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Abiotic Features of Seasonal Pond Habitat and Effects on Endangered Northeastern Bulrush, *Scirpus ancistrochaetus* Schuyler, in Central Pennsylvania

KENDRA A. LENTZ-CIPOLLINI* and WILLIAM A. DUNSON**

Department of Biology, The Pennsylvania State University, 208 Mueller Laboratory, University Park,
Pennsylvania 16802-1009

ABSTRACT

Seventeen seasonal ponds in Pennsylvania containing the federally endangered northeastern bulrush, *Scirpus ancistrochaetus*, were sampled for water chemistry, hydrology, and plant population area. [Na], [Mg], [Ca], [NH_3-N] and pH increased with decreased water level. [Mg], [Ca], [NH_3-N], [PO_4] and [K] were correlated with [Na], suggesting that they were controlled primarily by physical factors. Both surface and subsurface water contribute to water supply with five ponds dominated by surface water and four others dominated by subsurface water. Eight ponds show fairly equal inputs of surface and subsurface water during spring and fall, with subsurface water input becoming more important in midsummer. The difference between inputs of surface versus subsurface water was significantly negatively related to the percent change in population area during dry years and showed a positive trend in these two variables during wet years, indicating the sensitivity of this species to changes in surface water inputs.

INTRODUCTION

Scirpus ancistrochaetus Schuyler (Cyperaceae), northeastern bulrush, is a perennial emergent sedge, first described by Schuyler (1962). *Scirpus ancistrochaetus* grows in small acidic to circumneutral freshwater ponds, which are generally less than one acre in size and exhibit seasonal water fluctuations ranging from inundation to desiccation (U.S. Fish and Wildlife Service 1990). 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). Six bristles are attached to the achene, with retrorse, thick-walled sharply-pointed teeth densely arranged over the whole bristle length (Schuyler 1967). In established populations, *S. ancistrochaetus* most often reproduces vegetatively (Bartgis 1992) through formation of both nodal shoots on flowering stems and basal shoots from the rhizome (Schuyler 1967).

Scirpus ancistrochaetus is limited to approximately 75 populations in the northeastern United States (J. Kunsman, pers. comm.) and is listed as endangered by the U.S. Fish and Wildlife Service (1991). It is found in Maryland, Massachusetts, New Hampshire, Vermont, Virginia and West Virginia, but the majority of populations exist in Pennsylvania. Approximately one-third of these populations are found on private land (U.S. Fish and Wildlife Service 1993). Major threats to populations on public lands include disturbance due to logging, road building, deer browsing and trampling. Trash dumping, agricultural activities and residential and commercial development (U.S. Fish and Wildlife Service 1993) commonly threaten populations on private lands.

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* Present address: Department of Biology, Wilmington College, Wilmington, Ohio 45177-2499. email address: kal143@alumni.psu.edu
** Present address: 577 State Shed Lane, Galax, Virginia 24333-2386.

In order to conserve this species effectively, data must be collected concerning its basic life history and habitat characteristics (Brussard 1991, Lesica 1992, Lentz 1998). To date, very little information has been collected on the abiotic pond habitat of this species (but see Lentz and Dunson 1999). Since water chemistry can be an important influence in the distribution of many species (e.g., Catling et al. 1986, Shay and Shay 1986, Chee and Vitt 1989), seventeen ponds in central Pennsylvania, which support *S. ancistrochaetus*, were surveyed in 1996 and 1997 to provide summary statistics for and explore relationships between several water chemistry variables. To date, there has been no regional characterization of water chemistry and hydrology of ponds in which this species is found. In earlier local studies, ponds with *Scirpus ancistrochaetus* tended to have less forest canopy cover (60% vs. 75%), more soil [Na] (7.6 vs 3.6 ppm), higher water pH (4.5 vs. 4.2), higher soil percent organic matter (51% vs. 39%), and a higher seasonal pond area (437 vs. 263 m^2) (Lentz and Dunson 1999), when compared to ponds without *S. ancistrochaetus*. Nutrient levels affect root to shoot ratio and intraspecific interactions (Lentz 1999). Hydrology affects many ecosystem functions and can be unique for these depressional seasonal ponds (Shaffer et al. 1999). Water levels have been shown to affect growth in *S. ancistrochaetus* (Lentz and Dunson 1998). Since hydroperiod and/or type of input may affect *S. ancistrochaetus*, either directly through water availability/level or indirectly through changes in water chemistry, basic hydrologic measurements were made in each pond. Studies of how water level and hydroperiod affect the population status of this species are a high priority for the recovery of this species (U.S. Fish and Wildlife Service 1993). Population area was also measured in 1995–1997 at all ponds to follow trends in size over time in each pond and relate this information to hydrologic measurements.

