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Small-format aerial photography for assessing change in wetland vegetation, Cheyenne Bottoms, Kansas

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Cheyenne Bottoms is a Ramsar wetland site in central Kansas, where the Nature Conservancy (NC) has undertaken an effort since the mid-1990s to maintain and restore marsh and wet-meadow habitats for migrating shorebirds and waterfowl. Small-format aerial photography was conducted using kites and a helium blimp in order to document changing water and vegetation conditions during the years 2002-2005. Pictures were taken repeatedly throughout the growing seasons with various film and digital cameras from heights of 100-150 m. Invasive cattails (*Typha* sp.) are a major concern; the spread of cattail thickets during the 1990s reduced the open marshes on which migrating shorebirds depend for feeding. The NC adopted a strategy in which drought episodes are exploited for control of cattails. During our study, a drought cycle took place. Both color-visible and color-infrared images depict the impact of changing water level on cattails, which over the course of two years (2002 to 2004) were largely eliminated from the NC marshes. Dead cattail thickets were removed subsequently (mowing and burning), and these zones were restored into open marsh that supports beneficial emergent wetland vegetation—*Scirpus*, *Eleocharis*, *Sagittaria*, etc. Small-format aerial photography provided high-resolution, multi-view-angle imagery that depicts the consequences of NC management practices on marsh habitat conditions.

Keywords: Cheyenne Bottoms, small-format aerial photography, wetland vegetation, cattail, marsh.

INTRODUCTION

Located in the center of Kansas, Cheyenne Bottoms is considered to be the most important wetland site for shorebird migration in the central United States (Zimmerman 1990). It is designated as a Ramsar wetland of international importance. The "bottoms" is famous for great flocks of migrating waterfowl that include many rare and endangered species.

Cheyenne Bottoms is an enclosed drainage basin that encompasses approximately 170 km^2. It is managed in part by the Kansas Department of Wildlife and Parks (8000 ha) and partly by the Nature Conservancy (2880 ha). The State Wildlife Area is mainly in the downstream "sump" portion, whereas Nature Conservancy land is in the upstream "delta" portion (Fig. 1). During the middle 20th century, water supplies to Cheyenne Bottoms gradually diminished due to a combination of drought and upstream water diversions, mainly for irrigation (Zimmerman 1990). This situation reached a crisis level in the 1980s, which led to water restrictions for upstream users, most of whom had junior water rights. Reduced upstream water

