Biotic and abiotic thresholds to recovery of degraded spring wetland communities

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Abstract

Human impacts have dramatically altered the structure and composition of many communities often resulting in new or novel states that are difficult (and potentially impossible) to reverse. New ecosystem states may be irreversible once biotic and abiotic thresholds have been crossed. Artesian spring wetlands are rare vegetation communities restricted to areas of natural discharge from the Great Artesian Basin, south eastern Australia. Human impacts on disturbance regimes and hydrology have dramatically altered the structure and ecosystem function of these wetland communities. We explore the recovery potential of these communities by examining biotic and abiotic constraints to restoration. Abiotic thresholds to restoring ecosystem function are loss of ground water discharge, excavation and soil salinisation. Biotic thresholds include introduced stock grazing and propagule supply. The soil seedbank of the springs was examined to determine propagule availability, species endemism, and proportion of introduced vascular plant species. We found the biotic structure of these communities constrained by limited propagule availability in the soil seedbank, with species richness relatively low in all spring wetlands and no evidence of an endemic flora. We examined the response of the plant communities to the total removal of grazing, and found recovery dependent on site

characteristics, water and pre-existing vegetative species. We have suggested a state-and-transition approach that considers these abiotic and biotic constraints to enable land managers to assess transitions and thresholds between the main spring states. Rehabilitation of these degraded vegetation communities may require active management, including return of discharge water, to overcome some hard-to-reverse thresholds.

Introduction

Artesian spring wetlands dependent on groundwater discharge from the Great Artesian Basin of south-eastern Australia have been a focal point of human and animal activity in the rangelands for many thousands of years (Robins 1998). Human derived impacts (abiotic and biotic constraints) since European colonisation of the rangelands (some 150 years) have been documented to have delirious affects on the many endemic and relic flora and fauna species of the springs (Fensham and Fairfax 2003; Harris 1981; Noble *et al.* 1998; Pickard 1992). These observations suggests that the ecosystem functions that sustains spring attributes, including endemism and their capacity to act as refuge habitats, have been modified in many spring-groups on the rangelands of south eastern Australia. Degradation of these vegetation communities will continue without some form of active management with clear restoration objectives.

There has been increased urgency to preserve springs of high endemism and significance (Fensham *et al.* 2010), but few guidelines are available for the rehabilitation or management of low productivity springs in relatively degraded floristic condition. Springs that have suffered greater levels of degradation and human induced change may have already passed thresholds that prevent their natural linear recovery to a climax community over time. Thus threshold models has become increasingly applicable to land managers attempting to recovery human induced ecosystems elsewhere in the world (Suding and Hobbs 2009). We assess the drivers and biotic and abiotic constraints of artesian spring wetlands recovery in western NSW and south western Qld. We describe altered spring states that can develop among artesian spring wetland communities and predict the feedbacks (i.e. thresholds) that prevent the transitions to productive and biologically significant artesian spring communities.

Biotic and abiotic constraints in degraded artesian spring wetlands

Abiotic constraints

Human induced changes to artesian discharge and destruction of spring wetlands (excavation) negatively impact spring succession and species composition. For example, aquifer drawdown (abiotic impacts) since the early 1900s has resulted in the extinction of 53% of spring-groups, with a further 25% of the active spring-groups excavated in north western NSW and south western Queensland (Pickard 1992; Hamish A.R. Caddy, unpublished). Similarly in Queensland only 36% of the original spring-groups have at least some springs that are still active, and of these active spring-groups 26% have been excavated (Fensham and Fairfax 2003). Such rapid reductions in spring flow and habitat condition lead to a loss of moisture specific traits. These variations in vegetation composition have implications for the recovery of these vegetation communities as it provides a considerable threshold.

Propagule availability

The absence of plant propagules (i.e. seeds and other reproductive material) is a negative feedback that can prevent favourable transitions toward a climax state (Westoby *et al.* 1989). The soil seedbank and extant vegetation of degraded springs of western NSW and south western Queensland consist only of common flora similar to an overgrazed terrestrial plant community (Pickard 1992; Hamish A.R. Caddy, unpublished). Thus for most aquatic species and spring endemics a lack of propagule availability is likely to constrain artesian spring vegetation community succession after prolonged exposure to negative biotic or abiotic feedbacks (i.e. overgrazing or aquifer drawdown respectively).