METHODS

Seventeen ponds containing *Scirpus ancistrochaetus* were chosen for sampling based primarily on proximity to State College, Pennsylvania, as well as accessibility from land owners (Figure 1). Most of these were small seasonal ponds surrounded by mixed oak forest and all but one were found on public land. Elevations of ponds ranged from 370–612 m. Once per field season (1995–1997) in August or early September, the approximate width and length of each continuous stand of *S. ancistrochaetus* were measured and population area was calculated. Area of each population rather than number of plants was measured due to difficulties in distinguishing individuals in this rhizomatous species. We did not measure whether reductions in population sizes from year to year was due to plant death or due to plants not emerging due to stress or another factor. A change in population area, whether by plant death/senescence or dormancy, points towards reduced fitness during this time period, which has implications for this endangered plant. The seasonal pond area was measured in a similar fashion in 1995 only. Ponds were surveyed for water chemistry and hydrology from April to October in biweekly intervals in 1996 and from May to late September in monthly intervals in 1997. To monitor hydrology, two paired wells (surface well and piezometer) were installed per pond as described in Prosser (1994) and depth to water was monitored in each well at each sampling date. The surface well consisted of a slotted PVC pipe (5 cm diameter), installed to a depth of approximately 0.6 m, that allowed free horizontal flow of below-ground water (see Miner and Simon 1997). The piezometer consisted of a solid PVC pipe (5 cm diameter), installed to a depth of 1–1.5 m and sealed with bentonite clay (see McCullough 1999). By comparing the water level in the surface well to that in the piezometer, the relative hydrologic input from surface and subsurface flows can be determined, respectively (Prosser 1994). The contribution of surface water in relation to subsurface water (i.e., “surface water influence”) was calculated by subtracting the level in the subsurface well from the level in the surface water well at each sampling date. We did not have hydrologic data for 1995, which is the year that would affect population changes observed in 1996. However, hydrologic data were available for 1997, which, like 1995, was a lower than average year of precipitation. We therefore used linear regression to investigate the relationship between the average surface water influence in 1997 versus the

