Is Ecosystem-Based Management Necessary for Adaptation to Sea Level Rise in Shrimp Growing Areas of the Mekong Delta?

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Abstract

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Throughout history, society has relied on natural capital provided by the surrounding environment. The most successful societies have been those that have been able to adapt their practices in order to take advantage when changes occur in their environment. In the face of climate change, however, societies around the world are threatened by accelerated environmental change. Ecosystem-Based Management (EBM) has been suggested as a way to increase the resilience of vulnerable communities to impacts of climate change, but may be difficult to implement because information on the connectivity between various parts of a system is frequently lacking. This is especially the case in developing countries. The Mekong Delta of Viet Nam is inhabited by 17.6 million people and is an economically valuable region, producing nearly $2.5 billion USD in shrimp per year for export. With an elevation at or below one meter, the area is particularly vulnerable to climate change impacts including specifically, sea level rise (SLR). The national government of Viet Nam is exploring both hard and soft solutions to protect this highly productive delta. Through this study I explore three case studies to determine the extent to which EBM is necessary to maintain adaptability in shrimp growing areas. From these case studies I conclude that, while there are a variety of initiatives under way that do not acknowledge all components of EBM, those that are most promising are adaptive in nature and can address future uncertainty by maintaining flexibility. However, while these solutions are likely to maintain a greater number of ecosystem services, they sacrifice short-term economic productivity. I discuss lessons learned, limitations of an EBM approach, and provide recommendations for large-scale adaptation to SLR through an integrated mangrove shrimp green belt in the Mekong Delta.

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1. Introduction

Throughout history, society has relied on natural capital (Tallis et al., 2009) provided by the surrounding environment, whether or not this dependence was understood or acknowledged. Over time human beings have become extremely adept at extracting and utilizing the ecological goods and services they value, and are now pushing the production limits of many ecosystems through over-extraction and environmental degradation. Successful societies have been able to further enhance their development through adapting their practices in order to take advantage when changes occur in their environment. Now, however, in the face of global climate change, societies around the world are threatened by accelerated environmental change. This raises the central question of how humans can continue to access the services communities depend on. Especially coastal communities, while managing for continued future production in vulnerable areas.

Ecosystem-Based Management (EBM) has been suggested as a way to increase the resilience of vulnerable communities to impacts of climate change (UNEP, 2006). EBM embraces a more comprehensive approach to management than traditional methods, with an emphasis on system-thinking rather than fragmented and piecemeal decision-making. However, EBM has been criticized for lacking the scientific knowledge and concrete guidelines for implementation, and for being difficult if not impossible to benchmark (Corkeron, 2006). These barriers are especially prevalent in developing nations, where communities may be vulnerable to climate change impacts. This is the case in the Mekong Delta region of Southeast Asia, an important agricultural region that is severely threatened by the impacts of even modest sea level rise projections (World Bank, 2011). In response, a variety of sea level rise adaptation strategies have been suggested. It is generally accepted within the scientific community that those strategies that take the most holistic approach are most likely to achieve long-term resilience (UNEP, 2006). However, with the barriers to full EBM and a number of strategies already in various stages of implementation it is useful to ask whether the presence or absence of the accepted principles of EBM within each adaptation strategy are critical in achieving the short and long-term goals of the region.

In this thesis, I review the background and context of SLR in Viet Nam and its impact on mangrove ecosystems converted to shrimp culture by conducting case studies of three strategies for adaptation to sea level rise currently used in shrimp producing regions of Southeast Asia. Each case study is assessed using a framework of EBM principles adapted from Slocombe (1998), and ecosystem and societal resilience adapted from Leslie and Kinzig (2009). I then conduct a cross-case comparison, through which I derive lessons to be learned. Finally, I make recommendations for future climate change adaptation strategies in this region in light of the valuable shrimp aquaculture industry and the potential role of mangrove ecosystems in sustaining shrimp aquaculture and providing other necessary ecosystem services (Michaels, 2011).

1.1. Defining EBM in Contrast to Traditional Management Approaches

According to the consensus of over two hundred academic scientists and policy experts, Ecosystem-Based Management can be best defined as "an integrated approach to management that considers the entire ecosystem, including humans" (McLeod et al., 2005). In contrast to EBM, traditional approaches to management and conservation of environmental resources have been criticized for acknowledging only single sectors or goals and disregarding the value of ecosystem services in decision-making (Tallis et al., 2009). EBM differs from current management approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors and emphasizes the connections between those sectors (Barbier et al., 2008).

Even though it is widely accepted in the academic and environmental advocacy communities, EBM has been criticized for being conceptual rather than practical, and for lacking concrete guidance on how to balance the seemingly opposing goals of development and conservation (Douvere, 2008). The ambiguous goals of EBM are not easily measured, making it difficult to evaluate progress (Murawski, 2007).

The goal of EBM is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need (Barbier et al., 2008). An ecosystem approach to management is intended to directly address the future on-going delivery of ecosystem services and the resilience of ecosystems to perturbations (McLeod and Leslie, 2009). This approach inherently integrates humans into the management equation both as actors that can manipulate ecosystem function and as the recipient of the resulting services. Given that resilience is featured so prominently in the stated goals of EBM (Murawski, 2007), it is useful to discuss this concept in the context of EBM and social ecological systems because it provides a framework for thinking about the appropriate scale of management when considering an EBM approach.

1.2. Defining Resilience

It is important to have an adequate working definition of resilience that considers both the social and ecological components of an integrated system. Resilience is the extent that a system can maintain its structure, function, and identity in the face of disturbance (Walker and Salt, 2006). There are three key characteristics of resilience science to recognize. They are summarized by McLeod and Leslie (2009) in the following manner:

> "*1) The intimate coupling between social and ecological systems (SES), 2) The existence of multiple possible states and abrupt changes among them, and 3) The contributions to system resilience of diversity and interactions across scales of space, time, and organization.*"

McLeod and Leslie (2009) warn of the flaws in traditional approaches in environmental or natural resource management, most notably that the conservation of single species or processes in isolation ignores society's participation and reliance on the whole system. In the first characteristic of resilience, McLeod and Leslie (2009) suggest that, rather than viewing the influence of society on the environment as a detriment, strengthening the ties between societies and their environment can actually foster resilience. The second characteristic of resilience points to the fact that in nature nothing is static. Traditional management has often focused on trying to achieve and maintain systems in an optimal stable state, usually to maximize a single ecosystem service highly valued by humans (Folke, 2004). This suggests that managers should consider a range of possible states when making decisions, for example, states that do not provide humans with all of their desired goods, but still fulfill ecological processes. Finally, regardless of spatial, temporal or political borders, interactions shared with the system must be accounted for and considered in management decisions in order to be resilient. For an EBM approach to be successful it must have resilience as an underlying theme, and be able, at least, to meet the above characteristics.

1.3. Threats to Social-Ecological Systems

Social-Ecological Systems (SES) are vulnerable to anthropogenic and natural perturbations but given time, resources and political will, SES can adapt to these changes. In the face of accelerated climate change, however, it is possible that changes in the environment may occur faster than SES can respond. This increases the likelihood that previously stable regimes may change to a less desirable state (Adger et al., 2005), which could have significant detrimental impacts for communities, both social and ecological.

According to the scenarios produced by the International Panel on Climate Change (IPCC) project, an increase in global mean surface temperature of 2.0 to 6.4° Celsius above preindustrial levels, leads to the likelihood of increased number of incidents of floods and droughts, and a rise in sea level of an additional 8 to 88 centimeters between 1990 and 2100 (IPCC, 2007). The cumulative effects of anthropogenic pressures and climate change impacts can erode the resilience of coastal SES in particular (Adger et al., 2001) and allow for heightened vulnerability to natural disasters. Natural disasters such as hurricanes, tsunamis, coastal flooding and many other disasters are on the rise as a result of global environmental change (McClean et al., 2001). This rapid change in climate has already had significant impacts on biodiversity and ecosystems, including causing changes in species distributions, population sizes, the timing of reproduction or migration events, and an increase in the frequency of pest and disease outbreaks (MA, 2005).

1.4. Resilience in the Context of Social-Ecological Systems

As ecologists and anthropologists investigate the social welfare of communities in coupled SES the concept of resilience is useful in attaching value to the balance found in the interaction of a functioning ecosystem with the welfare of the society to which it is linked. According to Gibbs (2009), resilience is the ability for a system such as a coastal SES to "adapt" in response to large external perturbations. The Stockholm Resilience Centre (2012) defines ecosystem resilience as a measure of how much disturbance (storms, fire or pollutants) an ecosystem can handle without shifting into a qualitatively different state. Resilience is the capacity of a system to both withstand shocks and surprises and to rebuild itself if damaged[1]. It is widely accepted that the more pristine an environment, the more resilient it is to large-scale natural perturbations. This is based on the idea that ecosystems with greater biodiversity also tend to have functional redundancy built into their community structure (Kremen, 2005). When faced with a disturbance, these systems are more likely to retain their capacity to provide ecosystem services.

Social resilience is the ability of human communities to withstand and recover from stresses, such as environmental change or social, economic or political upheaval (Adger and Luttrel, 2000). Resilience in societies and the ecosystems on which they depend is essential in maintaining options for future human development. The Resilience Alliance differentiates between ecosystem resilience and resilience of social systems in that social systems have the added capacity of humans to anticipate and plan for the future[2]. The social component of the system has the ability to either reduce or improve resilience for the whole SES through acting out a premeditated strategy to interacting with its environment.

1.5. Can EBM Foster Resilience?

A number of authors have described the components required for the successful implementation of EBM (e.g., McLeod and Leslie, 2009; UNEP, 2006). In the face of the global issues the planet is facing, in combination with the current economic crisis, creating EBM strategies may appear to be out of reach for managers in many countries. With the barriers associated with implementing a complete EBM approach, it may be useful to think about the ability of current management plans to achieve the goal of EBM: resilience in social-ecological systems. This may provide guidance on how to move towards an EBM approach in the future. Leslie and Kinzig (2009) outline the characteristics of resilience, which provide an excellent framework that can be useful in evaluating management plans. In the following sections, I apply this framework, as well as a more traditional framework on the components of successful EBM, to three case studies concerning climate change adaptation strategies for shrimp culture in mangrove ecosystems in Thailand and Viet Nam and their ability to achieve long-term resilience through social, ecological and economic dimensions. I then use the three case studies to compare and contrast three different aspects using the ecosystem and resilience framework. The first comparison of cases illuminates how differences in the social structures of Viet Nam and Thailand play a crucial role in the acceptance and involvement in restoration of ecosystem services in each area. The second comparison of cases looks at two potential responses to managing sea level rise in Viet Nam's Mekong Delta, and discusses each in terms of its ability to adapt in the face of change. The final comparison of cases examines the cases under an economic lens, exploring the potential costs and benefits of each of the adaptation strategies. Together, these case comparisons

[1] http://www.stockholmresilience.org/research/whatisresilience/resiliencedictionary.4.aeea46911a3127427980004355.html Date last accessed (DLA) 06/5/2012

[2] http://www.resalliance.org/576.php DLA 06/5/2012

permit an in-depth look at the role of EBM in planning for adaptation to sea level rise and its ability to achieve resilience in shrimp growing mangrove areas and in similar SES. The resulting analysis illustrates what it means to be resilient to both anthropogenic and natural disturbances in shrimp growing areas, and highlights the importance of maintaining flexibility and adaptation when there is uncertainty.

2. Background and Context

The coastal provinces of the Mekong Delta of Viet Nam and Eastern Thailand are the top two shrimp producers in Southeast Asia (Tien and Griffiths, 2009). Each of these areas has haphazardly removed their mangrove ecosystems to increase land available for shrimp culture. I focus on these areas because of the high level of shrimp production and common vulnerability to impacts of climate change between these areas. In this section, I provide the background information necessary to understand the ecological, social and governance systems in the region and the threats posed to these systems by climate change sea level rise in particular.

