Aquatic Botany 126 (2015) 38–47

Contents lists available at ScienceDirect

Aquatic Botany

journal homepage: www.elsevier.com/locate/aquabot

Responses to water depth and clipping of twenty-three plant species in an Indian monsoonal wetland

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ARTICLE INFO

Article history:
Received 12 November 2014
Received in revised form 10 June 2015
Accepted 15 June 2015
Available online 25 June 2015

Keywords:
Cattle grazing
Floodplain wetland
Land use change
Protected area management
Seasonal drought
Supra-seasonal drought
Vegetation removal
Water level tolerance

ABSTRACT

Responses of species to disturbances give insights into how species might respond to future wetland changes. In this study, species of monsoonal wetlands belonging to various functional types (graminoid and non-graminoid emergents, submersed aquatic, floating-leaved aquatic) varied in their growth responses to water depth and harvesting. We tested the effects of water depth (moist soil and flooded) and clipping (unclipped and clipped) on the biomass and longevity of twenty-three dominant plant species of monsoonal wetlands in the Keoladeo National Park, India in a controlled experiment. With respect to total biomass and survival, six species responded positively to flooding and twelve species responded negatively to clipping. Responses to flooding and clipping, however, sometimes interacted. Individualistic responses of species to water levels and clipping regimes were apparent; species within a functional group did not always respond similarly. Therefore, detailed information on the individualistic responses of species may be needed to predict the vegetation composition of post-disturbance wetlands. In particular, as demands for fresh water increase around the world, studies of life history constraints and responses to hydrological changes will aid wetland managers in developing strategies to conserve biodiversity.

1. Introduction

Disturbances such as vegetation harvesting by farmers, grazing by domestic livestock, and seasonal water fluctuations play a major role in regulating plant species diversity in tropical seasonal wetlands (Osland et al., 2011). Thus, an understanding of the responses of wetland species to water regimes, and to harvesting/grazing can provide insights into the maintenance of biodiversity in monsoonal wetlands, which in recent years have been affected by both (Middleton, 1999a). In droughts, species can only survive if they can tolerate or exploit altered seasonal/inter-annual water level fluctuations and harvesting/grazing pressure (Bond et al., 2008). Severe supra-seasonal droughts can eliminate species lacking traits that allow them to survive prolonged drawdown (e.g., terrestrial forms or long-lived seed; Bond et al., 2008). At the same time, submersed species with high root growth rates may be able to recover quickly from such stresses, in contrast to species lacking these traits (Engelhardt, 2006). In particular, as wetlands become increasingly subjected to land-use and climate change (Bates et al., 2008), an understanding of how aquatic species respond to and cope with disturbances can help us better predict the impacts of these disturbances and even what will be required to restore these wetlands.

Species of monsoonal wetlands are well adapted to seasonal water level fluctuation, with certain species dominating during summer drawdowns and others after post-monsoon flooding (Finlayson, 2005; Hejný et al., 1998; Middleton, 1999a, 2009). Seasonal and long-term water level fluctuations help to maintain spatial and temporal heterogeneity of wetland zones (Květ et al., 1988; van der Valk et al., 2015), and thus the high biodiversity of many wetland types including arid Australian wetlands, prairie glacial marshes, and Indian monsoonal wetlands (Finlayson, 2005; van der Valk and Davis, 1978; Middleton, 1999a,b, respectively).

Despite their adaptations to disturbances, current levels of land-use change may be overwhelming Indian wetland species' abilities to persist, which could lead to permanent compositional changes in these wetlands. Along the Brahmaputra–Ganges–Meghna and Indus River in India, floodplain wetlands receive less water as

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http://dx.doi.org/10.1016/j.aquabot.2015.06.004

impoundments store water upstream for human usage. These activities may increase with climate change (Chauhan and Gopal, 2005), which has been linked to increased variability in monsoon precipitation, i.e., both longer droughts and larger floods (Mani et al., 2009). In addition, anthropogenic changes to river floodplains could alter their seasonal water-level fluctuations by impounding wetlands during the dry season, drying them during the wet season, or altering inter-annual patterns of drought (Bond et al., 2008). Virtually all of the original wetlands in this region have been lost due to conversion for agricultural and other development activities (Scott, 1993).

As predicted by the Intermediate disturbance hypothesis, moderate levels of grazing or cutting in wetland ecosystems can reduce the growth of dominant species and increase biodiversity by providing opportunities for sub-dominant species to grow (Middleton, 2013). Without some level of grazing or cutting, biodiversity may decline in many types of wetlands (Osland et al., 2011; Wesche et al., 2012; Middleton, 2013). For example, cutting of the above-ground portions of emergent species can cause a reduction in oxygen levels in the roots, an effect that is particularly pronounced in deep water, which can lead to the death of individuals of some species (Mathis and Middleton, 1999). Grazing and flooding together may affect the growth of individuals more than exposure to only one of these factors (Oesterheld and McNaughton, 1991). Reduced growth and mortality due to only cutting/grazing can occur in wetland species undergoing severe continuous grazing (Middleton et al., 1991), even though, terrestrial grassland species tend to tolerate moderate levels of grazing (Hickman et al., 2004). Drier conditions with accompanying lower water levels can result in overgrazing in semi-arid ecosystems (Fisher et al., 2004). The main underlying reason for survival after cutting may be whether or not cut individuals are able to reallocate resources from roots to shoots as based on the amount of stored carbon in the roots (Del-Val and Crawley, 2005).