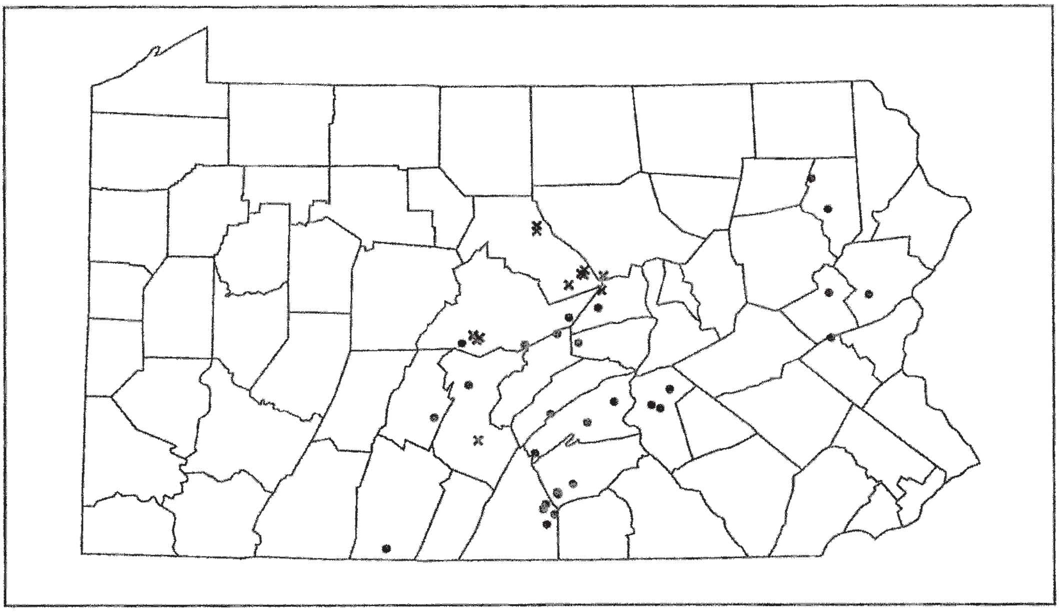

Figure 1. Distribution of *Scirpus ancistrochaetus* in Pennsylvania. X's indicate ponds surveyed for this study. Some X's have more than one pond per symbol due to coarse map scale.

change in population size from 1995 to 1996. The relationship between the percent change in population area from 1996 to 1997 and the average surface water influence for 1996 (the year that would affect the population change observed in 1997) was also analyzed using linear regression.

Specific conductance and pH were measured *in situ* at three haphazardly-chosen locations per seasonal pond using a specific conductance meter (Corning Checkmate 90) and a pH meter (Orion Model 290A). Water samples were collected from at least three haphazardly-selected locations in each seasonal pond, pooled, transported on ice to the laboratory, and filtered through a 0.45 µm nitrocellulose filter. Water samples were analyzed for [Na], [Ca], [Mg], and [K] using an atomic absorption spectrophotometer (Perkin-Elmer Model 2280). [NH_3-N] and [PO_4] were analyzed spectrophotometrically (with Hach water chemistry test kits and Milton Roy Spec 20) using Nesslers and ascorbic acid methods, respectively (Hach Company 1992). In 1997, samples were also analyzed for [NO_3-N] using a cadmium reduction method and for [SO_4] using a barium precipitate method (Hach Company 1992). Pairwise correlations for data from both years were conducted to determine relationships among parameters (SAS Institute, Inc. 1995). Values for pH were transformed to [H^+] for analyses. Due to lack of collectable standing water in 1997, data for [SO_4] and [NO_3-N] were not used in the above analysis since samples sizes were low. One pond (Pond #17) had an outlying high value for [PO_4], most likely due to the influence of a nearby cabin latrine. This pond was removed from all water chemistry analyses.

RESULTS

Most of the sampled ponds were rather small in size, with one pond (Pond #11) being the notable exception (Table 1). Population size in most ponds was drastically reduced in 1996 (Table 1). Hydrographs for 1996 and 1997 for six representative seasonal ponds are shown in Figures 2 and 3. Most ponds retained water for the entire field season in 1996, which was a record wet year. In 1997, ponds dried in early August and showed signs of refilling in late

Table 1. Pond area and population size summary of *Scirpus ancistrochaetus* for 1995–1997. All measurements are in m^2

		Population size in each year		
Pond No.	**Pond Area**	**1995**	**1996**	**1997**
1	510	6.5	4	7
2	940	228	224	224
3	891	5	4	2
4	220	40.5	42	30
5	510	168	33	48
6	567	0.25	0.25	0.25
7	447	12	7.5	1
8	225	45	23	10.5
9	612	135	98	70
10	736	309	215.5	259
11	122,00	4	4	3.5
12	425	65	42	38
13	541	96	39	35
14	286	286	81	70
15	390	45	29	52
16	~5,000	0.25	0.25	0.25
17	357	136.5	49.5	52

September. Eight of the 17 surveyed ponds were influenced by both surface and subsurface hydrologic inputs, with subsurface inputs more important during drier periods (Figure 2). In contrast, some ponds (5 of 17) were affected primarily by subsurface water (Figures 3A and 3B) while other ponds (4 of 17) were affected primarily by surface water (Figures 3C and 3D). All ponds showed variation in water levels, both within each season and between years (Lentz 1998). The relationship between surface water influence in 1997 (considered to be indicative of conditions in 1995) and percent population area change from 1995 to 1996 was significant at $\alpha = 0.10$ ($p = 0.07$, $r^2 = 0.20$) (Figure 4A). At the lowest levels of surface water influence, populations exhibited a low level of percent area change, while at the higher levels of surface water influence, populations exhibited larger negative percent area change during this dry year. The relationship between surface water influence in a very wet year, 1996, and percent population area change from 1996 to 1997 was nearly significant ($p = 0.12$, $r^2 = 0.15$) and there appears to be a general trend that as surface water influence increases the percent change in population increases during this wet year (Figure 4B).

