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Postprint: Snail Composition as Ecological Indicators in Typical Marsh Wetlands of the Sanjiang Plain

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Abstract

Snails, as an important biological group in wetlands, are sensitive to environmental changes, which makes them potential environmental indicator species. To investigate the differences in snail community structure among different wetland types in the marsh wetlands of Northeast China and the potential of snails as indicator species for different wetland types, snail samples were collected from 17 sampling sites across *Deyeuxia angustifolia* swamp meadow wetlands, *Carex schmidtii* wetlands, *Carex lasiocarpa* wetlands, and *Carex pseudocuraica* floating mat wetlands during September 2014 and May 2015. A total of 4,452 snail individuals were collected, comprising 17 species within 13 genera and 8 families. The study revealed that snails were predominantly represented by the families Planorbidae, Lymnaeidae, and Physidae; the species composition of snails varied among the four different wetland types, and this composition corresponded to wetland characteristics such as water depth and plant community composition. The snail biodiversity indices (Shannon-Wiener index and Margalef index) also exhibited certain differences among the different wetland types. Six indicator snail species were identified: *Aplexa* was the indicator species for *Deyeuxia angustifolia* swamp meadows, *Galba perversa*, *Polypylis hemisphaerula*, and *Pupilla iris* were indicator species for *Carex schmidtii* wetlands, *Succinea* was the indicator species for *Carex lasiocarpa* wetlands, and *Discus* was the indicator species for *Carex pseudocuraica* floating mat wetlands, demonstrating that snails are important indicator organisms for marsh wetland types. These findings also provide a scientific basis and data accumulation for the conservation, restoration, and ecological assessment of snail biodiversity resources.

Full Text

Preamble

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Study on the Assemblage and Indicative Characteristics of Aquatic Snails in Typical Marsh Wetlands on the Sanjiang Plain, China

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Abstract

Snails are an important biological group in wetlands that respond sensitively to environmental changes, making them potential environmental indicator species. To investigate differences in snail community structure among different types of marshes in northeastern China and the possibility of using snails as indicator species for wetland types, we collected snail samples from 17 sites across four wetland types: *Deyeuxia angustifolia* marsh meadows, *Carex schmidtii* wetlands, *Carex lasiocarpa* wetlands, and *Carex pseudocuraica* wetlands. Sampling in September 2014 and May 2015 avoided the influence of spawning on snail abundance and reduced identification interference from larvae. A total of 4,452 individuals were collected, belonging to eight families, 13 genera, and 17 species. Snails were predominantly from the families Planorbidae, Lymnaeidae, and Physidae. The species composition corresponded to wetland characteristics including water depth and vegetation type. Cluster analysis, non-metric multidimensional scaling (NMDS), and similarity analysis divided the snail communities into four groups corresponding to the four wetland types. Indicator species analysis identified six snail species as indicators for different wetland types: *Aplexa hypnorum* was an indicator for *Deyeuxia angustifolia* marsh meadows; *Galba pervia* and *Segmentina hemisphaerula* were indicators for *Carex schmidtii* wetlands; *Succinea* sp. was an indicator for *Carex lasiocarpa* wetlands; and *Valvata cristata* was an indicator for *Carex pseudocuraica* wetlands. Biodiver-

sity indices (Shannon-Wiener, Margalef, and Pielou) also differed significantly among wetland types. These results demonstrate that snails are important indicator organisms for marsh wetland types and provide a scientific basis for the conservation, restoration, and ecological assessment of snail biodiversity resources.

Keywords: snails; ecological indicators; different wetland types; aquatic invertebrates

Introduction

Wetlands are natural complexes formed by interactions between terrestrial and aquatic systems [1-2]. The Sanjiang Plain, located in northeastern China's Heilongjiang Province, is one of the most important wetland regions in Northeast China, with marsh and marsh meadow wetlands accounting for two-thirds of the total wetland area [3]. Water is a critical factor controlling wetland formation and functional maintenance. As flooding depth increases in Sanjiang Plain marshes, vegetation composition and species richness change accordingly, forming distinct zones dominated by *Deyeuxia angustifolia*, *Carex schmidtii*, *Carex lasiocarpa*, and *Carex pseudocuraica*.

