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Benefit and cost analysis of mariculture based on ecosystem services

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ABSTRACT

As a life-supporting system, marine ecosystem provides various services for human being. Based on ecosystem services, we developed a Benifit and Cost Analysis model to balance the conflicts between economic income and environmental loss caused by mariculture activities. This model not only calculates market income of mariculture but also monetizes the positive and negative effects of mariculture activities on ecosystem services. In this model, three indices, the NPV (Net Present Value), BCR (Benefit to Cost Ratio) and RC (Relative Coefficent) with consideration of discount rate, are developed to assess and prioritize the candidate mariculture modes. This Benefit and Cost Analysis model was applied to Sanggou Bay, one typical mariculture bay in China, to identify sustainable mariculture mode. In this paper, we find that benefit and cost analysis based on ecosystem services value provides a convenient and effective tool to compare different exploitation modes of marine ecosystem.

1. Introduction

Ecosystem services and their valuation research have become one of the most important research fields of applied ecology. Research on ecosystem services mainly focuses on the ecological theories, valuation methods, and their applications (Costanza et al., 1997; Daily, 1997). At the scope of ecological theory, the definition of ecosystem services, given by Daily (1997), was widely used. However, the definition by Millennium Ecosystem Assessment (MA, 2003) was more apt to the sociology and management. Although there is no standard to classify the ecosystem services now, the MA's classification is very useful and practical for valuation (MA, 2003). At the aspect of valuation methods, argues still exist (Farber et al., 2002; De Groot et al., 2002). Many techniques could be used to assess people's Willingness to Pay (WTP), however, the valuation for the non-market services is still weak. At the fact of applications, more attention is attracted. Most of the research focused on the tradeoff between economic activities and ecosystem services in order to guide the management of the ecosystem in a sustainable way. For example, Folke et al. (1991) argued that with the rapid increase of agriculture, industry and fishing, natural capital has become the major limiting factor for economic development of Balic Sea Region, and ecological engineering and the management for production are important measures to promote the sustainable development of economy. There are also many other relative studies (Alexander et al., 1998; Kreuter et al., 2001; Schröter et al., 2005).

In China, the concept of ecosystem services was introduced in 1990s, and there have been many studies about ecosystem services which involve the introduction of abroad studies, valuation methods and case studies. At present, the application research of ecosystem services attract more attention. Our study tries to apply benefit and cost analysis to quantify

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the influence of mariculture on marine ecosystem services, and identify a sustainable mariculture mode by optimizing the ecosystem services value.

Mariculture is a developing industry that makes a significant contribution to the national economy. Also it is an important animal protein supplement for majority of people in coastal area of China. On the other hand, mariculture in some areas causes the degradation of species (Zhu et al., 2000), the loss of biodiversity (Zhang et al., 2005b), and the decrease of ecosystem function (Zhu et al., 2000). In addition, it will lead to degradation of local environment due to mariculture wastewater (Cui et al., 2005), the death of mariculture living (Zhang and Zhang, 1999). Therefore, mariculture has various impacts on marine ecosystem services. Although it increases the value of some ecosystem services (for example, the increase of food production value), the value of some other ecosystem services will decrease possibly. Analyzing the impact of mariculture activities on the marine ecosystem services, and conducting benefit and cost analysis of mariculture based on ecosystem services, can help to identify the sustainable mariculture mode.

In this study, marine ecosystem services are classified firstly, according to the characteristic of China's marine ecosystem to give a framework of marine ecosystem services valuation. Then a benefit and cost analysis model based on marine ecosystem services is developed to assess and prioritize the candidate mariculture modes. Finally, this method was applied to Sanggou Bay, in the Yellow Sea, one typical mariculture bay in China, to identify the sustainable mode of mariculture.

2. Methods

2.1. Framework of marine ecosystem services

Based on the framework of the Millennium Ecosystem Assessment (MA, 2003), and considering the availability of the data of China's marine ecosystem, China's marine ecosystem services are classified into 14 types: 4 provisioning services, 4 regulating services, 3 cultural services and 3 supporting services adopted from MA (Chen et al., 2006; Shi et al., 2007).

Provisioning services refer to the products obtained from marine ecosystem. There are four provisioning services in China sea: i.e. (1) food production (seafood), (2) material production (biological material for chemical, pharmaceutical use, ornamental resources), (3) oxygen production and (4) provision of genetic resources.

Regulating services are the benefits obtained from the regulation of marine ecosystem processes, including (5) climate regulation, (6) waste treatment, (7) biologial control and (8) disturbance regulation.

Cultural services are the non-material benefits obtained from marine ecosystem through spiritual enrichment, cognitive development, reflection, recreation, aesthetic and educational experiences. There are three cultural services: (9) recreation value, (10) cultural value and (11) scientific value.

Supporting services are those that are necessary for all other marine ecosystem services. There are three supporting services: (12) primary production, (13) nutrient cycling, and (14) species diversity maintainance. Supporting service is different from provisioning service, regulating service and culture service as their impacts on people are often indirect or occur over a very long time. So when conducting assessment, supporting services aren't considered in order to avoid that the benefit or cost will be double-counted (MA, 2003).

2.2. A modified benefit and cost analysis model based on ecosystem services

Benefit and cost analysis (BCA) is a typical economic method of choosing which among a number of alternatives. The benefits and costs of a certain measure (program, project or investment) are weighed up against each other and the measure with the highest net value is recommended for adoption. In this paper, we will modify this method and apply it to the analysis of mariculture.

Firstly, some terms in benefit and cost analysis should be defined.

Benefit (B) refers to the increasing value of marine ecosystem services due to the change of mariculture mode, e.g. the increase of marine products due to the increase of mariculture area. If B_i is the increase value of ith marine ecosystem service, then

$$B = B_1 + B_2 + B_3 + \ldots + B_n \quad (1)$$

Cost (C) is the decreasing value of marine ecosystem services due to the change of mariculture mode. If C_i is the decreasing value of ith marine ecosystem service, then

$$C = C_1 + C_2 + C_3 + \ldots + C_n \quad (2)$$

Time is important in BCA because, even if we have future benefits and costs, decisions have to be made today. What is important is thus the calculation of present values. BCA is a decision supporting system where decisions have to be made today. This means that costs and benefits have to be expressed in present-day values, and thus future costs and benefits have to be discounted.

Let r be the discount rate, the Benefit in the tth year (B_t) and corresponding Cost (C_t) can be discounted to present values (PB_t, PC_t) respectively as:

$$PB_t = B_t/(1+r)^t \quad (3)$$

$$PC_t = C_t/(1+r)^t \quad (4)$$

Net present value (NPV) is the most important criteria in benefit and cost analysis. NPV is an absolute index for the net contribution of a program to economy. It is a sum of the net benefit in every year by the end of the program in terms of the present value. Those programs with net benefits greater than zero are the feasible programs. The formula of NPV is as the following:

$$NPV = \sum_{t=0}^{T} \frac{(B_t - C_t)}{(1+r)^t} \quad (5)$$

Where B_t and C_t are the benefit and cost in the tth year respectively during the program, r represents the discount rate and T is the timescale of the program.