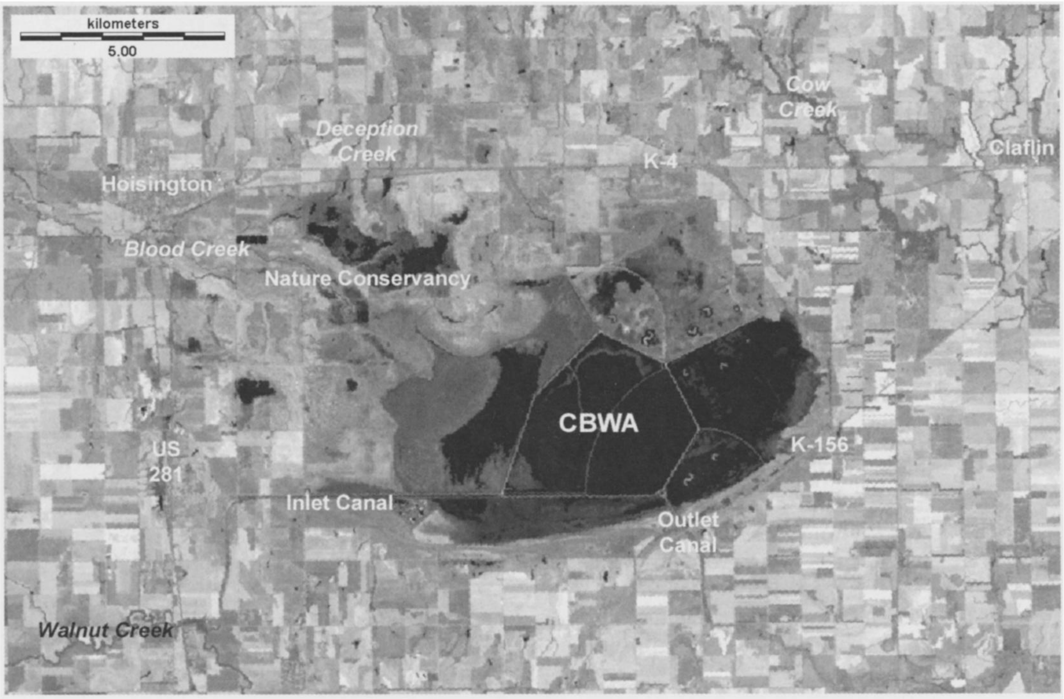

Figure. 1. Landsat satellite image of Cheyenne Bottoms and surroundings in central Kansas. CBWA - Cheyenne Bottoms State Wildlife Area, located in the downstream "sump" at the southeastern end of the bottoms. Nature Conservancy land includes deltas of Blood and Deception creeks in the upstream northwestern portion. Image date 25 June 2001; TM band 5 (mid-infrared).

diversion combined with relatively wet and cool climate of the 1990s resulted in stability for water supply to Cheyenne Bottoms.

Beginning in the early 1990s, the Nature Conservancy (NC) started to acquire land in the upstream portion of Cheyenne Bottoms, in the zone fed by Blood Creek and Deception Creek (Fig. 1). The management goal of the Nature Conservancy is to protect habitat for migrating shorebirds and waterfowl through maintenance and reclamation of natural marshes, mudlflats, and wet meadows. In pursuing this goal, the NC has undertaken substantial alterations of the previous agricultural land use in the acreage it owns and manages. Artificial barriers to water drainage, such as roads, levees, ditches and fence lines, have been removed in an effort to restore overland, sheet flow through a network of marshes and wet meadows. An important concern of recent years was the spread of cattail thickets during the 1990s, which threatened to cover open marshes and mudflats, thus rendering the wetland environment considerably less attractive for migrating shorebirds and waterfowl.

Cattails at Cheyenne Bottoms

Cattails are among the best-known emergent wetland plants worldwide. At Cheyenne Bottoms, both common cattail (*Typha latifolia*) and narrow-leafed cattail (*Typha angustfolia*) are present and have hybridized. However, cattails were not historically important plants at Cheyenne Bottoms (Zimmerman 1990). They first appeared in the 1960s, but were minor constituents of the wetland vegetation at that time; bulrush (*Scirpus* sp.) and spike rush (*Eleocharis* sp.) were the dominant emergent wetland plants.

Wet periods with high water levels favor expansion of cattail beds in marshes, and since the 1970s cattail has invaded aggressively into wetlands across the Great Plains. The spread of cattails at Cheyenne Bottoms was particularly dramatic during the 1990s, as documented by multitemporal Landsat imagery (Pavri and Aber 2004). Cattails may slow or stop the spread of other wetland plants by secreting chemicals that inhibit the germination of seeds (Whitley et al. 1999). As a consequence of this vegetation succession, cattail became the primary producer during the 1990s, and other emergent wetland plants were largely excluded from NC marshes at Cheyenne Bottoms.

Both the Kansas Department of Wildlife and Parks and the NC undertook measures to limit, reduce, or eliminate the cattail invasion at Cheyenne Bottoms. Several non-chemical methods may be employed for limiting cattail.

- Raising or lowering water levels beyond the tolerance limits for cattails.
- Mechanical removal—plowing and disking with large tractors.
- Introduction of muskrats, which feed on roots and use stems to build lodges.

The Nature Conservancy has no means to control water levels in its marshes, which are fed primarily by stream runoff during floods. The NC also lacks heavy equipment, such as catepillar-tread tractors, for efficient mechanical removal of cattails in wet soils. The Nature Conservancy adopted a strategy to exploit recurring drought conditions, when dead cattail thatch might be removed, as the primary means to control cattail infestation of its wetlands. Our goal has been to document details of seasonal and interannual changes in water and wetland vegetation, particularly cattails, using small-format aerial photography as our primary means.

