previous studies to be very important in determining the distribution of other wetland plants species (Catling et al. 1986, Chee and Vitt 1989, Gacia et al. 1994). In addition, pH can experimentally affect emergent plant species differentially (Roelofs et al. 1984, Boland and Burk 1992) and would thus be an important determinant of species distribution.

We have created a discriminant function that begins to describe the habitat characteristics of wetlands that support populations of *S. ancistrochaetus* using only five variables. The variables can be measured easily and cheaply, which is an important concern for land managers and conservation planners. However, other factors not investigated in this study need to be considered to gain a more complete picture of the ecology of *S. ancistrochaetus*. For example, in this study, the presence of this species at a given pond was determined by the existence of an established population of *S. ancistrochaetus*. This species could have been present in the seed bank in ponds from which we considered it to be absent. The presence of dormant seeds in seed banks can be an important component in vegetation dynamics (see Leck 1989 for review), but it is not known the degree to which *S. ancistrochaetus* forms a seed bank. Furthermore, some factors that were measured may be correlated with other unmeasured factors. For example, our results suggest indirectly that hydroperiod may be important, in agreement with other observations (USFWS 1993, Lentz, personal observation). However, hydroperiod may exert its effects through disturbance (which may be important in stimulation of seed germination) since ponds that contain water at the end of the growing season

usually have heavier and more prolonged use by animals than ponds that dry earlier in the season (Lentz, personal observation). Clearly, more field and greenhouse studies are needed to further refine our knowledge of the factors that control the distribution and vegetation dynamics of this endangered species. In the meantime, the development of this discriminant function gives managers and ecologists an important tool towards the conservation of *S. ancistrochaetus*.

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