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Recent *Azolla* bloom at Cheyenne Bottoms, Kansas

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In October 2009, low-height aerial photographs taken from a helium blimp revealed the presence of *Azolla* sp. over substantial portions of The Nature Conservancy (TNC) marsh complex at Cheyenne Bottoms in central Kansas. *Azolla* is a small, aquatic fern that has worldwide distribution; the mostly likely species for the central Great Plains is *A. cristata*. Although recorded previously in central Kansas, *Azolla* had not been seen in TNC marshes before, so its sudden appearance is remarkable. Widespread flooding in 2007 is considered the most likely means for transporting *Azolla* spores or plant fragments into TNC marshes; however, several other mechanisms are possible. The long-term significance of *Azolla* in TNC marshes is difficult to gauge at this point; both positive and negative consequences may happen in future years.

Keywords: Azolla cristata*, mosquito fern, Cheyenne Bottoms, marsh, aerial photography*

Introduction

Beginning in 2002, we have monitored environmental conditions at The Nature Conservancy (TNC) marsh complex in Cheyenne Bottoms, Barton County, central Kansas (Fig. 1). We have acquired low-height, large-scale aerial photography using kites and a small helium blimp annually and seasonally to document changing land-cover conditions with an emphasis on emergent wetland vegetation and water bodies (Aber et al. 2006; Buster and Aber 2009). As part of this routine observation program, aerial photography was conducted in October 2009, when distinctive maroon-colored vegetation was observed covering parts of TNC marshes. The plant was soon identified as *Azolla* sp.

Azolla is a genus with about half a dozen species having worldwide distribution (Lumpkin 1993). The genus was first described by Lamarck, who is usually associated with his incorrect evolutionary theory. It is a small aquatic fern typically described as a delicate, mosslike plant that floats or is stranded on the edge of quiet water bodies such as ponds, marshes and ditches (Steyermark 1963; McGregor et al. 1986). It often grows in large floating mats composed of masses of tiny ferns (Whitley et al. 1999).

Most botanists previously recognized four species of *Azolla* in the New World: *A. caroliniana, A. filiculoides, A. mexicana,* and *A. microphylla*. According to Evrard and Van Hove (2004), however, *A. caroliniana* and *A. microphylla* are synonymous with *A. filiculoides*, which is distinguished by unicellular leaf trichomes. In contrast, *A. mexicana* has bicellular leaf trichomes. Furthermore the name *A. cristata* has priority over *A. mexicana*. On this basis, they considered that only two species, *A. cristata* and *A. filiculoides,* exist in America.

The plants most usually reproduce asexually by fragmentation of the fronds as frequently as every two days (Watanabe 1982). *Azolla* also may reproduce sexually under special, poorly defined conditions. Each leaf has two lobes. The larger dorsal lobe is photosynthetic and hollow; the cavity is filled with the nitrogen-fixing blue-green bacterium *Anabaena azollae*. The lower lobe is colorless, cup-shaped, and provides buoyancy (Wagner, 1997). In China