We observed that one pond (Pond #17) had unusually high values for [PO_4], (0.61±0.20 mg/L, mean ± SE), [NH_3-N] (0.51±0.07 mg/L, mean ± SE) and [K] (3.31±0.46 mg/L, mean ± SE) and removed this pond from our analyses. Means of all water chemistry variables averaged over both years for all ponds (except Pond #17) are presented in Table 2. The water chemistry parameters are within the ranges for similar seasonal ponds in central Pennsylvania, although [SO_4] levels are noticeably lower than previous studies (Rowe and Dunson 1993). [SO_4] levels are reduced in this study most likely due to the Clean Air Act Amendments (Title IV) in 1990, which reduced the allowable amount of sulfur dioxide emissions. The correlation matrix for the data is displayed in Table 3. Specific conductance was positively correlated with [K], [Ca], [Mg] and [Na]. Of these cations, [Na] contributed least to the variation in specific conductance, as evidenced by its relatively low r-value. All of the cations ([K], [Na], [Ca] and [Mg]) were positively correlated with each other. [Ca] and [NH_3-N] were negatively correlated to [H^+]. Several variables were related to water levels in the surface wells. Hydrogen ion activity decreased (and therefore pH increased) with decreased water level. [Na], [Mg], [Ca], and [NH_3-N] were all inversely correlated with water level. [PO_4] was positively correlated with [Na] and [K].