Study Methods

Small-format aerial photography (SFAP) is based on compact film or digital cameras for acquiring low-height, high-resolution imagery from manned or unmanned platforms (Warner, Graham and Read 1996; Bauer et al. 1997). Applications for wetlands have proven particularly valuable as a means to obtain large-scale imagery at a low cost compared to other means of aerial photography (Aber and Aber 2001; Aber et al. 2002; Miyamoto et al. 2004). The typical resolution of SFAP is suitable for mapping and analysis of wetland vegetation at microstructural scales, 1:100 to 1:1000 (Masing 1998).

Beginning in 2002, we conducted SFAP at several sites on Nature Conservancy land at Cheyenne Bottoms. We returned repeatedly to one site, in particular, adjacent to a large marsh complex (Fig. 2). The upper marsh receives runoff directly from Deception Creek, and so may flood and has some standing water most of the year. In contrast, the lower marsh depends on overflow from the upper marsh, and as a result the lower marsh often has less standing water and is frequently dry.

This site has been photographed from late winter (March) to early autumn (September) under conditions ranging from completely dry to flood stage. Kites or a small helium blimp were utilized to lift various cameras up to 150 m above the ground (Aber et al. 1999; Aber 2004). The camera rigs are radio-controlled from the ground. We employed color-visible and color-infrared film (Aber, Aber and Leffler 2001), as well as compact digital cameras (natural color). Since 2005, digital cameras are utilized exclusively (Fig. 3). Images are acquired in a full range of depressions angles (0-90°) and compass directions (0-360°) and with various lens focal lengths to obtain all possible views of the study site.

The primary means of image interpretation is qualitative, visual examination and comparison of pictures from different seasons and years. Photographs were processed using *Adobe Photoshop* techniques to increase color contrast and image sharpness, in order to enhance the appearance and definition of objects. Images

