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Adult Odonata conservatism as an indicator of freshwater wetland condition

Thomas E. Kutcher[a,*], Jason T. Bried[b]

[a] Rhode Island Natural History Survey, University of Rhode Island, 200 Ranger Hall, Kingston, RI 02881, USA
[b] Department of Zoology, Oklahoma State University, 501 Life Sciences West, Stillwater, OK 74078, USA

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ABSTRACT

There is a growing need to identify effective and efficient biological indicators for wetland assessment, and adult damselflies and dragonflies (Insecta: Odonata) possess several attributes that make them attractive for this application. We introduce a general indicator of freshwater wetland condition based on objectively estimated adult Odonata species conservatism, or sensitivity to human disturbances. We used an extensive opportunistic survey dataset from Rhode Island (USA) to empirically assign a coefficient of conservatism (CoC) to each of 135 Odonata species, based on their exclusivity to categories of degradation among 510 wetlands; the mean CoC of species observed in the adult stage was applied as an index of wetland integrity. An independent sample of 51 wetlands was also drawn from the opportunistic survey to test the performance of the index relative to human disturbance, as measured by multimetric rapid assessment and surrounding impervious surface area. The index was well predicted by both disturbance measures and showed no evidence of dependence on sampling effort, wetland size, or geomorphic class. Our findings suggest that conservatism of adult Odonata averaged across species may provide a robust indicator of freshwater wetland condition. And because adult Odonata are generally easy to identify, especially relative to larval Odonata, the index could be particularly useful for wetland assessment. Our straightforward empirical approach to CoC estimation could be applied to other existing spatially referenced Odonata datasets or to other species assemblages.

1. Introduction

Biological indicators (or bioindicators) can provide reliable, quantitative characterizations of ecological condition, and there is a growing need to identify effective bioindicators for use in wetlands management and protection (Sifneos et al., 2010; U.S. EPA, 2002). Macroinvertebrates have long been recognized as useful bioindicators for aquatic and wetland ecosystems (Hilsenhoff, 1977; Karr and Chu, 1999; Rader et al., 2001; Wissinger, 1999), but the impracticalities of collecting, sorting, and identifying aquatic stages limit their use in rapid assessments (Cummins and Merritt, 2001; King and Richardson, 2002; Turner and Trexler, 1997). It is therefore worthwhile to evaluate taxa and life stages that are both ecologically important and logistically feasible for bioassessment. Aerial stages of aquatic macroinvertebrates are important for species dispersal and the transfer of energy across aquatic and upland systems and among trophic levels (Malmqvist, 2002; Sanzone et al., 2003), and are more sensitive than the aquatic stages to land use practices around wetlands (Anderson and Vondracek, 1999; Raebel et al., 2012; Tangen et al., 2003).

Dragonflies and damselflies (Odonata) are prominent in many freshwater habitats and may contribute a large proportion of total invertebrate biomass and species richness (e.g., Batzer et al., 1999; Blois-Heulin et al., 1990; Rader et al., 2001; Sang and Teder, 2011; Wittwer et al., 2010). Odonates are sensitive to conditions at the breeding site and surrounding terrestrial area, can react quickly to changes in environmental quality via active dispersal, and contain a tractable number of species for practical use (Chovanec and Waringer, 2001; Oertli, 2008). Adult odonates are conspicuous over water and relatively easy to identify at the species level (Bried et al., 2012a; Oertli, 2008; Raebel et al., 2010), and may be especially well suited for broad and integrative assessments of the wetland breeding site and surrounding landscape (Bried and Ervin, 2006; Dolný et al., 2012; Foote and Hornung, 2005; Foster and Soluk, 2006; Reece and McIntyre, 2009). Adult odonates are therefore well-suited for rapid assessment methods (Fennessy et al., 2007) and addressing the increased focus on wetland quality and not just quantity in the United States (Scozzafava et al., 2011).

Odonata are already established as focal organisms for freshwater conservation (Samways, 2008) and as good indicators of site value and habitat quality for ponds, lakes, rivers, and streams (Butler and deMaynadier, 2008; Chovanec et al., 2002; D'Amico

* Corresponding author. Current address: Department of Natural Resources Science, University of Rhode Island, Coastal Institute, Kingston, RI 02881, USA. Tel.: +1 401 536 4352.
E-mail address: tomkutcher@my.uri.edu (T.E. Kutcher).

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et al., 2004; Flenner and Sahlén, 2008; Primack et al., 2000; Raebel et al., 2012; Remsburg and Turner, 2009; Rosset et al., 2013; Silva et al., 2010). Bioassessment tools based on adult Odonata have been developed and tested in Europe and South Africa. Chovanec and Waringer (2001) combined species-specific abundance classes, niche width, and habitat preference into an Odonata Habitat Index meant to classify the ecological status of river-floodplain systems in Austria. Simaika and Samways (2009) combined species' geographical range, risk of extinction, and sensitivity to habitat change into a Dragonfly Biotic Index that has been effective for assessing river condition in South Africa (Simaika and Samways, 2011) and the conservation value of ponds and small lakes in Europe and South Africa (Rosset et al., 2013). These approaches show potential for assessing wetland condition, but they have not been tested in that capacity, specifically.

