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A trophic model for the Danshuei River Estuary, a hypoxic estuary in northern Taiwan

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Abstract

The estuary of the Danshuei River, a hypoxic subtropical estuary, receives a high rate of untreated sewage effluent. The Ecopath with Ecosim software system was used to construct a mass-balanced trophic model for the estuary, and network analysis was used to characterize the structure and matter flow in the food web. The estuary model was comprised of 16 compartments, and the trophic levels varied from 1.0 for primary producers and detritus to 3.0 for carnivorous and piscivorous fishes. The large organic nutrient loading from the upper reaches has resulted in detritivory being more important than herbivory in the food web. The food-chain length of the estuary was relatively short when compared with other tropical/subtropical coastal systems. The shortness of food-chain length in the estuary could be attributed to the low biomass of the top predators. Consequently, the trophic efficiencies declined sharply for higher trophic levels due to low fractions of flows to the top predators and then high fractions to detritus. The low biomass of the top predators in the estuary was likely subject to over-exploitation and/or hypoxic water. Summation of individual rate measurements for primary production and respiration yielded an estimate of -1791 g WW m^{-2} $year^{-1}$, or -95 g C m^{-2} $year^{-1}$, suggesting a heterotrophic ecosystem, which implies that more organic matter was consumed than was produced in the estuary.

Keywords: Food-chain length; Sewage effluent; Over-exploitation; System metabolism; Ecopath; Network analysis

1. Introduction

Estuaries have been widely recognized to be highly productive per unit area since the study of Georgia estuaries by Schelske and Odum (1962). Reasons for high estuarine productivity and understanding of the functioning of estuaries have been the inspiration and focus of estuarine ecology for the past 30 years (e.g. Nixon et al., 1986). However, the paradigm of high estuarine productivity has been based for the most part on the results from temperate estuaries. Studies on subtropical and tropical estuaries have lagged behind research on temperate estuaries (e.g. Baird and 'Ulanowicz, 1993), and the functioning of subtropical and tropical estuaries is therefore still poorly understood. Although fishery yields from tropical estuaries are much higher than those from other tropical waters (Blaber, 1997), ecosystem research has concentrated more on coral reefs than on other tropical coastal systems (Opitz, 1996; Johnson et al., 1995; Arias-Gonzalez et al., 1997; Niquil et al., 1999). There is a significant lack of detailed ecosystem studies on the functioning of tropical and subtropical estuaries.

The Danshuei River (25°10′N; 121°10′E), the largest river in northern Taiwan, is 159 km long and covers about 2726 km^2 of watershed area (Fig. 1). The estuary of Danshuei River is vegetated by the rare and endangered mangrove, *Kandelia obovata* Sheue, Liu and Yong (Rhizophoraceae). The fish assemblage caught in the mangrove

