Journal of Environmental Management 146 (2014) 309–319

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Integrated wetland management: An analysis with group model building based on system dynamics model

Hsin Chen [a, *], Yang-Chi Chang [a, 1], Kung-Chen Chen [b, 2]

[a] Department of Marine Environment and Engineering, National Sun Yat-sen University, 70Lienhai Rd., Kaohsiung 80424, Taiwan, R.O.C
[b] Graduate School of Public Policy, The University of Tokyo, Japan, Rm. 3106, No.1, Qingdao E. Rd., Taipei 10051, Taiwan, R.O.C

ARTICLE INFO

Article history:
Received 9 January 2014
Received in revised form
10 May 2014
Accepted 20 May 2014
Available online 3 September 2014

Keywords:
Group model building (GMB)
System dynamics (SD)
Wetland management

ABSTRACT

The wetland system possesses diverse functions such as preserving water sources, mediating flooding, providing habitats for wildlife and stabilizing coastlines. Nonetheless, rapid economic growth and the increasing population have significantly deteriorated the wetland environment. To secure the sustainability of the wetland, it is essential to introduce integrated and systematic management. This paper examines the resource management of the Jiading Wetland by applying group model building (GMB) and system dynamics (SD). We systematically identify local stakeholders' mental model regarding the impact brought by the yacht industry, and further establish a SD model to simulate the dynamic wetland environment. The GMB process improves the stakeholders' understanding about the interaction between the wetland environment and management policies. Differences between the stakeholders' perceptions and the behaviors shown by the SD model also suggest that our analysis would facilitate the stakeholders to broaden their horizons and achieve consensus on the wetland resource management.

1. Introduction

Wetlands are saturated with water, either periodically or permanently, and possess abundant nutrients sustaining highly productive ecosystems. Wetlands provide services for the environment and human societies, including water purification, flood regulation, germplasm conservation, recreation, research, and education (Brander et al., 2006; Copeland, 2010; Costanza et al., 1997; Woodward and Wui, 2001). Because wetlands form the interface of water, land, and atmosphere, they play a pivotal role in not only the flow of material between water and land, but also balancing the biogeochemical cycles of carbon, nitrogen, and phosphorus. However, wetlands around the world are facing a rapid and massive decline. Approximately 364,000 km^2 of 42 important wetlands throughout the world have disappeared in the past 14 years, that is, 26,000 km^2 per year. This huge coverage loss results in ecological disturbances and species disappearance (Coleman et al., 2008). The main reason for the declining wetlands is not fully understand wetland ecosystems services, thus wetlands are perceived as marginal lands. Although the services of the wetland ecosystem are self-valued, its ecological benefit is usually externalized and difficult to calculate in decision making. Thus, economic development is usually prioritized over conservation. Focusing only on the benefits of industrial development would neglect the non-market value of wetlands, and the neighboring environmental system. Casually filling a wetland or transforming it for industrial development would result in loss of primary functions of the wetland, even deteriorate to unrecoverable conditions (Ehrenfeld, 2000; Lee et al., 2006; Zedler and Kercher, 2005). Wetland loss causes ecosystem disintegration, which influences the structure of ecological species groups in the regional environment, and the economy of dependent and subsidiary industries. Furthermore, chain reactions from the declining environmental system could lead to an unsustainable state in the surrounding area.

Wetland management is established by considering multiple system behaviors including environmental economics, social development, and ecological conservation. As these behaviors interact with each other, wetland management in fact is extremely dynamic and complex (Bowen and Riley, 2003; Ghermandi et al., 2008; Lin et al., 2007; Turner, 2000). These interactions, nonetheless, are generally overlooked and only focus on examining a single system in wetland studies. Consequently, it is difficult to develop a holistic view of wetland development, and achieve effective wetland resource preservation. Moreover, as wetland structure and

* Corresponding author. Tel.: +886 7 5252000x5166.
E-mail addresses: hsinchen66@gmail.com (H. Chen), changyc@mail.nsysu.edu.tw (Y.-C. Chang), kc2710@columbia.edu (K.-C. Chen).
[1] Tel.: +886 7 5252000x5176.
[2] Tel.: +886 2 23588121.

http://dx.doi.org/10.1016/j.jenvman.2014.05.038
0301-4797/

function exhibit regional characteristics that vary with different constituent elements, such as the physical environment, biological composition and hydrological conditions, the wetland management strategies differ for each case. An inability to identify a wetland's regional characteristics may result in ineffective management.