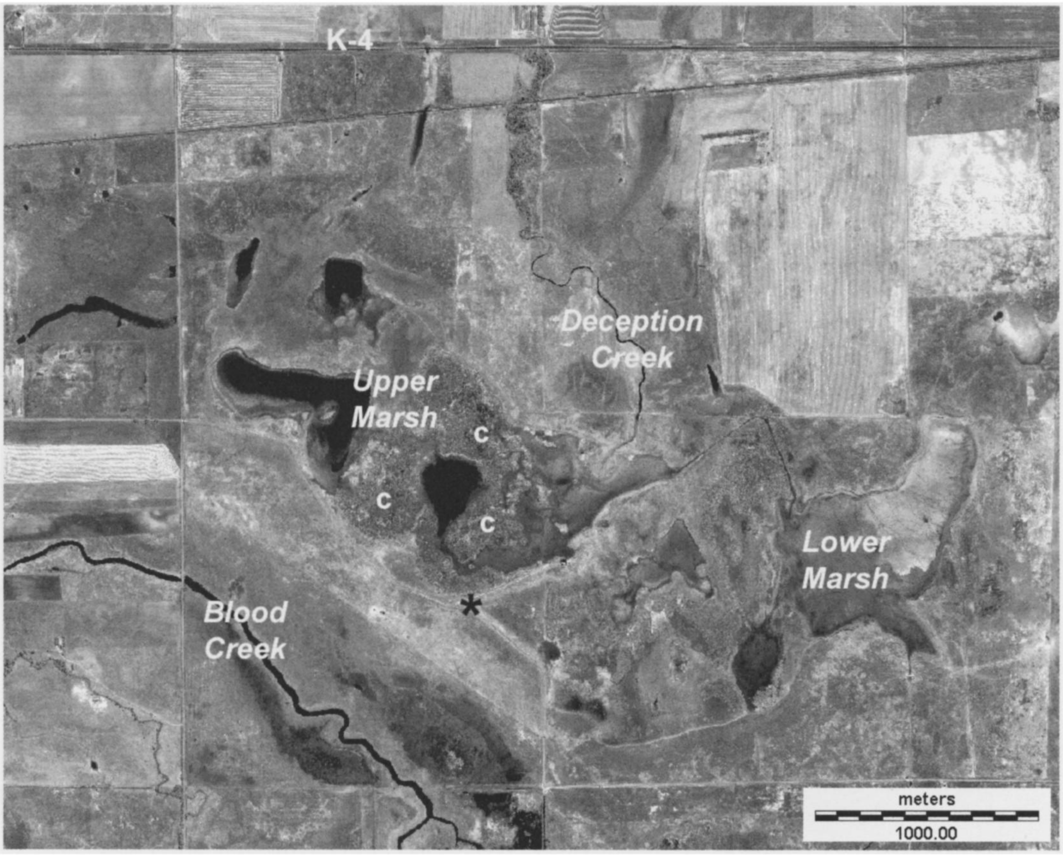

Figure 2. Ikonos satellite image showing NC marsh complex and main study vicinity. Asterisk marks the site used repeatedly for SFAP observations. This scene depicts drought conditions in which the upper marsh has small residual pools of water (black) and the lower marsh has no standing water. Cattail thickets (c) are indicated in the upper marsh. Image date 11 July 2003; Ikonos pan band (green + red + near-infrared).

were taken without reference to ground-control survey points, which do not exist for much of the study site. As most photographs were acquired in oblique vantages, no attempt has been made to rectify or georeference the images.

Extensive ground observations were carried out during four years of study, especially in the upper marsh, in order to identify suspicious or unknown features. Ground surveys were necessarily limited to those areas accessible on foot, but during dry stages much of the marsh floor was open to direct inspection. Special attention was placed on identification of emergent wetland plants—their color, texture and spatial patterns. Soil sections were examined, and signs of wildlife also were recognized, such as prairie dog towns, crayfish chimneys, and trails made by cattle.

Ancillary data included multi-year Landsat (30 m resolution) and Ikonos (1-4 m resolution) satellite imagery. These covered a period of several years prior to and during collection of SFAP and were utilized to provide context on surrounding land-use and land-cover conditions. Discussions with local informants provided background information on previous land use and changes in management practices. Precipitation data at Great Bend were obtained

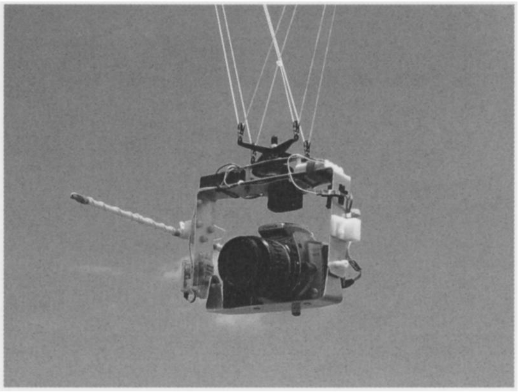

Figure 3. *Canon Digital Rebel* camera rig for kite or blimp aerial photography. The six-megapixel SLR camera is radio-controlled from the ground. It can pan (0-360°) and tilt (0-90°) to provide views in all orientations relative to the study site. Camera rig built by Brooks Leffler.

for the period 1980 to 2004 (NCDC 2005). In late August 2005, a detailed field analysis of vegetation was conducted in the upper marsh in conjunction with SFAP.

Results

Aerial photographs taken in the spring of 2002 depict the upper marsh with extensive, healthy cattail thickets that covered much of the marsh leaving little open water (Fig. 4). This phase represented the culmination of cattail expansion during the previous decade of relatively wet, cool climatic conditions (Fig. 5). Beginning in the summer of 2002, a drought took place in which water levels dropped and portions of the marsh dried up. In the spring of 2003, airphotos revealed that much of the cattails had died, although small patches and narrow zones of cattails survived, mainly around the margins of thickets (Fig. 6). Drought conditions continued through 2003 and early 2004.

In May of 2004, NC marshes were completely dry and all former cattail thickets were dead (Fig. 7). Upon the demise of cattails in early spring 2004, the Nature Conservancy began an attempt in marsh restoration. Three treatments were applied to different sections of dead cattail thatch in the study marsh. Some areas were mowed, some were burned, and some were left untouched. Mowing proved impractical, as the small tractor repeatedly became stuck in soft soil. Controlled burning was restricted for various logistical and safety reasons and was further limited by unsuitable weather conditions. The result was an unsystematic pattern in the removal of cattail thatch.

