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VEGETATION CYCLES IN BOREAL PEATLAND PONDS: EFFECTS OF DROUGHT AND FLOODING

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SUMMARY

The Boreal plain of Canada contains millions of small ponds surrounded by peatlands. Little is known about their response to variability in precipitation. We examined the response of Boreal peatland ponds in Utikuma, Alberta, to drawdown and reflooding. Drawdown produced concentric vegetation patterns that were transitional between herbaceous marshes, and bryophyte dominated fens. During wet years floating mats developed within the transitional vegetation. Areas topographically higher than the mats became wetter than the mats. Oscillations in water levels thus produced two unique features: transitional fen/marsh vegetation that has a blend of species indicative of both hydrological stability and instability, and a ring of wetter vegetation upslope of the transitional fen/marsh community.

KEY WORDS: Ponds, drawdown, transitional, vegetation

INTRODUCTION

The Boreal plain, the second-largest ecoregion in Canada has millions of small shallow lakes and ponds. These small lakes and ponds are generally bowl-shaped, shallow (<2 m), fringed by peatlands, and have unconsolidated sediments of partially-decomposed peat. As such these shallow lakes represent significant sinks for atmospheric carbon (Nicholson *et al*. 2006, Bayley and Mewhort 2004). Moreover, the shallow lakes of the Boreal Plain and their associated wetlands are crucial habitat to 12-14 million migrating ducks (Niemuth and Soldberg 2003) in addition to providing habitat for mammals, amphibians, and invertebrates (Afton and Anderson 2001). Studies of Boreal small wetland lakes are uncommon, with most of the recent work focused on larger lakes (Prepas *et al*. 2001), lake hydrology (Devito *et al*. 2005), water chemistry and plant production (Sass 2006, Norlin *et al*. 2005), and fire impacts (Charette and Prepas 2003).

Prairie potholes are known to have periodic cycles of drought and flood, and vegetative changes associated with cyclic water levels have been well documented (Merendino *et al*. 1990, Welling *et al*. 1988, van der Valk and Davis 1978). Zonational patterns and successional changes in

Boreal wetland ponds however have received less attention. A drought from the mid to late 1990s to 2002 and subsequent flooding in 2005 at Utikuma Lake in western continental Canada permitted examination of plant community dynamics in wetlands surrounding shallow lakes on the Boreal plain. The objectives of this study were to describe changes in plant communities in Boreal ponds during drawdown and flood, and to compare drought-flood cycles of the Boreal forest to that of the prairies.

MATERIALS AND METHODS

In 2002, two transects were laid out in eight ponds (16 transects). In addition, the vegetation along the sandy shores of a large lake in the outwash plain (Lake 500) was surveyed for comparison, yielding a total of 89 plots. In 2003 and 2005, limited sampling time allowed resurvey of only 15 and 5 transects respectively. All transect lines started from the highest point along the shore, marked by a vertical ledge of between 50-100 cm (Nicholson *et al*. 2006). Vegetation was sampled using a random-stratified method where concentric zones were identified and measured, and plots of 0.25 m^2 in size placed randomly in the middle. In each plot, species were described by percent cover. Vegetation plots were classified using TWINSPAN (Hill 1979), in PC-ORD with cut levels of 0, 2, 5, 10, 20, 40, 60, 80, and 90.

Sediments were removed to determine percent ash and percent carbon at spatial frequencies that varied with the width of the zone. For most it was 1/4, 1/2, and 3/4, of zone, for narrow zones, less frequently. Water table measurements were taken at zone boundaries in addition to the plots. When below the surface, the depth was determined by digging small open seepage pits. Percent ash samples were burned in a muffle furnace at 550 ˚C for 24 hours. For carbon, samples were ground with a ball mill and analyzed using an automated Dumas combustion system (McGill and Figueiredo 1993). Depth of the aerobic zone was determined in 2002 by inserting steel welding rods into the sediments and leaving them in place from July until the end of September (Bridgham *et al*. 1991).

