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An integrated model for marine fishery management in the Pearl River Estuary: Linking socio-economic systems and ecosystems

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ABSTRACT

The paper devises an integrated ecological–economics–social model to assess the implementation of ecosystem-based fisheries management in the Pearl River Estuary (PRE) in the South China Sea (SCS). In particular, this paper presents the development of an integrated model, which links a regional economics social accounting matrix (SAM) model to an ecological model constructed using Ecopath with Ecosim (EwE) software. The impacts on the ecological–economics–social system are examined by varying fishing efforts for four scenarios, including status quo management, fishing effort reduction policy, fishing gear switch policy, and summer closure extension policy. Key results from the predictions (2010–2020) and policy simulations illustrate that the collapse effect is apparent in the status quo scenario. Further, reducing or switching of fishing effort (e.g. elimination of overfishing and reduced habitat disturbance) positively affects the ecosystem and can lead to economic and social welfare gains in the PRE's economy. The gear switch scenario presents a compromise among the economics, social, and conservation metrics, and also outperforms other scenarios in terms of biomass at the end of the simulation period. The fishing effort reduction policy performs better than the summer closure extension policy in terms of the conservation metrics but does relatively poorly in economic terms.

1. Introduction

Marine and coastal areas are complex systems formed by the interaction among the population, economy, environment, and resources. Understanding the increasingly rapid and complex changes occurring in a coastal marine ecological–economics–social system, and the dynamic nature of the interactions within and between these systems, requires the knowledge of both nature science and social science [1,2]. Effective fishery management tools are urgently needed to control the problem of over-fishing in coastal ecosystems. The traditional fisheries management tool, which is based on the Gordon–Schaefer model [3–5], is more suitable for homogeneous fleets targeting one species and cannot easily analyse a large number of species [6]. As marine ecosystems comprise complex ecological interactions among species, many researchers argue that the traditional management of commercial fish stocks as single species is ineffective [7]. In this context, ecosystem-based fishing management (EBFM) has emerged as a promising approach to tackle the limitations of traditional fisheries management tools [8].

In order to analyse systems with a large number of interacting elements, such as species interactions in an ecosystem, or those between industries and consumers in a socio-economic system, ecologists and economists have explored the use of ecosystem models and regional fisheries economics models. Multispecies and ecosystem modelling approaches, such as multispecies production (MSP) models, multispecies virtual population analysis (MSVPA), multispecies bioenergetics (MSBE), and Ecopath with Ecosim (EwE), have shown considerable potential for fisheries management [7,9]. However, some ecosystem models are still limited and do not recognise that the objective should be not only to protect marine fishery resources but also to improve societal benefits such as livelihood, equity, and harmony in the fishery community. Conversely, fishery economists try to evaluate the economics and distributional effects on fishing communities and related industries by linking regional economic models with marine fisheries. Regional economic impacts of fisheries have often been

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analysed using linear models [10], such as Input–Output (IO) models [11–16], the Social Accounting Matrix (SAM) [17–22], and non-linear models, such as the Computable General Equilibrium (CGE) model [23–26]. However, fishery regional economics models work in an isolated manner and do not allow the dynamic flow of feedback from the ecological system to the socio-economics system.

To date, few ecosystem approach-based regional fisheries economics models have been implemented, because doing so requires multidisciplinary research [27], which may increase the complexity of the regional economic analysis [28,29]. Jin et al. [30] and Kaplan et al. [31] developed economic–ecological models by coupling a regional IO model of a coastal economy with a linear ecological model of a marine food web. The SAM has been used widely for policy analysis in recent years, but the potential for its application in ecosystem-based management has not yet been fully explored. Although researchers have begun to investigate the theoretical aspects of these ecosystem-scale models, more study is needed to investigate the practical application of such models as policy decision support tools. The challenge is to develop an economics model that incorporates several key economic sectors related to the ecosystem model, such as fish harvesting and seafood processing, and to estimate the changes in gains and losses within the integrated system when policies are implemented.

This paper presents an integrated ecological–economics–social model for important commercial fishes in the Pearl River Estuary (PRE), China. The integrated model is developed by merging a SAM model of the PRE's coastal economy with an ecological model constructed using Ecopath with Ecosim (EwE) software. Using this integrated model, the study estimates the impacts of fishery policy simulations on the PRE's economic, ecological, and social systems.

2. Methods and materials

2.1. Study area

After the Yangtze, the Pearl River is China's second largest river (2200 km) in terms of water discharge. The Pearl River consists of three major tributaries, the West River, the North River, and the East River, which converge at the PRE, forming a complex river network that discharges into the South China Sea (SCS) [32]. These factors have given rise to a very complex tropical marine ecosystem in this region. The interactions among fish species in the Pearl River are quite complex, primarily because of the large variety of species involved and their diverse habits and mechanisms of biological predation [33]. The PRE ecosystem in this study is less than 60 m deep and ranges from 112°30′E to 115°00′E, 21°30′N to 23°30′N (Fig. 1). According to these boundaries, the scope of this research covers an area of approximately 72,490 km^2 [34,35].