Drought conditions ended rather abruptly in June of 2004, when a series of heavy rains took place and the marshes were flooded. Wet conditions continued through 2004 into the summer of 2005. Some formerly dry mudflats were revegetated rapidly in the summer of 2004 (Fig. 8), particularly by blunt spike rush (*Eleocharis obtusa*). Scattered stands of great bulrush (*Scirpus validus*) appeared around the marsh margins, but cattail did not recover. By the spring of 2005, bulrush and spike rush had spread quickly to replace cattail in many portions of the marsh, and some small stands of cattail were beginning to come back as well. This resulted in a mosaic of emergent wetland vegetation. Former cattail thatch that had been removed by mowing or burning was replaced by shallow, open water or mudflats; whereas, untreated cattail thatch now supported a mix of emergent wetland vegetation (Fig. 9).

By late August of 2005, the marsh had reached a typical summer condition consisting of vegetated zones, dry and moist mudflats, and residual pools of shallow water. Detailed analysis of emergent vegetation at this time revealed a series of typical plant communities from the marsh margin to the edge of residual water pools in the marsh center. A total of 30 species were identified in these plant communities (Table 1; Gould 1975; Bare 1979; Weber and Wittmann 1990), and five plant zones were noted in the field and on airphotos (Fig. 10; Table 2).

Interpretation and Discussion

SFAP provided a means to identify and

Gramineae (grass family)	*Eragrostis reptans* (Michx.) Nees *Diplachne fascicularis* (Lamark) Gray. *Phalaris angustata* Nees ex Trin. *Hordeum jubatum* L. *Echinochloa crusgallii* (L.) Beauv.
Cyperaceae (sedge family)	*Scirpus validus* Vahl. *Cyperus acuminatus* Torr. *Eleocharis obtusa* (Willd.) Schultes
Typhaceae (cattail family)	*Typha latifolia* L.
Alismaceae (water plantain family)	*Echinodorus rostratus* (Nutt.) Engelm. *Sagattaria latifolia* Willd.
Polygonaceae (buckwheat family)	*Polygonum bicorne* Raf. *Polygonum lapathifolium* L. *Rumex* sp.
Chenopodiaceae (goosefoot family)	*Chenopodium berlandieri* Moq. *Chenopodium glaucum* L.
Amaranthaceae (amaranth family)	*Amaranthus album L.*
Euphorbiaceae (spurge family)	*Euphorbia serpens* (Humboldt, Bonpland&Kunth)
Malvaceae (mallow family)	*Abutilon theophrasti* Medic.
Boraginaceae (borage family)	*Heliotropium curassavicum* L.
Verbenaceae (verbena family)	*Phyla lanceolata* (Michx.) Greene
Solanaceae (nightshade family)	*Solanum americanum* Mill. *Physalis heterophylla* Ness.
Compositae (composite family)	*Cirsium vulgare* (Savi) Tenore. *Eclipta alba* (L.) Hassk. *Erechtites hieracifolia* (L.) Raf. *Aster subulatus* Michx. *Solidago graminifolia* (L.) Salisb. *Ambrosia psilostachya* (Torrey&Gray) Farwell *Xanthium strumarium* L.

Table 1. Listing of plant families and species identified in Nature Conservancy study marsh, late August 2005.

Zone	Location	Abundance	Representative species	# species
A	moist edge of marsh	85%	*Scirpus validus, Cyperus acuminatus, Diplachne fascicularis, Solanum americanum, Polygonum lapathifolium, Abutilon theophrasti, Solidago graminifolia, Xanthium strumarium*	14
B	A-C ecotone	60%	*Typha latifolia*	9
C	mud flat	variable (3-75%)	*Eragrostis reptans, Eleocharis obtusa, Sagittaria latifolia, Euphorbia serpens*	12
D	marsh thicket	65-98%	*Scirpus validus, Typha latifolia, Hordeum jubatum, Phalaris angustata, Phyla lanceolata, Aster subulatus, Solidago graminifolia*	16
E	moist edge of pool	< 15%	*Eragrostis reptans, Sagittaria latifolia, Echinodorus rostratus*	11