Macroinvertebrates constitute an important component of wetland biodiversity [4-5] and are influenced by hydrological characteristics, vegetation, and predation. Previous studies have revealed relationships between vegetation and aquatic invertebrates to varying degrees [6-8], showing that plant biomass affects invertebrate communities [7,9-12]. Snails (Gastropoda) are widely distributed across wetland types and have recently been recognized as good indicator species for freshwater wetland ecosystems [5,13-14]. They exhibit taxonomic diversity and physiological differences: pulmonate snails breathe air, can tolerate hypoxia, and often resist temporary or seasonal drying, while non-pulmonate snails use gills, require oxygenated water, and rarely tolerate drying [15]. Snails feed on plants, algae, and detritus while serving as prey for higher animals. Their slow movement, basal position in food webs, and physiological differences make them useful for describing various environmental factors in wetlands [13]. This study investigates snail communities in different vegetation types of marsh wetlands in northeastern China to analyze their compositional differences and indicative functions, providing a basis for wetland biodiversity conservation.

1. Study Area Overview

The Sanjiang Plain is located in Heilongjiang Province, northeastern China, formed by the confluence of the Heilong, Songhua, and Ussuri Rivers. The study area spans 130°13 E to 135°05 E and 45°01 N to 48°28 N, with an average elevation of 55 m. The climate is temperate humid monsoon, with a mean annual temperature of 1.9°C and mean annual precipitation of 600 mm. Freshwater sedge marshes are the primary wetland type in the Sanjiang Plain. Sampling sites were selected in the Honghe National Nature Reserve within the

Sanjiang Plain marsh wetland ecosystem. Basic water quality and substrate characteristics of the wetlands are shown in Table 1.

Basic characteristics of different wetland types [3,17]

2. Sample Collection and Laboratory Processing

Snails typically spawn and reproduce in summer. To avoid the influence of spawning on distribution patterns and reduce identification interference from juvenile snails, we conducted surveys in September 2014 and May 2015. We collected samples from 17 sites across four wetland types: *Deyeuxia angustifolia* marsh meadows, *Carex schmidtii* wetlands, *Carex lasiocarpa* wetlands, and *Carex pseudocuraica* wetlands. At each site, we randomly selected four net sweeps as replicate subsamples using a D-frame net (0.35 m × 1 m). The D-frame net can filter the entire water column and sweep across the surface of submerged and emergent vegetation, effectively collecting a relatively complete snail community [18-19]. The four subsamples were combined into one sample. In the laboratory, snails were sorted from sediment and plant debris under a stereomicroscope. Identification followed *Economic Fauna of China: Freshwater Mollusks* [20], *Atlas of Chinese Animals: Zoobenthos and River Ecology Assessment* [21], and other references to the lowest possible taxonomic unit. All species names were confirmed by Mr. Liu Yueying at the Institute of Zoology, Chinese Academy of Sciences in May 2016. Valloniidae were identified to genus, while other families were identified to species.

3. Data Processing and Analysis

To identify changes in snail community structure and potential groupings among sampling sites, we performed cluster analysis and non-metric multidimensional scaling (NMDS) at the species level using Bray-Curtis similarity as the distance measure. Data were square-root transformed to reduce the influence of dominant species. When cluster analysis revealed groupings, we used Analysis of Similarities (ANOSIM) to assess significant differences between groups. Indicator species analysis [23] was used to identify characteristic species for different wetland types. This analysis generates an indicator value (0-1) for each species based on its abundance and frequency in designated groups, with significance tested using Monte Carlo methods. We used ANOVA to analyze differences in snail individual numbers and diversity indices among wetland types. Diversity indices calculated included Shannon-Wiener, Margalef richness, and Pielou evenness. PC-ORD 5 and SPSS 21.0 software were used for indicator species analysis, while PRIMER software was used for NMDS and ANOSIM [24].