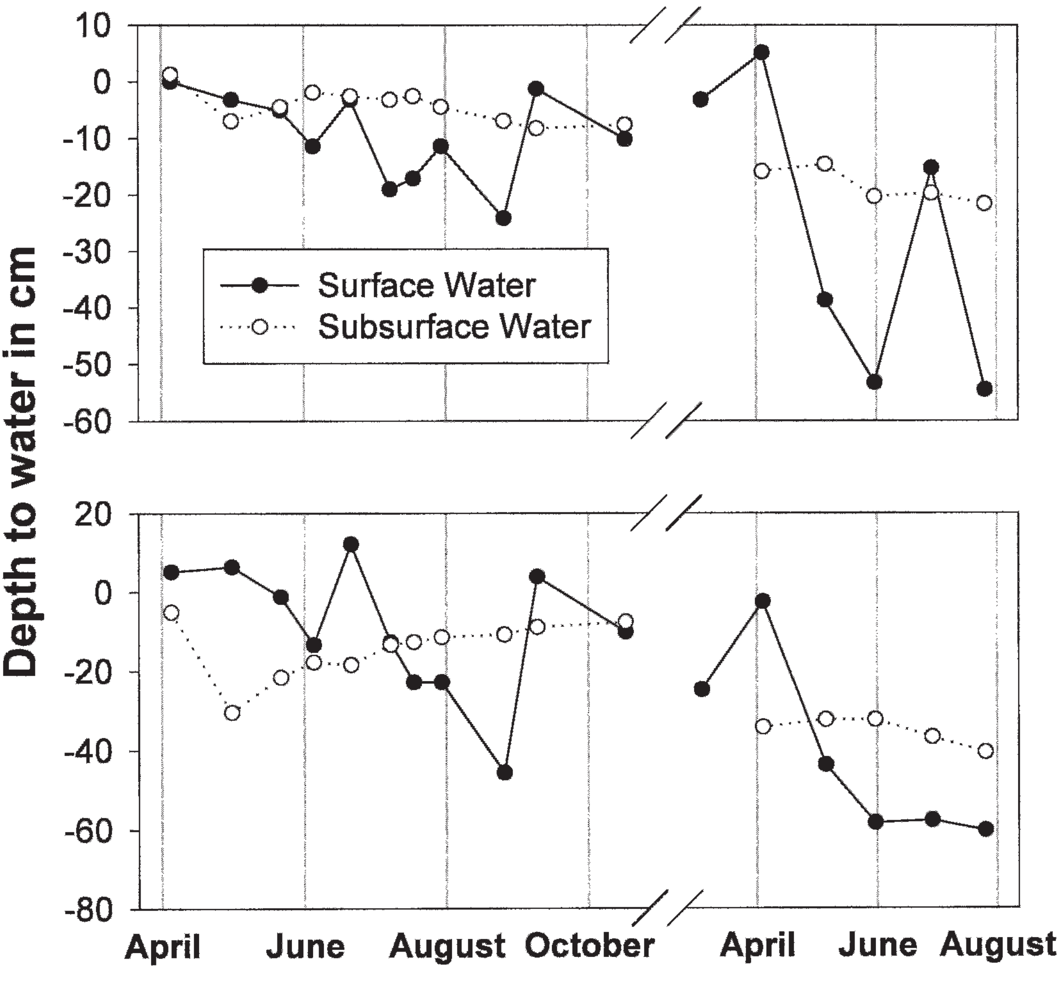

Figure 2. Hydrographs for 1996 and 1997 for two representative ponds, typically showing comparable inputs of surface and subsurface water in the spring and fall, with greater subsurface input in the dry summer months.

DISCUSSION

Woodland seasonal ponds in central Pennsylvania which contain *Scirpus ancistrochaetus* are generally small in size and have a period of drawdown in midsummer, depending on yearly conditions. One pond (Pond #11) is a notably large wetland that has large annual water level fluctuations created through yearly variation in beaver activity. *Scirpus ancistrochaetus* is found only at the edge of this wetland where water levels would perhaps mimic the pattern found in smaller seasonal ponds that dry in mid-summer. Indeed, at least a portion of the habitat at the edge of this wetland dried in mid-summer in 1995 and 1997. The statewide average precipitation in 1995 was 7 inches below the 30 year average, in 1996 was 14 inches above the 30 year average, and in 1997 was 4 inches below the 30 year average (State College National Weather Service Data, State College, Pennsylvania). In 1995, most ponds were dry by the end of July (some as early as early June) and did not show any signs of refilling as late as mid-October (K. Lentz-Cipollini, unpubl. data). This lack of precipitation is the most probable cause of the sometimes drastic decline in population area from 1995 to 1996, as plants were