Table 2. Characteristics of vegetation zones in Nature Conservancy study marsh, late August 2005. See Fig. 10 for locations.

determine qualitatively the distribution of specific types of emergent wetland vegetation in Nature Conservancy marshes at Cheyenne Bottoms. Attributes of SFAP that led to this successful application include: high resolution (<10 cm), large scale (1:100 to 1:1000), panoramic and multi-view angles, frequent image collection throughout the growing season, and low cost. Neither conventional airphotos nor satellite imagery provided the necessary spatial resolution, oblique views, or frequent repetition to allow this interpretation. On the other hand, SFAP is limited in areal coverage, and so is best suited to relatively small study sites no more than a few hectares in extent. It fills a niche in the scale and resolution of observations between ground-based studies and conventional remote sensing from higher altitudes.

During our investigations we identified three key emergent wetland plants that are indicators for habitat conditions in the Nature Conservancy marshes: bulrush, spike rush, and cattail. These plants thrive or diminish with climatic variations, particularly drought and flood cycles, that affect water level and soil moisture. The marshes were heavily infested with cattail as a consequence of relatively abundant rainfall and high water during the 1990s. When we began our initial observations in 2002, large portions of the marshes were filled with cattail thickets; little open water or mudflats existed. However, during a drought (2002-04), the marshes dried up and most cattails died.

The end of the drought in 2004 and beginning of a wet phase resulted in a succession of emergent wetland vegetation. Blunt spike rush was first to take advantage of moist mudflats within a month of the return of wet conditions, and bulrush became the dominant large emergent plant by the following spring. Cattail responded more slowly. Removal of dead cattail thatch by mowing or burning cleared the way for restoration of shallow, open-water or mudflat marsh conditions over substantial areas. We were not able to distinguish any difference in

Figure 4. Healthy cattail thickets (dark green) cover much of the upper marsh study site prior to drought. View toward west; image date 28 May 2002.

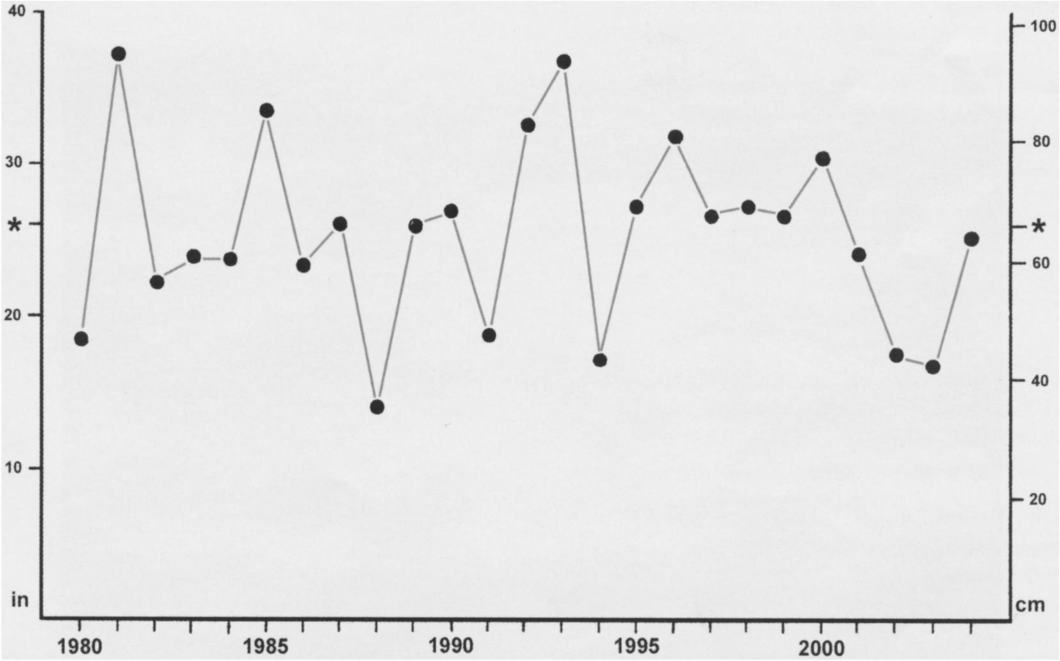

Figure 5. Chart of mean annual precipitation recorded at Great Bend, Kansas adjacent to Cheyenne Bottoms for the period 1980 to 2004. Long-term average indicated by asterisks (26 inches, 66 cm). A two-year drought took place in 2002-2003. Data obtained from NCDC (2005).