1. Characteristics of Snail Community Composition

Snail composition was diverse across the four wetland types. Total snail abundance was highest in *Carex schmidtii* wetlands (380.18 ± 104.83 individuals),

followed by *Deyeuxia angustifolia* marsh meadows (229.73 ± 44.47), *Carex lasiocarpa* wetlands (108.57 ± 55.48), and lowest in *Carex pseudocuraica* wetlands (61.29 ± 14.84). ANOVA results indicated significant differences in total snail abundance among vegetation types ($F = 5.727$, $p < 0.01$). The number of snail taxa was highest in *Deyeuxia angustifolia* marsh meadows (9.50 ± 1.04), followed by *Carex schmidtii* wetlands (6.50 ± 0.29), *Carex lasiocarpa* wetlands (6.40 ± 0.24), and lowest in *Carex pseudocuraica* wetlands (6.00 ± 1.22). Significant differences in taxon richness were also found among vegetation types ($F = 4.143$, $p < 0.05$). The abundance of pulmonate (air-breathing) and non-pulmonate (gill-breathing) snails differed significantly among wetland types (Table 2).

Species and abundance of snails in different wetland types

Dominant snail species varied by wetland type. *Aplexa hypnorum*, *Gyraulus centrifugus*, and *Segmentina hemisphaerula* were dominant in *Deyeuxia angustifolia* marsh meadows; *Radix peregra* and *Segmentina nitida* were dominant in *Carex schmidtii* wetlands; *Planorbis corneus* and *Segmentina hemisphaerula* were dominant in *Carex lasiocarpa* wetlands; and *Helicorbis cantori* was dominant in *Carex pseudocuraica* wetlands. Some species showed habitat specificity: *Bithynia ussuriensis* was only collected in *Deyeuxia* marsh meadows; *Radix lagotis* only in *Carex schmidtii* wetlands; *Valvata cristata* only in *Carex lasiocarpa* wetlands; and *Valvata sibirica* only in *Carex pseudocuraica* wetlands.

Diversity indices differed significantly among wetland types (Figure 1). One-way ANOVA showed significant differences in Shannon-Wiener diversity ($F = 7.190$, $p < 0.01$) and Margalef richness ($F = 5.524$, $p < 0.05$). Shannon-Wiener diversity was significantly different between *Deyeuxia* marsh meadows and *Carex lasiocarpa* wetlands, and between *Carex schmidtii* and *Carex lasiocarpa* wetlands, but not between *Carex schmidtii* and *Carex pseudocuraica* wetlands. Margalef richness showed significant differences between *Deyeuxia* marsh meadows and *Carex schmidtii* wetlands, *Deyeuxia* and *Carex lasiocarpa* wetlands, and *Carex schmidtii* and *Carex lasiocarpa* wetlands, but not between *Carex schmidtii* and *Carex pseudocuraica* wetlands or between *Carex lasiocarpa* and *Carex pseudocuraica* wetlands.

[Figure 1: see original paper] Four diversity indices of snails in different wetland types

2. Cluster Analysis and Indicator Species Screening

Based on cluster analysis results at 50% similarity, sampling sites divided into four groups corresponding to the four wetland types. NMDS ordination (2D stress = 0.11) also separated the sites into four distinct groups: *Deyeuxia* marsh meadow sites, *Carex schmidtii* wetland sites, *Carex lasiocarpa* wetland sites, and *Carex pseudocuraica* wetland sites (Figure 2). ANOSIM confirmed significant differences between groups ($R = 0.333$, $p < 0.05$) (Table 3).