2.1. Characterizing Real World Social-Ecological Systems: Shrimp Production in Southeast Asia

Coastal Southeast Asia as a region has a unique geographic and climatic situation, one that presents both opportunities and challenges in the face of climate change. Much of the Southeast Asian peninsula is low-lying, tropical wetland dominated by mangrove forests. It is flanked by two bodies of water, each with its own tidal cycle (Tran Thanh Xuan, 2001). During the dry season brackish water influences much of the coastal area and inland via large deltas, providing a perfect habitat for a variety of species of mangroves, that have adapted to live in standing water and tolerate a range of salinity levels (Polidoro et al., 2010). Traditionally communities have manipulated this region to take advantage of this wet tropical climate to grow rice, and have also depended on coastal and inland fisheries for subsistence and commercial livelihoods (Armitage and Johnson, 2006). However, in the last 50 years technological advances have led to increases in the level and extent of manipulation in this region in order to expand the area in rice culture and later in shrimp aquaculture. Environmental degradation and the fragmentation of ecosystem structure have resulted in a significant loss of ecosystem function due to prior management goals (Tri et al., 1996).

2.2. Mangroves and Ecosystem Services

Mangrove forests are made up of many different species of mangrove trees and other vegetation, insects, fish, shellfish, birds, reptiles and mammals. They provide numerous benefits to humans through ecosystem services (Polidoro et al., 2010). Mangroves act as a bio-filter, cleaning the water coming from the land before it reaches the sea. These salt tolerant trees sequester the excess nutrients coming from the land and convert them into plant matter, which feeds the biodiverse mangrove ecosystem. Mangrove ecosystems provide direct goods such as finfish and non-finfish commercial and subsistence fisheries, timber and firewood, dyes, and medicinal remedies (Michaels, 2011). Other less obvious but crucial services include air purification, flood control, erosion control, generation of fertile soils, detoxification of wastes, filtration of nutrients, pollination, nursery grounds for ecologically and commercially valuable fish species, and protection as biological barriers to climate change related events (Tri et al., 1996). Most importantly mangroves have been identified as one of the most crucial ecosystems in maintaining resilience to impacts of climate change (Michaels, 2011). Mangrove stands lining the coast are capable of significantly reducing wind and wave energy from storms[3] and act as a vegetated mat retaining sediments, which prevent erosion (Lewis et al., 2003).

2.3. Shrimp Production in the Mekong Delta, Viet Nam

In the heavily manipulated coastline of Southeast Asia, the mangrove ecosystem has been fragmented mostly for agriculture production. Historically, rice cultivation was advantaged by controlling river flow and by avoiding areas affected by salinity. This meant that coastal mangroves were largely left intact. However, improvements in the ability to manipulate the hydrology of an area through pumping, dikes, etc. have made it possible to convert areas that were previously saline to agricultural land. For example, in areas near to the main branches of the Mekong River mouth in Viet Nam, rice cultivation was at one time expanded out to the coastline as seen in Soc Trang Province. Additionally, advances in aquaculture, coupled with a demand for shrimp in global markets have led to a shift in land use of tidal areas (Lewis et al., 2003). This has led to significant clearing of mangrove forests to make room for this high value commodity, with some estimates placing the loss of mangrove forests as high as 80% in the Southeast Asia region (Polidoro et al., 2010).

With the expected global increase in human population pegged at about 2 billion over the next hundred years, aquaculture can play an increasingly prominent role in providing a source of protein (Delgado et al. 2003). Asia is the largest aquaculture producer and accounts for 88.8 percent of world's aquaculture production by quantity and 78.7 percent by value in 2008 (FAO, 2010). Shrimp (all species combined) is the most highly valued commodity, traded among all fisheries products globally. It accounted for 15 percent of the total value traded internationally in 2008 (FAO, 2010), with the major exporting countries being Thailand, China and Viet Nam.

In recent years Vietnamese shrimp exports have been valued at $2.4 billion USD. Approximately 80% of this shrimp is produced in the Mekong Delta4. The Mekong delta has been formed by the Mekong river system, which flows 2,500 miles from its source in Quinghai province, China, until it empties into the South China Sea. The Mekong Delta lies on a peninsula between the Gulf of Thailand to the west and the South China Sea to the east (MRC, 2011). During the dry season, brackish water influences much of the delta. The Mekong delta typically experiences

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3 http://czm-soctrang.org.vn/Publications/EN/Docs/Mangroves%20of%20Soc%20Trang%201965-2007%20EN.pdf DLA 06/12/2012

4 http://vietnamseafoodnews.com/?p=3602 DLA 06/12/2012

year round temperatures ranging from 20-35° Celsius. This allows farmers to grow two crops of shrimp every year (Tri et al., 1996).

2.4. Social and Environmental Impacts of Shrimp Farming

Shrimp aquaculture has been a rapid way to economically diversify and to earn money. It may also play a local role to alleviate poverty and grow the local economy. Shrimp aquaculture has played a central role in the economic development of Viet Nam (Tien and Griffiths, 2009). In reality, the vast majority of shrimp production methods are not sustainable and the bulk of the profits go to the companies, government officials and wealthy elites (Primavera, 2000). Poverty alleviation must address the basic needs of impoverished people, and thus an effective poverty alleviation intervention should at the very least address food security. Shrimp production does not equate to food security (Rivera-Ferre, 2009) because the shrimp are being produced for export. Additionally, expansion of intensive/industrialized ponds limits access of traditional users to mangrove areas. As the ponds expire, new areas are claimed for aquaculture development, and communities are removed with no compensation (Quarto, 2009).

Shrimp farms are prevalently located in sensitive wetland ecosystems -- mainly where mangroves were present. When ponds are constructed, mangroves are cleared and natural hydrology is manipulated by building walls, and sluice gates are installed to control tidal flow (Lewis et al., 2003). The construction of shrimp ponds, depending on the method, cuts off ecosystem services in variable degrees. Loss of mangrove habitat means that valuable nursery areas for young fish and other commercially valuable species are not available and thus diminish future fish harvests.

Shrimp in densities typical to industrial aquaculture farms are susceptible to diseases, especially white-spot syndrome virus (WSSV), a virus that causes 100 percent mortality in 3 to 10 days[5]. WSSV has collapsed shrimp production systems around the world (Pham, 2010). Due to the high stocking density and the nature of intensive shrimp culture there are high levels of organic waste, chemicals and antibiotics flowing out from the farms. These aquaculture wastes are not only harmful to the land surrounding the pond, but also to the rivers agriculture farmers rely on for irrigation, which are tainted with salt and chemicals (Lewis et al., 2003). The cumulative effects of biota removal, disruption of abiotic components and introduction of harmful chemicals to the ecosystem result in a loss of ecosystem function and thus a decrease in services provided to the community. While these practices in some areas have been addressed, it is safe to say that they are the dominant form of shrimp culture today.

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[5] http://www.fao.org/fishery/culturedspecies/Penaeus_monodon/en DLA 05/13/2012

2.5. Shrimp Aquaculture and Human Communities

Traditional human communities in mangrove-dominated ecosystems evolved to rely on mangrove systems for subsistence. This dependence can form the basis for a strong SES which, when in balance, can prove beneficial, both to the humans who depend on the goods and services provided by the environmental and to the ecological system that the humans have a vested interest in protecting. Provided that the social component does not put too much pressure on any one aspect of the mangrove ecosystem, ecosystem function will be maintained. However, rapid changes in recent years, especially the access to new technology through development, are changing the landscape in a way that compromises ecological services. These changes are exacerbated by the fact that coastal communities of Southeast Asia are generally poor and are vulnerable to fluctuations in markets and the environment (Lewis et al., 2003). Community members may see shrimp production as a way to ensure short-term survival in an unpredictable and changing world. As a result, natural land is rapidly being converted to aquaculture, at the cost of the ecosystem services mangrove communities once depended on.

In shrimp producing areas of Southeast Asia there are various types of shrimp production methods. They vary inversely by the degree the environment is manipulated, and by the level of yield that the system produces. This equates to a spectrum of ecosystem function and social benefit through shrimp revenue. According to the UN FAO, there are three types of shrimp culture techniques: Extensive, Semi-intensive and Intensive[6]. In the Mekong Delta there is a fourth production technique, the Integrated Mangrove Shrimp Aquaculture System (Pham, 2010), which allows for mangroves and other seafood species to be cultured simultaneously with the shrimp. SES can range from being ecologically dominant to socio-economically dominant. Each of the shrimp farming techniques described below represents a different place on the SES continuum.

The Integrated Mangrove Shrimp Aquaculture System (Figure 1.) demonstrates a SES that maintains mangrove ecosystem function and provides significant benefits to the human component receiving revenue not only from shrimp, but also timber, fish, crab and mollusk harvesting as well as other ecosystem services such as protection from SLR (Pham, 2010). The social communities in these areas are most often characterized by capital-poor households that have been encouraged by an NGO or government program to increase mangrove coverage or decrease degradation (Conversation with IUCN-Viet Nam staff). Farmers are trained by extension agents from these organizations to increase the value of their ponds by promoting growth of multiple species simultaneously. The farmer maintains 50 to 70 percent of the pond with mangroves for rotational timber harvest, and designates the other 30 to 50 percent of the land for production of shrimp and other species in canals and for living quarters. Part of the program goal is having the farmer be responsible for the maintenance of ecosystem services, he will see the value and the goods they provide and continue with this type of farming on his own. Though the system is susceptible to shrimp disease and other hazards of stocking density,

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[6] http://www.fao.org/fishery/culturedspecies/Penaeus_monodon/en DLA 05/13/2012

farmers remain financially resistant to production fluctuations by supplementing their income with the secondary benefits from the healthy mangrove system.

The next method in the continuum is extensive shrimp farming (FAO website)[7]. This is the most common method of shrimp production in the Mekong Delta, and is most often practiced by small-scale farmers producing very low yields for both export and personal consumption. These farmers are likely to be poor and uneducated, and live in much the same manner as some of the earliest aqua-culturists have for thousands of years. Because of the large area that extensive ponds cover and the lack of need for chemicals and expertise, farmers are relatively isolated and have less interaction with other farmers. Extensive culture requires lower initial investment and does not require pumping water or machinery to construct the ponds, which are five hectares in area or larger. Shrimp seed naturally flows in with the initial filling of the pond, and farmers can purchase additional wild seed from collectors (Lewis et al., 2003). No additional food, chemicals or fertilizers are needed because food and nutrients come in with the tide. This is a low impact type of production in terms of hydrology and water quality, yet the pond is void of vegetation and thus mangrove ecosystem function is poor. Given the more natural hydrology of extensive ponds, they are very susceptible to disease thus yields and revenue can remain low.

Moving further down the scale towards a human dominated SES is semi-intensive shrimp farming (FAO website)[8]. Semi-intensive culture requires a greater initial investment, as it requires the purchase of seed from a hatchery and fertilizers to enhance natural pond feed. As a result, the farmers who undertake this kind of aquaculture tend to be extensive farmers that have access to investment capital as well as the chemical, feed sellers and export market that are necessary to increase revenue through the improvements to their traditional pond. Farmers have closer interactions with other farmers, as there is need to trade experience with neighbors to replicate successes. Also, middlemen buy product from groups of semi-intensive farmers to bring to the processor, creating the opportunity for teamwork as farmers attempt to barter and sell at a higher price. The ponds are regularly flushed by the tide, but are supplemented with pumping (Lewis et al., 2003). These systems usually operate in one to five hectare ponds and yield mid-level revenues depending on disease. Ecosystem function is heavily degraded due to the removal of vegetation and the use of chemicals, which further degrades the surrounding environment. Over time semi-intensive ponds must be dredged and maintained in order to keep the system from eutrophication (Corsin et al., 2007).