Figure 6. View toward northwest over partially dead cattail thickets (brown) in upper marsh. Small patches and narrow zones of cattails survived (green), particularly around the margins of thickets. Image date 12 June 2003.

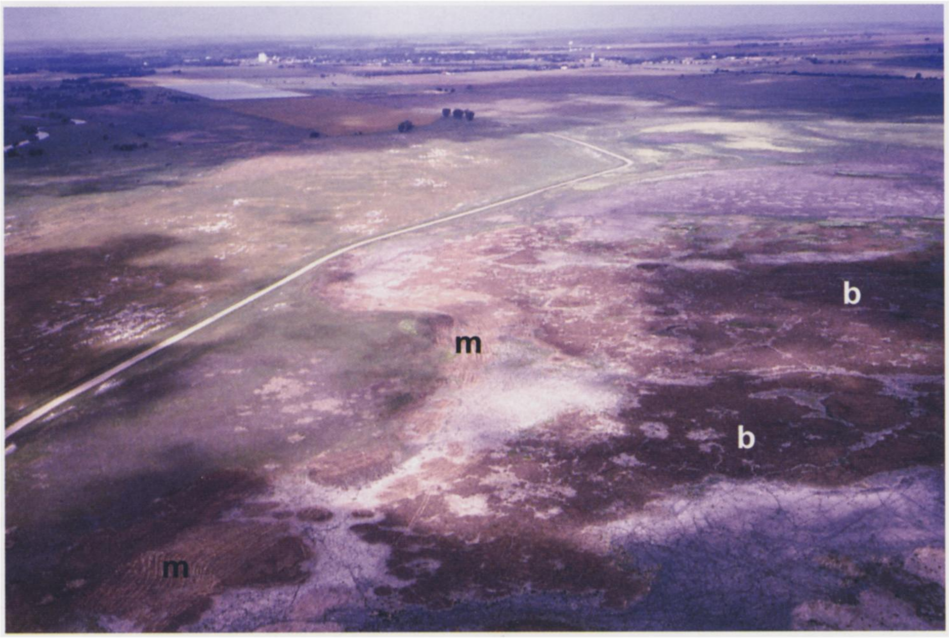

Figure 7. Completely dry soil and dead cattails (reddish brown) in the upper marsh study site. Areas treated by mowing (m) and burning (b). Compare with Figs. 4 and 10. View toward west; image date 26 May 2004.

Figure 8. Revegetation of former dry mudflat by blunt spike rush (*Eleocharis obtusa*), which appears dark green at scene center. Muddy water from recent flooding fills the marsh in the foreground, and cattle are grazing on wet meadow in background. Image date 7 July 2004.

Figure 9. Mosaic of emergent wetland vegetation types with extensive open water in Nature Conservancy marsh. Superwide-angle view; image date 22 May 2005. Kite flyers are visible in lower right corner.