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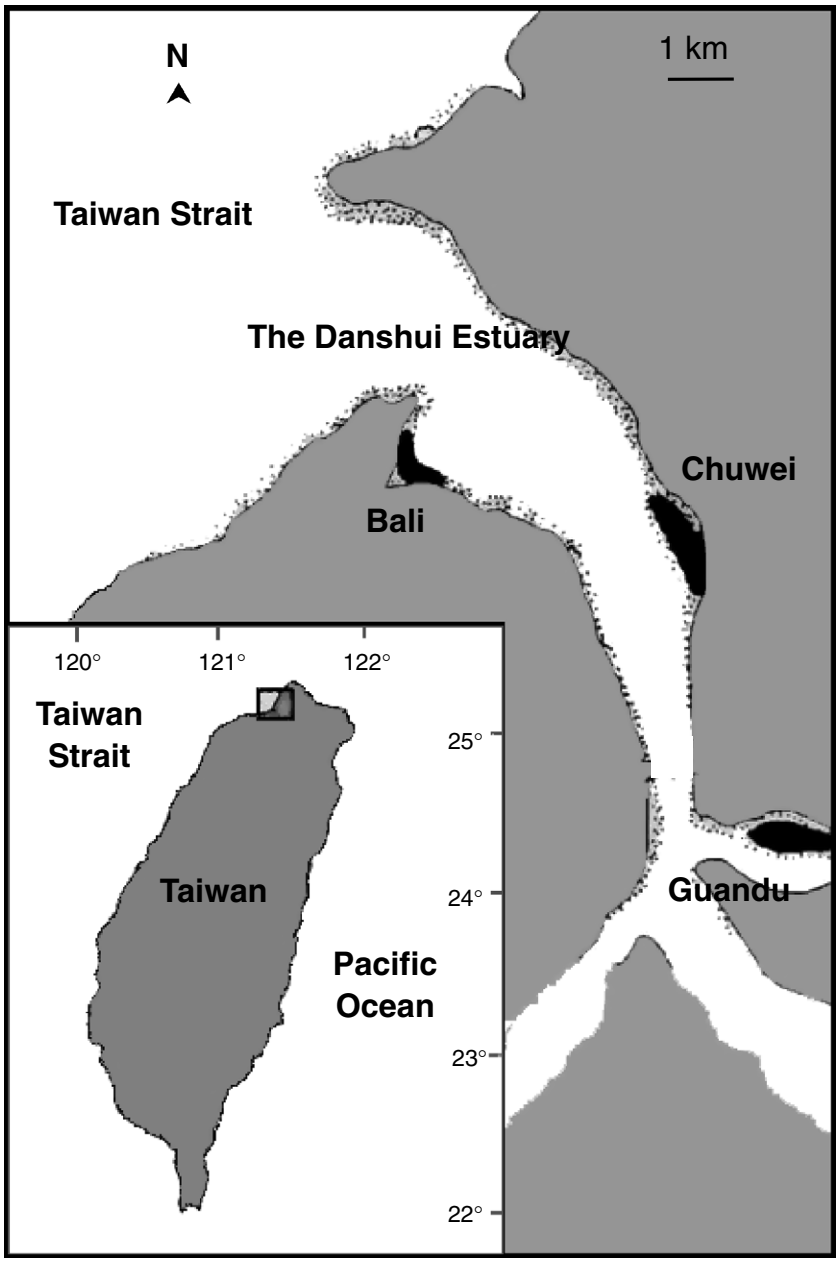

Fig. 1. Study area of the Danshuei Estuary and locations of mangroves along the estuary.

swamp is dominated by small-sized and commercially important species (Lin et al., 1999). The Danshuei Estuary has been a commercial fishing ground important for the harvesting of juvenile engraulids and clupeids for seafood, as well as anguillid elvers for aquaculture (Tzeng and Wang, 1992). However, the Danshuei River flows through the metropolitan area of Taipei (6 million people) and receives both treated and untreated domestic sewage effluents. The river pollution index (RPI) of the 1999 annual report of water quality of the Danshuei River by the Environmental Protection Agency showed that more than 90% of the area of the estuary is moderately or heavily polluted. As a result, dissolved oxygen contents in the bottom waters decline temporarily to near-zero levels (Jiann et al., 2005; Liu et al., 2005). Denitrifier microbes were detected in the sediments at 1 cm deep (Fan et al., 2006). Scarcity of integrated information for understanding its functioning has hindered the much-needed assessment of the Danshuei Estuary to determine an appropriate strategy for its ecosystem management.

Quantitative descriptions of matter flow have been used to provide significant insights into the structure and functioning of a variety of temperate aquatic ecosystems (e.g. Baird and Ulanowicz, 1993; Christensen and Pauly, 1993; Wolff, 1994), coral reefs (Opitz, 1996; Arias-Gonzalez et al., 1997), and tropical lagoons (Lin et al., 1999, 2006). Very little is known about these mechanisms in tropical/subtropical estuaries. In order to better understand the