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Four desert waters: Setting arid zone wetland conservation priorities through understanding patterns of endemism

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ABSTRACT

Long-lasting surface water in arid-lands provide oases for aquatic biota, but their values as biological refugia have rarely been assessed. This study identified and mapped permanent natural wetlands across the Eastern Lake Eyre Basin in Australia and classified them into four types: riverine waterholes, rockholes, discharge springs and outcrop springs. Waterholes are the most widespread and numerous source of lasting water, while springs and rockholes are confined to relatively discrete clusters. The characteristics of each wetland type are summarised, and their biological values compared by examining various scales of endemism for vascular plant, fish and mollusc species. Discharge springs contain an exceptional concentration of endemic species across all three lifeforms at a range of scales. Waterholes are critical drought refugia for native fish species that also utilise a vast network of ephemeral streams during and after floods. Rockholes and outcrop springs do not contain any known specialised endemics, although the latter have disjunct populations of some plants and fish. The existing knowledge of antiquity, connectivity and habitat differentiation of the wetland types is compiled and their role in determining biological endemism is discussed. Exotic fish are a major conservation issue, the recovery of the discharge springs should be paramount, and the intact network of permanent waterholes should be preserved. A focus on endemism, combined with an understanding of the biogeographical processes underlying the observed patterns provides an effective and systematic approach to setting priorities for regional biodiversity conservation.

1. Introduction

The sharp contrast of permanent surface waters with the surrounding environment in arid-lands engenders assumptions about their biological importance. Desert wetlands encompass a range of hydrochemical, hydrophysical and morphological characteristics (Williams, 1999) that create many different habitat types for aquatic organisms. Biological diversity and endemism of wetlands has been assessed on a global scale (Junk, 2006; Abell et al., 2008; Balian et al., 2008) and regional studies have focused on single wetland types (Sorrie, 1994; Pinder et al., 2000; Fensham and Fairfax, 2003; Timms, 2007; Strong et al., 2008) or taxonomic groups (Simovich, 1998; Kingsford et al., 1999; Ponder and Walker, 2003; Arthington et al., 2005; Balcombe et al., 2006; Brock et al., 2006; Ponder and Slatyer, 2007). These studies reveal that some desert wetlands exhibit local endemism, but more typically they support species with broad ranges, including fish across entire catchments and many plants with cosmopolitan distributions. With good quality survey data, biological diversity can be analysed in relation to habitat specialisation and endemism can be circumscribed, allowing for a rigorous assessment of the conservation significance of the various wetland habitats (Keddy and Sharp, 1994; Fensham and Price, 2004; Horwitz et al., 2009). Focussing conservation efforts on hotspots of biological endemism is judicious because these species often have small populations, are vulnerable to extinction (Gaston, 1998) and represents the efficient accumulation of species for reserve planning (Lamoreux et al., 2006).

Conservation priorities will be better informed by an understanding of ecosystem processes and biogeographic history. In general, wetlands tend to have low levels of endemism, because severe fluctuations in water levels during the Pleistocene and Holocene favour plants and animals that are mobile or readily dispersed (Junk, 2006; Horwitz et al., 2009). In particular, species occupying ephemeral wetlands must have dispersal capabilities and generally exhibit little genetic structure (Marten et al., 2006; Abellan et al., 2009). However,

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wetlands that have persisted through glacial periods of aridity provide habitat for relictual species that were more widespread in wetter times (De Deckker, 1986; Davis et al., 1993; Horwitz et al., 2009; Murphy et al., 2010). For example, artesian springs fed by the Great Artesian Basin have many endemics (e.g., Ponder, 2003; Fensham et al., 2010) and wetlands within sandstone formations in northern Australia harbour a relatively high number of endemic amphibians and reptiles that live in ancient, permanent wetlands (Finlayson et al., 2006).

The physical and chemical conditions presented by some wetland habitats are also important for promoting differentiation of organisms and ultimately speciation (King et al., 1996; Hopper et al., 1997; Simovich, 1998; Ponder and Colgan, 2002). For example the endemic flora of vernal pools in California is associated with the physical and chemical nature of different pool types (Holland and Jain, 1981). Isolation is another factor that begets genetic divergence and allopatric speciation (Moritz et al., 2000; Krosch et al., 2009). Rivers act as conduits allowing for the dispersal of aquatic species between wetlands within catchments and isolation between catchments. As such, freshwater fish assemblages are typically characterised by low levels of endemism within catchments (Burridge et al., 2008; Nogueira et al., 2010).