Intensive culture (Figure 1.), at the end of the SES spectrum, is an advanced, high-investment and technical production system. Ponds are small; less than one hectare in area. This type of farming is very resource intensive. The farmers who practice intensive farming are either wealthy, have leveraged their leased land for credit or are working for an enterprise (a government owned company). The wealthy farmers have likely done well with the conversion of

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7 http://www.fao.org/fishery/culturedspecies/Penaeus_monodon/en DLA 05/13/2012

8 http://www.fao.org/fishery/culturedspecies/Penaeus_monodon/en DLA 05/13/2012

their large, low yield extensive ponds to smaller semi-intensive ponds, gained capital and then invested in order to fragment their land into even smaller ponds for intensive production. Wealthy farmers usually display that wealth by building large, modern concrete houses. Poor farmers, observing shrimp production successes of neighboring farms, are then susceptible to approaches by feed, seed and chemical brokers to explain financial avenues to leverage leased land for loans to invest in the lucrative venture of intensive shrimp farming. Enterprises will often lease large sections of land and pay farmers to work and live on the farm. Shrimp are fed artificial diets four to five times a day, which represents over 50 percent of production costs (Lewis et al., 2003). Due to the development of various shrimp diseases, the use of antibiotics and antifungals in closed systems is common. With the lack of fresh tidal water exchange, ponds must be constantly aerated by either electric or diesel motors to keep the water quality at safe levels, which must be regularly measured. Due to the high stocking density, disease is a large risk, but if the crop is successful this method returns high revenues.

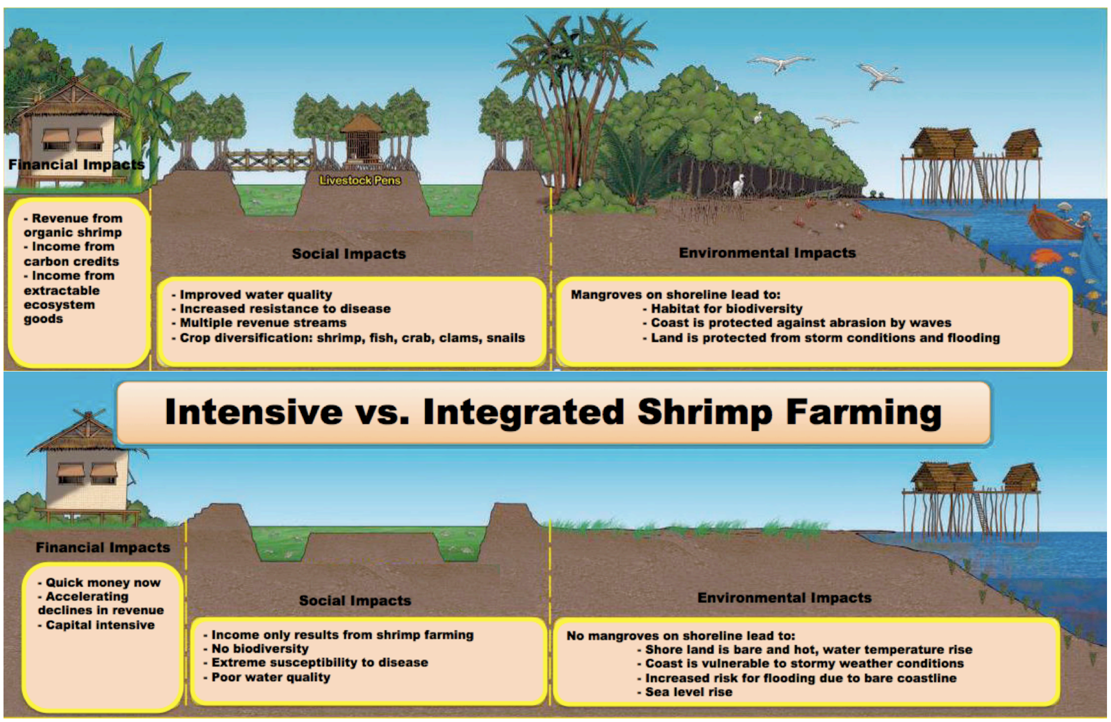

Figure 1. Intensive Shrimp Farming in contrast to Integrated Mangrove Shrimp Farming. Modified from Wetlands International's silvo-fishery concept. [1]

Ensuring that the SES can persist in a desirable state is a difficult task in the face of global demands from the production of ecosystem goods and a changing environment. The intentional removal of native plants and animals and manipulation of substrate and hydrology leave the SES vulnerable to a variety of perturbations. The intensive shrimp production system, where farmers deliberately sterilize the pond area through physical extraction and the use of chemicals, is a heavily manipulated system. This type of management prioritizes the maintenance of a single service above all other ecosystem services, but may be destabilizing to the SES as a whole because the social component becomes increasingly dependent on that single service. Production of that single service may be high for a time, but with the continued loss of other stabilizing services the entire system is at risk of collapse. We see this not only in the ecological parts of the system but in the social components as well. As farmers attempt to increase production through the intensification of their shrimp farms they must often take out loans, likely by leveraging their land lease. However, this puts these farmers and their families at risk to crop losses from disease. If this occurs, the farmers may be unable to pay back their loans and could lose their lease and be forced off their land. In contrast, extensive or integrated systems provide lower production, but in the event of shrimp disease, the farmer can fall back on the other products in his pond for income. By maintaining a lower yield system, the natural environment can persist and multiple ecosystem services can continue to be provided while maintaining resilience to threats.

2.6. Climate Change Related Threats to Southeast Asia

Climate change poses many threats to societies throughout the globe. For coastal communities there is a likelihood of general temperature increases, frequent heavy precipitation events, drought event increases, intense tropical storms and increased incidence of extreme high sea level. Increased atmospheric temperatures and the subsequent de-glaciation of Greenland and the West Antarctic ice sheets will cause global sea level rises (IPCC, 2007). The IPCC has identified mega-deltas, heavily populated large river deltas, such as the Mekong to be the most vulnerable to this change.

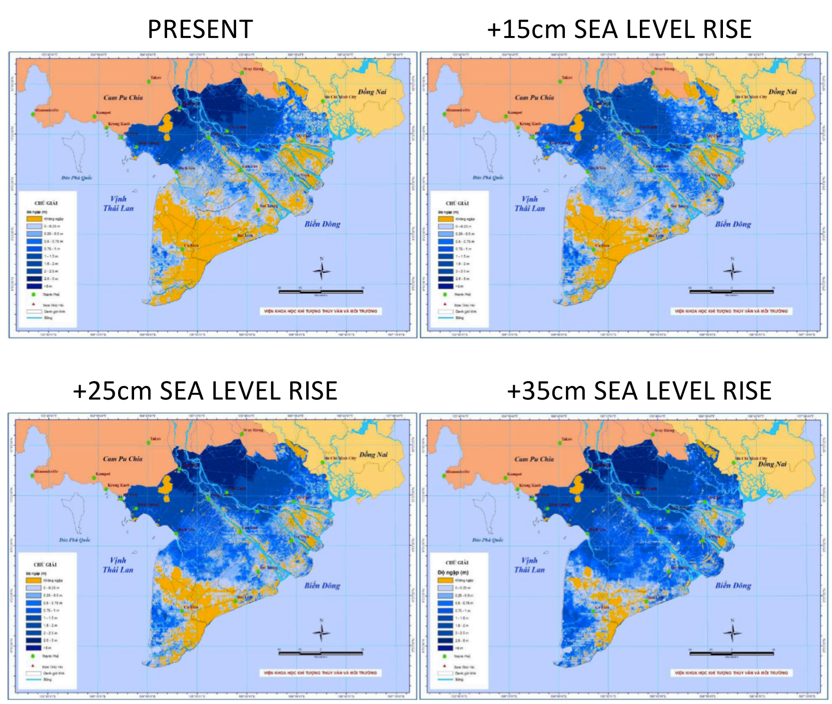

Figure 1. Expansion of wet season flood zone with various sea level rise projections in Mekong Delta (Guillaume 2011)

2.7. Goals for the Region

The National Governments, Non-Governmental Organizations (NGO) and International Agencies have outlined a set of goals for the Mekong delta region (McNally et al., 2010). While most stakeholders agree on the value of environmental conservation, conflicting goals make comprehensive solutions difficult. The main goals for the region are described below:

- *National Economic Development* — According to the Vietnamese Association of Seafood Exporters and Producers (VASEP), seafood exports reached over US$5 billion in 2010 and is expected to reach US$8 billion by 2020[9]. Thus, the imputed goal (goal from a national plan) is to maximize production of shrimp for export and revenue.

- *Resilience to Impacts of Climate Change* — International NGO's are working with the National Government of Viet Nam to increase coastal resilience to the impacts of climate change. IUCN is heading a four-year project to strengthen the ability of local government and communities to plan for and adapt to future climate risks in Coastal Provinces of the Mekong Delta. The Mekong Delta is predicted to be one of the most affected by sea-level rise. Adaptation is the key to reducing the impacts associated with climate change, and conservation and restoration of natural ecosystems are a key link to effective adaptation[10].

- *Mangrove Conservation* — Ministry of Agriculture and Rural Development (MARD) is implementing the Mangrove Forest Restoration and Development project with the goal of planting 100,000 hectares of mangrove forest by 2015[11].

2.8. Managing for Short-term vs. Long-term goals

Agricultural production, specifically shrimp aquaculture has made tremendous contributions to the development of coastal nations of Southeast Asia (Primavera, 2001). Though it is has caused detrimental impacts to coastal ecosystems and degraded the overall resilience of SESs to impacts of a rapidly changing climate, shrimp aquaculture is a core part of the economic development strategy for these areas. Management plans which focus on protecting pristine coastal environments ignore the tremendous economic pressure of shrimp export revenue (Rivera-Ferre, 2009) on the societies living in mangrove areas and are not acknowledging the short term goals of society. A successful management plan must focus on the long-term preservation of ecosystem function while addressing the economic needs of the society in the short-term.

2.9 The Future of the Mekong Delta: Proposed Management Approach

The comparison of the effectiveness of various land-use strategies in Southeast Asia to promote

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[9] http://www.vasep.com.vn/vasep/edailynews.nsf/HomePage DLA 05/16/2012

[10] http://iucn.org/about/union/secretariat/offices/asia/regional_activities/building_coastal_resilience/about_bcr_project/ DLA 06/10/2012

[11] http://www.agroviet.gov.vn/en/Pages/news.aspx?CategoryId=9 DLA 06/19/2012

SES that I undertake in this thesis, and the subsequent discussion about the need to retain flexibility in mitigating threats, is particularly timely. Viet Nam's vulnerability to impacts of climate change has recently become an item on the national government's agenda. Since 2009 when the United Nations Climate Change Conference was held in Copenhagen, the Vietnamese National Government has sought assistance from the Netherlands in protecting the Mekong Delta from climate change (Cong Van, 2009). Dutch expertise has been consulted in the planning for raising, reinforcing and expanding the existing coastal dike system for the Mekong Delta to save Viet Nam's rice bowl. This diking plan includes multiple large-scale sluice gates across the northern rivers of the Mekong, thus creating the direct opposite approach to adaptation from EBM. At this time of uncertainty in the Mekong delta's history it is particularly important to thoroughly evaluate alternatives for future management.

3. Methodology

I conducted three exploratory case studies (Yin, 1993) in order to describe the extent to which EBM and resilience characteristics were present in existing management approaches to SLR adaptation in the shrimp growing regions of Southeast Asia. Sites for each case study were selected based on common ecological attributes, past and current land usage, and vulnerability to SLR. Each case study was informed by a literature review on the socio-economic, political, environmental characteristics of the region as well as the current status of SLR impacts and adaptation in each area. In addition site visits and conversations with shrimp farmers, government representatives, and aid workers were had. I then created EBM and resilience frameworks based on the work of Slocombe (1998), and Leslie and Kinzig, (2009) for use in analyzing the extent to which each of the strategies examined included the components of EBM (Table 1.) and characteristics of resilience (Table 2.) (See section 3.2 below). After evaluating the case studies using the EBM and resilience frameworks, I then carried out a cross-case comparison to evaluate the performance of each adaptation strategy against one another.

