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Snail (Mollusca: Gastropoda) assemblages as indicators of ecological condition in freshwater wetlands of Northeastern China

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ABSTRACT

The utility of aquatic macroinvertebrates as indicators of the ecological conditions has long been established in rivers and streams. However, useful invertebrate indicators of wetland conditions remain more poorly developed probably because wetland macroinvertebrates have many attributes that reduce their ability to reflect wetland environmental quality. Snails, however, possess several attributes that should make them useful as potential environmental indicators. In this study, we sampled snail assemblages in 16 wetlands across a range of conditions, from relatively pristine "best available" reference sites to obviously human-impacted sites in Northeastern China's Sanjiang Plain. We aimed to investigate the utility of snail taxa for indicating environmental variation across these wetland habitats. Results showed that study wetlands divided into three major groups using multivariate analyses: the five wetlands provided the most protection and having the least impacts grouped as apparent "references", and ten other wetlands in obviously developed areas separated into two other groups of wetlands. Overall snail abundance was higher in the reference wetlands than the impacted wetlands. Seven of the snail species were indicators of specific wetland types. Five pulmonate species including *Segmentina nitida*, *Segmentina hemisphaerula*, and *Planorbis corneus*, *Aplexa hypnorum* (Physidae), and *Galba pervia* (Lymnaeidae) were indicators of reference wetlands. Non-pulmonate *Bithynia ussuriensis* (Bithyniidae) and *Valvata sibirica* (Valvatidae) were indicators of one of the categories of impacted wetlands. In NE China, snail assemblages and certain indicator species may provide a robust and rapid indicator of environmental impacts on wetlands. Because snails are distributed widely and are generally easy to sample and identify, this overall approach should have applicability in the many wetlands worldwide where diverse snail assemblages naturally occur.

1. Introduction

Developing scientific tools to assess the condition of wetlands and determine the efficacy of conservation or restoration efforts is an important area of research (Weilhoefer, 2011; Deimeke et al., 2013). Biomonitoring is often used to evaluate environmental conditions, monitor ecological trends, provide early warning signs of environmental change and human disturbance, diagnose causes of change, and direct management activities (Brooks et al., 2007; Weilhoefer, 2011; Rooney and Bayley, 2012). Plants (Bried et al., 2013; Deimeke et al., 2013), birds (e.g., DeLuca et al., 2004 Smith-Cartwright and Chow-Fraser, 2011), amphibians (e.g., Stapanian et al., 2015), and aquatic macroinvertebrates (e.g., Boix and Batzer 2016) have all been used as biotic indicators in wetlands. Weilhoefer (2011) reviewed the indicators of estuarine tidal wetland condition, and found that biotic metrics comprised the majority of indicators (81% of all indicators), with macroinvertebrate metrics comprising 28% of all biotic indictors.

Among freshwater ecosystems, the utility of aquatic macroinvertebrates as indicators of the ecological conditions has been particularly well established for streams and rivers (e.g., Rosenberg et al., 2008; Southerland et al., 2008). Given that success, workers have attempted to extrapolate the approach to freshwater wetland environments, regrettably with very limited success. While macroinvertebrates in wetlands share some of the attributes that make macroinvertebrates in streams/rivers useful (e.g. ubiquity,

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sedentary nature, moderately long life cycles, environmental sensitivity; see Rosenberg and Resh, 1993), wetland macroinvertebrates have many other attributes that reduce their ability to reflect environmental quality (e.g. strong responses to weather and seasonality, frequent dispersal into and out of habitats, a lack of adequate taxonomic keys for many groups; Rosenberg et al., 2008). Insects in the orders Ephemeroptera, Plecoptera, and Trichoptera (collectively the EPT taxa) are considered particularly useful in stream/river bioassessment because so many of these taxa are environmentally sensitive (Rosenberg et al., 2008), but these groups are poorly represented in most wetlands, except for some habitats with lotic characteristics (e.g. springs, river floodplains; Boix and Batzer, 2016). Populations of many wetland macroinvertebrates, especially the insects, seem to either be habitat generalists that are largely impervious to environmental variation, or be hypersensitive to environmental change with highly varied and unpredictable responses (see Batzer, 2013); neither scenario would lead to wetland insects being particularly reliable indicators of environmental impacts. So strong aquatic invertebrate metrics have not been consistently developed for freshwater wetland systems. Recent work has started to explore invertebrate alternatives to the insects for wetland bioassessment, and some support is now emerging for the Mollusca (snails: Gastropoda; clams/mussels: Bivalvia).

Ruhí and Batzer (2014) assessed macroinvertebrate assemblages in 381 wetlands across the Nearctic and Western Palearctic geographic regions, and found that Mollusca richness (mostly snails) was a useful surrogate for overall macroinvertebrate taxon richness. Similarly, Ormerod et al. (2010) found that specific snail species were useful indicators of high richness of other mollusks and of plants. As high quality habitats are typically more taxonomically rich than low quality habitats, this suggests that molluscan/snail richness may reflect environmental health (Ormerod et al., 2010). In another meta-analysis of wetlands worldwide, Boix and Batzer (2016) found that the Mollusca, again especially the snails, consisted of many taxa (families) with "constrained" distributions; i.e. are not ubiquitous across all habitats, and are successful in only a limited range of habitats.