A reliable attribute in the biological assessment of environmental condition is species *conservatism*, referring to the relative sensitivity (vulnerability) of different species to habitat degradation (Cohen et al., 2004; Lopez and Fennessy, 2002; Miller and Wardrop, 2006). Conservatism is commonly associated with floristic quality assessment, wherein a coefficient of conservatism (CoC) ranging from 0 to 10 is assigned to vascular plant species, based on the expert opinion of a team of botanists. High CoC are given to species that are relatively sensitive to habitat degradation, whereas low CoC are assigned to species that are non-native or highly tolerant. The collective conservatism of a species assemblage should, in theory, reflect the ecological condition of a given area (Swink and Wilhelm, 1979; Taft et al., 1997). In the United States, interest in developing and applying CoC for the assessment of wetland condition is rapidly growing (Bried et al., 2012b); yet to date, conservatism has been applied almost exclusively in the context of floristic quality (e.g., Bried et al., 2013; Cohen et al., 2004; Cretini et al., 2012; Ervin et al., 2006; Lopez and Fennessy, 2002; Medley and Scozzafava, 2009; Matthews et al., 2005; Miller and Wardrop, 2006; but see Micacchion, 2004).

In this study we apply the conservatism concept to adult Odonata. We use an extensive opportunistic survey dataset to introduce an objective, empirical method of assigning CoC based on species occurrence and exclusivity to categories of wetland degradation. We then aggregate the CoC into an index of freshwater wetland condition, and evaluate index performance using independent odonate data and metrics of human disturbance.

2. Materials and methods

2.1. Data

We conducted our study in Rhode Island located in the northeastern United States. We relied on data from the Rhode Island Odonata Atlas Project (hereafter "Atlas") for this study. The Atlas was conducted from 1999 through 2004 as a statewide inventory of adult Odonata administered by the Rhode Island Natural History Survey and the Rhode Island Chapter of The Nature Conservancy (Brown and Briggs, 2013). Professionals and trained volunteers cataloged 135 Odonata species throughout Rhode Island, collecting ∼13,000 verified voucher specimens across 1090 aquatic, wetland, and upland sites. As with other citizen-based statewide Odonata inventory projects (e.g., White et al., 2010) or any opportunistic atlas-type surveys (Robertson et al., 2010), sampling effort was not standardized over time or space.

2.2. Generation of CoC and the wetland integrity index

Assignment of CoC using expert judgment relies on specific knowledge of species distributions relative to the degradation of their habitats. Subjectivity and bias are introduced by the limitations of experience, a focus on geographic or habitat range, perception of habitat degradation, and interpretation of the CoC designations (Bried et al., 2012b). To avoid these problems, we generated Odonata CoC empirically, using georeferenced point records from the Atlas and a Geographic Information System (GIS).

We assigned the CoC based on species' occurrences among freshwater wetlands. To account for dataset spatial inaccuracies and increase the likelihood that sampling points were associated specifically with wetlands, only points that occurred within or near (<50 m) previously mapped wetlands were considered. Points associated with unvegetated surface waters or uplands were excluded from analysis. Qualified points were assumed to be representative wetlands, and were sorted by the proportion of developed and agricultural land within 300 m. Points in the lower quartile were selected as least-disturbed wetlands, points in the upper quartile as most-disturbed wetlands, and an equal number of points surrounding the median as intermediately disturbed wetlands; this resulted in a training sample of 510.

Following the indicator species analysis proposed by Dufrene and Legendre (1997), a CoC was determined for each species by:

$$\frac{(N_{\mathrm{LD}}/N)+(1-N_{\mathrm{MD}}/N)}{2}\times 10$$

where N_{LD} is the number of least-disturbed wetlands in which a given species was detected, N_{MD} is the number of most-disturbed wetlands where that species was detected, and N is the total number of wetlands (including intermediately disturbed sites) where that species was detected. This approach averages the "affinity" for least-disturbed wetlands and the inverse affinity for most-disturbed wetlands, multiplying by 10 to scale the output to the traditional CoC scale of floristic quality assessment. Thus the CoC range from 0 if a species occurs exclusively in the most-disturbed group to 10 if a species occurs exclusively in the least-disturbed group. In line with recommendations for floristic quality assessment (e.g., Bried et al., 2013; Rooney and Rogers, 2002; Taft et al., 2006), we recommend the mean CoC of all species found at a particular wetland site as an Odonata Index of Wetland Integrity (OIWI).

2.3. Index performance

To evaluate the OIWI, we used a sample of Atlas wetlands that was independent of the training sample described above. Prior to extracting the training sample, we isolated wetland features that were surveyed at least three times and produced at least 10 specimens over the Atlas project period. From that subset, we selected 51 study sites spanning a gradient of surrounding land use intensity. We used photointerpretation of recent leaf-off, high-resolution aerial imagery to delineate a polygonal wetland assessment unit for each study site according to Kutcher (2011). Wetland assessment units ranged in size from 0.12 to 36 ha with an average of 5.3 ha. Many (43) of the units contained multiple vegetation classes. The most frequently represented vegetation classes (per Cowardin et al., 1979) within the study sample were Emergent Wetland (40 sites), Forested Wetland (37 sites), and Shrub Swamp (36 sites), and the most common hydrogeomorphic settings (modified from Brinson, 1993) were Connected Depression (16 sites), Isolated Depression (16 sites), and Floodplain-riverine (16 sites).

We tested the OIWI against the Rhode Island Rapid Assessment Method, or RIRAM (Kutcher, 2011), which follows federal guidelines for establishing reference conditions for wetlands (Faber-Langendoen et al., 2009; U.S. EPA, 2002). This evidence-based tool produces a relative index of freshwater wetland condition and focuses on estimation, rather than interpretation, to maximize objectivity. RIRAM scoring is based on the premise that diverse human disturbances additively contribute to the degradation of general wetland condition (Fennessy et al., 2007;