3.1. Data Collection

Sites were selected using the following three criteria:

1. It is located in a river delta of the Southeast Asia eco-region with similar climate and seasons.
2. The site must have been a mangrove forest in the past and currently or have in the past produced shrimp for export.
3. There must be a strategy in place to adapt to SLR.

Based on this, three provinces were selected for comparison: Soc Trang, Viet Nam; Samut Sakhon, Thailand; and Ben Tre, Viet Nam. The two provinces in Viet Nam are about 100km in distance from each other and are surrounded by multiple branches of the Mekong River. The site in Thailand was chosen because Samut Sakhon, which sits between the mouths of the Chao

Phraya and Tha Chin Klong rivers, has lost vast areas of mangroves to shrimp aquaculture in the past and has now began to identify solutions to deal with the resulting loss of ecosystem function (Duriyapong and Nakhapakorn, 2011). The adaptation measures currently being used in this site have been suggested for implementation in Viet Nam through European Union funded International Union for the Conservation of Nature's (IUCN) Building Coastal Resilience to Climate Change (BCR-CC) project[12].

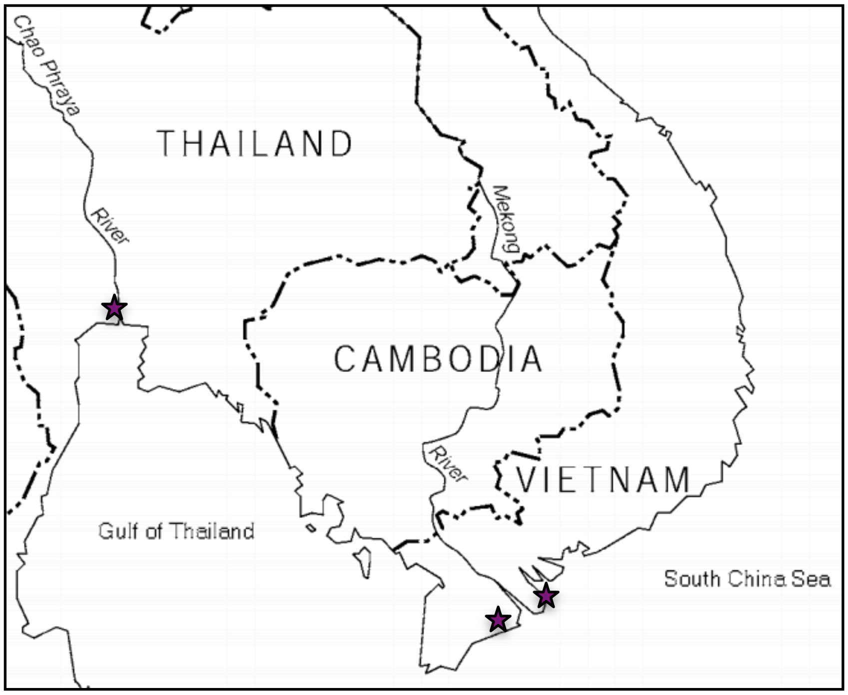

Figure 3. Southeast Asia eco-region map. Case Study Sites left to right Samut Sakhon, Thailand; Soc Trang, Viet Nam; Ben Tre, Viet Nam. Map modified from N. Enfield[13].

Details from the three case studies came from three sources. The first was fieldwork in Viet Nam with support from IUCN under the BCR-CC project. I traveled to the two Viet Nam sites between the dates of February 13th and March 18th 2012 for a total of 13 days. My direct observations from field visits in shrimp growing areas of Thailand and Viet Nam included photographs, Global Positioning System coordinates and informative conversations with other researchers, IUCN staff and consultants.

Second, I collected observations through the exchange of stories and presentations with representatives from organizations and village members from Thailand, Cambodia, Viet Nam, Myanmar and Indonesia at the BCR-CC 2012 Coastal Forum (February 28th to March 2nd 2012) in Chanthaburi Province, Thailand. I had various conversations with IUCN staff, consultants and program managers as well as other organizations such as Deutschen Gesellschaft für

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12 http://www.iucn.org/about/union/secretariat/offices/asia/regional_activities/building_coastal_resilience/about_bcr_project/ DLA 6/12/2012

13 http://www.annualreviews.org/doi/pdf/10.1146/annurev.anthro.34.081804.120406 DLA 06/12/2012

Internationale Zusammenarbeit (GIZ) the German development organization, the Netherlands Development Organization (SNV), and the World Wide Fund for Nature (WWF). A field visit to Chanthaburi Province was part of an IUCN workshop. Interpreter guides were present to explain the history of the area and the adaptation strategy in use. The adaptation strategy used in Chanthaburi was a smaller-scale version of what was already in place in Samut Sakhon Province. I was not able to travel to Samut Sakhon due to time constraints but I was able to speak with managers of the large-scale adaptation project going on in Samut Sakhon and listen to their presentations on the project parameters and results during the BCR-CC Coastal Forum.

Third, I carried out an extensive literature review on Thai and Vietnamese mangrove ecosystem composition and history as well as shrimp farming in general and specific to Viet Nam and Thailand.

3.2. Analysis

I created a framework based on the characteristics of successful EBM identified by Slocombe (1998), as well as the five principles identified by Rosenberg and Sandifer (2009, pg. 14) to guide ecosystem-based approaches (listed below):

1. Diverse ecosystem service provision
2. Importance of natural boundaries
3. Integrated management
4. Accounting for cumulative impacts an necessary trade-offs among services
5. Making decisions under uncertainty

The characteristics from both of these sources were modified to create a framework suitable for evaluating the extent to which EBM was reflected in the case adaptation strategies. Characteristic 1. encompasses the adaption strategy's adherence to specific values and limits regarding land devoted to shrimp culture or stocking densities. Characteristic 2. was modified from Rosenberg and Sandifer's principle of diverse ecosystem service provisioning and the need to recognize this and other higher values and ethical principles. "Higher values" refers to considering the rules of ecosystem processes for guidance in management. Rosenberg and Sandifer discuss the principle of "integrated management", which refers to combining disparate management goals for the same SES through the consideration of the wide range of interests, goals and objectives that exist, found in characteristic 3. Characteristic 4. is based on the idea promoted by Slocombe (1998) of accepting complexity rather than the reducing it. Recognizing the inevitability of change (characteristic 5.) was included in the framework to evaluate the adaption strategy's ability to remain flexible in a region with an unpredictable future. Characteristic 6. involves the recognition of the need to synthesize a wide range of knowledge to include Rosenberg and Sandifer's recommendation of including multiple sectors of guidance in the management approach. Transferability of the management plan into other areas is something that Slocombe (1998) introduces as a crucial characteristic that ensures the strategy will be able to be utilized in future similar scenarios (characteristic 7.). This is especially important for the shrimp growing areas of Southeast Asia as multiple coastal provinces are at a point where the trading of ideas is a crucial process in capacity building and climate change solution discovery. Characteristic 8. pulls from Rosenberg and Sandifer's principle 3., which calls for integrated management where it is necessary to not only inform actors, stakeholders and the public, but also to involve them in the process of a management plan. A management plan, which recognizes that we are making decisions under uncertainty as discussed by Rosenberg and Sandifer in principle 5., must be inherently tentative and evolving as the only one thing certain is that conditions, knowledge and the environmental conditions will continue to change (characteristic 9.).

I then evaluated each of the cases against the EBM framework and scored them based on whether each component was present (2), not present (0), or partially present (1).

Table 1. Ecosystem-Based Management Framework (Slocombe, 1998) and (Rosenberg and Sandifer 2009).

#	Characteristics of EBM
1	Reflects specific values and limits
2	Reflects ''higher'' values and ethical principles and rules
3	Reflects the wide range of interests, goals and objectives that exist
4	Accepts, rather than artificially reduces, complexity
5	Accept and recognize the inevitability of change
6	Synthesize a wide range of information and knowledge
7	Be applicable to a wide range of ecosystem types and conditions
8	Involve actors, stakeholders, public
9	Be inherently tentative and evolving as conditions and knowledge change

Because the end goal of each of the management strategies I examined is to mitigate the threat of SLR rather than to implement EBM for its own sake, I also evaluated each case study using a second framework (Table 2). This resilience framework was based on the work of Leslie and Kinzig, (2009), which listed the characteristics necessary for resilience to threats. I scored each of the cases based on the presence (2), absence (0), or partial presence (1) of each of the characteristics of resilience. This type of analysis allowed me to identify the adaptive capacity of each adaptation strategy to achieve resilience, regardless of whether each strategy had the components of EBM. After evaluating the case studies using both frameworks, I then used the framework scores to carry out a cross-case comparison to evaluate the performance of each adaptation strategy against one another.

I created the resilience framework from ”Key Elements of Resilience Science” and “Characteristics that contribute to ecological and social resilience” provided by Leslie and Kinzig (2009). The authors highlight principles found in resilience science and resilient SES. I modified these principles into eight characteristics that are applicable to evaluating the resilience of a shrimp-growing mangrove SES in South East Asia. As discussed earlier, they emphasize that the recognition of human communities and environment as coupled entities is necessary for resilience. This formed the basis for characteristic 1. (Table 2). The understanding that ecosystems can exist in multiple states of functioning and that SES must be flexible to that change is captured in characteristic 2. Leslie and Kinzig subscribe to the viewpoint, along with many other academic scientists, that “more diversity is better” (Leslie and Kinzig, 2009). They are almost certainly referring to natural diversity, but I have expanded this definition in my characteristics to reflect both the diversity of natural species (characteristic 4.) and diversity in livelihood and production models, which are distinguishing features between monoculture and poly-culture. I have also included a metric to represent institutional diversity, which refers to the variety of policy-influencing organizations including the national, provincial, district or commune government, development and environmental organizations (characteristic 5.). Diversity of sources of knowledge (characteristic 6.) is similar to institutional diversity, but sources of knowledge drawing on academic institutions and other agencies or experts as well as the use of the World Wide Web as a capacity building tool. Leslie and Kinzig (2009) suggest that accounting for interactions across scales of space, time and organization are essential for maintaining long-term diversity. In the context of a climate adaptation strategy this means that plans must acknowledge that the scale of the threat likely exceeds the jurisdictional borders and time frames under which most governance structures operate (characteristic 7.). Finally, characteristic 8. requires the acknowledgment of vulnerabilities for the SES, both present and future.

Table 2. Resilience Framework. Based on the work of Leslie and Kinzig, (2009).

#	Characteristics of Resilience
1	Acknowledge coupling between social and ecological systems
2	Flexible to change with acceptance of multiple possible states
3	Diversity - natural species
4	Diversity - livelihood or production model/crop variety
5	Diversity - institutional
6	Diversity - sources of knowledge
7	Interactions across scales of space, time, and organization
8	Acknowledgment of vulnerabilities

The frameworks described above provide a way to analyze and evaluate the information gained though my data collection activities. They have been adapted to reflect the current scientific literature on the theories of EBM and resilience while still remaining pertinent to real world management strategies. They allowed me to paint a detailed picture of the current situation in shrimp growing areas of Southeast Asia and evaluate the efficacy of three proposed SLR adaptation strategies against a common set of criteria.

4. Results

4.1. Case Study Overview

I observed three climate change adaptation strategies that are currently in use in Southeast Asia and constructed high level of generality and descriptive case studies of each strategy. All three cases shared similar environmental characteristics, economic industries and threats associated with climate change, allowing me to assess the extent to which each strategy, a) contained the components necessary for successful EBM, and b) would result in an approach that allowed the inhabitants of each area to adapt to the impacts of climate change. Soc Trang is an example of the traditional "hard" approach, a concrete dike. Samut Sakhon demonstrated a community-based adaptation initiative through the construction of a bamboo wave barrier, and Ben Tre is an example of an integrated mangrove shrimp green belt.