A climate moisture index (CMI) was obtained using a simplified Penman-Monteith calculation of P-PET. This data is a monthly 10 Km gridded data set corrected for elevation and interpolated using ANUSPLIN (McKenney *et al*. 2006). Differences between years and TWINSPAN groups was assessed using a nonparametric Kruskal-Wallis, and statistical significance determined using ANOVA with a post hoc Tukey’s, or Fisher’s test.

RESULTS

Since 1980, climate near Red Earth has been experiencing a gradual decline in the amount of available moisture (Fig. 1). Before this study, moisture deficits (P-PET) were seen as early as 1998; lasting until 2005. The driest year during the duration of this study was the year 2002 and 2005 had a positive moisture balance.

In total, 172 vegetation plots containing 116 species were sampled during the three years. The ponds begin with a ledge that drops approximately 0.7- 1m below the forested peatlands

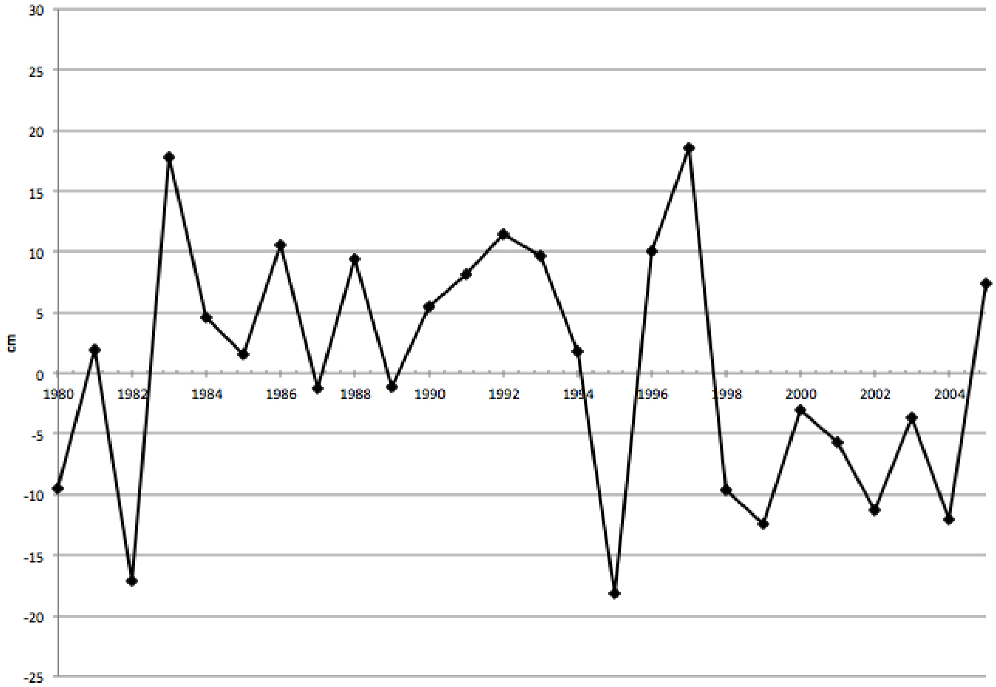

Figure 1. Climate Moisture Index (cm), for the Red Earth Climate Station, the closest station to Utikuma Lake. Data are a gridded Climate Change Impacts on Productivity and Health of Aspen (CIPHA) monthly data set calculated from climate interpolations using the ANUSPLIN program (McKenney et al. 2006) reconstructed and summarized on an annual basis (Aug 1-July 31). CMI is a P-PET (precipitation – potential evapotranspiration) index based on the simplified Penman-Monteith method of Hogg (1997).

(Nicholson *et al*. 2006). Below this ledge the vegetation is not treed and consists of concentric rings. Outermost communities below the ledge were older than one year as they contain thatch, and woody shrubs. Rings internal or pond side were more recent and contained newly exposed sediments with germinating seedlings or mats of dead aquatic vegetation. Seven vegetation communities were identified. Community 1 and 2 were aquatic. Community 3 consisted of newly emerging plots dominated by *Agrostis*, *Sagittaria*, *Drepanocladus*, *Lemna*, and *Rumex*. Community 4, was strongly dominated by two species, *Eleocharis* and *Drepanocladus* with smaller amounts of *Epilobium* and *Senecio*. Community 5 was dominated by species of *Carex*, along with a significant cover of *Drepanocladus* and *Eleocharis*. Grasses were dominant in community 6, while community 7 had the highest abundance of *Salix*, *Carex*, and grass, and was the oldest of the vegetational zones.

