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Assessment and analysis of ecological quality, macroinvertebrate communities and diversity in rivers of a multifunctional tropical island

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ABSTRACT

This study aims to assess the macroinvertebrate communities, diversity and ecological quality (expressed as BMWP-Viet) of rivers on a tropical island. Environmental factors associated with macroinvertebrate communities, diversity and ecological quality were identified to assist conservation planning and management. Biological (macroinvertebrates), chemical, physical and hydromorphological characteristics of 85 river reaches were assessed in Leyte island, Philippines. Canonical Correspondence Analysis (CCA) and multivariable linear regression (LRM) were performed to relate environmental variables and macroinvertebrates. Several taxa of snails, shrimps, dragonflies, beetles, bugs and caddisflies were found on the island. Although many sites had good to very good ecological quality and high diversity, about 41% had moderate to very bad ecological quality and low diversity. Based on CCA, we can conclude that macroinvertebrate communities were associated with velocity, sediment, conductivity and dissolved oxygen. Particularly, sensitive and tolerant taxa were encountered at high and low flow velocities, respectively. LRM indicated that macroinvertebrate diversity and ecological quality were associated with physical (turbidity), chemical (chlorophyll), hydromorphological characteristics (bank slope & pool/riffle class), habitat degradation (gravel/sand quarrying, erosion) and the presence of logs and twigs. Consequently, this study gives support to the use of invertebrates as indicators of certain environmental conditions and the results of this investigation can serve as a basis to set up dedicated experiments to further prove the causality of these discovered relations. Strikingly, organic pollution, as reflected by biological oxygen demand and chemical oxygen demand, was in general weakly related to invertebrate composition, diversity and ecological quality. This might be linked to the low input in most sites and the relatively short rivers which are closely connected to the marine system. Thus, typical midstream and downstream systems were not encountered and the accumulation of these pollutants along the river is less likely. Although the island is situated in the western Pacific Ocean and encounters intensive natural disturbances (severe typhoons), the taxa (families) are similar to other tropical systems and the effects of the environmental conditions are comparable. Findings of this study are valuable in understanding tropical island systems and provide insights into the effects of environmental conditions on stream invertebrates, which aids in protecting and conserving tropical insular systems.

1. Introduction

Globally, biodiverse ecosystems are severely threatened due to rapid population growth and increasing anthropogenic activities (Hill et al., 2015). Conserving and protecting a biodiverse ecosystem is essential as biodiversity is connected to the functioning of ecosystems and is therefore related to the society (Cardinale, 2012). Biodiversity supports ecosystem services (Francis et al., 2014). For instance, a biodiverse forest supplies pollination services to agriculture, which increase crop yield and quality (Ricketts et al., 2004). Thus, a biodiverse ecosystem is more productive as they comprise key species that largely influence productivity (Cardinale, 2012;

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Helm and Hepburn, 2012). Biodiversity is also strongly associated with certain regulating services (Cardinale, 2012). Creating a biodiverse set of habitats in non-production agricultural areas increases multiple ecosystem functions (e.g. water regulation and carbon storage) of agricultural lands (Smukler et al., 2010). Lastly, biodiverse natural environments stimulate better health and well-being (Lovell et al., 2014).

Biodiversity hotspots are defined as areas featuring exceptional concentrations of endemic species (plant and vertebrates) which experience exceptional loss of habitat (Myers et al., 2000). These hotspots are identified as priorities for protection, conservation and management. The Philippines, composed of 7100 islands, is identified as a biodiversity hotspot and one of the world's biologically richest countries (Myers et al., 2000; Proches et al., 2015). Endemic invertebrates are numerous in the country. However, information on spatial distribution of invertebrate communities in the Philippines is limited (David, 2003; Dyer et al., 2003; Freitag, 2004).

Aquatic invertebrates inhabit different types of aquatic systems. Most of them live part or most of their life cycle attached to submerged rocks, logs and vegetation (Gabriels et al., 2010). They are critical in the stream's food web (USEPA, 1997). Thus, macroinvertebrates may be crucial in the overall biodiversity as the extinction of one species within a food web can result in secondary extinctions due to bottom-up effects (Calizza et al., 2015). They are also commonly used in environmental monitoring and assessment (Lock and Goethals, 2014; Resh and Rosenberg, 2010) because they reflect the quality of an aquatic system due to their varying degrees of tolerances towards disturbances (De Pauw et al., 2001; Morse et al., 2007) and integrate environmental stresses that have occurred over an extended period (Rosenberg and Resh, 1996). They reveal not only the cumulative impacts of pollution but also the impacts from habitat loss not detected by traditional water quality assessments (USEPA, 1997).

