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Physiological responses of the seagrass *Thalassia hemprichii* (Ehrenb.) Aschers as indicators of nutrient loading

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ABSTRACT

To select appropriate bioindicators for the evaluation of the influence of nutrients from human activities in a *Thalassia hemprichii* meadow, environmental variables and plant performance parameters were measured in Xincun Bay, Hainan Island, South China. Nutrient concentrations in the bay decreased along a gradient from west to southeast. Moreover, the nutrients decreased with an increase in the distance from the shore on the southern side of the bay. Among the candidate indicators, the P content of the tissues closely mirrored the two nutrient loading gradients. The epiphytic algae biomass and the N content in the tissues mirrored one of the two nutrient loading trends. The leaf length, however, exhibited a significant negative correlation with the nutrient gradients. We propose that changes in the P content of *T. hemprichii*, followed by epiphytic algae biomass and N content of the tissues, may be the useful indicators of nutrient loading to coastal ecosystems.

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1. Introduction

Nutrient over-enrichment, particularly the over-enrichment of nitrogen and phosphorus, has degraded many coastal waters and has been invoked as a major cause of seagrass disappearance (Burkholder et al., 2007). Excessive nutrient loading from anthropogenic sources, such as sewerage and aquaculture inputs, can inhibit seagrass growth and survival through direct physiological influence and indirect light reduction due to algal growth (Hauxwell et al., 2003) and further affect both the functioning and structure of seagrass communities (Apostolaki et al., 2009; Ruiz et al., 2010; Fertiga et al., 2013). Thus, the early detection of eutrophication in seagrass ecosystems is critical. However, the value of traditional water quality monitoring programs is often questioned (Tomasko et al., 1996). Traditionally, the instantaneous measurement of the nutrients concentrations in seawater may lead to an inaccurate judgment of the nutrient loading status due to the excellent exchange of water in some estuaries or bays (Lee et al., 2004). Moreover, previous studies have shown that phytoplankton and submerged macrophytes can rapidly remove nutrients from the water column (Zhang et al., 2011), and the over-enrichment of coastal ecosystems can rarely be detected through direct measurements of the water column nutrient concentrations. Thus, it is necessary to identify proper bioindicators for the evaluation of the influence of nutrient loading originating from human activities on seagrass meadows.

The need to monitor the environmental condition of ecosystems worldwide has resulted in a large number of potential bioindicators being proposed in the scientific literature. Seagrasses, such as *Posidonia oceanica*, *Zostera marina*, *Zostera noltii*, and *Cymodocea nodosa*, in temperate latitudes have often been recommended as indicator species of the condition of an environment (Ferrat et al., 2003; Lee et al., 2004; Romero et al., 2007; Perez et al., 2008; Oliva et al., 2011; Martínez-Crego et al., 2011; García-Marín et al., 2013). However, *Thalassia hemprichii* (Ehrenb.) Aschers, which is one of the most common seagrass species and found from the western Pacific to the West Indian Ocean (Short et al., 2007), has rarely been studied as an indicator of nutrient loading.

The seagrass meadow in Xincun Bay comprises one of the most extensive seagrass communities in South China and provides critical habitat and food resources for commercial and traditional fishery species (Fan et al., 2011). However, studies of the seagrass meadows in the Hainan Island region have largely been limited to mapping their presence and species composition (Huang et al., 2006). Although it is generally considered to be relatively unimpacted compared with other regions in continental China with large urban and industrial centers, the Xincun Bay seagrass meadow in Hainan Island has been subjected to a variety of anthropogenic impacts (e.g., floating net cages culture, shrimp farm, sewerage effluent, dredging, and overfishing). These activities have introduced a potential eutrophication risk to this coastal ecosystem due to the nutrients and organic matter released into the environment. Thus, methods and strategies to evaluate the effects of the nutrient input into this ecosystem are required.

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Consequently, in this study, we combined the use of seagrass bioindicators, environmental variables, and spatial analysis to (1) confirm whether a nutrient gradient exists in the Xincun seagrass meadow, (2) elucidate the physiological responses of the seagrass *T. hemprichii* to nutrient loading, and (3) report the capacity of each descriptor that responds to the nutrient regime and evaluate their usefulness as early indicators of marine environmental degradation caused by aquacultural activities and sewage effluent.