Grazing and invasive species

As time since human induced change increases time and intensity of floristic degradation increases and spring productivity declines, we predict constraints on the abundance and diversity of artesian spring flora are determined by their response to grazing and interaction with invasive species, as has been found in other natural ecosystems (Lunt *et al.* 2007). The dynamic nature of the spring ecosystems has resulted in conflicting observations of the biotic responses of spring wetlands following prolonged exposure to grazing and invasive flora (Fatchen 2001; Fensham *et al.* 2004; Kovac and Mackay 2009). Where grazing has been removed from some South Australian spring wetlands weed invasion, mainly from

Phragmites australis, has threatened spring activity and displaced endemic species including Salt Pipewort *Eriocaulon carsonii* (Davies 2005; Fatchen 2001). Fensham *et al*. (2004) reported grazing exclusion may have resulted in an increased spring wetland area and supported associated successional change to a structurally diverse endemically species rich wetland matrix in western Queensland. Our own work on degraded (active and extinct) springs of western NSW and south western Queensland have shown an improvement in the herbage mass production, but no significant changes in species richness or weed infestation potential after that short-term grazing exclusion (2 years), in a season of average rainfall. Vegetation responses of artesian spring wetlands to grazing exclusion appears to vary among spring groups and types, with predictions regarding their response to grazing exclusion needing to be made on a case by case basis.

Alternative spring states

There are five spring states in our suggested model that when combined with the previously described drivers and constraints will enable land managers to assess the transitions and thresholds to spring recovery. First, the undegraded spring states (Fig. 1, Fig. 2 (a)) these are spring-complexes with unique endemic species (state 1a) as listed by Fensham *et al*. (2010) and state 1b that contains endemic and relict species known to occur at other locations, state examples in NSW include Peery Springs. The second state refers to springs-complexes that form habitat for isolated relic flora and flora species not known from habitat other than spring wetlands within 250 km (Fig. 1). The third state contains springs without identified biological values (Fig. 1, Fig. 2 (b)). The fourth state includes active but highly degraded springs including those that are completely excavated (Fig. 1, Fig. 2 (c) and (d)). Finally the fifth spring state is inactive or extinct springs, including naturally extinct springs and inactivity resulting from aquifer drawdown and floristic degradation from exposure to introduced herbivore grazing and trampling (Fig. 1, Fig. 2 (e) and (f)).

