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Changes and drivers of freshwater mussel diversity and distribution in northern Borneo

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ABSTRACT

Human activities are threatening Borneo's unique biodiversity, but little is known on the status of freshwater invertebrates. We assessed changes in diversity and distribution of freshwater mussels (Bivalvia: Unionida) in northern Borneo, and identified drivers of present distribution and threats. Past distribution data were collected from literature and museum resources. Present distribution data were collected from 21 river basins, and 47 water quality, climatic, landscape and human variables explored as potential predictors of species presence/absence. Species delimitations were identified by morphology and COI barcoding, and haplotype networks generated. Our data indicate that over the past 50 years, four of originally five native species have become very rare or possibly locally extirpated. Since these four species are endemic to Borneo, other Bornean river basins should urgently be surveyed to identify any remaining populations. In the same time span, the non-native *Sinanodonta woodiana* has become the most widespread freshwater mussel in northern Borneo. The fifth native species was identified as *Rectidens sumatrensis* and found in four Sarawakian river basins, thus contradicting previous assumptions of an endemic Bornean *Rectidens* species. Although a number of stable *R. sumatrensis* populations are retained across Sarawak, the species' strong spatial contraction in mainland Sundaland and apparent low tolerance to eutrophication suggest that it is vulnerable to further habitat alteration. Our results indicate that Borneo's (endemic) freshwater invertebrate biodiversity is declining rapidly. Comprehensive surveys targeting an array of invertebrate and vertebrate taxa are needed to identify Borneo's freshwater biodiversity hotspots, where conservation efforts should be concentrated.

1. Introduction

Freshwater biodiversity is declining at a rate far greater than terrestrial or marine ecosystems (Sala et al., 2000; Dudgeon et al., 2006; Strayer and Dudgeon, 2010). Meaningful conservation efforts, at the minimum, require knowledge on the diversity, distribution and habitat requirements of species. However, data on freshwater biodiversity is poor, so that undetected species extinctions are common, particularly for invertebrate taxa and in tropical habitats (Harrison and Stiassny, 1999; Dudgeon et al., 2006). At the same time, available data indicate that freshwater species-richness and levels of endemism peak in the tropics (Dudgeon et al., 2006 and references therein). Nevertheless, in

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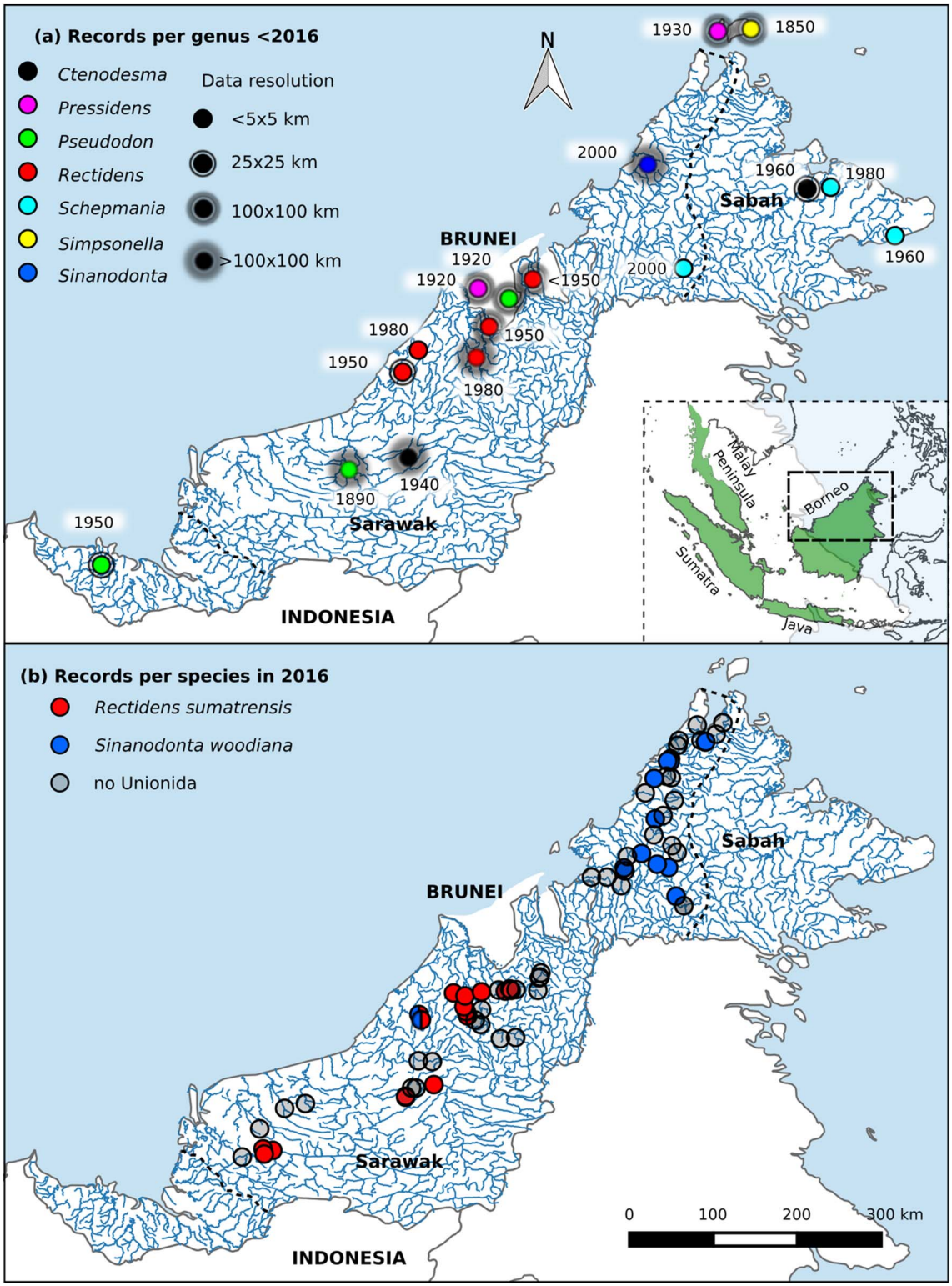

Fig. 1. Distribution records per freshwater mussel genus/species across Malaysian Borneo collected (a) before 2016, including the decade of most recent record, and (b) in the course of the present study in April, July and August 2016. Insert shows position of study region within Sundaland (green area). Dashed lines indicate western and eastern borders of study area. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

contrast to terrestrial systems, the world's freshwater biodiversity hotspots "featuring an exceptional concentration of endemic species and experiencing exceptional loss of habitat" have yet to be identified (Myers et al., 2000).

For the designated terrestrial tropical biodiversity hotspot Sundaland, which includes the Malay Peninsula, Sumatra, Java and Borneo (Fig. 1), levels of freshwater biodiversity richness and endemism appear to be similarly high as for the terrestrial taxa studied by Myers et al. (2000). According to Mittermeier et al. (2005), this hotspot supports about 950 species of freshwater fish, 350 of which (representing about 3% of global diversity) are endemic to the region. Within Sundaland, Borneo hosts about 430 freshwater fish species, 164