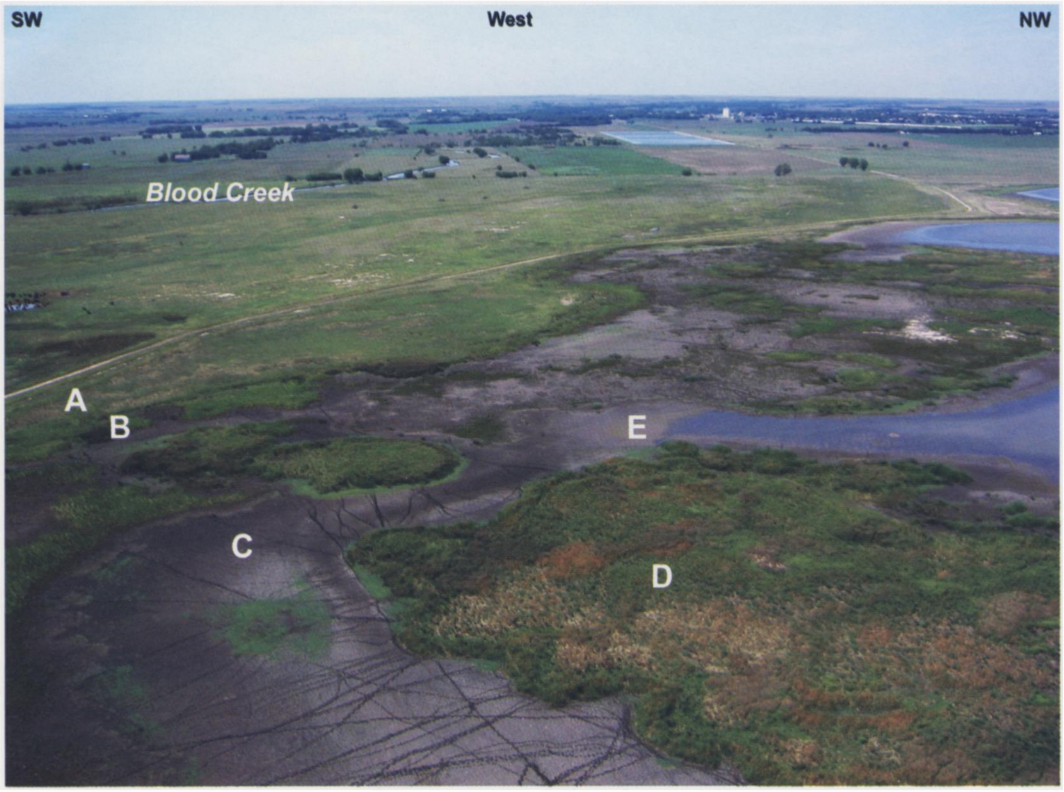

Figure 10. Late-summer view over study marsh in partly dry condition. Marsh vegetation zones (A-E) identified in Table 2. Image date 29 Aug. 2005.

vegetation succession, however, between areas treated by mowing and by burning. It would seem that either means of removing dead cattail thatch was effective for restoring open marsh habitat at the NC study site. Similar management techniques may be useful for controlling cattails at other wetland sites under comparable circumstances.

The mix of typical emergent wetland vegetation and dry prairie species of various plant communities indicates the dynamic character of this ecosystem. Frequent changes in water levels lead to alternate flooding and drying of marsh zones on a seasonal and interannual basis. As a result of these cycles, the vegetation is always in a state of flux. This situation mimics other wetland conditions in the Great Plains region and thus should provide optimal environments for migrating birds.

In light of these dramatic changes in vegetation and water cover, it appears the strategy of the Nature Conservancy was partly successful for restoring open-water and mudflat marsh habitat attractive for migrating shorebirds and waterfowl. SFAP proved invaluable for visual interpretation and documentation of these changing vegetation and water conditions.

Conclusions

SFAP conducted during 2002-05 provided a means to identify and determine the distribution of water bodies and specific types of emergent wetland vegetation at high spatial and temporal resolutions in Nature Conservancy marshes at Cheyenne Bottoms. SFAP gives wetland managers a low-cost means to acquire highly detailed imagery that depicts the consequences of land management practices at the microstructural scale. This method could be applied to similar wetlands in which high-resolution imagery would be useful for documenting vegetation and water conditions for relatively small study sites.

Changing habitat conditions are indicated by three key emergent wetland plants—bulrush, spike rush, and cattail, which can be identified readily in small-format aerial photographs. Following a drought cycle, the Nature Conservancy achieved modest success in limiting cattails. Those areas in which dead cattail thatch was removed by mowing or burning have become open-water or mudflat habitats. In contrast, untreated thatch areas have recovered as dense stands of emergent vegetation. Thus, removal of dead cattail thatch at the end of a drought cycle is necessary for open marsh conditions to become established during the subsequent wet phase. The initial success of cattail management at the Nature Conservancy site is a basis for expanding the geographic application of this approach for controlling cattails at similar drought-prone wetlands throughout the Great Plains region.

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