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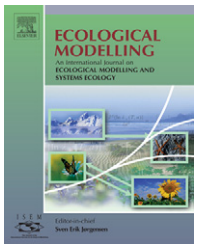

A system dynamic based DSS for sustainable coral reef management in Kenting coastal zone, Taiwan

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ABSTRACT

Kenting is located at the southern end of Taiwan, and is famous for its abundant marine resources, especially diverse coral species. This beautiful coastal zone attracts millions of tourists every year. However, growing human activities and increasing land reclamation pressure have resulted in negative impact to the coral reef ecosystem. Thus, exploring an integrated approach for sustainable coral reef management is urgently needed. The current study adopts the integrated coastal zone management (ICZM) concept and develops a system dynamic (SD) based decision support system (DSS). The SD model, built as a DSS to facilitate scenario analysis, can solve the complex coastal zone management problem. Four subsystems, socio-economic, environmental, biological, and management, join with the SD model configuration for integrated assessment of the particular problem. The model identifies four critical management strategy variables, including land development, wastewater treatment, local fish consumption rate, and entrance fee collection, and presents users with a user-friendly DSS interface. Several scenario analyses are conducted and presented in this paper. Decision makers can also fine tune DSS variables and evaluate preferable scenarios through simulations. Sustainable management strategies for the coral reef ecosystem can hopefully be developed using the DSS and implemented in the near future.

1. Introduction

Coral reefs, particularly fringing reefs, are often located close to the coast and should be considered as parts of the coastal zone. They are one of the most important ecosystems on Earth in terms of productivity and biological diversity (Connell, 1978). Besides, coral reefs serve people in multiple ways, such as providing seafood, recreational possibilities, coastal protection, and aesthetic and cultural benefits (Done et al., 1996). However, extensive coastal development pressures from increasing demands for industry, tourism, housing, transportation, and other human activities, have a major impact on coral reefs. Westmacott et al. (2000) suggested that the coral reef sustainability may best be addressed by appropriate coastal zone management.

Coastal zones are complex regions influenced by numerous interrelated issues, including socio-economic, administrative, and hydrological systems. Multiple human-interest convergence, such as tourism, agriculture, raising stock, fisheries, and other industries, makes these areas the most populated yet fragile regions in the world. Recuperation and conservation efforts to sustain natural resource and environment quality are therefore critical. However, coastal zone management faces serious challenges. Inefficient cross-organizational cooperation deserves particular attention, since effective management strategy cannot succeed without

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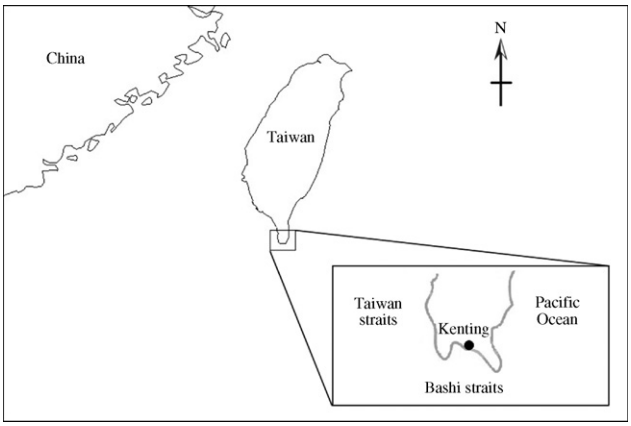

Fig. 1 – Location of Kenting.

considering system coexisting entities. Therefore, exploring an integrated approach for dealing with coastal zone management problems is strongly needed. Integrated coastal zone management (ICZM) has become the global guideline for environmental planning and management in coastal area (Cicin-Sain and Knecht, 1998).