Although tropical systems are reported to support greater species diversity than temperate systems (Myers et al., 2000; Pianka, 1966; Proches et al., 2015), knowledge of tropical stream invertebrates is generally limited (Jardine, 2014). In tropical island systems, it is believed that macroinvertebrate faunas are sparse (Bass, 2003). However, according to Covich (2006), diversity of species in a tropical island may depend on the age, location, height and size of an island.

Anthropogenic activities are increasingly growing in tropical islands (Fomba et al., 2013; Kura et al., 2015; Somboonna et al., 2014). Investigation of the impacts of anthropogenic activities on the ecology and biodiversity in tropical island systems is limited (Ramirez et al., 2009). Janse et al. (2015) reported that there is a negative relation between biodiversity and environmental stressors (land use changes, climate change, nutrient emissions) in all types of freshwater ecosystems. Thus, knowledge of the impact of human activities on stream invertebrates in the tropical islands facilitates conservation planning and management of these systems (Covich, 2006).

The framework and objectives of this study are reflected in Fig. 1. We aim to assess the macroinvertebrate communities based on two indices (BMWP-Viet and diversity) and use this information as a proxy for the river quality status. For this, biological (macroinvertebrates), chemical, physical and hydromorphological characteristics of river reaches were monitored in Leyte island, Philippines. Subsequently, Canonical Correspondence Analysis (CCA) and multivariable linear regression (LRM) were performed to relate environmental variables and macroinvertebrates (phase 1 in Fig. 1). Although the results do not guarantee a proof for causality, they can contribute to determine key variables and indicators that serve as a basis to identify relevant management and policy actions, such as water quality standards, habitat restoration and regulations related to sand quarrying. Cause deduction (phase 2 in Fig. 1), as indicated in the framework, is not covered in our study since this would require additional experiments in labs or in (artificial/actual) rivers.

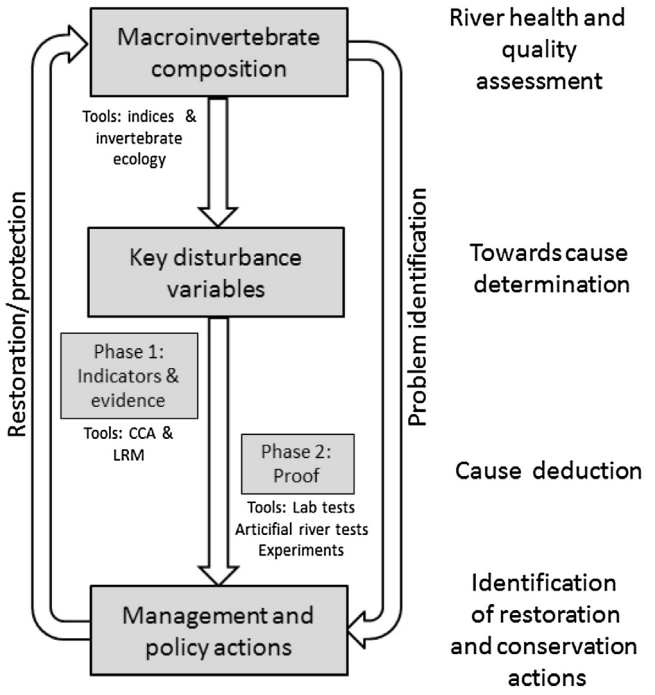

Fig. 1. The applied framework for water restoration and management, of which phase 1 was practically implemented in this study.

2. Material and methods

2.1. River quality assessment

2.1.1. Study area

The Leyte island is the eighth largest island in the Philippines and has a surface area of 7368 km^2 (Fig. 2). The island is irregular in shape and has mountains in the centre. The highest mountain reaches 1,349 m. A complex system of short streams drains from the mountains to the coasts. Plains are found in the coastal areas, mainly in the north (Pletcher, 2015). The climate of the island is characterized by a relatively high temperature (24–33 °C), a high humidity and abundant rainfall. Average annual rainfall is 2100–4500 mm. Typhoons occur every year, usually in the period of June-December.

Human activities within the island include crop cultivation, industry, quarrying, urbanization and aquaculture. Rice and coconut are the main crops. Other crops include corn (maize), abaca, tobacco, bananas, pineapple and sugarcane. Manganese deposits, sandstone and limestone are quarried in the northwest. Coconut oil mills, a copper smelting plant, a phosphate fertilizer and ethyl alcohol production plants and a geothermal production field are located on the island.

2.1.2. Data collection

Aquatic macroinvertebrates were sampled on the island at 85 different locations with varying degrees of disturbances. The sites were selected to ensure safety and accessibility of all locations. The sampling campaign was conducted during the dry season (April–May 2015). Macroinvertebrates were monitored through kick sampling with a standard handnet (conical net with a frame size of 20 × 30 cm and a mesh size of 500 μm, attached to a stick)