In this study, we apply an integrated and systematic approach to examine wetland resource management. We first use the group model building (GMB) method to comprehend the regional environmental characteristics, and explicitly determine the vision of the stakeholders toward wetland development. Several auxiliary instruments are introduced to address the distributed cognition involved in group decision making, such as Nominal Group Technique (Delbecq and Van de Ven, 1971; Delbecq et al., 1975), Brainstorming (Osborn, 1963) and Delphi method (Linstone and Turoff, 1975). These instruments facilitate collecting information and help participants focus on main topics, they are incapable of presenting the internal complicated causal links within an intricate issue. In order to facilitate the participants to understand the dynamic interaction among each component, a systematic approach to self-reflect and examine the causality is needed. Only by this approach can one seek out the nature of an issue among its fuzzy appearances.

The objective of this study is to evaluate the sustainable management of the Jiading Wetland and its implications for regional development. We introduce system dynamics (SD) to address the dynamic and complex issues related to the multiple systems in the wetland environment. With SD simulations, we are able to quantitatively analyze the environmental changes in the wetland, and to conduct scenario analyses based on various management strategies. Stakeholders may refer to our findings when developing their proposals for wetland management. This study provides an opportunity for stakeholders to improve their perceptions of wetland development, and subsequently achieve a consensus on wetland management.

2. Study area

The primary region in the case study is the Jiading Wetland, located in Kaohsiung City, in southern Taiwan (Fig. 1). To spur economic development in the Jiading District and Xingda Port, the local government brought in the yacht manufacturing industry to promote a regional industrial upgrade. A part of the Jiading Wetland was transformed into the yacht industrial zone, and the future expansion of the yacht industry may threaten the existence of the Jiading Wetland. This study focuses on the impact brought by the yacht industry on the environment and ecology of the wetland, and the socioeconomic effect of the regional development in the Jiading area.

The Jiading Wetland (previously known as the Juhu Salt Flat; TW061) is located on the northern and eastern shores of the Xingda Port (previously known as Rao Port), covering approximately 171 ha (Yang and Ueng, 2011). To meet the industrial need of salt during the Japanese colonial period (1895–1945), the Southern-Japan Salt Industry Corporation was established in 1937. Numerous sand-paved salt fields were established in areas such as Budai, Qigu, and Whshulin to produce industrial salt. The once prosperous salt production gradually declined due to its price compared with the international market, and eventually many salt fields closed.

The embankment structures in the abandoned Jiading salt field formed shallow depressions, and the salt flat gradually developed into wildlife habitats. A long-term ecological monitoring survey conducted by the Jiading District Ecological and Cultural Association of Kaohsiung City documented a total of 34

Fig. 1. Location of the Jiading Wetland (120°11′44″E, 22°53′05″N).

families and 141 species of waterfowl inhabiting the Jiading Wetland, including *Egretta eulophotes*, *Platalea minor*, *Ciconia boyciana*, *Accipiter soloensis*, *Butastur indicus*, *Pandion haliaetus*, *Accipiter virgatus*, *Spilornis cheela*, *Falco peregrinus*, *Glareola maldivarum*, and *Sterna albifrons* (Jiading District Ecological and Cultural Association, 2009, 2010, 2011, 2012). Statistics indicate that the average number of birds in this area is approximately 1500 to 1700 per day, and may reach 20,000 in September during the migration season. The recorded species and number of waterfowl indicate that the ecological structure of the Jiading Wetland is stable and diverse.

However, once the wetland is transformed into a larger yacht industrial zone, the original habitats will inevitably be fragmented, resulting in disturbance or even devastation of the ecosystem. It is urgent to manage effectively a healthy environment for the Jiading Wetland.

3. Methodologies

Wetland assessment and management exhibit a dynamic complexity and require an integrated perspective. The reductionism is ineffective for interpreting the interactions in wetland environmental systems. We adopt GMB method to elucidate the holistic system of the wetland, with complete regional characteristics. Then, we build a GMB-based SD model, to simulate the behavior of the wetland system over time, and to evaluate the performances of the designated management strategies.

3.1. Group model building

A group of people represented by local stakeholders is essential for building a sound dynamic model, because they involve in system operations and have the most in-depth understanding of system behaviors. Group model building (GMB) is an effective means to overcome problems with local people in policy-oriented studies (Hovmand et al., 2011).

GMB is defined as a method involved facilitators (usually a modeling team) and a group of stakeholders co-build a model to solve problems within a complex system (Vennix, 1996). During the GMB process, the facilitators only provide technical support for system building, whereas the stakeholders are responsible for system formulation by providing data, information, and a system framework (Andersen and Richardson, 1997; Hines, 2001; Rouwette et al., 2002; Luna-Reyes et al., 2006). The participation of stakeholders effectively enhances the authentic representation of the system. Furthermore, the discussion and analysis of model behaviors under various scenarios and strategic options allow introspection and revision of the mental model of the stakeholders. The cohesive process of information in GMB facilitates the overall environmental system development and policy promotion.