The Keoladeo National Park has undergone a number of different water and grazing management strategies in past decades. Cattle grazing and harvesting of grasses were common in the Keoladeo National Park during the 1980s (Middleton et al., 1991), and in other wetlands in north-central India (Chauhan and Gopal, 2005; Middleton, 2013). Water discharge to the Keoladeo National Park (Fig. 1) has been decreasing since the early 1990s (Fig. 1) so that concerns have been raised about the drying of these wetlands (Sebastion, 2012). Nevertheless, a counter-trend has developed in recent years in Asia, so that wetland restoration programs have emerged, particularly to create wildlife corridors and recreational parks (Wang et al., 2013).

Many attempts have been made to group wetland species into various kinds of growth or life form groups (see Hutchinson, 1975, pp. 118–132), and to review classifications of wetland species by their morphological characteristics and functional groups (see Casanova and Brock, 2000 and Boutin and Keddy, 1993). Casanova and Brock (2000) classified wetland species based on their hydrological tolerances (submersed, amphibious fluctuations tolerators, amphibious fluctuations responders, etc.) while Boutin and Keddy (1993) recognized seven guilds (functionally similar species) based on their growth characteristics (e.g., ruderals, matrix species, interstitial). We have adopted a classification of the wetland macrophyte species of the Keoladeo National Park following Hutchinson (1975) and Rejmánková (2011) based primarily on their morphological characteristics. These macrophyte types include free-floating, floating-leaved, and emergents, with emergents further differentiated as creeping emergents, and erect emergents (graminoid and non-graminoid). As with other attempts to group species into functional types, it is assumed that all the species of a certain type will respond in a similar way to disturbances (Hutchinson, 1975; Casanova and Brock, 2000). If this were true, it would greatly simplify predicting the composition of post-disturbance vegetation.

The objective of this study was to determine if the responses of these wetland species to disturbances were consistent within their functional type. Specifically, we examined the responses of all the dominant wetland species in an Indian monsoonal wetland in the Keoladeo National Park, Rajasthan during the 1980s, to two different water (saturated soil and flooded) and clipping (unclipped and clipped) regimes. We hypothesized that the responses of the species in each functional type would be similar e.g., submersed species would die or have lower biomass when clipped under moist conditions.

2. Materials and methods

2.1. Study site description

Keoladeo National Park is a 29 km^2 monsoonal wetland complex of seasonally and temporarily flooded grassland and thorn woodland in the floodplain of the Gambhir and Banganga Rivers (27°13′N, 77°32′E; Fig. 1; Middleton et al., 1991). The climate is semi-arid and characterized by three seasons including a dry summer from March–June (mean maximum to minimum temperatures: 41–28 °C), monsoon from July–September, and winter from October–February with low temperatures above 0 °C (mean maximum to low minimum temperatures: 19–6 °C; Chauhan and Gopal, 2005). Before 1990, Park wetlands filled with water depending on the amount of monsoon rain and river water discharge (Fig. 2), stayed flooded to varying extents during the cool winter season, and then rapidly dried during the hot summer season (Middleton et al., 1991). Mean annual precipitation in this region is quite variable from year to year (Irrigation Department, Bharatpur, Rajasthan; Fig. 2), averaging about 69 cm $year^{-1}$; the majority of annual rainfall falls during the summer monsoon season (96% during June–September; Koteswaram, 1978). Rainfall may be less predictable in this region because of atmospheric warming in recent decades (Mani et al., 2009). Perhaps a more important factor in water supply for the Keoladeo National Park is that demands for water have been increasing in north-central India (Chauhan and Gopal, 2005), so that discharge into Park has been decreasing (Fig. 2).

Floating marsh characterized the deepest zones of the Park wetlands during the 1980s and included submersed species such as *Hydrilla verticillata*, floating-leaved species such as *Nymphoides cristatum* and grasses such as *Paspalum distichum*, all species with very low root biomasses (van der Valk et al., 1993). Shallower seasonally flooded zones were dominated by graminoids such as *Cynodon dactylon*, *P. distichum*, and *Scirpus tuberosus*. Drier grassland and woodland were dominated by *Acacia nilotica* and *Vetiveria zizanioides* (van der Valk et al., 1993). Although, water buffalo grazing stopped after the designation of the national park in 1981, feral cattle grazing and hand-cutting of vegetation were common after this time (Middleton et al., 1991).

In recent years, after a number of dry years following upstream diversion of river water and drought, the Park reflooded via precipitation in 2008. To restore seasonal winter flooding, water was diverted to the Park via the Govardhan drain pipeline in 2012, so that longer term seasonal flooding may become more common in the future (Sebastian, 2012).

2.2. Experimental design of water depth-clipping study

Twenty individuals of each species were established in October 1986 from root or rhizome cuttings in cylindrical clay pots (12 cm circumference by 25 cm depth) filled with clay soils from the wet-