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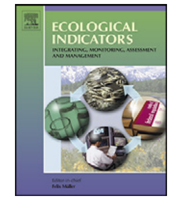

Using Auchenorrhyncha (Insecta: Hemiptera) to develop a new insect index in measuring North American tallgrass prairie quality

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A B S T R A C T

Auchenorrhyncha (i.e., leafhoppers, treehoppers, spittlebugs, and planthoppers) represent some of the most diverse groups of herbivorous insects in the tallgrass prairie biome, they have close associations with many native prairie grasses and forbs, and respond in predictable ways to changes in native grassland degradation. These attributes make Auchenorrhyncha ideal candidates in the development of a habitat quality index to measure tallgrass prairie quality. In this study we propose the development of a species-based habitat quality index called the Auchenorrhyncha quality index or AQI as a useful method in tracking the condition of tallgrass prairie quality. The AQI is computed by summing six ecological characteristics (i.e., host plant specificity, voltinism, overwintering microhabitat, wing length, habitat fidelity, and origin) for each Auchenorrhynchan insect encountered, yielding coefficient of conservatism (CC) values that range from 0 (habitat generalist/tolerant to disturbance) to 18 (habitat specific/intolerant to disturbance). These CC values are averaged and combined with species richness producing un-weighted by abundance AQI ($AQI_{w/outN}$) and weighted by abundance AQI ($AQI_{w/N}$). The performance of the AQI was evaluated by examining the effects of sampling intensity on this index using a sweep net and a vacuum apparatus from 10 sites located on the three main North American tallgrass prairie communities, wet-mesic, sand, and loess hill. Scientists and land managers can adequately sample Auchenorrhyncha from four transects using a vacuum. Also, the highest AQI values were found from loess hill and sand prairies, indicating that conservation efforts should focus on these prairie communities. Additional applications of the AQI may include: (1) discriminating prairie quality at various spatial scales; (2) testing hypotheses about the effects of disturbance on prairie habitat (e.g. prescribed burning); (3) using the AQI as a model in developing habitat quality indices based on other diverse groups of grassland insects; and (4) the AQI has the capacity to be readily modified in assessing the quality of other biomes. Ultimately, the AQI should be used in combination with other habitat quality indices based on other diverse groups of organisms, such as plants and other insects, to provide a more complete assessment of native habitat quality.

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1. Introduction

The tallgrass prairie is the most endangered ecosystem in North America (Robertson et al., 1995, 1997). Of this once vast type of grassland, only 3–5% remains, most of which is highly fragmented and restricted to nature preserves, parks, and along railroad right-of-way (Whiles and Charlton, 2006). Vegetative data has been used almost exclusively in measuring changes in quality and management success of the remaining habitat patches of this dwindling ecosystem (Higgens et al., 2001; Taft et al., 2006). However, recent evidence (Harper et al., 2000; Panzer et al., 1995; Swengel and Swengel, 2007) indicates that some groups of prairie arthropods respond to management differently than plants. Thus, vegetation-based measures of habitat quality (e.g., species richness, Shannon Wiener index, floristic quality index) may not be able to detect negative impacts for either management or other degrading factors on arthropods.

Terrestrial arthropods are the most diverse group of organisms in the tallgrass prairie and play crucial roles in ecosystem function, such as pollination, nutrient cycling, and energy flow (Whiles and Charlton, 2006). Many of these species are restricted to a few remnant prairie communities (Hamilton, 1995a; Panzer et al., 1995; Reed, 1996, unpublished report). Yet, despite their contribution to the maintenance of ecosystem quality and their affinity to native prairie remnants, only a few studies have used arthropods to track changes in native grassland quality over time and space (Hamilton, 1995a; Harper et al., 2000; Nickel and Hildebrandt, 2003; Panzer, 2002). This dearth in literature may be attributed to the lack of

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ecological information or life history of arthropods that are associated with environmental disturbance (duration, frequency, intensity) and/or stress (habitat favorability) (Novotny, 1995). Some evidence has also indicated that populations of some arthropod species fluctuate dramatically from year to year in response to short term changes in climate (e.g., rainfall, temperatures, humidity, etc.) and this makes it difficult to distinguish management response from natural fluctuations in populations (Waloff, 1980). Another factor that has hindered the selection of terrestrial arthropods as bioindicators is the availability of taxonomists (Majer et al., 2007). Ultimately, which arthropod taxa are the most practical, inexpensive to handle, and the most suitable for measuring prairie quality must be chosen with care (Nickel and Hildebrandt, 2003).

The following criteria may be useful in selecting indicator taxa: (1) groups need to be selected that are diverse in both species and individuals so as to comprise a significant component of biodiversity, allowing them to be easily sampled for quantitative studies; (2) they should be treated thoroughly in the taxonomic literature to allow for rapid identification by both professionals and non-professionals; and (3) they should include conservative (i.e., habitat specific and intolerant to degradation) and non-conservative (i.e., habitat generalist and tolerant to degradation) species, allowing for a more accurate assessment of prairie quality. Conservative species are needed because they may reflect the original condition of the prairie. Including non-conservative (i.e., adventives and generalist species) species is also important because they are a source and response of habitat degradation (Bourdaghs et al., 2006), and thus their inclusion will reduce the chance of generating inflated assessments of prairie quality. One group of arthropods that meets these criteria is Auchenorrhyncha, phytophagous (plant feeding) insects in the order Hemiptera. Auchenorrhyncha include planthoppers (Fulgoroidea), treehoppers (Membracidae), spittlebugs (Cercopoidea), and cicadas (Cicadoidea), with the majority of these species being leafhoppers (Cicadellidae [Hamilton, 2005]).