The PRE is an important fishing ground in the SCS, and it provides abundant fishery resources for Guangdong province. The current trends of overfishing and biodiversity losses in the PRE are responsible for the collapse of many commercial marine fisheries established in the last century [36–39]. Furthermore, large increases in the number of fishing boats, improvements in fishing technology, and intensified fishing pressure on commercial fish species have resulted in a decline in the biomass of many large-size and high-quality species and 'prey release' of some low-valued species of small fish [37,39]. The overcapacities of the PRE's

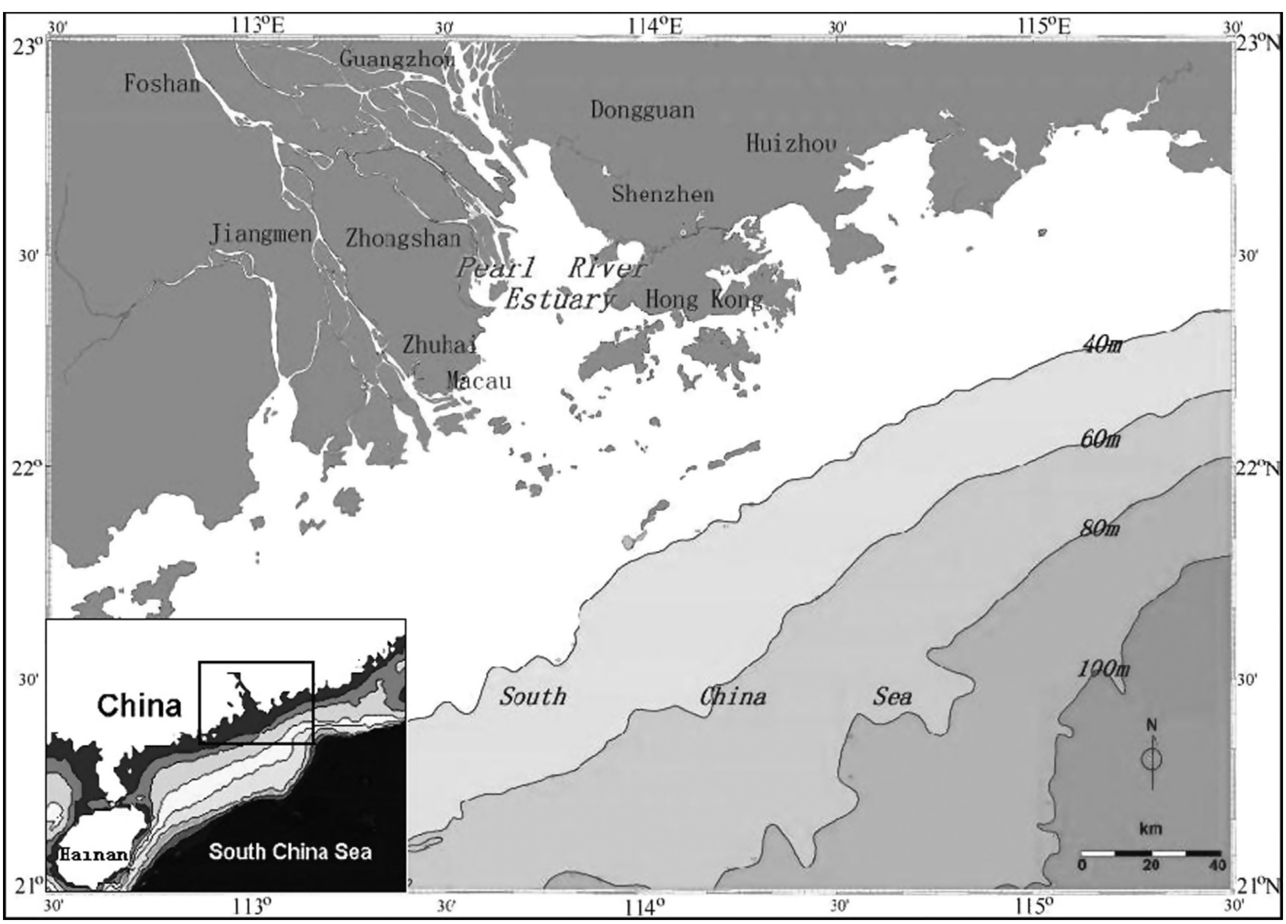

Fig. 1. Map of the Pearl River Estuary.