4.1.1. Case 1. Soc Trang Province, Viet Nam

Soc Trang Province is located in the far southern region of Viet Nam in the Mekong Delta. It lies at 9°19'N, 105°59'E (Figure 3.) where the major branches of the Mekong river distribute rich alluvial soils throughout the province before emptying into the South China Sea. Soc Trang has a tropical climate with a rainy season from May to October, dry season from November to April. Temperatures range from 25-33°Celcius [14]. Viet Nam has a communist government, which operates at different jurisdictional levels ranging from national to provincial to district down to commune. The population of Soc Trang is 1,276,200 with a large proportion of ethnic Khmer (28.9%)[15]. Soc Trang's major industries include rice, sugar cane and shrimp[16]. Soc Trang has a land title system where individuals or households can rent the land for a 10 to 30 year lease period that can be passed down, traded or leveraged for credit, but is never owned by the resident. The land leaser must pay taxes and obey the land-use plan of the Provincial government (Quy and Lakshmi, 2008).

Soc Trang had vast expanses of mangrove forest, but as early as the beginning of the 20th Century[17], the mangroves were converted to rice production and the rice fields were protected from salt water by dikes. In the last 30 years, remaining mangroves and vast areas of rice fields have been converted to shrimp aquaculture (Lewis et al., 2003). According to GIZ staff members working in Viet Nam, Soc Trang Province had suffered land loss from a rising tide coupled with severe typhoons, but in 1997 the Provincial government built a dike to prevent further erosion (Conversation with Klaus Schmitt of GIZ-Viet Nam). This dike is now degraded, resulting in

[14] http://www.portalen.soctrang.gov.vn/wps/portal/ DLA 06/12/2012
[15] http://www.portalen.soctrang.gov.vn/wps/portal/ DLA 06/12/2012
[16] http://www.agroviet.gov.vn/en/Pages/default.aspx DLA 06/12/2012
[17] http://czm-soctrang.org.vn/Publications/EN/Docs/Mangroves%20of%20Soc%20Trang%201965-2007%20EN.pdf DLA 06/13/2012

saltwater intrusion in some areas. As a result, residents living in coastal areas have suffered from the loss of workable land[18].

Because Viet Nam is a communist country, the government owns all of the land. Individuals can lease land from the government, gaining the right to reside on and work a certain plot of land during that time period (Quy and Lakshmi, 2008). The government usually decides what products and method of cultivation can be practiced in each parcel. If residents cannot pay taxes or afford to work their plot their lease can be revoked (Quy and Lakshmi, 2008). This can happen when shrimp farmers have taken out loans to intensify their shrimp production and then experience crop loss through a disease event. People are then forced to move to another area and may try to gain another land lease, but frequently become part of the population migration to urban areas in search of better opportunity (Adger and Luttrel, 2000). Additionally, residents can be removed if a company offers more promising investment terms to provincial government for a parcel. This results in displaced residents moving to less desirable land looking to lease, or additions to the already large impoverished landless population.

Residents whose parcel of land is being taken away with each lapping wave must wait for the government to take action and give direction. International organizations such as GIZ have established erosion control projects, but are only permitted to attempt restoration outside the dike (Conversation with GIZ-Viet Nam). In the areas lacking mangroves GIZ has worked with engineers to come up with a method to break waves and retain land.

The provincial government of Soc Trang has stated that its priority is to retain all arable land (Conversation with IUCN-Viet Nam staff)[19], and is currently examining hard solutions, such as a larger dike, as a way to ensure land security. Unfortunately, these types of hard solutions tend to be extremely expensive and, as seen through the failure of the dike currently in use to protect communities in Soc Trang, do not usually provide long-term service. Without a buffer of mangrove forest, this management scheme ignores the contributions of diversity to system resilience as well as the links between ecosystem health and long-term social welfare. Shrimp farmers can no longer rely on wild caught post-larvae to seed their ponds as the dike cuts off access of adult wild shrimp and other migratory species reliant on the mangrove ecosystem as a nursery ground for young (Michaels, 2011). Dikes can also have alternative effects on shorelines. As waves make perpendicular contact with the dike face, the energy can be directed vertically causing substrate loss at the base of the dike (Figure 2.), furthering shoreline erosion (Dugan et al. 2008). As all goods, services and benefits of the coastal mangrove ecosystem are sacrificed for the production of a single ecological good (i.e., shrimp), the overall SES is left vulnerable to impacts of climate change as well as disease events stemming from a lack of crop diversification. Furthermore, the use of dikes to block SLR and other threats associated with climate change may

18 http://czm-soctrang.org.vn/Publications/EN/Docs/Mangroves%20of%20Soc%20Trang%201965-2007%20EN.pdf DLA06/13/2012

19 http://www.portalen.soctrang.gov.vn/wps/portal/ DLA 06/12/2012

preserve short term function, but will require continual upkeep to maintain that function, and comes at the cost of a loss of adaptability to future unforeseen changes.

Figure 2. Soc Trang. Photo taken by Ralph Riccio

Soc Trang rated low in both the EBM and Resilience frameworks, but interestingly rates higher for characteristics of EBM than for resilience because it had almost none of the characteristics of resilience. In terms of the EBM framework, the dike strategy does not reflect limits (Table 3.; characteristic 1.), specifically the potential environmental limits of this system. Instead, the dike strategy attempts to overcome these limitations through engineering. The dike strategy also does not reflect "higher" values (characteristic 2.); while it does aim to preserve this land for the purported benefit of Viet Nam's citizens; this land is specifically being protected for economic reasons rather than for the protection of homes or communities. With this limited intent, it clearly does not reflect the wide range of objectives that exist (characteristic 3.). The purpose of the dike is to control natural processes of water, nutrients and life. This activity reduces complexity and so did not contain characteristic 4. The adaptation strategy is addressing a present change, which is erosion of the land, but does not accept the inevitability of future change as described in characteristic 5. The knowledge base used for the dike is perhaps broad from the perspective of engineering expertise and advice from development organizations such as the World Bank. However, it lacks input from ecosystem science, impact assessments and conservation organization guidance and thus received a score of 1 for characteristic 6. The dike strategy may be applicable in a wide range of ecosystem types and conditions, including any low-lying area that is under threat of inundation by seawater, though it might have similar detrimental effects on other types of ecosystems as well. Thus it scored a one on characteristic 7.

However, the plan does not include stakeholders or the public (characteristic 8.), something that is typical of strategies in Viet Nam given their system of government. Most notably, hard solutions such as dikes do not account for altered ecosystem states (characteristic 9.), such as some type of system-wide change that renders shrimp and rice production unfeasible in the area, nor does it maintain adaptability to allow for the new knowledge in the future. The diking strategy in Soc Trang earned a score of 2 against the EBM framework.

Table 3. Characteristics of EBM – Soc Trang (Slocombe, 1998) and (Rosenberg and Sandifer 2009). Scored on whether characteristic of EBM was present (2), not present (0), or partially present (1).

#	Characteristics of EBM	Soc Trang
1	Reflects specific values and limits	0
2	Reflects ''higher'' values and ethical principles and rules	0
3	Reflects the wide range of interests, goals and objectives that exist	0
4	Accepts, rather than artificially reduces, complexity	0
5	Accept and recognize the inevitability of change	0
6	Synthesize a wide range of information and knowledge	1
7	Be applicable to a wide range of ecosystem types and conditions	1
8	Involve actors, stakeholders, public	0
9	Be inherently tentative and evolving as conditions and knowledge change	0
SCORE		**2**

When the diking strategy is evaluated against the characteristics of resilience it scores even lower (Table 4.). There is no acknowledgment of the fact that the delta system is a coupled SES (characteristic 1.). Instead, this plan primarily views the system as one that can be manipulated without limits and still provides continued economic benefits to humans. Additionally, it does not acknowledge the complex linkages of the system as a whole, specifically those related to ecosystem function, as demonstrated above. Construction of a large-scale dike actually decreases flexibility, potentially leaving the area more vulnerable to larger hazards in the event that the dike is breached. As a result, it scored a 0 for characteristic 2. Diversity of natural species does not exist with the presence of a dike (characteristic 3.). Once natural hydrology is cut off mangrove propagules, wild shrimp, fish, crab and larvae of various species no longer have access into the manipulated coastal wetland. If some do make it in through the sluice gate, there are only narrow canals used for emptying the waste from intensive ponds for life to survive in. The only type of livelihood available among the diked coastal zone of Soc Trang is intensive shrimp production, and so this is a monoculture void of crop variety diversity, as described in characteristic 4. Characteristic 5. recommends institutional diversity, but there is only the involvement of the provincial government and government-owned enterprises, without the assistance of other organizations assisting in the implementation. The dike adaptation strategy does contain some diversity of knowledge sources (characteristic 6.). It is necessary for decision-makers to seek engineering expertise for the construction of a dike, but not necessarily other types of knowledge such as ecosystem science or environmental assessments. As a result, this strategy received a score of 1 for this characteristic. Interactions across political borders are not embraced in dike construction or in shrimp production. One province can have a drastically different management plan from a neighboring province. The dike adaptation strategy does not promote interactions across scales of space, time and organization and so received a score of 0 for characteristic 7. The construction of a dike seems to inherently acknowledge vulnerabilities, but I gave the adaptation strategy a 0, for the disregard of heightened future vulnerabilities (characteristic 8.). Building a concrete dyke allows for additional development on the land side of the concrete, which sets up the SES for increased detriment in the case of a dike breach, which is often a possibility for the future of exposed armored shorelines (Dugan, 2008). This evaluation of the Soc Trang case illustrates the fact that it is possible for a plan to possess some of the characteristics of EBM without meeting the characteristics of long-term resilience for the system as a whole (Table 4.).

Table 4. Characteristics of Resilience – Soc Trang (Leslie and Kinzig 2009). Scored on whether characteristic of resilience was present (2), not present (0), or partially present (1).

#	Characteristics of Resilience	Soc Trang
1	Acknowledge coupling between social and ecological systems	0
2	Flexible to change with acceptance of multiple possible states	0
3	Diversity - natural species	0
4	Diversity - livelihood or production model/crop variety	0
5	Diversity - institutional	0
6	Diversity - sources of knowledge	1
7	Interactions across scales of space, time, and organization	0
8	Acknowledgment of vulnerabilities	0
SCORE		**1**

4.1.2. Case 2. Samut Sakhon Province, Thailand

Samut Sakhon province in the Kingdom of Thailand is located at 13°28′N, 100°13′E between the mouths of the Tha Chin Klong and Chao Phraya rivers (Figure 3.). Samut Sakhon has a tropical climate, with temperatures ranging from 26-34°Celcius, and experiences typhoons and frequent flooding in the wet season[20]. The study area has a coastal plain topography and has rich alluvial soils from river sedimentation (Duriyapong and Nakhapakorn, 2011). Samut Sakhon is bordered by the Gulf of Thailand with historically vast areas of mangroves lining the shores. Samut Sakhon, as with the rest of Thailand, has a constitutional monarchy under a parliamentary democracy. In the 1950's the King of Thailand donated the nation's land to the Thai people (Feder, 1991), giving most families a plot of land, over which they then had full tenure to exploit, pass down or sell. The population of the province is 1,220,998[21]; with the major industries being marine captures fisheries, shrimp and saltwater fish aquaculture and salt fields. The shrimp aquaculture industry has heavily degraded the mangrove ecosystem, and presently only small patches of mangroves line the shore.

20 http://www.hindawi.com/journals/ijeco/2012/171876/ DLA 06/13/2012

21 http://thailandembassy.org/about/government.html DLA 06/13/2012

The major climate-related threats to the area are land erosion and flooding associated with SLR (Duriyapong and Nakhapakorn, 2011). According to WWF Thailand, the high tide mark/water line has moved inland over 50 meters over recent years in the province of Samut Sakhon (Conversation with WWF-Thailand staff). The loss of houses and shrimp farms in Samut Sakhon due to SLR coupled with shoreline erosion caused great concern among the affected villages. This concern fostered a dialogue via previously established social systems (likely through shrimp cooperatives) about the issue of a rising tide on their land. Community action was supported by the Thai government and NGO (i.e., WWF) entities, but initiated by the community. The community, through trial and error, discovered that submerging bamboo poles in the mud in rows parallel to the shoreline reduced wave energy and trapped sediment, thus halting land erosion in that area (Figure 5.). Mangrove propagules were then planted in the mud and WWF-Thailand has reported that the shoreline is regenerating (Conversation with WWF-Thailand staff). This adaptation strategy employed by Samut Sakhon Province is a community-based adaptation initiative, where community members came together to address their land being washed away with the tide (Duriyapong and Nakhapakorn, 2011).