Communities predominantly followed a water table gradient (Fig. 2). The number of communities that developed along the shoreline in 2002 appeared to be related to the slope of the shore as depicted by the slope of the aerobic zone (Fig. 3). The pond with the sharpest slope (2.279 cm/m), developed only one community while the pond with the flattest slope (0.032 cm/m) developed four. The most frequent number of communities developing along the shores was 2, ranging in slopes from 0.035 to 1.287 cm/m. Percent carbon, and percent ash demonstrate the predominantly organic nature of the sediments (Fig. 4). All communities except 5 were predominantly organic; mean percent % ash is less than 35%, and mean carbon > 35%. Community 5 is the most unique, having higher ash (> 40%) and lower carbon (> 30%).

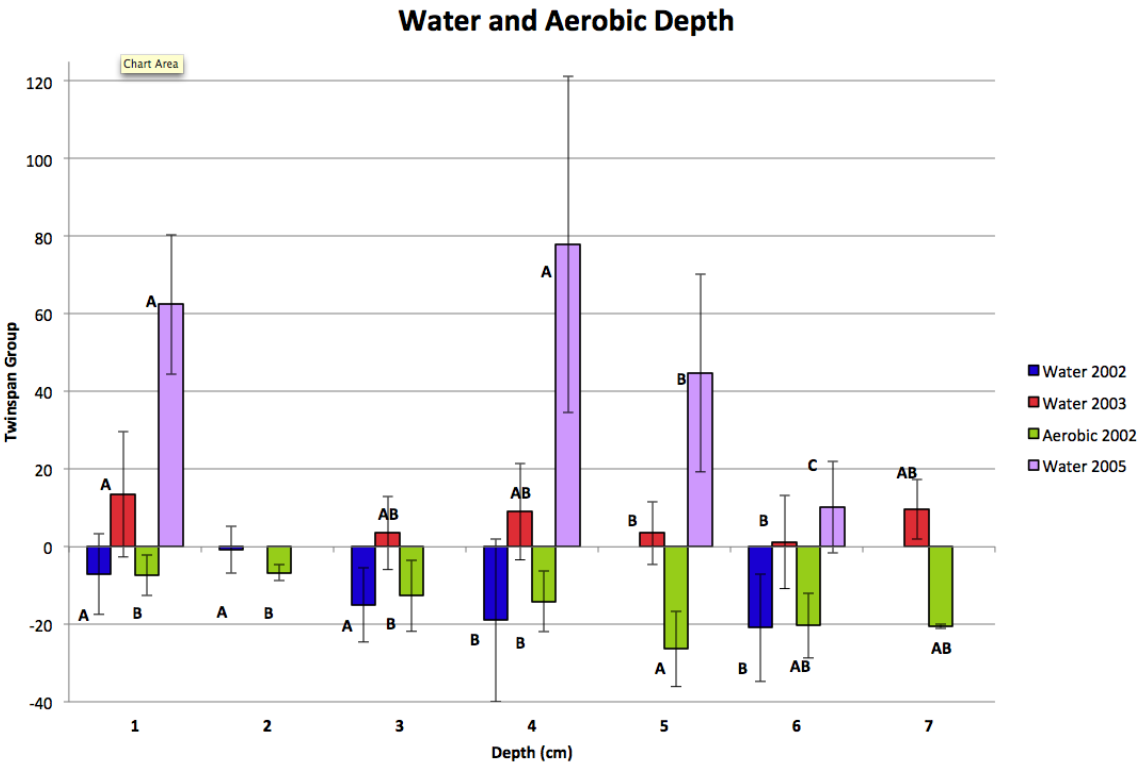

Figure 2. Mean water depth and aerobic zone measurements (2002-2005). Letters indicate Tukey's or Fisher's grouping information. Water and aerobic zone depths for 2002 are below the x-axis and water depths for 2003 and 2005 are above. Bars represent standard deviation for each community.