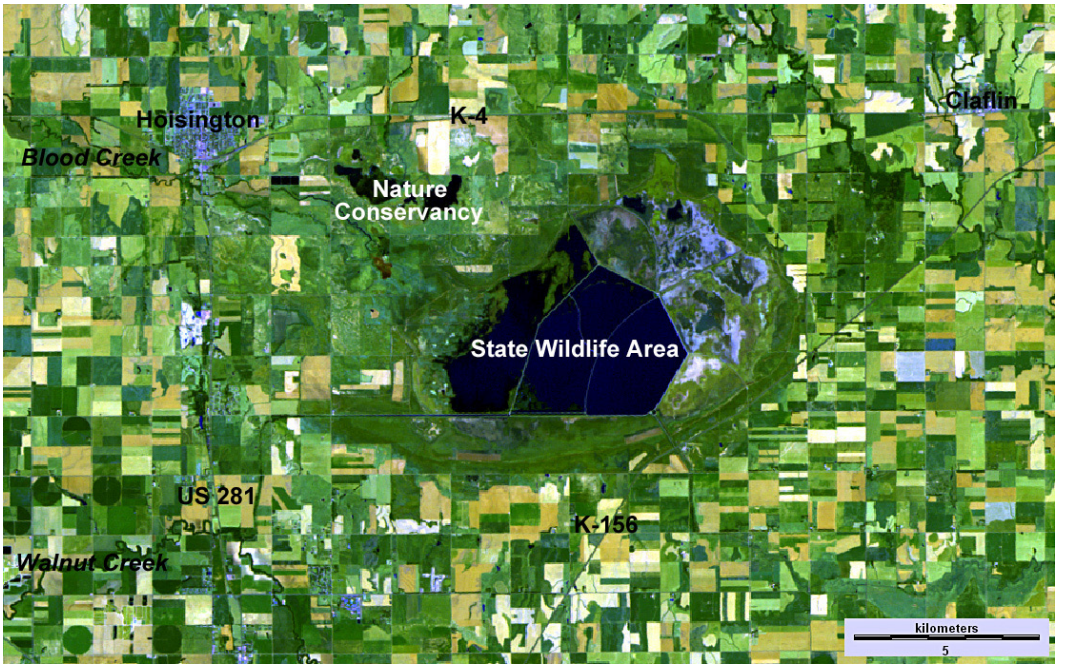

Figure 1. Satellite image of Cheyenne Bottoms vicinity, Barton County, central Kansas, showing location of Nature Conservancy land southeast of Hoisington. Landsat 5 TM false-color composite based on bands 2, 5, and 7 color coded as blue, green and red; Sept. 3, 2009. Active vegetation is green, fallow fields and pasture are pale yellow and tan, and water bodies are dark blue. Landsat TM dataset acquired from the U.S. Geological Survey, EROS Data Center; image processing with *Idrisi Taiga* software.

and southeastern Asia, it is grown as a natural fertilizer in rice paddies releasing up to 1100 kg N per hectare per year, nearly three times the rate compared to legume root nodules (Watanabe, 1982).

In winter, *Azolla* survives as either sporocarps, which fall to the bottom of water bodies, or as sporophytes that float. Color varies from gray-green to bright red-purple, but only sporophytes display red-purple colors. The reddish color is intensified by stress, such as exposure to sunlight, poor nutrition (especially phosphorus deficiency), salinity or high temperature (Steyermark 1963; Lumpkin 1993; Whitley et al. 1999).

The name *Azolla* is derived from *azo*, to dry, and *ollo*, to kill, which may signify that it is killed by drought (Whitley et al. 1999). Other common names include mosquito fern, water fern, fairy moss, water velvet, duckweed fern, floating fern, and variations on these names.

Azolla at Cheyenne Bottoms

When observed in early October 2009, *Azolla* had spread over sizable portions of TNC marshes forming continuous mats in places and isolated clumps and patches in other parts (Fig. 2). It was distributed both in central and marginal zones of the marsh complex. Examination on the ground revealed bright green algae on *Azolla* roots just below the water surface and light pink to dark maroon color where exposed to air just above water level (Fig. 3).

Azolla cristata is considered to be the most likely species (Van Hove, pers. comm.), although it is difficult to distinguish various species of the genus, and we have not made a