[Figure 2: see original paper] NMDS ordination of snail abundance (Bray-Curtis similarity) found in different wetland types

ANOSIM of floodplain snail abundance among wetland types

Indicator species analysis identified six snail species as significant indicators for the four wetland types (Table 4). *Aplexa hypnorum* (pulmonate) was an indicator for *Deyeuxia angustifolia* marsh meadows (indicator value = 0.0114). *Galba pervia* and *Segmentina hemisphaerula* were indicators for *Carex schmidtii* wetlands (indicator values = 0.0346 and 0.0018, respectively). *Succinea* sp. (terrestrial pulmonate) was an indicator for *Carex lasiocarpa* wetlands (indicator value = 0.0350). *Valvata cristata* (non-pulmonate) was an indicator for *Carex pseudocuraica* wetlands (indicator value = 0.0222).

Indicator snail species of different wetland types

3. Discussion

Freshwater wetland snails worldwide primarily belong to Planorbidae, Lymnaeidae, and Physidae [25]. In northeastern Chinese marsh wetlands, most snails belong to these three families, which accounted for 76.5% of all species in this study. *Radix peregra* and *Planorbis corneus* were collected across all four wetland types, indicating broad environmental tolerance.

Compared to river floodplains, marsh wetlands may have lower snail diversity. The Ussuri River floodplain in the same geographic region yielded 24 snail species [14], while our four marsh wetland types yielded 17 species. However, snail density in marsh wetlands (179.81 ± 87.83 individuals/m²) was slightly higher than in the Ussuri River floodplain (14.58 ± 0.67 individuals/m²), likely due to slower water flow and abundant food resources [4].

Snail species richness decreased with increasing water depth, as pulmonate and terrestrial snails declined. However, maximum snail density occurred in *Carex schmidtii* wetlands, which experience strong water-land interactions that favor pulmonate snails. As depth increases, the difficulty for pulmonate snails to reach the surface to refill their air supply increases [15]. Water chemistry (pH 6.0-6.7) showed little variation among sites and had minimal effect on distribution, though extreme pH values significantly affect snail species distribution [26]. Pulmonate snails lack an operculum, making them sensitive to water chemistry changes, while non-pulmonate snails have an operculum that provides protection and short-term tolerance [26]. Mineralization, reflecting water exchange cycles and dilution conditions, also affects snail distribution [27].

Indicator species analysis supported our hypothesis that snail species correspond to vegetation types. Five of the six indicator species are pulmonate snails sensitive to environmental conditions [29-30]. *Aplexa hypnorum*, indicator for *Deyeuxia* marsh meadows, is an endangered species in Europe [28] that prefers temporary, periodically dry habitats. Its eggs are desiccation-resistant and can hatch after reflooding. *Succinea* sp., indicator for *Carex lasiocarpa* wetlands,

is a terrestrial pulmonate genus whose presence indicates strong water-land interactions. *Valvata cristata*, indicator for *Carex pseudocuraica* wetlands, is a non-pulmonate snail associated with deeper water.

Biodiversity indices varied significantly among wetland types. *Deyeuxia* marsh meadows had the highest Shannon-Wiener diversity and Margalef richness, consistent with the highest species number collected there. *Carex schmidtii* wetlands showed high diversity indices despite moderate species richness, likely due to aggregation of several species at this ecotone. *Carex lasiocarpa* and *Carex pseudocuraica* wetlands had lower taxon richness but moderate diversity.

Vegetation significantly influences snail distribution and abundance through both direct and indirect effects. Direct effects include providing habitat complexity and food resources from roots, detritus, and algae. Indirect effects include providing stable habitats and refuge from predation through complex stem and root structures [32-33]. In the Sanjiang Plain, different microtopographies create hydrological and thermal gradients that produce distinct vegetation communities [34], which in turn structure snail communities.

This study demonstrates that snail community composition and diversity differ significantly among marsh wetland types, with distinct indicator species for each type. Snails can serve as effective indicators for wetland type identification, ecological health assessment, and monitoring environmental changes. Compared to other invertebrates, snails are relatively easy to collect, have hard shells for preservation, and can be separated quickly from plant debris, making them particularly suitable as environmental indicators [13]. Using snail assemblages from adjacent intact wetlands to indicate biological recovery in restoration projects is a viable approach for assessing wetland restoration success.

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