2. Materials and methods

2.1. Study area

The study was conducted in Xincun Bay on the southeast coast of Hainan Island, China (Fig. 1; 18°24′N, 110°E). *T. hemprichii* grows on sediment consisting of sandy terrigenous mud and occupies an area of approximately 200 hectares (Huang et al., 2006) near Xincun Town and Nanwan village (Fig. 1C). Xincun Bay is an almost closed bay with only one narrow channel connecting with the open sea to the southwest. The water quality has deteriorated in recent years due to frequent human activities, such as fish and shrimp aquaculture. The nutrient inputs from the fish cage culture systems that are located near the bay's entrance and adjacent to the navigation channel are the dominant sources. There are approximately 450 floating cage units, which usually consist of 3 m × 3 m net cages configured in a square with 3 cages per side. The tides are semi-diurnal, and the tidal amplitude ranges from 0.50 m on neap tides to 1.75 m on spring tides. The *T. hemprichii* meadows extend along a vertical gradient of approximately 2 m in the intertidal and subtidal areas.

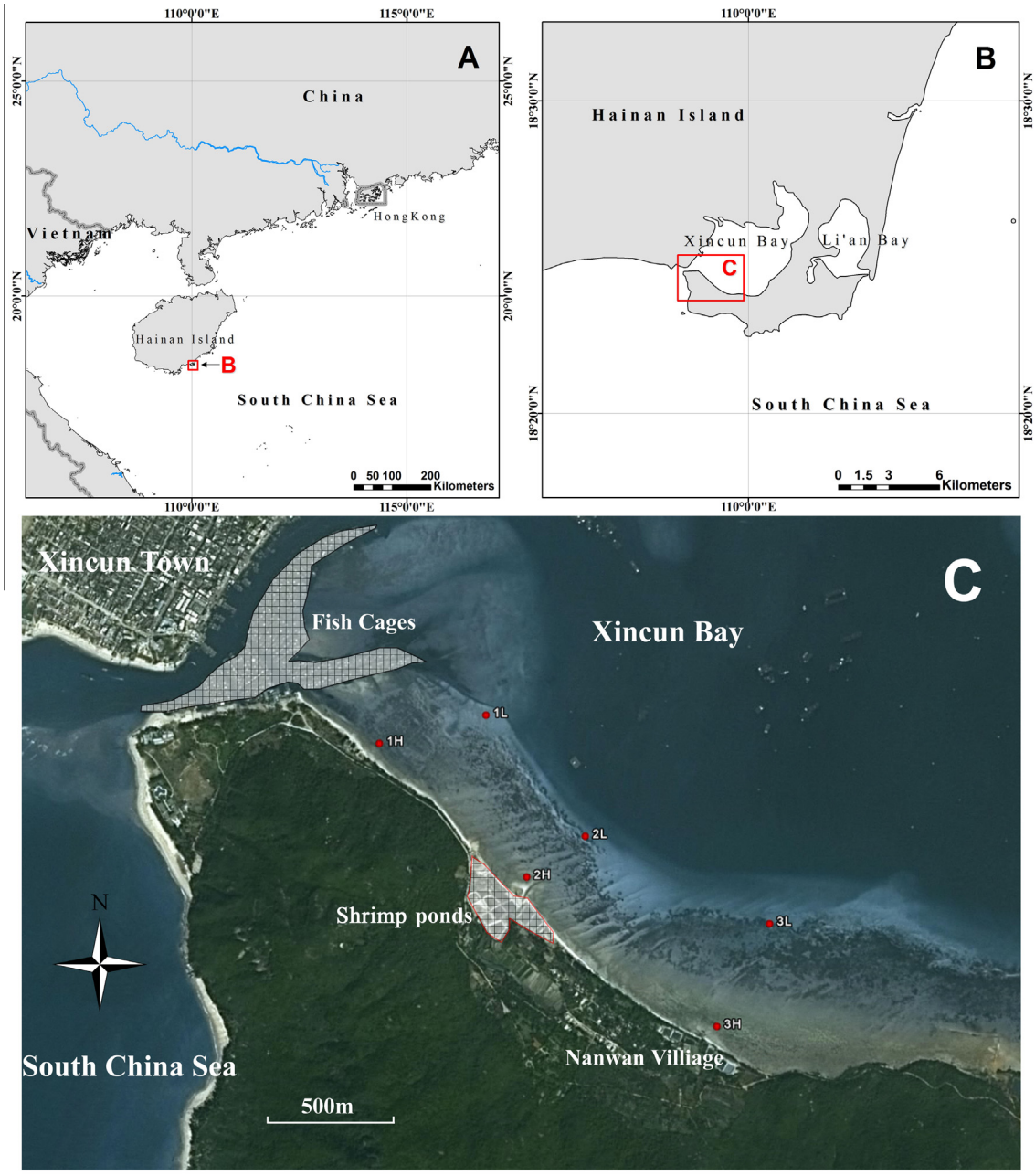

Fig. 1. Map showing the sampling sites in Xincun Bay, Hainan Island, China. (A) Hainan Island in South China Sea and Xincun Bay in Hainan Island. (B) Study area in Xincun Bay. (C) Six sampling sites with three transects in the Xincun Bay seagrass meadow.

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