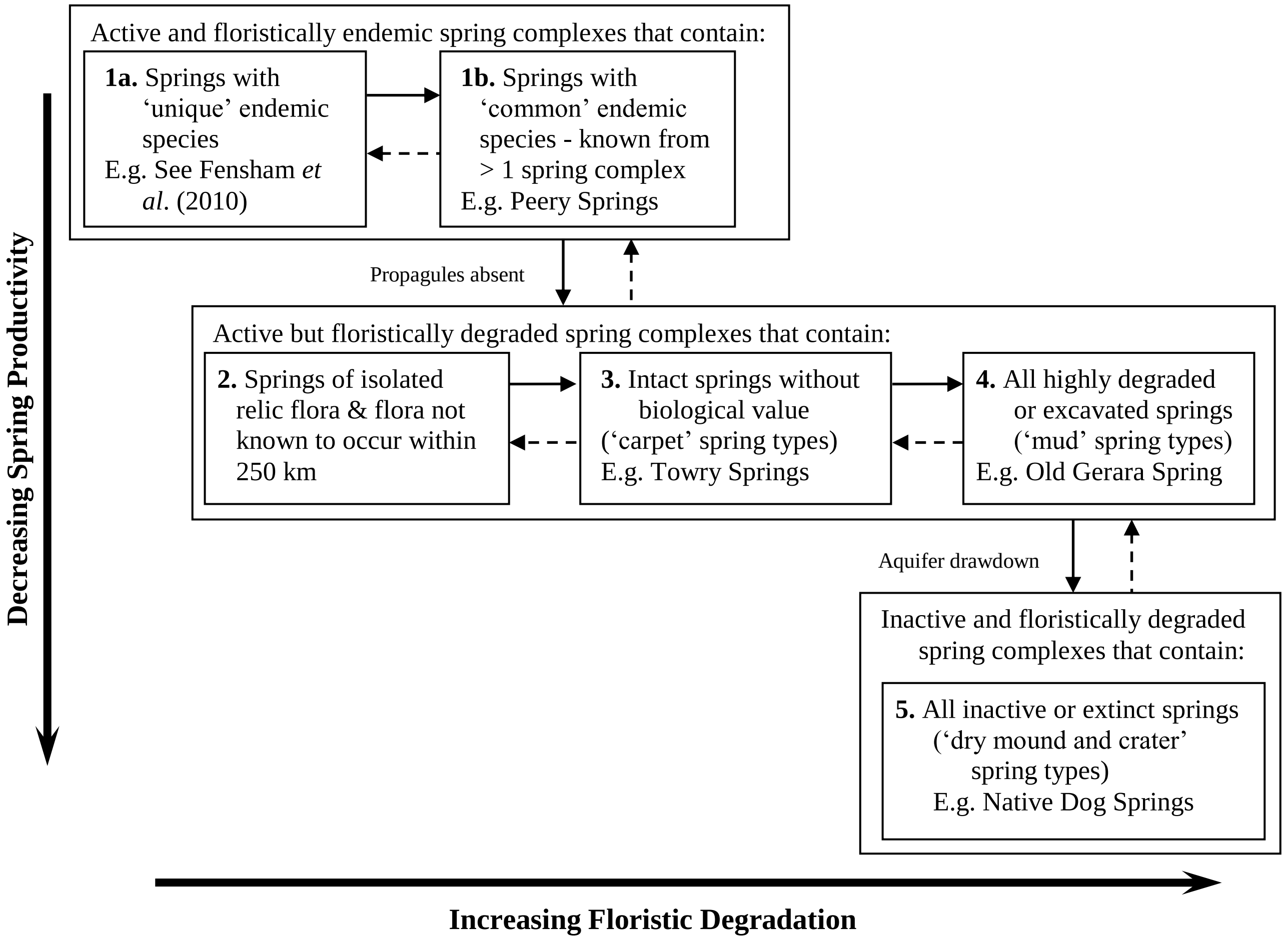

Fig. 1. State-and-transition model for community change in artesian spring wetlands dependent on discharge from the Great Artesian Basin depicted along axis of spring productivity and floristic degradation. Boxes representing spring states are maintained by balancing feedbacks. States align with conservation categories proposed by Fensham *et al.* (2010). Spring type descriptions (in parentheses) refer to the different morphological spring types identified by this study to occur in western NSW and south-western Qld. Transitions towards more degraded states are indicated by the solid lines, favourable transitions indicated by dashed arrows represent hypothesised recovery transitions prevented by a threshold (including, absence of propagules and aquifer drawdown).

Fig. 2. Examples of the artesian spring states included in our model from western NSW and south-western Qld: (**a**) Late succession 'old' Peery Springs vent with spring endemic Salt Pipewort *Eriocaulon carsonii* (state 1b; photo by H.A.R. Caddy); (**b**) Towry Springs, Culgoa Floodplain National Park Qld, no endemic or relic species present (state includes, 'pooling vent' or 'carpet' type springs) (state 3; photo by H.A.R. Caddy); (**c**) Mother Nosey Spring, NSW, highly degraded springs no vegetation on spring vent ('mud' springs type) (state 4; photo by H.A.R. Caddy); (**d**) Excavated spring state, Old Gerera Spring Ledknapper Nature Reserve NSW (state 4, photo by H.A.R. Caddy) (**e**) Collapsed inactive or extinct 'crater' type springs are common in western NSW and souoth-western Qld (state 5; photo by H.A.R. Caddy); (**f**) Inactive or extinct 'dry mound' type spring at Tharnowanni Spring-group, NSW (state 5; photo by H.A.R. Caddy).

Conclusions

Our findings demonstrate that multiple constraints could be addressed on active spring wetlands by exclusion of introduced herbivores and where appropriate addition of native seed. Our research will assist land managers prioritise springs for rehabilitation, set realistic and achievable restoration goals, to identify constraints to recovery and how to best prioritise and address hard-to-reverse thresholds.

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