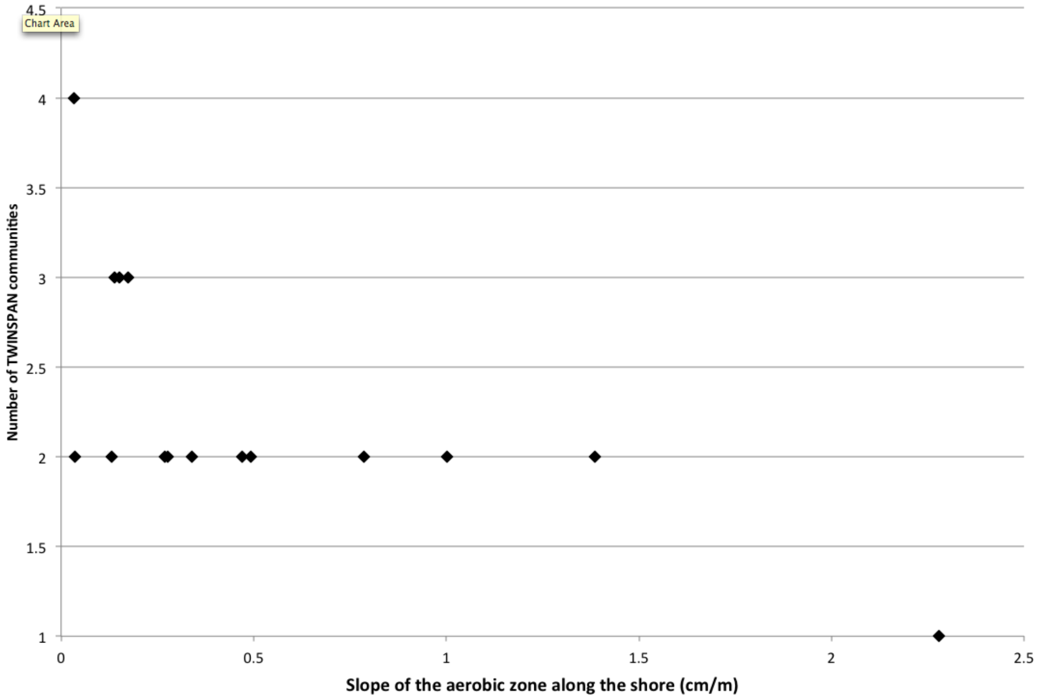

Figure 3. Relationship between the number of TWINSPAN communities and the slope of the aerobic zone along the shore measured in 2002.