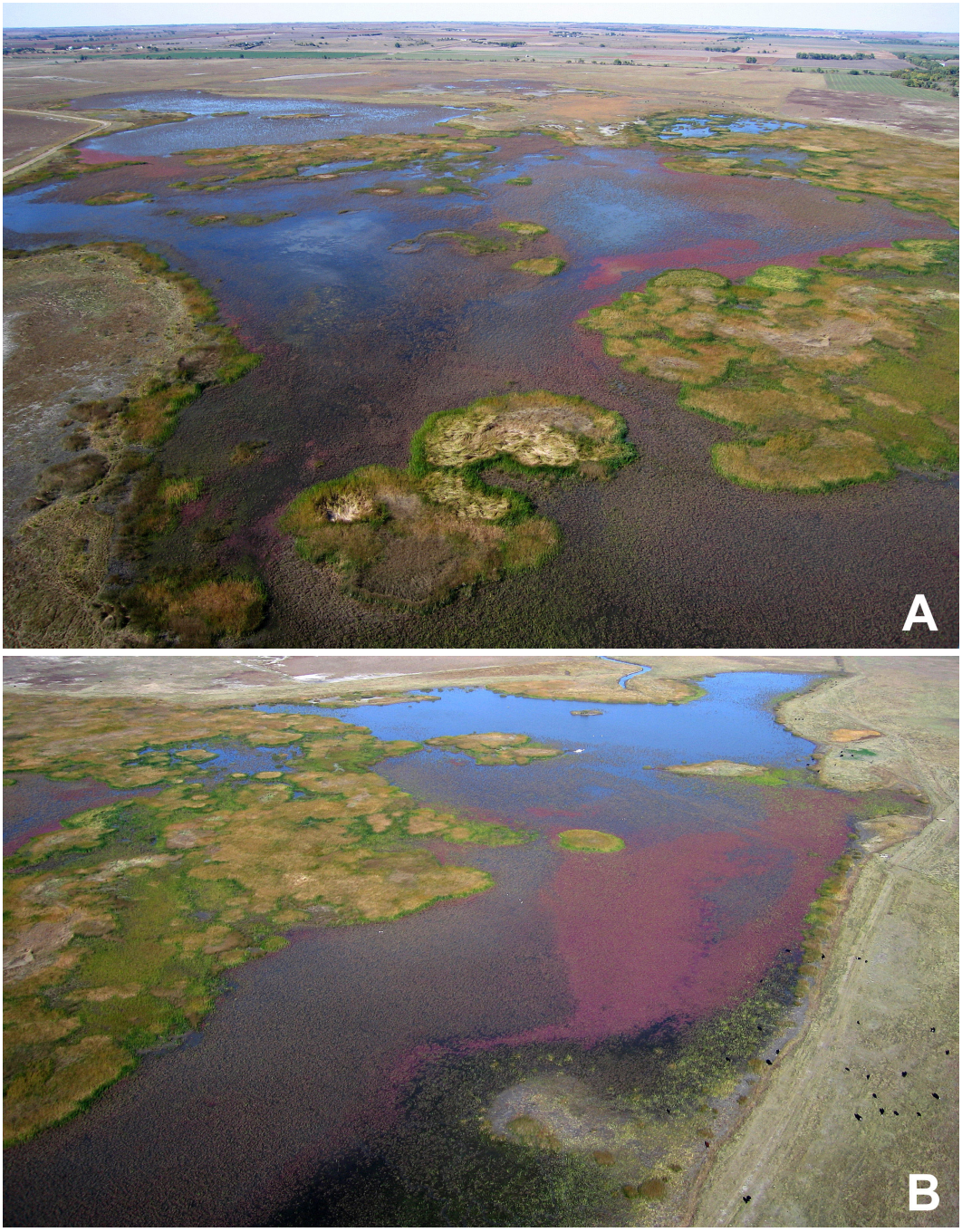

Figure 2. Aerial overviews of Nature Conservancy marsh at Cheyenne Bottoms. A - wide-angle view toward the northwest. B - closer shot looking toward the northeast; cattle in lower right corner for scale. Note the patchy distribution of maroon-colored *Azolla* in both scenes. Green emergent marsh vegetation includes great bulrush (*Scirpus validus*) and cattail (*Typha* sp.). Images acquired with a small helium blimp from a height of ~150 m, Oct. 9, 2009.

Figure 3. Ground photograph of *Azolla* on marsh margin; vertical close-up view, ~25 cm across. Green-colored algae is below water level; maroon-colored *Azolla* is above water. Oct. 9, 2009.

positive identification. *A. cristata* is found west of the Mississippi (USDA Plants 2009) and is reported by several authorities from the central Great Plains region, including Nebraska, Missouri, Kansas, and Oklahoma (Steyermark 1963; McGregor et al. 1986). *A. cristata* is listed for several counties in eastern Kansas (USDA Plants 2009) including the McKinney Marsh in Lyon County (Ronsse 1977). In central Kansas, it is reported from three counties: Barber, Barton and Harvey (USDA Plants 2009), and Zimmerman (1990) listed it for Cheyenne Bottoms State Wildlife Area.

Azolla has not been noted in TNC marshes before. It was not recorded in a detailed botanical survey of this same marsh in August of 2005 (Aber et al. 2006). Nor did Aschenbach and Kindscher (2006) mention it in a 1998 plant survey on salt-affected soils in salt flat mixed prairie and grass lake playa plant communities of nearby TNC land. Neither do local informants recall seeing it before in these marshes. Furthermore, *Azolla* was not visible in similar aerial photographs taken during the past eight years. In particular, it was not observed just one year before in late September 2008, when water levels were relatively high (Fig. 4). On this basis, the 2009 bloom of *Azolla* in TNC marshes is remarkable.

Dispersal of *Azolla*

How *Azolla* entered TNC marshes is unknown, but several means are possible. *Azolla* megasporocarps containing fertilized gametophytes or accompanied by microspores (containing massulae or sporophytes) could be brought in on the feet of waterfowl or shorebirds migrating northward in the spring. For example, some ponds around College Station, Texas were completely covered with *Azolla* during the summer of 2008.

