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Ecological damage compensation for coastal sea area uses

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ABSTRACT

Rapid economic growth has resulted in significant ecological degradation in many coastal areas in China. Control measures involving marine ecological damage compensation (MEDC) have been introduced to curb unsustainable development. The study presents a practical framework for developing the MEDC standard. The standard considers spatial variation in ecological services and includes many different types of ocean uses that are common in coastal waters around the world. We illustrate the framework and specific procedures through a case study of Xiamen. Results of our calculation show that damages from many ocean uses to the ecosystems are not adequately compensated under current management regime, and a carefully designed MEDC standard is crucial for sustainable development.

1. Introduction

Rapid development of marine industries and the coastal economy in China has resulted in the deterioration of coastal ecosystems and the environment (CCICED, 2012; Peng et al., 2009). Apart from direct economic values, such as seafood production, the coastal and marine ecosystems provide various other services to the society, such as nutrient recycling, shoreline protection, and climate regulation (De Groot et al., 2002). These services are vital for human survival and wellbeing. Unsustainable coastal development is diminishing the capability of marine ecosystems to provide the services. To ensure sustainable development in China's coastal regions, government agencies, such as the State Oceanic Administration (SOA), have introduced market-based control measures involving marine ecological damage compensation (MEDC). The basic idea is to make developers of ocean space pay the full costs associated with their activities, including damages to the marine ecosystems (SOA, 2009). Without MEDC, ocean users only pay private costs (e.g., construction and operating costs), the ecological compensation mechanism is designed to internalize the externalities of different ocean uses so that excessive development activities can be curbed (CCICED, 2007). The collected compensation payments can be used to restore damaged marine ecosystems, as determined by local governments.

There is a substantial literature on the assessment of and compensation for ecological damages. Most of the studies focus on the ecological damages associated with accidental spills of oil or other hazardous substances or waste disposals (Ryan, 1994; NOAA, 1997; Mason, 2003; Kim, 2003; McCay et al., 2006). Another set of studies examines the ecological damages related to coastal reclamation or wetland drainage in China (Wang et al., 2010a,b; Peng et al., 2011) and around the world (Cendrero et al., 1981; De Mulder et al., 1994; Hoeksema, 2007; Airoldi and Beck, 2007; Halpern et al., 2008; Elliott and Cutts, 2004; FAO, 1999; OSPAR, 2008). In contrast, little attention has been paid to the ecological damages related to coastal development and ocean use activities that are consider regular or routine, such as aquaculture, sea bridges, and anchorage.

Although regular ocean space uses need the approval from relevant government agencies in China, under current management system, ecological damages associated with these uses, especially at small scales, are often excluded from compensation considerations. However, these damages are typically long lasting and have considerable cumulative effects on marine habitats and the environment.[1] Under these circumstances, there are continuous and uncompensated losses to the marine ecosystems due to these "regular" uses. Thus, it is urgently needed to establish of a MEDC system that covers a wide range of ocean uses and is easy for coastal managers to implement.

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[1] Marine aquaculture affects the marine ecosystem through biological, chemical, and organic pollutions, habitat modification, as well as wild-caught fish as feed ingredients (Goldburg et al., 2001). Coastal recreation and tourism may cause physical alteration or destruction of habitats (UNEP, 2002). The anchors of recreational boats can cause damages to marine habitats (Lloret et al., 2008).

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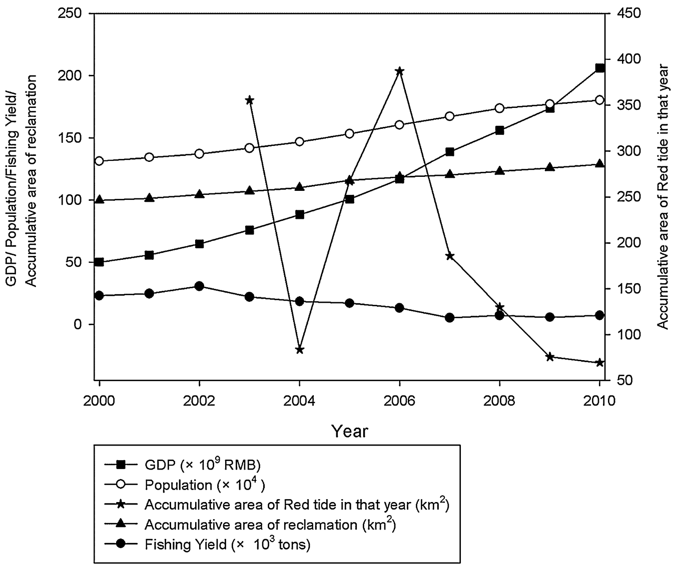

Fig. 1. Socioeconomic development and ecosystem conditions in Xiamen, 2000–2010.