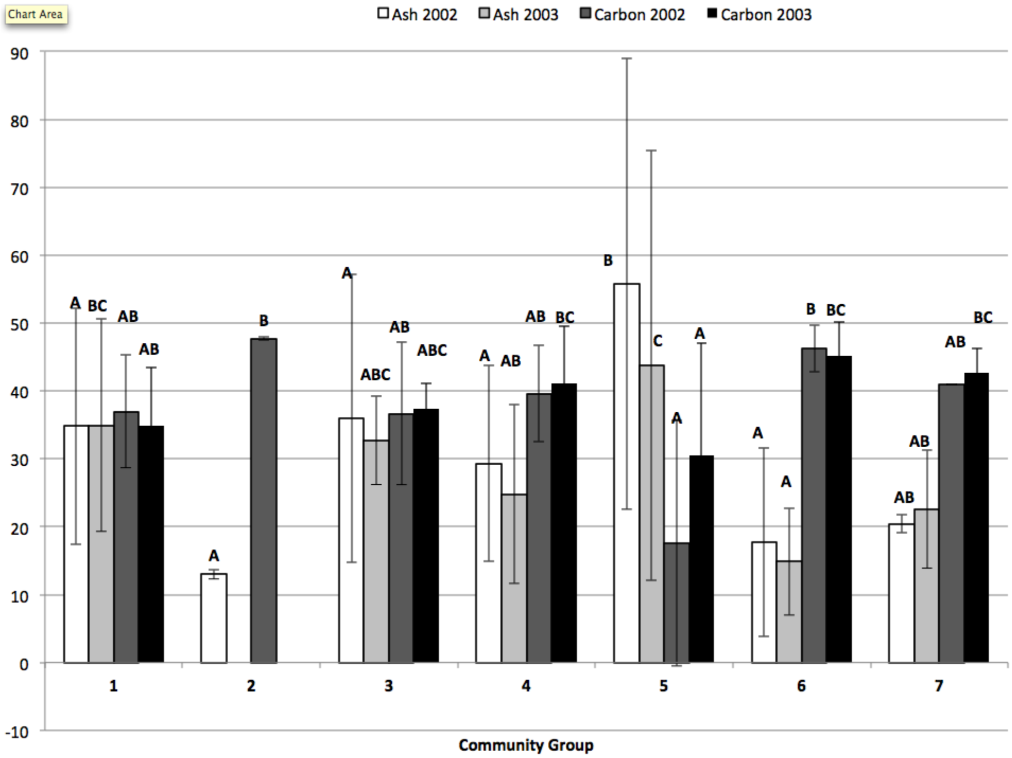

Figure 4. Mean percent ash and carbon in each TWINSPAN community with standard deviations. Letters indicate Tukey's or Fisher's grouping information.

Community Changes

With water level rise in 2003, contraction of shoreline occurred on 19% of transects, and the maximum number of communities became reduced from 4 to 3 (Fig. 5). On most transects (81%), the shoreline vegetation continue to expand towards the water. Uppermost communities expanded towards the water as well, often at the expense of lower elevation communities. In some cases the middle community was eliminated, in others it narrowed. Additional water level rise in 2005 had a more dramatic effect causing contraction of 60% of transects, with a complete flooding on one.

The most common community found at the water's edge in 2002 was Community 4 (*Drepanocladus* fen/marsh) and 3 (*Agrostis/Sagittaria*), at 56% and 25% respectively. In most cases, community changes in 2003 occurring pond-side involved changing to a higher number community, the most frequent from 4 to 5. Community 3 appears to be an early successional stage as this community disappears from most shorelines in 2003. Only 25% of the pond-side communities remained the same. On the upper elevation portion of the shore, less change occurred; 38% of transects had communities conversions to higher (drier) community types.

Along four transects lower numbered (wetter) communities appear between in the middle of drier communities. In three cases, Community 4 occurs between 2 sections of Community 5 in response to water table rise, and on one transect a Community 3 was present between community 6 and 4 at the start of the study.