The eastern Lake Eyre Basin of Australia is a vast area with renowned wetland values, a range of wetland types and difficult conservation challenges (Morton et al., 1995; Kingsford et al., 1999; Fensham and Fairfax, 2003; Ponder, 2003; Reid, 2010). This paper describes a classification scheme and compiles comprehensive mapping of all permanent natural surface waters for that region. The biological endemism of each wetland type is then explored and compared, using the distribution of vascular plants, fish and molluscs. These groups were chosen because they exhibit endemism (unlike other vertebrates) and there taxonomy is adequate (unlike other invertebrates). Patterns of endemism are discussed in relation to the antiquity, habitat differentiation and isolation of the wetland habitats. The implications for conservation and wetland management in the Australian arid zone are presented. Given limited conservation resources, a focus on endemism provides an effective and systematic approach to setting priorities for regional biodiversity conservation.

2. Methods

2.1. Study area

The Eastern Lake Eyre Basin covers an area of 679,000 km^2, or approximately one-seventh of the Australian continent, and comprises the catchments of the Georgina and Diamantina Rivers and Cooper Creek (Fig. 1). The climate is semi-arid to arid, with average annual rainfall ranging from 500 mm in the northern and eastern headwater regions to 120 mm in the southwest (McMahon et al., 2008). These rivers are characterised by low gradients, wide floodplains, large transmission losses, limited base-flows and are probably the most variable in the world (Puckridge et al., 1998). In their mid and lower catchments, they spread out to form extensive braided river channels and floodplains. The surrounding matrix of grassland, stony plains, low ranges and open shrublands (Tyler et al., 1990; Sattler and Williams, 1999) are used for extensive grazing (predominantly cattle), with relatively small areas of mining leases and conservation reserves.

2.2. Mapping and classifying permanent natural wetlands

Wetlands were mapped using a combination of satellite imagery, which identified long-lasting waters from a time-series of Landsat scenes (Wainwright et al., 2002; Environmental Protection Agency, 2005), historical sources (Fensham and Fairfax, 2003) and interviews with 170 long-term land managers using annotated maps to guide discussions (Silcock, 2009). All wetlands containing water for more than 70% of the time were included in a spatial database, but the permanent wetlands are the focus of this paper. Permanence is defined as never having been without free water during European pastoral settlement, as ascertained through the oral and written record. Information about the permanence of large waterbodies has usually been passed down through successive land managers, so records typically begin around 1870–1880. The classification of wetland types is regionally specific, based on geomorphology and hydrology (Semeniuk and Semeniuk, 1995; Kingsford et al., 2004).

2.3. Assessing biological values

The most complete surveys for the permanent wetlands in the study area are for vascular plants, fish and molluscs. For some wetland types surveys of these groups have been comprehensive and there is also substantial information in Herbaria and Museum databases (Table 1). Only native species that are dependent on surface water for all or nearly all of their life-cycle within the study area were included in the analysis. Waterbirds have been well studied, but were excluded because they move large distances between wetlands so are not intimately dependent upon permanent waters (Kingsford and Norman, 2002; Roshier et al., 2002). Plants such as *Eremochloa bimaculata*, which are restricted to permanent water in the study area but occur in other habitat outside the arid zone were included in the analysis. Undescribed species were included where a taxonomic expert regards the taxa as a species, but subspecies were excluded.

Endemism only has meaning in a geographic context (Anderson, 1994) and the term is applied here at a range of scales for each wetland type. Each species was given a 'geographic endemism' score, ranging from 1 to 5 depending on meaningful scales for the particular wetland type (Table 2). Sites were ranked according to their concentration of narrow endemics (category 5, Table 2).

3. Results

3.1. Overview of classification

Permanent natural wetlands in the ELEB are classified into four types: riverine waterholes, rockholes, outcrop springs and discharge springs (Fig. 2). None of the lakes in the study area are permanent. There are 260 permanent waterholes across the ELEB (200 in the Cooper catchment, 38 in the Diamantina and 22 in the Georgina), 18 rockholes, 52 outcrop spring complexes and 24 active discharge spring complexes. Many of the wetlands have been subject to modification. Most of the wetlands are subject to disturbance by domestic or feral grazing animals. Some of the springs (both outcrop and discharge) have been excavated to the extent that the extinction of local populations has probably occurred. Many of the discharge springs have been deactivated with reduced groundwater pressure (see below). There are also artificial (human constructed) permanent water sources including aboriginal wells, bore-drains and large dams. Some of these have conservation values (Noble et al., 1998), including occasionally providing habitat for endemic species (Appendix A) associated with discharge springs, but they are not considered further in this paper.

3.2. Waterholes

Waterholes are enlarged segments of an ephemeral or seasonal watercourse which hold water after stream-flow has ceased