In this paper, we describe a framework for the development of a MEDC standard with an application to Xiamen. The study area and general method to calculate the values of MEDC are described in Sections 2 and 3, respectively. Estimation procedures are detailed in Section 4. Results are summarized in Section 5. Discussions and conclusions are presented in Sections 6 and 7.

2. Study area

Located on the southeastern coast of China's Fujian Province, to the west of Taiwan Strait, Xiamen covers a land area of 1565 km^2 and a sea area of 390 km^2 with a coastline of 234 km. Xiamen's economy and its well-being depend heavily on its surrounding seas for natural resources, goods and services. Rapid growth of local economy, population and urbanization in past decades has resulted in more diversified and intensified utilization of ocean space and resources, which significantly altered the coastal environment. Marine pollution continues to increase. The frequency, geographic coverage, and duration of harmful algae blooms (red tide) have significantly increased since 2000 (Cai, 2008). In addition, large-scale coastal reclamation has destroyed natural habitats of various living resources. These changes together with over fishing and illegal fishing have led to collapses of many fisheries (Fig. 1).

In order to protect its marine environment and ecosystems, the Xiamen People's Congress promulgated *Several Regulations of Marine Environmental Protection* in 2010, which called for the implementation of a compensation regime for marine ecological damages resulted from sea area uses.

3. Methods

Since different sea areas may have different ecosystems that provide different ecosystem services, and the severity of damages to the marine ecosystems also vary by the types of ocean uses, our framework to develop the ecological compensation standard for a coastal region involves five steps (Fig. 2). First, the study area is divided into eco-zones according to natural conditions, key habitats, natural resources, unique ecological components (e.g., endangered and threatened species), and management tradition (e.g., protected areas). Next, specific ecosystem services that each eco-zone provides are identified. The ecosystem service values are then estimated at the unit level for each zone. Also, the level of damages to each ecosystem service is assessed for different types of ocean uses by a panel of experts. Finally, the MEDC standard is developed as follows.

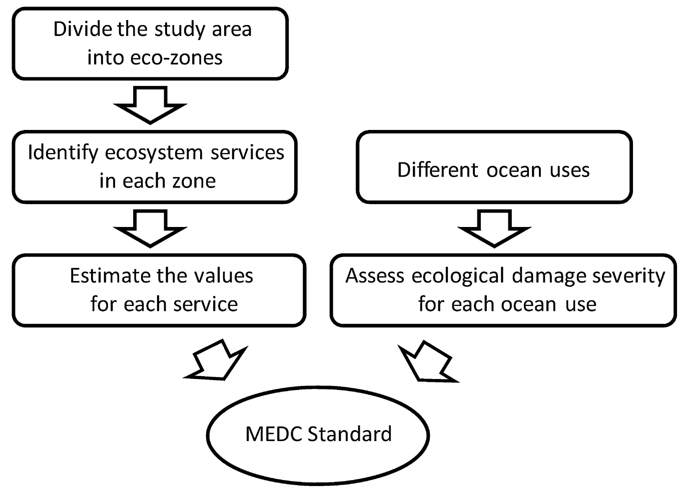

Fig. 2. Framework for developing MEDC standard.

The annual ecological damage (*ED*) for a specific use in an eco-zone is calculated as:

$$ED_{ik} = \sum_{j=1}^{j=J} v_{ij} d_{kj} \quad (1)$$

where i (=1, 2, . . ., I) is the index for eco-zones; j (=1, 2, . . ., J) is the index for ecosystem services; k (=1, 2, . . ., K) denotes each specific ocean use; v_{ij} stands for the annual value of service j provided by an unit area in zone i; and d_{kj} is an adjustment factor representing the severity of damage to ecosystem service j of ocean use k.

For a long-term use of a sea area (e.g., a bridge or a fixed structure), a lump-sum payment for the ecological damage, ED^{LS}, can be calculated as:

$$ED_{ik}^{LS} = ED_{ik} \frac{(1+r)^n - 1}{(1+r)^n r} \quad (2)$$

where r is the social discount rate[2]; and n is the number of years. For a permanent loss of ecosystem services, such as in the case of coastal reclamation, the ecological damage can be computed as ED/r.

4. Estimation

4.1. Division of sea areas

As mentioned above, different sea areas have different ecosystems and natural resources. In order to reflect these differences, we divide Xiamen's coastal waters into six management areas, Western Sea, Jiulong River Estuary, Southern Sea, Eastern Sea, Tongan Bay and Dadeng Sea, according to local marine function zoning scheme and management traditions. In the six management areas, a total of 27 eco-zones are identified according to marine ecological and resource features (Fig. 3). Note that Fig. 3 shows only the primary ecosystem in each eco-zone, and there may be multiple ecosystem types in a specific zone.

[2] This study takes the 2% as the social discount rate.