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An ecological network is as good as a major protected area for conserving dragonflies

James S. Pryke [a,*], Michael J. Samways [a], Kathleen De Saedeleer [a,b]

[a] Department of Conservation Ecology and Entomology, Stellenbosch University, P/Bag X1, Matieland 7602, South Africa
[b] L'Ecole de Biologie, Université Catholique de Louvain, Louvain-la-Neuve, Belgium

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ABSTRACT

Freshwaters are highly threatened ecosystems, with agro-forestry being a major threat to sub-tropical wetlands. In the Maputaland–Pondoland–Albany global biodiversity hotspot of South Africa, large-scale ecological networks (ENs) of remnant vegetation have been set aside with the aim of mitigating the adverse effects of plantation forestry. However, the effectiveness of these ENs for maintaining freshwater biodiversity, especially that of still waters, is poorly known. In response, we compare mud wallows of large mammals, ponds and small marshes in an EN with those in an adjacent World Heritage Site protected area (PA) as reference. For this comparison we used dragonfly adults in view of their effectiveness as bioindicators. A total of 47 species was recorded at 105 sites. The EN shared 74% of its species with the PA. However, equal numbers of range restricted species were recorded from the EN and the PA. Five species were recorded as particular to the EN and seven to the PA, probably due to habitat heterogeneity across this type of landscape. Pond size, habitat heterogeneity, elevation and dissolved oxygen were important determinants for species richness and diversity. Proximity of plantation trees had only a minor effect, and then only on species composition. Mud wallows were the poorest habitat in terms of dragonfly diversity, owing to the intense disturbance. Wallows, ponds and marshes were largely complementary in their species composition. Overall, the freshwater system in the EN was a good surrogate for that in the PA, indicating the effectiveness of these ENs for maintaining the dragonfly assemblage.

1. Introduction

Freshwaters have seen high loss in biodiversity, mostly through intensive human activity (Geist, 2011; Holland et al., 2012; Strayer and Dudgeon, 2010). Threats to freshwater biodiversity include loss and degradation of habitat, pollution, overexploitation, invasion by alien species, water extraction, flow regulation and global warming (Amis et al., 2009; Brinson and Malvarez, 2002; Ott, 2010; Samways and Taylor, 2004). In sub-tropical wetlands, habitat modification, storage and abstraction of water for agriculture and forestry are major threats to freshwater integrity (Cubbage et al., 2010; Dye, 2012; Junk, 2002).

In the relatively wet, eastern region of South Africa is the globally important Maputaland–Pondoland–Albany Hotspot (Mittermeier et al., 2004), which is rich in biodiversity yet coincides with one of the main timber production areas of the country. Protected areas (PAs) are important for conserving the endemic and threatened biota of the region, as well as for protection of ecosystem services such as the supply and improved quality of freshwater. On the other hand, the demand for wood continues to rise globally, with plantation forestry responding to that demand (Cubbage et al., 2010). This means that a balance between timber production on the one hand, and preservation of wetlands on the other, needs to be found (Brinson and Malvarez, 2002; Vörösmarty et al., 2010). A solution to realizing this balance has been the development of large-scale ecological networks (ENs) (Samways et al., 2010). These are interconnected set-aside corridors of remnant indigenous vegetation that connect high value conservation areas, and have become increasingly important in biodiversity conservation and ecosystem management (Jongman et al., 2004).

ENs are a major component of the Maputaland–Pondoland–Albany hotspot timber areas, amounting to roughly a third of the overall landscape, with the aim of mitigating the adverse effects of plantation compartments on local biodiversity and ecosystem processes. ENs are designed and managed to supply suitable habitats for organisms and to encourage their movement within the production landscape (Bazelet and Samways, 2011) based on principles of maintaining habitat heterogeneity and rare species (Pryke and Samways, 2015), as well as for maintaining ecological integrity and resilience. ENs also improve connectivity between PAs (Opdam et al., 2006) and extend the effectiveness of PAs (Pryke and Samways, 2012a, 2012b). However, when considering ENs as a tool for conservation, we need evidence of their efficacy and efficiency for maintaining biodiversity (Boitani et al., 2007).

* Corresponding author.
E-mail address: jpryke@sun.ac.za (J.S. Pryke).

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Since it is not possible to monitor the whole ecological community, adequate ecological indicators, representative of the structure, function, and composition of ecological systems are needed. These are required even if the relationship between potential indicator species and total biodiversity is still not well established owing to the complexity of ecological systems (Dale and Beyeler, 2001). Dragonflies are good ecological indicators for wetland and river quality assessment, as they are well known taxonomically and easier to identify than many other taxa, especially in the case of the adults (Chovanec et al., 2014; Kutcher and Bried, 2014; Oertli et al., 2005; Simaika and Samways, 2010). Although the sampling of exuviae is the only way to determine that the water body has allowed the breeding success of a dragonfly species (Raebel et al., 2010), in an African context, sampling of dragonfly adults has many advantages over the sampling of the earlier life stages (Bried et al., 2012a). Dragonfly species assemblages are also large enough for complex compositional assessments, and often comprise generalist as well as specialist species, the latter being important indicators of change (Simaika and Samways, 2009a). Here we use "dragonfly" for the whole order Odonata, unless otherwise specifically stated. They respond strongly to changes in water body conditions, especially vegetation structure (de Paiva Silva et al., 2010; Samways and Sharratt, 2010).