Snails are ecologically diverse with the pulmonate taxa being air breathers able to tolerate hypoxia and often capable of resisting temporary or seasonal drying, and the non-pulmonates using gills to breathe and requiring oxygenated water to survive and rarely being able to tolerate drying (Pennak, 1989). All snails tend to feed on biofilms, assimilating both algal- and detritus-based carbon (Underwood and Thomas, 1990; Stoler et al., 2016). In wetlands, some snails have very restricted distributions (i.e. rare taxa: Boix and Batzer, 2016), while others can be widespread invasives (Cooper and Uzarski, 2016), further indicating a range of environmental response across the group. Finally, the passive, relatively-poor dispersal capabilities of snails and other mollusks may enhance their abilities to serve as bioindicators, at least in comparison to aerially dispersing insects. Because extant populations of mollusks in a specific wetland are likely derived from ancestors from that habitat, chronic impacts of an environmental stressor may become evident over time (impacts develop across generations). Alternatively, acute impacts of a severe episodic stressor may persist in molluscan populations or communities over the longer term because post-impact recolonization may be slow. A diversity in taxonomy, ecology, and physiology, a basal position in food webs, and passive dispersal may make snails and other mollusks particularly useful for delineating impacts of assorted environmental factors in wetlands. For example, of wetlands worldwide, mollusks are particularly diverse and widespread in coastal marshes of the Great Lakes of North America (Boix and Batzer, 2016; Cooper and Uzarski, 2016), and these are the some of the few wetland habitats where efforts at bioassessment using invertebrates have been notably successful (with mollusks being used as prominent indicators; see Uzarski et al., 2004; Cooper and Uzarski, 2016).

In this study, we investigate the utility of snail taxa (genera and species) for indicating environmental variation across freshwater wetland habitats of Northeastern China's Sanjiang Plain. The Sanjiang Plain supports a diversity of wetland habitats, although most have been impacted by humans to various degrees (Wang et al., 2011). Freshwater wetlands of this region support a diversity of snail families, genera, and species, and this is one of the few wetland macroinvertebrate groups where adequate taxonomic keys and taxonomic expertise exist regarding the region's fauna, permitting a rigorous description of snail assemblages. We sampled snail assemblages in 16 Northeastern China wetlands across a range of conditions, from relatively pristine "best available" reference sites located in ecological preserves to ones impacted by fragmentation, drainage ditches, and/or adjacent intensive agriculture. We hypothesized that snails assemblages would differ between "best available" reference wetlands and obviously human-impacted sites, and that certain snail species or genera would be indicators of either environmentally healthy or unhealthy wetlands. If true, snail assemblages or indicator species could be developed into useful rapid indicators of environmental impacts on wetlands, or indicators of wetland restoration success, in Northeastern China, an approach that may have much broader application.

2. Materials and methods

2.1. Study sites

The Sanjiang Plain is located between 45°01′N and 48°28′N, latitudinally, and between 130°13′E and 135°05′N, longitudinally, in Heilongjiang Province of Northeast China, formed by the Heilong, Songhua and Wusuli rivers, with a total area of 10.9 million ha (Liu and Ma, 2002). The Sanjiang Plain supports one of the largest freshwater wetland complexes in China, and its wetland areas are strongly affected by agriculture drainage and reclamation efforts. Over the past 60 years, wetlands have been extensively drained for soybean or rice production and 77% of the original wetland area has been lost (Wang et al., 2011); this has also led to the fragmentation of formerly wide-spread wetland areas.

The study was carried out at 16 sites between 47°30′N and 48°15′N in the Nongjiang River watershed in the center of North Sanjiang Plain (Fig. 1). These marshes were similar in plant composition and topography. However, these marshes ranged from near-natural wetlands to those being highly impacted by agriculture. Locations and general characteristics of the sites are listed in Table 1. The most protected sites included two in the Sanjiang Mire Wetland Experimental Station of the Chinese Academy of Sciences (W1, W5 in Table 1), and three in the Honghe National Nature Reserve (W2–W4). Eleven neighboring wetland habitats were impacted by agriculture, ditches and/or fragmentation to various degrees (W6–W16).

The study region experiences a temperate moist monsoon climate with a mean annual temperature of 1.9 °C and a mean annual precipitation of 600 mm. The study site is in a seasonally frozen zone and the frost-free period is 125 days. The average monthly temperatures range from −21 °C in January to 22 °C in July. More than 60% of the annual precipitation falls between July and September. The average altitude of the study area is 55 m. Freshwater sedge marsh is the major type of original wetland in the Sanjiang Plain. Plant composition varies with water depth, and includes *Carex pseudocuraica* F. Schmidt., *C. lasiocarpa* Ehrh., *C. meyeriana* Kunth., *C. appendiculata* (Trautv.) Kük., and *C. schmidtii* Meinsh (Wu et al., 2013). Hydrologic regimes are primarily perennial moist or