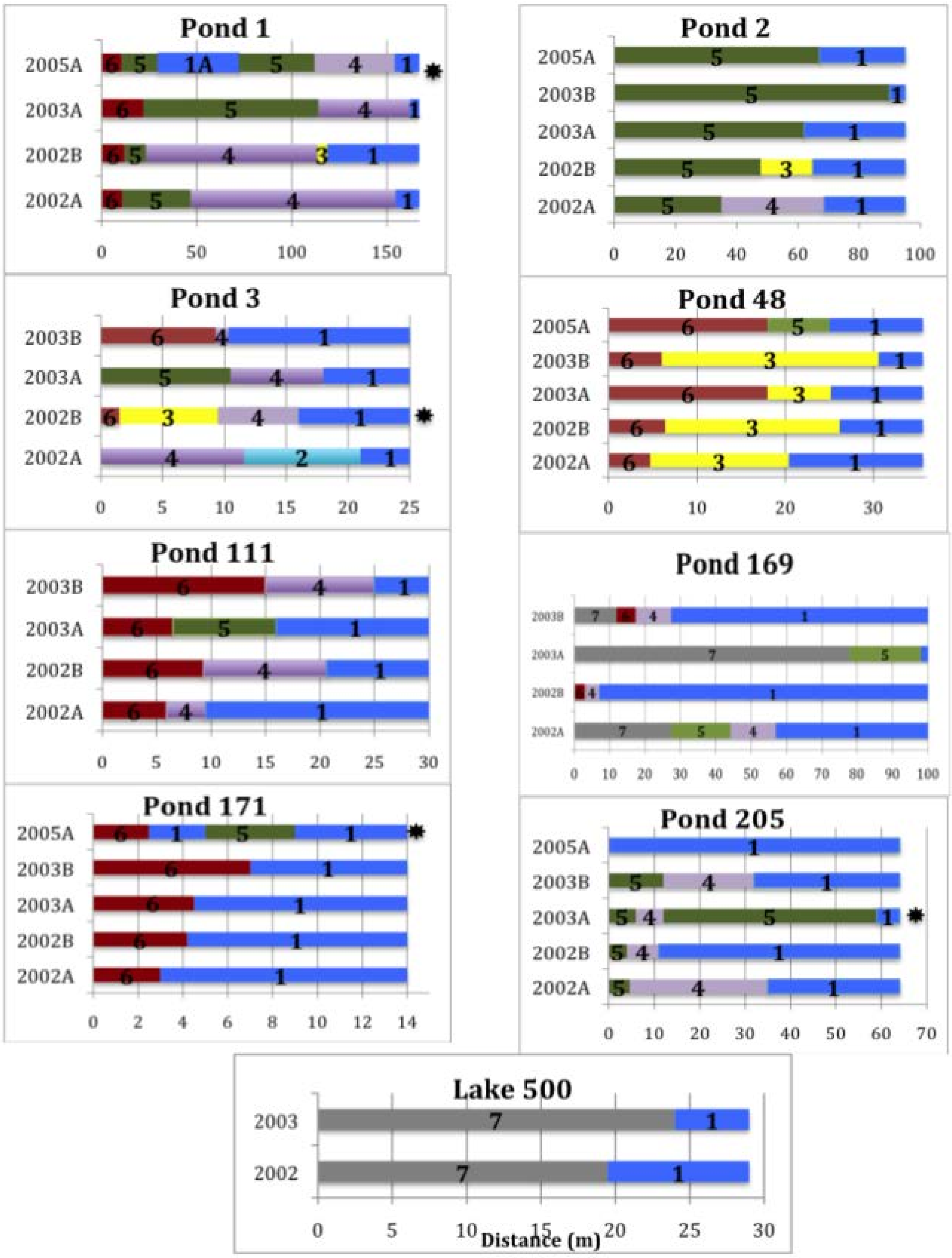

Figure 5. TWINSPAN community changes along the shores of each pond for the years 2002-2005. Distance along the shore (m) is the horizontal axis. Width of each bar is the length of the TWINSPAN community along the shore in a given year. Colors and numbers designate TWINSPAN community type. Asterisk denotes transects with a section of wetter vegetation in front of a floating mat.

DISCUSSION AND CONCLUSION

Precipitation cycles cause episodic drawdown in the small ponds that are surrounded by peatland complexes in the Boreal forest region of Alberta. Species and concentric zones that establish are similar to those found in prairie potholes, except here lower zones have a mixture of vascular plants and bryophytes, not quite fen vegetation, but not quite marsh either. Lockey *et al*. (2005) described similar vegetation in Boreal Manitoba wetlands. During drawdown this transitional zone is grounded and emergent species germinate between moss stems. When water levels return, this section of the shoreline floats or partially floats. The upper edge of the mat is however grounded, and becomes flooded when water levels rise. If water levels are high the entire shoreline becomes flooded and the shore returns to an open lake similar to prairie pothole wet/dry cycles. If water levels only partially rise, the grounded area upslope of the floating mat becomes effectively wetter and a wetter ring of vegetation ensues. Two conditions present at Utikuma Lake appear to favor floating mat vegetation. Organic substrates and plants with extensive fibrous roots such as *Eleocharis* (Holm *et al*. 2000, Sasser *et al*. 1996). Our fen/marsh (Community 4 and 5) contains *Eleocharis, Typha, Scirpus* and *Drepanocladus,* species that have the potential to contribute to the ability of these communities to float, and organic matter percentages in the range reported for floating mats by Holm et al. (2000). On wave washed shores suspended sediments tend to be deposited over the buoyant mats weighing them down (Holm *et al*. 2000). Thus floating marshes are more prevalent in low energy systems, like Utikuma Lake ponds.

Oscillations in water levels produced two unique features found on these shores. These two features are fen/marsh transitional vegetation that has a blend of species indicative of hydrological stability and instability, and wetter marsh and/or aquatic vegetation upslope of the floating section.

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