Figure 5. Samut Sakhon[22]

Samut Sakhon's community-based adaptation strategy scored average on both the EBM and the resilience frameworks (Tables 5. and 6.). The plan displays an attempt to manipulate physical forces rather than accepting environmental limits, and thus receives a zero on characteristic 1.

[22] http://kurtzjack.photoshelter.com/image/I00007lTdm94v3mg DLA 6/13/2012

The bamboo wave barriers are an effort to combat the current threats to people's homes and livelihoods rather than higher level of ethical principles or values. However, it is perhaps unreasonable to expect a community of shrimp farmers to enact a plan that would meet the scientific community's standards of higher-level principles. This is a prime example of why many practitioners find EBM to be difficult to implement. In this case the Samut Sakhon community's actions reflect a desire to save their homes and retain their family land. As a result, the strategy scored a 1 on characteristic 2. The adaptation strategy reflects a wide range of interests, goals, and objectives that exist including community members, scientists and conservation organizations (characteristic 3.). The community-based adaptation initiative demonstrates a clear intersection of interests as multiple stakeholders came together and supported the action once the community had initiated it. It only partially accepts ecosystem complexity because (characteristic 4.), although the plan does restore vegetation, the species used are only from the Genera *Rhizophra* (conversation with WWF-Thailand staff), while the native mangrove assemblage also includes *Avicennia* and *Sonneratia* species. When the restored mangroves grow to adult size, what will be standing will not be a diverse forest but a monoculture plantation, which leaves the coastline susceptible to strong storms where single species can fail (Tri et al., 1996). However the presence of bamboo barriers and retained sediment with one species of mangrove is far better than a shoreline that lacks of vegetation all together and is eroding away. The bamboo wave barrier clearly recognizes the inevitability of change (characteristic 5.). By using soft solutions, as conditions change the wave barrier can be enhanced or even moved seaward to keep growing land. The method only used information and resources (characteristic 6.) from a limited pool, mostly established through trial and error experimentation by the community. Therefore it received a score of 1. Collaboration with engineers or an NGO such as GIZ could have refined the strategy to increase efficiency in some way. Given the specificity of the strategy it is unlikely that it would be effective in a broad range of ecosystems (characteristic 7.). However, it seems very well suited for use in coastal mangrove habitats, which sit at the mouth of a sediment rich river. It is also not likely to be effective in a broad range of social systems but may be effective in a Thailand-specific community-based approach, which has the involvement of stakeholders ranging from government to public and even conservation organizations. The strategy does not explicitly include a method for continued evolution as knowledge and conditions change, but it is also easily reversible should the need arise. Because of this, I gave this strategy a one for characteristic 9. This strategy received a total score of 9 using the EBM framework.

Table 5. Characteristics of EBM – Samut Sakhon (Slocombe, 1998) and (Rosenberg and Sandifer 2009). Scored on whether characteristic of EBM was present (2), not present (0), or partially present (1).

#	Characteristics of EBM	Samut Sakhon
1	Reflects specific values and limits	0
2	Reflects ''higher'' values and ethical principles and rules	0
3	Reflects the wide range of interests, goals and objectives that exist	2
4	Accepts, rather than artificially reduces, complexity	1
5	Accept and recognize the inevitability of change	2
6	Synthesize a wide range of information and knowledge	1
7	Be applicable to a wide range of ecosystem types and conditions	0
8	Involve actors, stakeholders, public	2
9	Be inherently tentative and evolving as conditions and knowledge change	1
SCORE		**9**

Samut Sakhon's adaptation strategy rated average for resilience with a score of 9. Viewing the community of Samut Sakhon as a coupled SES was only partially acknowledged (characteristic 1., Table 6.). The farmers that devoted time and energy towards saving their land from washing away were only doing that because they had already fully removed their mangrove buffer and were just trying to stop the forces of nature from taking their homes. Characteristic 2. was partially present as the bamboo wave barrier did present flexibility to change and the acceptance to multiple states. However the shoreline of Samut Sakhon was changing to another state, one that was void of vegetation and quickly washing away. It is difficult to know if this altered state was brought on by the removal of mangrove vegetation, or if this change would have occurred in response to SLR regardless of the vegetation level. Regardless of the cause, the community sought to restore the previous state. Diversity of natural species (characteristic 3.) was removed over 20 years ago for the production of shrimp so the replanting of one genera of mangrove did not adequately represent the diversity of natural species. The replanting of only one species does not represent the species composition of a resilient mangrove forest and so was scored a 0 for characteristic 3. Samut Sakhon is not currently producing large amounts of shrimp due to its land erosion problem. This has caused the community to adopt other livelihood types. Interestingly, one of these industries is the construction of additional layers of bamboo walls, which community members were financially supported to install by WWF – Thailand. Samut Sakhon scored a 1 on characteristic 4. There was a clear presence of institutional diversity including involvement from the Thai government and WWF (characteristic 5.). A diversity of knowledge sources was present, including the Thai government - Ministry of Forestry, WWF Thailand and access to the World Wide Web and other educational devices for community capacity enhancement, and so this strategy received a 2 for characteristic 6. Interactions across space, time and organizational levels (characteristic 7.) were not apparent, as this adaptation strategy was only applicable for the farmers losing their land on the outer strip of a delta coast. Characteristic 8. is clearly present and received a score of a 2 in the strategy's acknowledgment of vulnerabilities, as community members do not have many options for that area besides restoring mangroves in vulnerable, degraded areas. Community livelihoods are especially vulnerable in this area, even if the shoreline is restored through the adaptation strategy, there will need to be options for alternative livelihoods to intensive shrimp production discovered.

Table 6. Characteristics of Resilience – Samut Sakhon (Leslie and Kinzig 2009). Scored on whether characteristic of resilience was present (2), not present (0), or partially present (1).

#	Characteristics of Resilience	Samut Sakhon
1	Acknowledge coupling between social and ecological systems	1
2	Flexible to change with acceptance of multiple possible states	1
3	Diversity - natural species	0
4	Diversity - livelihood or production model/crop variety	1
5	Diversity - institutional	2
6	Diversity - sources of knowledge	2
7	Interactions across scales of space, time, and organization	0
8	Acknowledgment of vulnerabilities	2
SCORE		**9**

4.1.3. Case 3. Ben Tre Province, Viet Nam

Ben Tre Province is located at 9°51'N, 106°38'E which is approximately 100 km from Soc Trang in the Mekong Delta (Figure 3.). Ben Tre has essentially the same climate and political situation as Soc Trang with a slightly larger population of 1,400,000[23]. Ben Tre produces a wide variety of agricultural crops including fresh and saltwater fish, mud crab, goby, clam and shrimp aquaculture, coconuts, sugarcane, fruit orchards and wild caught fisheries. Ben Tre is vulnerable to SLR and increased frequencies of typhoons. To address this, in 1998 Viet Nam enacted "Decision 661", a national program supported by the World Bank to restore five million hectares of forest, including both terrestrial and wetland areas[24]. Under Decision 661 the Forestry Department of Ben Tre, with assistance from DANIDA (Denmark's development organization), adopted a versatile land-use plan (Lewis et al., 2003) in which a gradient of mangrove coverage extends inland from the highest coverage areas along the coast. At the time of the instatement of the Decision 661, Ben Tre had little rice production and was a prime target for restoration projects along the coast. Thus, the government was able to adopt a land-use plan that was radically different from more heavily agricultural areas near by. Along the coastal edge a belt of protected mangroves rings the shoreline, followed by another belt of integrated mangrove shrimp aquaculture ponds (Figure 6.). Inside of this is a belt with 50 percent mangroves and 50 percent shrimp ponds, followed by intensive ponds void of mangroves[25]. These gradations reflected a desire to use mangroves to buffer the land from storms (Conversation with IUCN-Viet Nam staff).

During recent shrimp disease outbreaks in the Mekong Delta farmers of Ben Tre, though affected by shrimp disease, had the benefit of crop diversification and were able to ride out large shrimp

[23] http://english.bentre.gov.vn/node/3 DLA 06/12/2012

[24] http://www.theredddesk.org/countries/vietnam/plans_and_policies DLA 06/13/2012

[25] http://mit.biology.au.dk/cenTER/EnvInd_WB.html DLA 06/13/2012

losses through income from the other commodities they are able to produce in extensive ponds or integrated ponds, such as mud crabs, gobies and timber (Conversation with IUCN-Viet Nam staff). This crop diversification is crucial for the sustainable livelihoods (Sukardjo, 1989) of the farmers in the region and is the key to farmers being resistant to the boom-and-bust cycles associated with intensive production and shrimp disease outbreaks.

Ben Tre's thick barrier of vegetation has allowed for the province to retain its land and even gain land through natural processes of pioneering mangrove species on sedimentation (Conversation with IUCN-Viet Nam staff). Ben Tre's economy has also benefited from the sustainability certification of a local clam fishery by the Marine Stewardship Council[26]. The clams are able to flourish there in the mud adjacent to the shoreline in part because of the clean water coming out of the mangroves. In order to ensure the protection of these trees upstream from the muddy banks where the clam fishery operates, the fishery managers pay inland managers to maintain the mangroves (Conversation with IUCN-Viet Nam staff).

Ben Tre's approach acknowledges the benefits of economic and ecological integration into its coastal land-use plan (Lewis et al., 2003). The integrated mangrove shrimp aquaculture gradient model of land-use planning retains the valuable ecosystem function that mangroves provide on the coast while simultaneously allowing for diversified production. This succession of manipulated mangrove areas is an ideal composition of social-ecological balance as the province extracts a variety of goods and services from the environment, but the ecosystem still maintains its function and flexibility to change.

Figure 6. Ben Tre. Photo taken by Ralph Riccio

26 http://www.msc.org/track-a-fishery/certified/pacific/vietnam-ben-tre-clam-hand-gathered DLA 06/10/2012

Ben Tre's integrated mangrove shrimp green belt adaptation strategy scored higher than the others in the EBM framework (Table 7.) with a score of 12. The strategy acknowledged specific limits to production and valued the retention of forest and so received a score of 2 for characteristic 1. of Table 7. By retaining vegetation in heavier density along the coastline there is a clear sacrifice of shrimp growing area, demonstrating a specific value to limiting production in order to maintain vegetation. The strategy did reflect higher ethical principles (characteristic 2.) by considering the global good through limited production and increased vegetation rather than a production style that sought immediate plot-by-plot benefits and received a score of 2. The integrated mangrove shrimp green belt strategy partially reflects the wide range of interests, goals and objectives that exist in the area and so it received a 1 for characteristic 3. It could have better reflected a wide range of goals if it had demonstrated an ability to increase revenue in the areas dominated by mangroves, perhaps through market certifications or other programs. The strategy demonstrates an acceptance of complexity through integration of multiple production densities and crops and received a score of 2 for characteristic 4. The strategy embraces complexity through its layered vegetative coverage system. When he plan was initially adopted much of the land in Ben Tre was degraded mangrove forest, which was restored to achieve the various levels of mangrove coverage seen today. It also incorporated the inevitability of change (characteristic 5.), which was the original driver for the land-use plan, and so scored a 2. Ben Tre's adaption strategy synthesized knowledge from a wide range of sources including DANIDA and academic institutions as well as the Department of Agriculture and Rural Development and Department of Forestry. The integrated mangrove shrimp green belt received a 2 for characteristic 6. This strategy is not applicable to a wide range of ecosystem types (characteristic 7.) and received a 0 in the framework. The green belt is only useful in mangrove ecosystems that have the ability to grow shrimp within. The adaptation strategy was not inherently tentative or evolving as conditions and knowledge change and so received a 0 for characteristic 9. There was no clear plan for Ben Tre as sea level rises and farms become flooded. Ben Tre is better buffered from strong weather events and erosion because of the green belt, but if the conditions change towards extreme high water, the adaptation strategy still does not ameliorate the impacts.