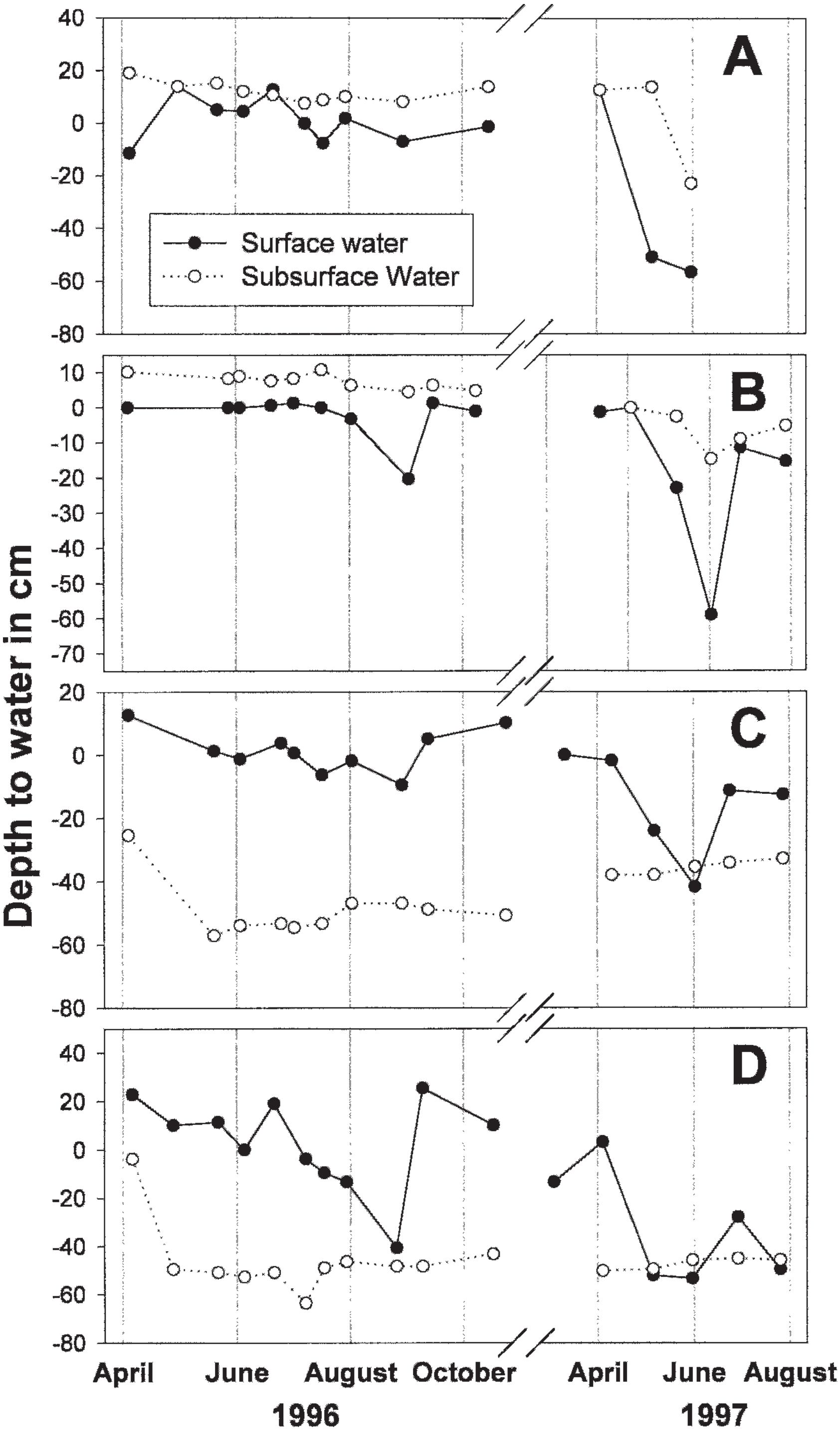

Figure 3. Hydrographs for 1996 and 1997 for four representative ponds. A & B illustrate ponds with greater subsurface water inputs. C & D illustrate ponds with greater surface water inputs.

