Nutrients distribution and trophic status assessment in the northern Beibu Gulf, China*

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Abstract Using historical and 2010 field data, the distribution of nutrients in the northern Beibu Gulf of China is described. There was a decreasing trend in the concentration of nutrients from the north coast to offshore waters of the northern Beibu Gulf, reflecting the influence of inputs from land-based sources. High concentrations of dissolved inorganic nitrogen (DIN) and phosphate (PO$_4$-P) occurred mainly at Fangchenggang Bay, Qinzhou Bay, and Lianzhou Bay. Four different methods were used to assess eutrophication. The trophic status of the Beibu Gulf was characterized using the single factor, Eutrophication index (EI), Trophic index (TRIX) and Assessment of Estuarine Trophic Status (ASSETS) methods. Based on nutrient concentrations, 73.9% of DIN and 26.7% of PO$_4$-P samples exceeded the fourth grade Seawater Quality Standard of China. Eutrophication index values varied widely, but higher levels of eutrophication were generally found in bays and estuaries. TRIX values ranged from 2.61 to 7.27, with an average of 4.98, indicating a mesotrophic and moderately productive system. A positive correlation between TRIX and harmful algal species richness and abundance was observed. The ASSETS model evaluates eutrophication status based on a Pressure-State-Response approach, including three main indices: influencing factors, overall eutrophic condition, and future outlook. The Beibu Gulf was graded as moderate using ASSETS. The single factor and Chinese nutrient index methods were considered inadequate for the assessment of trophic status. TRIX can be used as an indicator of trophic state and ASSETS showed good potential to assess eutrophication. The results of TRIX and ASSETS depend on threshold values. To establish these values, further research is required within the northern Beibu Gulf.

Keyword: nutrient; eutrophication; Trophic index (TRIX); Assessment of Estuarine Trophic Status (ASSETS); Beibu Gulf; Guangxi Province

1 INTRODUCTION

Human-induced nutrient enrichment is becoming a serious problem for coastal marine areas around the world (Bricker et al., 2003; Garmendia et al., 2012). Nutrient enrichment has resulted in a series of adverse effects including ecosystem degradation, socio-economic losses, and serious threats to human health (Whitall et al., 2007). Strong public concerns about eutrophication have led to increasing levels of scientific research to assess eutrophication. To resolve these problems, a number of legislative and integrative assessment methods have been developed worldwide (Borja et al., 2008; Ferreira et al., 2011). For example, in Europe, the Water Framework Directive (WFD; EC, 2000), the Marine Strategy Framework Directive (MSFD; EC, 2008), and the Oslo Paris Convention (OSPAR; OSPAR, 2003, 2008) models have been developed. In the United States, the National Oceanic and Atmospheric Administration’s National Estuarine Eutrophication Assessment (NEEA) (Bricker et al., 1999), and Assessment of Estuarine Trophic Status (ASSETS) (Bricker et al., 2003) eutrophication models have been developed. However, nutrient

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index methods focusing on chemical indices are still widely applied in Chinese waters (Xiao et al., 2007). Consequently, in China, these programs have been the sources of inspiration for the development of a marine strategy framework and integrative eutrophication assessment methods with Chinese characteristics. To use the European Union’s WFD and OSPAR assessment procedures, natural background values and region-specific thresholds determined from previous studies and long-term reference data are required (Xiao et al., 2007; Devlin et al., 2011). Because of the lack of long-term monitoring data, it is difficult to determine natural background values, and thus the EU MFD and OSPAR procedures may be inadequate for the assessment of eutrophication in many Chinese coastal systems. The ASSETS model is an integrative and adaptive methodology developed as part of the United States NEEA program, based on a Pressure-State-Response approach. It includes the evaluation of influencing factors, overall eutrophic condition and an evaluation of future outlook (Bricker et al., 2003; Ferreira et al., 2007). ASSETS usually uses uniform eutrophication-related criteria and the model has been successfully applied to different estuaries and coastal systems in the United States, Europe (several systems under the EU WFD requirements), Australia, Brazil and China (Ferreira et al., 2007; Wang, 2007; Xiao et al., 2007; Cotovicz Junior et al., 2013; http://www.eutro.org/syslist.aspx). Given this background, the ASSETS model may be a promising tool for the assessment of trophic status in the northern Beibu Gulf.

The Beibu Gulf, located in the northwest of the South China Sea, is a semi-enclosed sea shared by China and Vietnam. More recently, the northern Beibu Gulf has been subjected to a high loading of anthropogenic nutrients from agriculture, domestic and industrial wastewater, caused by rapid development of the economy and urbanization of coastal areas (Kaiser et al., 2013). As a result, signs of eutrophication have developed in the Gulf, leading to an urgent call for studies that diagnose and evaluate the present trophic status of coastal waters. To date, very few studies describing nutrient characteristics and eutrophication in the northern Beibu Gulf have been published (but see Qin et al., 2000; Wei et al., 2003; Xin et al., 2010; Xu et al., 2012; Kaiser et al., 2013). The main objectives of this work were: 1) to determine the distribution and variation of nutrient levels in the northern Beibu Gulf, 2) to assess the eutrophication status of the study area using the single factor, eutrophication index, TRIX and ASSETS methods, and 3) to compare the results of the four eutrophication assessment methods to help inform managers of the most suitable methods for assessment.

2 MATERIAL AND METHOD

2.1 Study area

The study area is located along the Guangxi coast, adjacent to the Beibu Gulf, a semi-enclosed gulf surrounded by the land territories of China and Vietnam (Fig.1). The coastal system of Guangxi extends approximately 1628 km from Tieshan Bay in the east to the Beilun River estuary in the west, and has an area of about 1438 km² with shallow water of