Ecological Indicators 93 (2018) 358–364

Contents lists available at ScienceDirect

Ecological Indicators

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

Original Articles

Principles of cross congruence do not apply in naturally disturbed dune slack habitats: Implications for conservation monitoring

Aoife Delaney*, Jane C. Stout

School of Natural Sciences, Trinity College Dublin, Ireland

ARTICLE INFO

Keywords:
Cross-congruence
Indicator species
Dune slacks
Invertebrates
Snails
Water beetles
Plants
Conservation
Assessment

ABSTRACT

Cross congruence, where diversity or composition of multiple species follow similar patterns, underlies the use of indicator species in conservation practice. However, there are circumstances in which cross congruence has been shown to break down, for example after disturbance events. If cross congruence does not occur in habitats which experience natural disturbance, then conservation measures based on indicator species may yield misleading results. We assessed the degree of cross congruence among three biological taxa in dune slacks, which are temporary ponds found in coastal sand dunes. We also investigated the efficacy of a national monitoring assessment based on a single taxonomic group, plants, to predict the diversity and composition of two other taxonomic groups: snails and water beetles. We found no evidence of cross congruence among these three groups and the plant-based monitoring system did not predict the composition or diversity of snails or water beetles. The potential for dune slacks to support species of conservation interest was demonstrated here as eight snail species and two water beetle species listed as Near threatened or Vulnerable on the Irish Red Lists were found within the 24 sites surveyed, and the Irish populations of two of these are of international significance (*Vertigo angustior*, *Leiostyla anglica*). Some of these species of conservation interest were found in dune slacks which were of poor conservation status according to the monitoring methodology applied. Our results show that indicator species drawn from a single taxonomic group are not adequate to monitor the general habitat condition of dune slacks. Dune slacks are among many habitats of conservation interest which experience natural disturbance, and this research has implications for conservation practice in other habitats such as seasonal wetlands and fire-dependent habitats.

1. Introduction

Global biodiversity decline has been associated with reductions in ecosystem productivity (Liang et al., 2016) and consequent ecosystem service provision (Cardinale et al., 2012), across many different habitat types. Identifying, preserving and restoring habitats of conservation interest have been recognised as means to slow biodiversity loss. These activities require knowledge of the status of organisms using the habitat, but resource constraints rarely allow exhaustive studies of all the living things within systems of interest (Heino, 2010). Using a small number of surrogate or indicator species to infer the conservation status or biological diversity of a habitat or area has been suggested as an achievable alternative (Lambeck, 1997; Landres et al., 1988; Hillard et al., 2017; Cheyne et al., 2016).

Using species as indicators or surrogates in this way assumes cross-congruence, where the diversity or composition of many taxa are linked, so that changes to the diversity or composition of the broader biological community can be determined by surveying the indicator species alone (Westgate et al., 2017; LIndenmayer et al., 2014; Hunter et al., 2016). Cross congruence has been shown to occur in nature and is very influential in conservation planning and policy (Gioria et al., 2010; Howard et al., 1998b; Lund and Rahbek, 2002; Wolters et al., 2006). However, there is a growing body of published data which indicates that relationships between diversity of different taxa are variable (Westgate et al., 2014). For example, taxa which are very strongly associated with a particular habitat type are likely to be more congruent than generalist species (Prendergast, 1997), but in highly heterogeneous habitats, cross congruence may be inflated due to species turnover between habitats, regardless of their conservation value (Ekroos et al., 2013). Therefore species are most effective as indicators of habitat conditions or diversity if they are used within a specific, homogeneous habitat. In addition, habitat scale can affect the strength of cross congruence (Hess et al., 2006), but this can be mitigated by using taxa with small body-sizes in habitats characterised by small patches (Wolters et al., 2006). Disturbance is an important factor (Heino, 2010), as was demonstrated in a survey of Canadian wetlands

* Corresponding author at: Botany Building, School of Natural Sciences, Trinity College Dublin, Dublin 2, Ireland.
E-mail address: amdelane@tcd.ie (A. Delaney).

https://doi.org/10.1016/j.ecolind.2018.04.075
Received 10 November 2017; Received in revised form 8 April 2018; Accepted 27 April 2018

where weak cross-congruence was associated with historical human disturbance, and individual species varied in their response to stress gradients (Rooney and Bayley, 2012).

Despite the observed variability in the strength and occurrence of cross congruence, biological indicators and surrogate species are embedded in conservation policies all over the world (US EPA, 2002; "Fauna Wetland Indicator Species List" 2018; Ramsar Convention Secretariat, 2010), including international conservation policies such as the European Union (EU) Habitats Directive (Council Directive 92/43/EEC). The ultimate aim of the Habitats Directive is that all of the habitats and species of conservation interest achieve favourable conservation status (Evans and Arvela, 2011). Conservation status is assessed under four parameters: range, area, structure and functions and future prospects. The use of positive and negative indicator species is central to the habitat structure and functions assessment. The characteristic species listed in guidance documents are predominantly plants, and this appears to have had a strong influence on the choice of indicator species among signatory states, although the authors encourage the inclusion on non-plant species in the structure and functions assessment (European Topic Centre On Biological Diversity). Clearly since this principle is being applied for monitoring of high-level conservation objectives, its efficacy should be assessed, particularly in habitats which experience frequent natural disturbance.