Kenting is located at the southern tip of Taiwan, on the Hengchun Peninsula, with the Pacific Ocean to the east, the Taiwan Straits to the west, and the Bashi Straits to the south, as shown in Fig. 1. With its unique spatial location, where the famous Kuroshio current brings abundant marine organisms, Kenting coastal water nourish 60% of coral species found in the world. The abundances of marine resources in Kenting have drawn the worldwide attentions from academic communities, and ocean lovers. Meanwhile, by providing a variety of scenic resources, this tiny coastal zone is one of the most popular resorts in Taiwan. Kenting attracts million of tourists every year, who enjoy not only sightseeing, but also many recreational activities and the taste of fresh seafood. Consequently, the public sector are confronted with the over-developed tourism which usually accompanying with serious problems, such as increasing land reclamation pressure, depletion of coral reef fish stocks due to overfishing, and degradation of the marine resources.

Uncoordinated human activities in the coastal zone can cause severe impact on marine environment. Bryant et al. (1998) observe that more than 80% of Southern Asia coral reefs are at risk, primarily owing to human impact. Many studies, as summarized by Moberg and Folke (1999), also indicated that unsustainable use of coastal and marine resources by human activities would destroy the resilience of coral reefs. There are some nature threats to coral reefs in Kenting, such as intrusion of unusual cold water mass, typhoon, and El Nino. Natural disturbances behave like random discrete events appearing occasionally, whereas human-induced disturbances function like continuous events occurring all the time. Nyström et al. (2000) explained the interactions between the two types of disturbances. The natural disturbance regime affects the dynamic development of coral reefs; nevertheless, the chronic stress by human activities would alter the capacity of reefs to cope with natural threats, thus leading to unpredictable synergistic effects. To mitigate human-induced effect, the goal of the current study is to develop effective coastal zone management strategies toward sustainable coral reef ecosystem. Therefore, the factors of nature disturbances are excluded from the modeling process.

A system-dynamics-based (SD) decision support system (DSS) developed in this study and based on the ICZM concept, incorporates multidisciplinary research efforts with coastal zone management dynamics for effective decision-making. An SD model formulation does not require a complex mathematical system presentation and therefore allows for much easier system integration compared with traditional system analysis techniques. The dynamic behavior of and the interactions among Kenting socio-economic, environmental, and ecological factors can be seamlessly coupled using the SD modeling software STELLA®. This tool also facilitates DSS building, providing a user-friendly interface that allows decision makers or stakeholders to perform effective scenario analysis for sustainable coral reef management under the ICZM framework.

2. Methods

The ICZM is a dynamic, continuous, and iterative process designed to promote sustainable management of coastal zones (EC, 1999). Coastal areas have traditionally been regarded as indistinct from the "wider environment" and have consequently suffered from lack of policy and regulatory coordination (Huggett, 1998). There is growing realization with the passage of time, that the coast is not only a complex natural environment but also a complex policy area where numerous agencies with differing, but often overlapping objectives, responsibilities, and powers operate (Scottish Office, 1997). Sustainable coastal zone management strives for maximum long-term social good, including environmental, ecological, economic, social, and cultural considerations.

Integrated management is the ICZM conceptual framework, aggregating not only target area terrestrial and marine components, but also spatial and temporal dimensions of focus issues. Achieving such integrated management requires that ICZM utilize a range of core management principles. For example, it seeks to balance benefits among economic development, human uses, and natural resources of the coastal zone over a long time period. All activities should also be confined by natural dynamics and carrying capacity limits. In practice, ICZM implementation should encompass information collection, planning, decision-making, and implementation management and monitoring, as suggested by the European Commission in 1999.

System dynamics is a powerful yet simple method that uses causal-loop and stock-flow diagrams for describing interrelated systems. It is therefore easy for SD to model dynamic and complex components as an integrated system. Various system elements with long lasting influences simultaneously affect many coastal zone management problems. SD capability of dealing with complex, nonlinear, and feedback-loop structures inherent in social and physical systems make it appropriate for ICZM use. SD provides users with better understanding of system dynamic behavior by giving insight into feedback processes.