Amis et al. (2009) commented that biodiversity conservation measures are most efficient where both the freshwater and terrestrial priority zones overlap. Therefore, the whole dragonfly assemblage is useful for providing an indication of the quality of freshwaters and their adjacent terrestrial habitats (Declerck et al., 2006) and they are also useful for selecting new areas for protection (Simaika and Samways, 2009b) and identifying important landscape characteristics (Raebel et al., 2012a).

Although ENs have been implemented to offset afforestation, there is little information on whether the freshwater fauna is benefitting from this large-scale intervention. Kietzka et al. (2015) showed that conserving a variety of ecological gradients, i.e. high habitat heterogeneity, leads to increased species richness. Yet we still do not know how well ENs conserve dragonfly diversity compared to the natural standard of a PA. ENs are also a way to address the challenge articulated by Biggs et al. (2005) that we need to find ways to establish long-lasting improvements for establishing networks of conservation ponds. As dragonflies are good indicators of freshwater condition, this study hypothesizes that dragonfly diversity and assemblage structure are the same in the EN (within the agro-forestry mosaic) as in an adjacent reference area, a major PA (iSimangaliso Wetland Park, Zululand, South Africa). We focus on ponds and small marshes, as they were commonly present in both the PA reference area and in the EN, and are important water bodies contributing to local and regional biodiversity (Briers and Biggs, 2005; Davies et al., 2008a,2008b; Kadoya et al., 2004; Raebel et al., 2012a).

2. Sites and methods

2.1. Sites

This study was conducted in the KwaZulu-Natal Province, South Africa (28°18′S, 32°24′E) (Fig. 1). A total of 105 lentic freshwater sites were sampled, of which 47 were in the EN (part of SiyaQhubeka New Generation Plantation) between *Eucalyptus* spp. plantation compartments (Fig. 1). A further 58 sites were sampled inside iSimangaliso Wetland Park, a major PA and a World Heritage Site. The iSimangaliso park is a 332 000 ha park that stretches from the town of St Lucia to the Mozambique border (Hart et al., 2014). Sampling here was restricted to the Western Shores section of the park in a ca. 30 km belt that runs between a commercial forestry areas and the protected area (Fig. 1). There was no fence between the PA and EN, which allowed indigenous large mammals to roam between the two. This area is a flat coastal landscape with many ponds and wetlands but few streams. The few lotic areas in this landscape are in the protected area and are dominated by wooded vegetation (Hart et al., 2014). Freshwater areas studied here were 1) mud wallows created by the large mammals (particularly African elephant, white rhinoceros and African buffalo) (Fig. 2(i), (ii)), 2) ponds (Fig. 2 (iii)), and 3) marshes (Fig. 2 (iv)). However, in reality, these three divisions were a spectrum with 'mud wallows' being ponds with little vegetation, 'ponds' being those water bodies with a distinct open water zone (Oertli et al., 2005) and well-vegetated margin, and 'small marshes' being water bodies with a complete cover of emergent macrophytes/floating vegetation. All water bodies that could be located were sampled, with the greatest distance between any two sites was 27 km and the closest distance was ca. 30 m.

2.2. Dragonfly sampling

EN sampling days were alternated with PA sampling days to avoid temporal bias. Adult dragonfly sampling took place during the rainy season, when daily temperatures and water availability were at their highest. However, dragonflies were sampled only on sunny days between 14–26 February 2013, from 07 h30 to 15 h30. Unaided visual sampling is 100% accurate for Anisoptera and 80% accurate for Zygoptera when sampling species presence and abundance (Moore, 1991). It is even more accurate for Zygoptera when using close focus binoculars (Samways and Sharratt, 2010), as we did here.

This was a species presence/absence study comparing dragonfly species composition of EN and PAs at the height of the unimodal subtropical flight season. To achieve this EN/PA comparison expediently without invoking changing conditions, the aim was to cover as many sites as possible at the height of the flying season i.e. an emphasis on spatial replication. This means that we only sampled each site once. This was done by two observers recording all adult dragonfly individuals encountered along a >20-m linear transect (each observer out and back = 80 m in total) around the margin of a wallow or a pond, or across a marsh. Species of doubtful identity were captured for later identification. Sampling was considered complete once a 10-min period had elapsed when either observer had not encountered any new species (Moore, 1991). The total average time spent recording per site was 47 min, which has previously been shown to be adequate for recording species presence in this region (Kietzka et al., 2015) and more than the 20–40 min recommended by Bried et al. (2012b).

At ponds in South Africa, dragonfly species do not appear to have assembly rules i.e. species assemble based on habitat characteristics rather than which species are already present (Osborn and Samways, 1996). Sampling continued until a near asymptote of total species richness was reached at 105 sampling sites. A total of 47 species were recorded with Chao2 estimate of 56.7 (+/− 10.27) species and Jackknife2 estimate of 58.86 species.

2.3. Environmental variables

For each site, the following continuous environmental variables (EVs) were measured: water temperature, dissolved oxygen and conductivity with an YSI 556 MPS instrument. Cloud percentage coverage was estimated, time of day recorded, and the distance of each site from the nearest plantation compartment edge was measured using QGIS 2.0 (QGIS Development Team, 2015). Categorical EVs were: whether the water body was in an EN or PA, the water body type (pond (a discrete water body with open water in the centre and a fringe of emergent vegetation) vs marsh (a wetland of continuous emergent vegetation) vs mud wallow (a muddy pool where large mammals had recently wallowed)), and water body size (>20 m diameter was considered large, <20 m diameter was considered small).

Sala et al. (2004) and Carchini et al. (2007) were used as guidelines for measuring the vegetation component of the sites. However, as the various water bodies were not necessarily distinct from each other, and as the area was prone to grazing, trampling and wallowing by large mammals, the categories had to be adapted to local conditions