Auchenorrhyncha are ideal candidates in indicating the condition of grassland quality because they represent some of the most numerically dominant herbivorous organisms in grasslands making them an important resource in grassland food webs for invertebrate and vertebrate predators and parasitoids, such as parasitic Hymenoptera, ground beetles, and small birds (Biedermann et al., 2005; Curry, 1994; Hamilton, 1995a; Nickel, 2003; Nickel and Hildebrandt, 2003; Waloff, 1980; Waloff and Jervis, 1987). As primary consumers, they can damage plant tissue through oviposition and transmit plant pathogens, and thus can potentially influence plant species composition (see also Brown, 1985; Nickel and Hildebrandt, 2003). These insects represent a significant component of the North American prairie biota, with over 1100 species associated with native grasses, sedges, and forbs (Breakey, 1928; Doering, 1940, 1941; Kopp and Yonke, 1970; Hamilton, 1995a, 1999, 2005; Hamilton and Whitcomb, 2010) and more than half of these are endemic to prairies (Hamilton and Whitcomb, 1993; Wilson et al., 1993). Also, these taxa are economically and logistically feasible to survey, being sampled simultaneously in large numbers with only a few visits throughout the growing season (Nickel and Hildebrandt, 2003; Stewart, 2002) using active sampling techniques such as a suction sampler (Stewart, 2002; Wilson et al., 1993). Lastly, their taxonomy is well-known in North America, with keys based on easily identifiable features of the external morphology in most instances (DeLong, 1948), and non-taxonomists can be trained in their identification.

One of the most prominent advantages in using Auchenorrhyncha as bioindicators of grassland quality is their well documented life history traits or ecological characteristics, such as host plant affinity, voltinism, wing length, diapause or overwintering microhabitat preference, and geographic range (Brown and Southwood, 1983; Brown, 1985; Denno and Perfect, 1994; Hamilton and Whitcomb, 2010; Nickel, 2003; Novotny, 1991, 1994a,b, 1995). These traits span a wide range of conservatism to grasslands and respond in predictable ways to habitat degradation. For example, Whitcomb et al. (1986, 1987, 1988) observed that polyphagous Auchenorrhyncha feeding on ruderal plants consistently occur in early successional stages of grasslands and in highly disturbed prairie habitat whereas monophagous Auchenorrhyncha that feed on native perennial plants (e.g., grasses and sedges) are consistently found in undisturbed grasslands (Brown, 1985; Denno and Perfect, 1994).

Given this information key life history traits (see Table 1) can then be combined to provide an objective measure of the expected conservatism of a particular species. The conservatism scores for individual Auchenorrhynchan species occurring on a particular site can be summed or averaged, providing an overall measure of habitat quality, because higher quality, less biologically degraded prairies of higher conservation value are expected to harbor a higher proportion of conservative species. This measure can be

Table 1
Six key Auchenorrhyncha life history traits (i.e. ecological characteristics) that were used in calculating coefficient of conservatism values. References are provided for each of these traits.

Life history strategies
Voltinism:
Auchenorrhyncha with two (bivoltine) three (trivoltine) or more (polyvoltine) generations are found in recently disturbed habitats [e.g. agriculture and fallow fields (Nickel, 2003; Novotny, 1995)]
Auchenorrhyncha with one (univoltine) generation are dominant in undisturbed habitats (Nickel, 2003; Novotny, 1994b, 1995)
Origin
Auchenorrhynchan species that are geographically restricted to a few areas (endemic) occur in undisturbed grassland habitat (Hamilton, 1995a,b, 1997, 2004; Hamilton and Whitcomb, 2010)
Grassland Auchenorrhyncha that are found over a wide geographical range tend to be found in degraded grasslands. (Novotny, 1994a,b, 1995)
Overwintering microhabitat (Hamilton and Whitcomb, 2010; Nickel, 2003; Whitcomb et al., 1987)]:
Highly migratory species, often overwintering in fallow fields and other non-native grassland ecosystems
Species overwintering in ruderal plant species, are often native, but are more common in early successional stages of grassland ecosystems
Species that overwinter in the soil or dead vegetation
Species that conduct their entire life cycle in native grassland communities
Wing-Length:
Auchenorrhyncha with long-wings (macropterous) are dominant when host plant quality begins to deteriorate (Denno et al., 1990, 1991; Denno and Roderick, 1990; Roff, 1986, 1990)
Auchenorrhyncha with short-winged (brachypterous and submacropterous) often occur in habitats, where host plant quality is not deteriorating and long-lasting (Nickel, 2003)
Habitat fidelity:
Auchenorrhynchan specialists tend to be restricted to one or few native grassland communities, such as alvars (Bouchard et al., 2001; Hamilton, 1995a,b; Hamilton and Whitcomb, 2010).
Auchenorrhyncha fauna that are well-adapted to frequently disturbed or degraded grassland communities tend to be habitat generalists (Hamilton, 1995a,b; Panzer et al., 1997)
Host-plant specificity:
Leafhoppers feeding on ruderal plants are polyphagous, occurring in early successional stages of grasslands (Whitcomb et al., 1986, 1987, 1988)
Monophagous Auchenorrhyncha feed on perennial plants (e.g., grasses and sedges), commonly found in undisturbed grasslands (Brown, 1985; Denno and Perfect, 1994; Hamilton and Whitcomb, 2010; Whitcomb et al., 1988)