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A capital-based framework for assessing coastal and marine social–ecological dynamics and natural resource management: A case study of Penghu archipelago



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Abstract Human behavior and the environment interact reciprocally. It is necessary to understand social and ecological systems as an integrated co-evolving social–ecological system (SES) to reveal why an environment is in its current condition and how humans have impacted upon and been influenced by the dynamics of natural system. Many societies in coastal and marine SESs rely on marine natural capital for their livelihoods. They have adjusted to changes in natural capital by utilizing human-made capital (i.e., physical, human, and social capital), and their behavior is simultaneously influencing the natural capital. This study conceptualizes a capital-based framework for investigating the adaptation and transformation of a social–ecological system on temporal scale and provides a case study of Penghu Archipelago, Taiwan, with a 110-year historical review of the period of 1900–2010. It is furthermore examined how human society adapts to marine natural resource problems in order to understand the coping strategies. The results show human-made capital is inadequate with respect to sustaining marine natural resources. Appropriate investment in human-made capital is required for solving the problem. The challenge is to invest in social capital so as to form functional institutions that employ physical and human capital in a sustainable manner.

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Introduction

Humans affect and are affected by the natural environment. In order to understand their interactions and the dynamic processes, an increasing number of studies have emphasized social systems and ecological systems as an integrated social–ecological system (SES) and placed focus on their co-evolution

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trajectories (Olsson et al., 2004; Folke, 2006; Liu et al., 2007; Brondizio et al., 2009; Glaeser et al., 2009; Ostrom, 2009; Norgaard, 1994). As defined by Glaser et al. (2012), an SES “consists of a bio-geo-physical unit and its associated social actors and institutions”. It can be “delimited by spatial or functional boundaries surrounding particular ecosystems and their problem context”. It is composed of resources, actors, and its governance (Holdschlag and Ratter, 2013; Ostrom, 2009). In a coastal and marine SES (CM-SES), ecosystems provide extensive services that support the livelihood of human beings (Glaser et al., 2012; Ferrol-Schulte et al., 2013). The amount of coastal and marine natural resources directly influences those whose livelihoods depend on it. Since the coastal and marine environment and its associated natural resources are highly uncertain, societies must adapt to the dynamics of the system not only to sustain but also to develop their livelihoods (Marshall, 2013). In addition, adaptation is a dynamic process involving actions of an individual or a group of people to better cope with social and ecological change (Chakravarthy, 1982; Smit and Wandel, 2006; Nelson et al., 2007; Marshall, 2013). These actions simultaneously change the environment and require further adaptation. This study focuses on the adaptation process of human society in this complex interaction on a temporal scale and proposes a capital-based framework using natural and human-made capital to explore the complex interactions within a CM-SES. A case study of the Penghu Archipelago, a regional CM-SES, is used for understanding the main research question: how a society adapts to the dynamics of an CM-SES for sustaining livelihoods using human-made capital. The focus on Penghu helps provide a general picture of the causes and effects of current problems as well as their linkages upward to national and downward to community levels in the globalized world (Glaser and Glaeser, 2014). This paper sets out the concept of the capital-based framework and the rationale for using natural capital, human-made capital, and their interaction for understanding the reciprocal dynamics of a CM-SES. The roles that human-made capital play in societal adaptation and transformation in light of SES dynamics are discussed following a historical overview of the Penghu CM-SES. Bearing in mind the current marine natural resource crisis, which threatens people’s livelihoods, suggestions are made for appropriately constructing human-made capital for sustainable use of natural capital.

A capital-based framework: interactions between natural and human-made capital

Costanza and Daly (1992) define natural capital as “the stock of natural ecosystems that yields a flow of valuable ecosystem goods or services into the future”. Natural resources are stocks that generate ecosystem services and benefit human beings. For an example, fish stocks are natural capital utilized by fishermen for their livelihoods (Hein et al., 2006). For fishermen, fish cannot only be food but must also be goods that can be exchanged for other needs. The combination of fish stocks, fishermen, and governance (institutions regulating fishing activities) comprise a fishery SES (Ostrom, 2009; Holdschlag and Ratter, 2013), which is a subsystem of a CM-SES on a functional scale (Wu, 2013). Compared with natural capital, human-made capital is seen as the ability of societies to adapt

to changes (Walker et al., 2006). Different components of human-made capital have been utilized for different purposes. In the sustainable livelihood (SL) framework used for poverty reduction, human, physical, financial, and social capital are regarded as human-made capital interacting with natural capital (Ellis, 1999; Krantz, 2001). To understanding how to sustainably use natural capital, Berkes and Folke (1994) do not discuss the forms of human-made capital *per se* but instead utilize the concept of cultural capital, which links natural capital and human-made capital. In a capital assets framework, Bennett et al. (2012) regard human, physical, social, financial, cultural, and political capital as human-made capital for assessing tourism development capacity. In contrast, Ostrom (1999, p.174) adopts human, physical, and social capital as components of human-made capital, which is “created by individuals spending time and effort in transaction and transformation activities to build tools or assets today that will increase individual and social welfare in the future”. Although human, physical, and social capital are the only human-made capital elements in Ostrom’s concept, financial, cultural, and political aspects are elements composed by her three human-made capitals or are produced by their interactions.

In this study we adopt the Social-Ecological System Framework conducted by Resilience Alliance (2007, p.8) (Fig. 1) as a basis and conceptualize the ‘capital-based’ framework for assessing social-ecological dynamics (Fig. 2). In the capital-based framework, this study uses a more inclusive notion of human-made capital, presenting human, physical, and social aspects as a whole (human-made capital) for investigating their interactions with natural capital (Fig. 2). The concepts of human, physical, and social capital are examined as followed:

Human capital

Schultz (1961) claims that human capital includes not just the labor force but also the knowledge and skills of individuals, which can facilitate productive activities and help people change themselves to fit their changing surroundings (Coleman, 1988). This study discusses human capital in the form of number of fishermen, outsourced labor, increasing knowledge, and fishery sector skills. Social capital can influence human capital through information distribution and cooperation between individuals or groups (Brondizio et al., 2009; Cash et al., 2006).

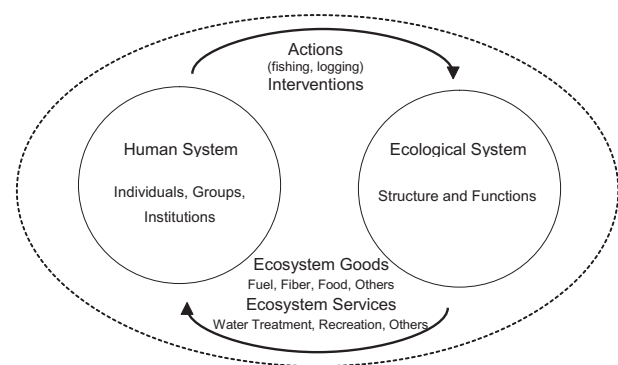


Fig. 1 Conceptual diagram of a social-ecological system (Resilience Alliance, 2007, p.8).

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