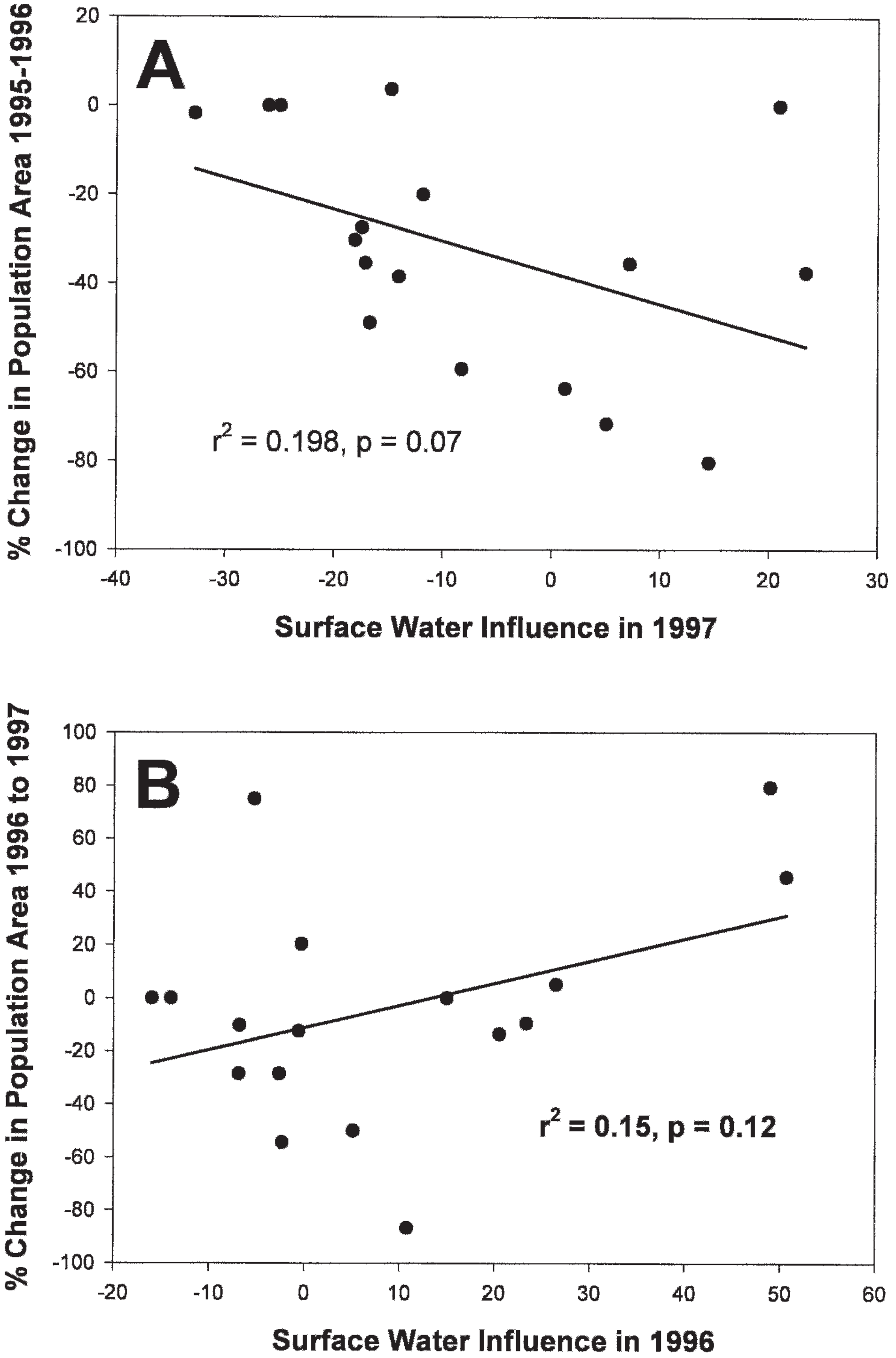

Figure 4. Relationship between percent change in population size and surface water influence (i.e., average difference between water level in surface water well and subsurface water well) in 17 ponds. A. Percent change in population size from 1995 to 1996 and surface water influence in 1997, a rather dry year. Hydrology data from 1997 was used as a surrogate for hydrologic data from 1995, another dry year. B. Percent change in population size from 1996 to 1997 and surface water influence in a very wet year, 1996.

Table 2. Water chemistry parameters (mean ± SE) for 17 surveyed ponds, averaged over 1996 and 1997. The lowest and highest pond mean are also displayed. The minimum and maximum median for 65 seasonal ponds sampled over two years in three geographic regions of central Pennsylvania are included for comparison (Rowe and Dunson 1993). SpCond = Specific conductance

Parameter	Minimum Pond Mean	Maximum Pond Mean	Mean for all Ponds	Min, Max Median in Rowe & Dunson
SpCond (in μS/cm)	19.8 ± 1.6	45.6 ± 6.8	30.7 ± 0.78	29.0, 21.5
K (in mg/L)	0.47 ± 0.05	2.82 ± 0.75	1.10 ± 0.08	0.460, 2.152
Na (in mg/L)	0.35 ± 0.04	1.23 ± 0.18	0.64 ± 0.05	0.324, 0.324
Mg (in mg/L)	0.31 ± 0.03	1.10 ± 0.10	0.54 ± 0.02	0.551, 0.820
Ca (in mg/L)	0.36 ± 0.10	1.49 ± 0.18	0.80 ± 0.04	0.340, 1.471
pH (in pH units)	4.38 ± 0.06	5.91 ± 0.07	5.17 ± 0.38	4.48, 5.07
NH_3-N (in mg/L)	0.15 ± 0.03	0.46 ± 0.06	0.28 ± 0.01	
PO_4 (in mg/L)	0.01 ± 0.01	0.07 ± 0.04	0.03 ± 0.004	0.008, 0.010
NO_3-N (in mg/L)**		0.06 ± 0.01	0.019, 0.042	
SO_4 (in mg/L)**		0.02 ± 0.0003	6.385, 9.040	