Table 7. Characteristics of EBM – Ben Tre. (Slocombe, 1998) and (Rosenberg and Sandifer 2009) Scored on whether characteristic of EBM was present (2), not present (0), or partially present (1).

#	Characteristics of EBM	Ben Tre
1	Reflects specific values and limits	2
2	Reflects "higher" values and ethical principles and rules	2
3	Reflects the wide range of interests, goals and objectives that exist	1
4	Accepts, rather than artificially reduces, complexity	2
5	Accept and recognize the inevitability of change	2
6	Synthesize a wide range of information and knowledge	2
7	Be applicable to a wide range of ecosystem types and conditions	0
8	Involve actors, stakeholders, public	1
9	Be inherently tentative and evolving as conditions and knowledge change	0
	SCORE	**12**

The strategy employed in Ben Tre demonstrates a number of qualities necessary to achieve resilience and received a 12 on the resilience framework (Table 8.). Ben Tre's adaptation strategy showed a strong acknowledgment of the coupling of humans and nature as a linked SES and received a 2 for characteristic 1. Humans live closely with a functioning mangrove forest and rely on the processes to provide extractible goods for their livelihoods. It retains flexibility to change with acceptance of multiple possible states through the succession of mangrove vegetation spanning inland and so scored a 2 for characteristic 2. The strategy presents multiple possible states as the shrimp-production-to-mangrove ratio changes spanning inland. Natural species diversity was only partially present and so received a 1 on characteristic 3. Diversity of natural species were only partially present as the administrative protocol for mangrove restoration is to use species from the Genera *Rhizophra* (Tri et al., 1996) leaving out a range of other species naturally occurring in the area. Characteristic 4., livelihood diversity, scored a 2 as it provided the greatest amount of crop variety and production method. Ben Tre is the perfect model of crop diversity, maintaining resilience in case of shrimp disease; Ben Tre farmers can rely on multiple species for revenue. Ben Tre scored a 1 for institutional diversity (characteristic 5.), as it was limited to the provincial government and DANIDA, with no other outside institutional involvement from neighboring provinces. The adaptation strategy had input from the government of Viet Nam, DANIDA, Can Tho University in creating this plan to maximize outcomes. This clear diversity of sources of knowledge received a score of 2 for characteristic 6. The green belt adaptation strategy received a 1 for only partially representing characteristic 7. The land-use plan encouraged interactions across scales of space, time and organization and was not limited by residential borders, but this could have been due to the lack of land tenure in Viet Nam and the ability to relocate inhabitants of the coastal zone to other areas. The adaption strategy had a limited ability to acknowledge vulnerabilities and thus scored a 1 on characteristic 8. There was a clear acknowledgment of vulnerabilities as the land-use plan was initially created to increase vegetation of the exposed coastline. However, the plan lacks future vulnerability mitigation as the tide reaches further inland. The high score in resilience is not necessarily due to the components of EBM being present and is likely from diversified land-use planning and the foresight of the organizations brought in to make the plan.

Table 8. Characteristics of Resilience – Ben Tre (Leslie and Kinzig 2009). Scored on whether characteristic of resilience was present (2), not present (0), or partially present (1).

#	Characteristics of Resilience	Ben Tre
1	Acknowledge coupling between social and ecological systems	2
2	Flexible to change with acceptance of multiple possible states	2
3	Diversity - natural species	1
4	Diversity - livelihood or production model/crop variety	2
5	Diversity - institutional	1
6	Diversity - sources of knowledge	2
7	Interactions across scales of space, time, and organization	1
8	Acknowledgment of vulnerabilities	1
	SCORE	**12**

4.2. Summary of EBM and Resilience Analyses

Each of the cases was scored on whether it contained each of the nine characteristics of EBM in the framework. Each case was given a score on whether each component was present (2), not present (0), or partially present (1), for each of the characteristics. Ben Tre's integrated green belt (Case 3.) rated the highest with a total of 12 points (66% of the total possible), followed by Samut Sakhon's bamboo wave barrier (Case 2.) with a score of 9 (50%), then Soc Trang's dike (Case 1.) with a score of 2 (11%). While the integrated mangrove shrimp green belt in Ben Tre contained over half of the characteristics in the framework, it still lacked a number of the characteristics necessary in an EBM approach.

Table 9. Characteristics of EBM. (Slocombe, 1998) and (Rosenberg and Sandifer 2009). Scored on whether characteristic of EBM was present (2), not present (0), or partially present (1).

#	Characteristics of EBM	Case 1	Case 2	Case 3
1	Reflects specific values and limits	0	0	2
2	Reflects ''higher'' values and ethical principles and rules	0	0	2
3	Reflects the wide range of interests, goals and objectives that exist	0	2	1
4	Accepts, rather than artificially reduces, complexity	0	1	2
5	Accept and recognize the inevitability of change	0	2	2
6	Synthesize a wide range of information and knowledge	1	1	2
7	Be applicable to a wide range of ecosystem types and conditions	1	0	0
8	Involve actors, stakeholders, public	0	2	1
9	Be inherently tentative and evolving as conditions and knowledge change	0	1	0
	SCORE	**2**	**9**	**12**

Each of the cases was also rated on using eight characteristics of resilience. They scored similarly to the EBM framework. Ben Tre (Case 3.) rated the highest with 12 (75%) points, followed by Samut Sakhon (Case 2.) with 9 (56%) points, then Soc Trang (Case 1.) with 1 (6%) point. Ben Tre's model rated the highest with 75% of the characteristics of resilience present.

Table 10. Characteristics of Resilience (Leslie and Kinzig 2009). Scored on whether characteristic of resilience was present (2), not present (0), or partially present (1).

#	Characteristics of Resilience	Case 1	Case 2	Case 3
1	Acknowledge coupling between social and ecological systems	0	1	2
2	Flexible to change with acceptance of multiple possible states	0	1	2
3	Diversity - natural species	0	0	1
4	Diversity - livelihood or production model/crop variety	0	1	2
5	Diversity - institutional	0	2	1
6	Diversity - sources of knowledge	1	2	2
7	Interactions across scales of space, time, and organization	0	0	1
8	Acknowledgment of vulnerabilities	0	2	1
	SCORE	**1**	**9**	**12**

4.3. Cross-Case Comparison

There was a clear correlation between having EBM characteristics and components of resilience. Ben Tre had 66% of the characteristics of EBM and 75% of the characteristics of resilience. In contrast, the Soc Trang case rated very low on both EBM (5%) and resilience (6%). However, although there is a clear relationship between EBM and resilience, it might not be the only path to achieving resilience.

Table 11. Cross-Case Comparison

Location	Climate Adaptation Strategy	EMB	Resilience
Soc Trang, Viet Nam	Dike	2	1
Samut Sakhon, Thailand	Community-based Adaptation Initiative	9	9
Ben Tre, Viet Nam	Integrated Mangrove Shrimp Green Belt	12	12

5. Discussion

The case studies demonstrate a few main points regarding achieving resilience through EBM. These include 1) the importance of viewing systems holistically and accounting for connectivity and feedback between sectors, and 2) the need to maintain flexibility in the face of uncertainty. These factors may play a much larger role in risk mitigation than has previously been suggested in the EBM literature. This indicates that, despite the numerous obstacles to the implementation of EBM approaches, especially in developing countries, long-term resilience to environmental change may still be achievable. In this section I summarize the lessons learned from these three case studies and make recommendations for the delta-wide adaptation plan currently under consideration in Viet Nam.

5.1. Lessons learned

One of the central tenets of EBM is to acknowledge and address linkages within systems. This includes not only linkages between communities and their environment but also linkages between communities, governance systems, and economic actors. A comparison of our three case studies under multiple lenses (social, ecological and economic) provides the opportunity to assess potential climate change impact, mitigation measures and derive lessons learned about adaptation strategies to SLR in vulnerable areas.

5.1.1. Understanding Social Linkages

The first lesson is that in order to be successful EBM must consider the system as a whole. This includes social components that may play a role in achieving a desired management response. As illustrated in a comparison of case studies one (Soc Trang) and two (Samut Sakhon), those communities with access to land ownership and support from the government for community movements were more likely to take a proactive stance towards maintaining resilience in the face of climate change. In Thailand, community networks and environmental movements appear to be supported by the government. It is clear that land ownership is crucial to encouraging communities to take action. Without land tenure, the social component of Soc Trang's SESs has different motivations than that of Samut Sakhon. The government discourages community networks and so if there is a problem with land loss or other impacts from the environment, the solution must come from the government.

Thailand's system of land tenure has resulted in the empowerment of individuals to make their own decision about their land. Because communities are often defined by their economic and environmental commonalities, this can provide a platform for action at a higher level. Individuals downstream of destructive land use activities can meet with other communities to discuss the impacts on the community as a whole (Conversation with IUCN-Thailand staff[27]).

Given that land tenure has been shown in a number of different systems to foster stewardship (Adger and Luttrel, 2000), and that communities have formed around these land rights, the shrimp farmers of Samut Sakhon are more likely to communicate with one another and discuss their shared environmental issues. Having ownership over the land that is being washed away is likely to motivate the farmers to find solutions, or to look for assistance in finding them. As such, these communities are likely to be more receptive to community-based, bottom-up approaches to land conservation and management (Adger and Luttrel, 2000). Additionally, Samut Sakhon would benefit from education programs promoting sustainable production methods to ensure continual ecosystem function

Farmers of Soc Trang do not have secure rights for the land on which they reside. They lease the land and therefore are more likely to have a renters' mentality, taking the view that the landlord (in this case, the government) should take care of any problems that arise (Quy and Lakshmi, 2008). The government does not encourage communication among citizens and usually addresses most issues without consultation of the citizens (Conversation with IUCN-Viet Nam staff). Intensive shrimp farmers on the coast of Soc Trang would suffer a loss of investments if the walls of their ponds were breached and their crop destroyed. However, these farmers are more likely to apply to be relocated or given other types of government assistance rather than seek to address the changes through community-based approaches because the platform for that type of action has not historically existed in Viet Nam.

It is likely that negative impacts of rapid climate change will persist and perhaps increase in these areas. Because of this, it is important to understand what will make coastal SESs resilient to these disturbances. When viewed through the context of their social systems, it is evident that while community-based management strategies are likely to be effective for Thai farmers who are watching their land wash away, a top-down approach is likely needed for Vietnamese land renters who are unsure if they will be allowed to reside there when their lease runs out. While this type of solution does address the short term social needs of this system (the preservation of

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[27] http://www.iucn.org/about/union/secretariat/offices/asia/regional_activities/building_coastal_resilience/about_bcr_project/ DLA 06/12/2012

arable land for continued economic growth), it does not address or maintain the ecological linkages in the system that are necessary for the continued delivery of ecosystem goods and services.