Another means of dispersal could be spores and plant fragments carried on boats or other

Figure 4. Northeastward view over Nature Conservancy marsh at Cheyenne Bottoms, in which *Azolla* is not visible on shallow water anywhere within the pool. Kite aerial photograph taken Sept. 19, 2008; compare with Fig. 2B.

Figure 5. Waxing flood conditions in Nature Conservancy marsh at Cheyenne Bottoms. Super-wide-angle view toward the northwest; kite aerial photograph taken May 17, 2007. The Hoisington sewage treatment plant is visible in the left background. Compare with Fig. 2A.

equipment. This is considered unlikely in this case, because boats and other equipment are rarely used in TNC marshes. Still another possibility involves common use of *Azolla* as a freshwater aquarium plant; when aquarium water is released it may be transported into sewers and waterways (Whitley et al. 1999). The sewage treatment plant for the city of Hoisington is located less than one km directly west of TNC marshes.

Perhaps most importantly for plant dispersal, Cheyenne Bottoms experienced flooding of historic proportion in 2007. Cheyenne Bottoms previously had major floods in 1885-87, 1902-05 and 1912. During the flood of 1927-28, a large lake covered at least 80 km^2 to as much as 140 km^2 (Schwilling 1985), which was comparable to the 2007 flood.

Following a drought that culminated in the autumn of 2006, the winter and spring of 2007 were wet. Repeated, heavy rains resulted in partial flooding of Cheyenne Bottoms in May (Fig. 5). Heavy rains continued through the month of June. The combined May and June rain exceeded 20 inches (50 cm), which set a precipitation record. Virtually the whole of the state wildlife area was flooded, and about 20% of Nature Conservancy land was inundated (NC 2007). At the flood peak in July, most of Cheyenne Bottoms was covered by a continuous pool of water connecting all portions of the basin (Buster and Aber 2009). Flooding finally began to recede during the winter and spring of 2008, although water levels remained high in pools and marshes throughout the year.

During the flood of 2007 many weed seeds were washed into Cheyenne Bottoms, and upstream fish were found later in pools they normally would not inhabit. It is entirely possible that *Azolla* spores and plant fragments also were transported by flood water into TNC marshes from other sources both within and outside Cheyenne Bottoms. As long as water levels remained high during 2007 and 2008, conditions were not favorable for *Azolla* to thrive. As water levels returned to near normal in 2009, however, *Azolla* was able to spread rapidly as documented by aerial and ground observations.

Significance of *Azolla*

The unexpected appearance of *A. cristata* in TCN marshes potentially has both positive and negative consequences. On the beneficial side, *Azolla* is considered a good food source for waterfowl and provides cover for small invertebrates (Whitley et al. 1999; Dept. Ecology 2009), which could enhance the role of these marshes for migrating waterfowl. On the other hand, extensive mats of *Azolla* might not be attractive for those shorebirds that probe for invertebrates in shallow water or mudflats.

Azolla spreads rapidly by vegetative reproduction and may form extensive mats (CAIP 2008). It should never be introduced intentionally, as it quickly may overspread a water body and become a nuisance (Whitley et al. 1999). In such cases, its nitrogen-fixing ability may stimulate excessive algal growth, which could lead to eutrophic conditions. In some situations, *Azolla* is considered quite a pest. But in other places, such as British Columbia, *A. cristata* is regarded as a threatened species (Dept. Ecology 2009).

TNC marshes experience substantial changes in water from year to year during drought and flood cycles (Buster and Aber 2009). Given this setting, *Azolla* may not pose a serious long-term problem, as the basin dries up periodically. Climatic variations, changes in upstream human land use, sedimentation within the basin, and other factors, however, could affect future water supply to the marsh complex. Thus, it remains problematic to predict the long-term significance for *Azolla* in TNC marshes.

Conclusions

A bloom of *Azolla* sp. took place during the growing season of 2009 in marshes of The Nature Conservancy at Cheyenne Bottoms, Kansas. This bloom was discovered in the course of routine low-height aerial photography in early October. Based on species ranges and reports in the literature, *A. cristata* is considered to be the most likely species, although definitive identification has not been determined. *Azolla* had not been observed or reported from TNC marshes in previous years, so its rapid spread over sizable portions of the marsh complex is noteworthy. Among many possible ways for *Azolla* to reach TNC marshes, major flooding in 2007 is considered a leading mechanism for dispersal of spores or plant fragments. The long-term significance of *Azolla* in TNC marshes is difficult to predict at this point in time. Both positive and negative consequences are possible; we will continue to monitor the situation using low-height aerial photography.

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