** Averages for each pond were not calculated, due to low sample size of these parameters.

exhibiting water stress and early senescence at the end of the field season in 1995. Further, the significant negative relationship between percent change in population size from 1995 to 1996 and the relative contribution of surface water to a given seasonal pond (as measured during a similar drought year in 1997) points to the drought as the likely cause. Only one of our regressions of percent change in population size versus surface water influence was significant at $\alpha = 0.10$. Even though the other regression during the wet year was only approaching significance ($p = 0.12$), the fact that the directional trend of the relationship changed during drought and wet years, given all the other environmental variables that differ between ponds, makes both regressions worth mentioning.

Levels of dissolved ions in these ponds were found to be generally low in comparison to other aquatic habitats (Hem 1985). Many water chemistry variables changed over the course of the season in these ponds. [Na], [Mg], [Ca], and [NH_3-N] were all inversely correlated with water level, indicating a possible concentration effect due to decreased pond volume through evaporation (e.g., Daborn and Clifford 1974). Calcium was negatively correlated with pH, which is expected given the chemistry of calcium in natural waters (Hem 1985). Nutrient levels were low, indicating that these ponds are oligotrophic in nature and are not receiving a large amount of anthropogenic nutrient inputs, as would be expected in these public forested sites with no recent logging activity. The only pond (Pond #17) that showed signs of nutrient enrichment was the one found on private land adjacent to a hunting cabin. Since Na dissolves easily and is not significantly absorbed by organisms in comparison with its abundance, [Na] is primarily controlled by physical factors such as evaporation rather than other factors, such as biological

Table 3. Pairwise correlation matrix of seasonal pond survey data from 1996 and 1997. * = $p <$ 0.05, ** = $p < 0.01$. SpCond = Specific conductance, SWater = water depth in surface well

	SpC	[K]	[Mg]	[Na]	[Ca]	[NH_3-N]	[PO_4]	[H^+]
[K]	0.37^{**}							
[Mg]	0.52^{**}	0.17^{**}						
[Na]	0.19^{*}	0.18^{**}	0.20^{**}					
[Ca]	0.37^{**}	0.31^{**}	0.48^{**}	0.34^{**}				
[NH_3-N]	0.08	0.21^{**}	0.02	0.16^{*}	0.34^{**}			
[PO_4]	0.01	0.26^{**}	0.06	0.16^{*}	0.04	0.05		
[H^+]	0.13	−0.12	−0.11	−0.11	-0.17^{*}	-0.14^{*}	0.02	
SWater	−0.09	−0.13	-0.15^{*}	-0.29^{**}	-0.33^{**}	-0.27^{**}	−0.11	0.22^{**}

factors. If other compounds are correlated with [Na], it suggests that they too are controlled primarily by physical processes (Cole and Fisher 1979, Dunson et al. 1997). In this study, [Na] was correlated with [Ca], [Mg], [K], [NH_3-N] and [PO_4], suggesting these are controlled by physical rather than other processes.

The long-term future of *S. ancistrochaetus* at the surveyed ponds is unknown and future surveys need to be conducted. The effect of uncontrollable stochastic, abiotic environmental factors on the population dynamics of this species is well illustrated by the drought of 1995. After the drought reduced (in some cases severely) the size of several populations between 1995 and 1996, populations either showed no signs of recovery by 1997, continued to diminish, or appeared to rebound quickly (Table 1). The conclusion that populations of *S. ancistrocheatus* in ponds with greater surface water influence are more sensitive to changes in surface water inputs gives conservation managers the knowledge to target areas for protection. For example, managers may want to focus protection and restoration efforts on areas that have a greater groundwater influence and would exhibit less year to year variation in population size. These populations would be potentially less prone to local extirpation. Additional information on whether the groundwater system is local or regional would provide the necessary information to protect the hydrology of these ponds. This study provides important basic knowledge needed to begin to understand the complex relationship between habitat characteristics and population status of this rare and endangered species. The effects of biotic influences were not examined here in the field, and more detailed information on multiple and potentially interacting abiotic and biotic habitat characteristics and population demography can only be ascertained by continuing field surveys and experiments.

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