5.1.2. Understanding linkages between economic productivity and ecological function

Nowhere is the Vietnamese proverb, "tấc đất tấc vàng" meaning "a bit of land is worth a bit of gold", more true than in the Mekong Delta. Nearly every meter of land is utilized for production. The strong will of societies to improve their situation relies once again on their ability to convert natural capital into social capital, and at Viet Nam's current rate of growth, there is no sign of slowing. Asking farmers to give up gold for trees just in case there might be a problem in the future is not likely to be a winning strategy in Viet Nam. For Viet Nam, continued economic development and growth is of paramount importance, and any considerations of environmental impacts will be secondary to economic ones. This raises the question of whether it will ever be possible to implement EBM in such a landscape. For the proponents of EBM to make any headway, Viet Nam's economic priorities must be addressed head on. Additionally, a holistic approach requires consideration of the fact that continued economic production is simultaneously intimately tied to ecological function as well as the single biggest threat to ecological function. For a model like that in the Ben Tre case, which accepts a reduction in shrimp production in order to maintain other ecological services, to succeed delta-wide, incentive programs must be established to ensure that farmers stand to make a profit while transitioning to new production methods. While this loss in shrimp production may be partially offset by the production of other commodities in this multi-use model, there are a number of new programs being established that may be able to reward Ben Tre's farmers for the preservation of ecosystem services

At present, there appear to be three potential incentive programs to motivate farmers to convert the coastal zone of the Mekong Delta from intensive monoculture shrimp aquaculture systems to an integrated mangrove shrimp green belt. The first mechanism is market driven, and would harness market demand for a sustainable shrimp product through certifications or eco-labels[28]. The second entails payments for carbon credits or retained ecosystem-services through international organizations[29]. Finally, the third component is the economic resistance to shrimp disease that results from a diversified income stream through the harvesting of extractable ecosystem goods (as described earlier) and poly-culture techniques. It is unlikely that any one program alone would be enough of an incentive to motivate mangrove restoration by the farmer, because they each meet different aspects of the problem.

With the restoration of mangrove ecosystem services to 50 percent of traditionally monoculture shrimp pond area, that is a significant boost in biodiversity and thus consumable protein. Through basic poly-culture techniques and natural pond stocking farmers can harvest an

[28] http://www.naturland.de/certifiedorganicaquaculture.html DLA 06/19/2012
[29] http://v-c-s.org/develop-project/agriculture-forestry-projects DLA 06/19/2012

assortment of fish, crabs, clams, snails and other organisms for consumption and to bring to local markets (Pham, 2010). These products are not highly valued on the global market, but they are quick in production and thus can make a significant contribution to local food security. Additionally, mangrove wood can be harvested through regulated thinning practices at varying times over the course of the mangroves development, and can be used for building material or brought to market.

Soc Trang and Ben Tre are less than 100 km away from each other and share many similarities in social structure and ecosystem composition. However, farmers in Soc Trang have reported damage to farms from erosion (Conversation with GIZ-Viet Nam/direct observation), while Ben Tre is steadily producing various products[30] from its land with little erosion (Conversation with IUCN-Viet Nam/direct observation). This difference may be attributable to a difference in land use strategies that have been adopted by each provincial government. On the other hand, many hectares of farms have been lost in Soc Trang due to erosion, causing the relocation of communities, while the human/fishery/conservation cooperative network seen in Ben Tre demonstrates how ecological and social interdependence can strengthen the system as a whole, and provides an example of EBM that can be learned from in moving forward.

While the social and environmental components of the SES in Ben Tre are similar as in Soc Trang, the management plans that have been implemented in each region are very different. This difference will likely influence how each area responds to SLR and other climate change related impacts in the coming years. This comparison highlights the importance of maintaining the connections between communities and a variety of ecosystem services rather than focusing on maximizing one highly valued service at the cost of other services. When adaptation strategies focus on preserving a single service, this actually puts both ecological and social communities at risk in the long-term, especially in the face of unforeseen changes. Instead, when management strategies encourage the retention of a variety of ecosystem services, they also foster relationships between communities and the services provided by that system. This increases long-term resilience because communities benefit from a variety of services, and when something happens that compromises a service, they may be able to focus on other services instead. Additionally, there is the creation of mechanisms in which the communities begin to work to protect the services they value, as seen with the clam fisheries and co-management Payment for Ecosystem Services programs[31].

Soc Trang's approach to coastal management demonstrates an SES that is out of balance. The Province has attempted to maximize social benefit by converting the entire ecosystem into a high value monoculture in which intensive shrimp farms abut the dike. This is the antithesis of the EBM approach described in the framework. Connections between farmers and their land are ignored, and the main focus is on actively manipulating the environment to achieve an enhanced product. Thus, a strong concrete wall may reduce resilience in the long-term, especially when a

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30 http://english.bentre.gov.vn/node/3 06/13/2012 DLA 06/13/2012

31 http://www.iucn.org/about/union/secretariat/offices/asia/asia_where_work/vietnam/ DLA 06/12/2012

more expansive definition of resilience is considered.

5.1.3. Importance of balancing short and long-term goals through adaptation

The proposed dike management plan has the stated goal of attempting to preserve a natural system that produces the goods and services humans rely on (Cong Van, 2009), which aligns with the stated goal of EBM. However, the dike plan fails to acknowledge the services that would be lost by creating a barrier between the delta and the ocean. Through concentrating on only provisioning ecosystem benefits, the land users of Soc Trang have disrupted crucial ecosystem processes, and as a result regulatory and supporting ecosystem services and the benefits they provide have been jeopardized or lost. Once the dike is constructed to protect rice or shrimp production, this barrier acts as a tourniquet and cut off the natural hydrological flows of the dynamic delta environment, as well as propagule dispersal, nutrient cycling, biodiversity/nursery habitat, water quality maintenance and carbon sequestration (Michaels, 2011). Furthermore, seawalls constructed at the landward edge of mangrove areas will prevent inland migration of these systems if sea-level rises, potentially causing loss of nursery and foraging grounds for fish and shorebirds (Gilman et al., 2007). In the long-term, this plan is estimate to cost over $2 billion USD, and will require expensive maintenance throughout its lifetime (Cong Van, 2009). An accurate valuation of the ecosystem services lost might prove that this plan may not be economically beneficial, despite its attempts to preserve current agricultural land.

The dike plan lacks the flexibility needed in a changing world. One of the key components of resilience is to acknowledge that systems can shift between multiple states (Walker, 2006). There is no guarantee that future rainfall or temperature patterns would allow for the continued production of these commodities in this region. Additionally, if the dike is later removed the opportunity for the natural retreat of the system will have passed and normal succession of species is likely to have difficulty colonizing and establishing a diverse community there (Moreno-Mateos, 2012). Walker (2006) describes regime shifts in ecosystem function as a disruption of ecological processes that pushes the SES to a point of change at which the coastal SES functions in a different state. As illustrated in the case studies, the maintenance of flexibility within the social structure as well as the physical environment ensures the best chance at remaining adaptable to disturbances incurred by the SES. The ability to adapt to change goes hand-in-hand with resilience, and comprehensive management strategies need to address this. This is one of many obstacles for Viet Nam's adoption of an EBM approach.

5.2. Overcoming Obstacles to EBM: Recommendations for large scale adaptation in the Mekong Delta

The EBM framework used to evaluate the three case studies attempted to reflect the principles necessary for an ecosystem-based approach (Rosenberg and Sandifer, 2009). However, from analysis of the case studies, some of fundamental barriers to establishing an EBM approach in

Viet Nam are evident. While managers should set goals that include the full range of ecosystem services, it is difficult to compete with economic goals as they are often prioritized. In a dynamic environment such as a river delta, great measures must be taken to ensure reliable production. Without a compromise in yield goals and integration of agro-ecological methods, Viet Nam is a long way from basing goals on the maintenance of ecosystem services. Determining the spatial scale of management should be part of any ecosystem-based approach. Viet Nam does have an extensive collection of agencies and institutions focusing on Global Information Systems and remote sensing, but to fully achieve this would require great knowledge about ecosystem change and ability in determining the spatial scale for management planning, but as with remote sensing programs globally, there is a lag in the capacity for processing the vast amount of data. The Ministry of Agricultural and Rural Development and Forestry Department should incorporate private enterprise initiatives into land-use plans in order to integrate forest rehabilitation objectives with shrimp production goals. Management plans should account for cumulative impacts within and across sectors. This is especially important as all activities in the delta are connected by water in some way, but there is a barrier to EBM in a lack of communication across borders, from one District to the next or even at the Commune level. One strength of Viet Nam is in the arena of decision-making under uncertainty. Unfortunately, the decisions are not likely to be in the favor of EBM, or at least the resilience of SES in the focus area. Unless these barriers are addressed, EBM will have to remain a theoretical topic for the Mekong Delta.

Viet Nam may not have the components necessary to implement EBM at this point, but the Ben Tre green belt adaptation strategy scored well on resilience characteristics and is already a proven method of diversified production and land-use in Ben Tre. The government of Viet Nam should consider a large-scale, delta-wide green belt plan as a potential adaptation option. In addition, the ability of the various financial mechanisms outlined above to offset reductions in production should be explored. In order for the coastal provinces of the Mekong Delta to mitigate impacts of climate change, the Vietnamese government must recognize that retaining the ability to adapt to change is the key to resilience. An ecosystem-based understanding of the implications of the proposed delta-wide dike system makes it evident that this strategy neither maintains flexibility nor acknowledges linkages.

Conclusion

While the literature on the components of successful EBM emphasizes the need to address linkages across spatial, temporal and organizational scales, as well as to preserve diversity across those scales, there is considerably less focus on the role flexibility plays in maintaining resilience (Leslie and Kinzig, 2009, Walker and Salt, 2006). These case studies demonstrate that there is value in choosing a strategy, which is flexible, especially given that there is uncertainty surrounding how climate change impacts will manifest themselves. According to Walker and Salt (2006), the heart of resilience is to embrace change. By ignoring or resisting change is to increase vulnerability. This suggests that perhaps rather than focusing on finding “hard” solutions, which attempt to prevent change entirely, we should be thinking more about adaptive solutions, which may allow us to detect changes and respond to them in a beneficial way as more information becomes available..

The wide application of integrated green belts would result in increased mangrove coverage in sync with the Viet Nam National Government's goals for restoration, while still meeting the economic needs of the people of Viet Nam. The challenge for shrimp producing areas has been figuring out how to slow the unregulated growth of this environmentally detrimental but profitable industry while still achieving economic growth. The Ben Tre model demonstrates that restoring degraded mangrove areas helps to maintain economically valuable ecosystem function. This not only slows environmental and social degradation, but also increases the resilience of the shrimp producing social-ecological mangrove system to the potential impacts of climate change.

Given the top down decision-making structure in Viet Nam, this strategy is most likely to succeed if adopted by its government. However, to be successful it must still address the economic needs of the farmers. A number of financial mechanisms exist for increasing mangrove coverage in shrimp producing areas in the Mekong delta. These programs include a carbon credit program through the Verified Carbon Standard (VCS), which delivers payment to farmers for planting and raising mangroves. However, these payments are predicted to be too low to compete with some form of aquaculture. Additionally, payments are only made after plants have reached a certain size, which may prove a barrier to adoption unless required by the government. There is an organic certification through the German NGO 'Naturland' that provides a great opportunity for sustainable shrimp production. The certification standard requires farmers to re-plant at least 50 percent of the pond area with mangroves of original species composition in return for premiums in revenue compared to normal shrimp. However, it is unknown if the additional revenue due to certification would offset the loss of pond area and production associated with organic aquaculture. Poly-culture techniques, in which many species are farmed together, are not commonly promoted in Viet Nam. The benefits to farmers from a poly-culture system is not likely to be enough to motivate farmers to replant mangroves because shrimp is so much more valuable than other aquaculture species. While no single program is enough to economically make up for the loss in shrimp production by mangrove integration into shrimp ponds, they can be combined to close the gap. The combination of the VCS carbon program with the market-driven organic certification and poly-culture presents the most realistic incentive for conversion. This has not been done and the idea of forfeiting shrimp growing space for mangroves is a foreign concept to farmers, but given the high likelihood of disease crashing shrimp systems in the area, the integrated mangrove shrimp production system provides a far less risky alternative.

While the SLR adaptation strategies in the case studies presented here were generally initiated to meet a single (often financial) objective rather than a suite of ecosystem-based objectives, I was still able to learn something about EBM approaches: it is possible to manage for resilience without all the components of EBM. Additionally, one of the case studies presented included a land-use plan, which is to a certain degree, resilient to impacts of SLR, and may provide a model for the rest of Viet Nam's Mekong Delta going forward.

With an uncertain future in such a dynamic region as the Mekong Delta it is essential to maintain adaptability while producing for the present.

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