Thus in this study, we specifically addressed two key questions:

1) is cross congruence maintained in habitats of conservation interest where natural disturbance occurs?
2) in a habitat which experiences natural disturbances, do indicator species provide reliable information regarding diversity and habitat use by the wider community of organisms?

We sought to answer these questions by comparing the composition and diversity of taxa with contrasting biological and habitat requirements in dune slacks, a habitat which experiences natural disturbance. We applied the EU Habitats Directive habitat monitoring guidelines for Irish dune slacks (Delaney et al., 2013) to assess dune slacks in Ireland and tested the ability of this assessment to discriminate between dune slacks on the basis of two invertebrate groups: water beetles and snails.

1.1. Study system and target taxa

Dune slacks are damp depressions in sand dune systems ranging in size from a few square metres to several hectares. They arise from areas of low-lying bare sand such as former beaches or erosion features within larger sand dune systems. Unlike the dry dunes that surround them, the water table in dune slacks is close to the surface and it typically exceeds the slack floor when groundwater rises in late winter (Davy et al., 2006). Although dune slacks are dynamic and experience succession over their lifetime (Bossuyt et al., 2003; Smith, 2006), extreme habitat heterogeneity is rare within an individual dune slack at a single point in time unless there is a history of different management regimes or disturbance patterns within the slack (Adema et al., 2002). The clear delimitation between dune slacks and dry dune habitats and their relative lack of human disturbance correspond with the conditions in which strong cross congruence might be expected. Conversely, annual flooding and desiccation events act as natural disturbances and the presence of a dry phase and an aquatic phase means that the habitat experiences temporal heterogeneity. This natural disturbance could result in a breakdown of cross congruence despite the relatively low human impacts on most dune slacks.

The conservation value of dune slack habitats has been recognised under the EU Habitats Directive and they are designated as 2190 Humid dune slacks (Council Directive 92/43/EEC). They are recognised as being important refuges for some animal species and the inclusion of animal indicator species in the structure and functions assessment is encouraged (Evans and Arvela, 2011). Within the Atlantic biogeographical region of the EU, the typical species listed for Ireland (Delaney et al., 2013), the UK (Joint Nature Conservation Committee, 2004), France and Portugal do not contain any animal species (European Topic Centre on Biological Diversity), while Germany, the Netherlands and Belgium have included some bird species or the natterjack toad in their dune slack habitat assessments (European Topic Centre on Biological Diversity) but typical species for Denmark are not available.

The three taxa chosen for this study were plants (vascular plants and bryophytes), snails and water beetles. Both of the invertebrate taxonomic groups represent a subset of species within large phyla which share specific characteristics; snails (class Gastropoda, phylum Mollusca) have a shell into which their body can retract (Cameron, 2008) and water beetles (Order Coleoptera, Class Insecta, Phylum Arthropoda) live underwater for part of their lifecycle and so are likely to be caught in sweep-net samples (Foster et al., 2014). Vascular plants and bryophytes are currently used to assess habitat condition in dune slacks in accordance with the EU Habitats Directive in all of the signatory states. Water beetles and snails were chosen because they have small body size, because they are well described and can be identified to species, and because they are diverse groups which are sensitive to environmental changes (Bilton et al., 2006). Both have been demonstrated to exhibit cross-taxon congruence in ponds (Bilton et al., 2006; Gioria et al., 2010) and they are commonly found in temporary waterbodies in Britain and Ireland (Nicolet et al., 2004; Reynolds, 1985). However, because of differences in dispersal and lifecycles, water beetles and snails are likely to differ in their responses to flooding and desiccation. Although records suggest that dune slacks represent an important refuge for aquatic species due to the loss of inland wetland habitats (Cameron, 2008; Foster et al., 2014; Foster and Friday, 2011; Davidson, 2014), comprehensive surveys of aquatic invertebrates in dune slacks have not been carried out on a large scale in Europe or elsewhere. There is therefore no list of the aquatic invertebrates associated with good habitat condition in dune slacks.

2. Methods

2.1. Site selection

We used pre-existing habitat maps (Delaney et al., 2013; Ryle et al., 2009) to select twenty-four dune slacks across the Republic of Ireland (Fig. 1). They were evenly distributed among the regions containing the greatest concentration of dune slacks in Ireland: counties Donegal, Mayo, Kerry, and the east coast from Dublin to Wexford. Selected slacks conformed to a similar range in area from small (0.2–0.29 ha) to large (6–8 ha) within each region. This research focussed on calcareous dune slacks with predominantly herbaceous vegetation and a shallow water table which were located inside EU Natura 2000 Special Areas of Conservation (SACs). Slacks with permanent water bodies, acidic conditions or very sparse vegetation were not included. We did not include any slacks where human interference in the substrate such as sand or sod removal was known to have occurred. These exclusion criteria ensured that the most common dune slack types in Ireland were available for selection while variability in the history, anthropogenic disturbance and fundamental abiotic conditions affecting the slacks was limited. We selected only one slack from any sand dune system to ensure that all sites were independent.

2.2. Vegetation survey

We recorded vegetation in $2\,m \times 2\,m$ quadrats from June to September 2015. Sampling intensity was deemed adequate when the number of new vascular plant species recorded in each new quadrat was equal to one or zero, resulting in 3–9 quadrats per site. We recorded plant species cover in percent digitally in the field using *Turboveg for Windows 2.120* (Hennekens and Schaminée, 2001) and