

Disaster Preparedness within the Resiliency Management Framework

- A Case of Sarasota Bay Ecosystem -

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Abstract

Diagnosing a region's ecosystem and its level of resiliency would provide an alternative viewpoint of risk management and disaster preparedness. As a result, the region would become more resilient to its environmental vulnerability and long-lasting human impact on the ecosystem. This study is intended to provide a framework to diagnose a region's natural resiliency by assessing possible disturbance, threshold, and the adaptive cycle. These three are critical components to properly understand a region's natural resiliency and thus frequently implemented in various research projects. Using the three key components, we analyzed the levels of resiliency of Sarasota Bay ecosystem in the state of Florida in the U.S. The study findings provide policy guidelines and recommendations for a better disaster preparedness strategy.

Key words: resiliency, disaster preparedness, ecosystem management, Sarasota Bay, Florida

1. Introduction

Resiliency has been spotlighted by many disciplines and, it is a multi-disciplinary in nature, requiring a multi-faceted perspective to understand and prepare for a better sustainability of a region. In this extent, diagnosing a region's ecosystem and its level of resiliency would provide an alternative viewpoint of risk management and disaster preparedness. And as a result, the region would become more resilient to its environmental

vulnerability and long-lasting human impact on the ecosystem.

This study is intended to provide a framework to diagnose a region's natural resiliency by assessing possible disturbance, threshold, and the adaptive cycle. These three are critical components to properly understand a region's natural resiliency, and for that reason implemented frequently by various research works. Using the three key components, the authors analyze the level of resiliency of Sarasota Bay in the state of Florida

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in the U.S. In addition, study results also provide some possible policy guidelines and recommendations for a better future.

II. Study Boundary

1. Sarasota Bay, Florida, U.S.A.

Sarasota Bay is located on the southwestern coast of Florida, U.S.A. between Anna Maria Sound to the north and the area just north of Venice Inlet to the south. It is bordered by coastal barrier islands on the west and two mainland counties on the east. The coastal barrier islands include Palma Sola Bay, Sarasota Bay, Roberts Bay, Little Sarasota Bay, and Blackburn Bay. Two counties along Sarasota Bay are Manatee and Sarasota Counties. Sarasota Bay covers fifty two square miles of surface water area. Average depth of the Bay is 6.5 feet, and it is approximately 33-mile long. Sarasota Bay is one of 28 estuaries in the U.S., named by the U.S. Congress as an estuary of national significance in 1987 and officially designated as a National Estuary Program in 1989. More than 600,000 people reside in two counties, and the number of native species exceeds more than 1,400.



Figure 1. Geographic location of Sarasota Bay

2. Disturbances

2-1. Channelization of the intracoastal waterway

In late 1800s, the predevelopment condition of Sarasota Bay could be summarized as a narrow channel with shallow depth and redundant mangrove and wetlands. For example, the width of Big Sarasota bay ranged between one-half and three miles, and the water depths were from 6 to 10 feet. These resulted in low connectivity across Sarasota Bay. In order to meet settlers' requests for the federal government to improve the waterways across Sarasota Bay to transport local products, the U.S. Army Corps of Engineers started to create the Gulf Intracoastal Waterway, a 9-foot-deep by 100-foot-wide channel in 1896 (Antonini, 1999). Construction of the Gulf Intracoastal Waterway began in 1895 and was completed in 1967.

More than seven decades of channelization of the Intracoastal Waterway included activities, such as dredging to widen, shorten, and deepen the channel for people living and working along Sarasota Bay. The channelization caused harmful impact, such as wetland loss, habitat loss, the bay bottom modification, turbidity, and salinity change. From a human perspective, the channelization on Sarasota Bay created a commercial waterway for people, goods and services. However, at the same time it started to slowly create disturbance on ecosystem.

2-2. Dredging and filling for land development

Dredging and filling activities were also applied to coastal land development on barrier islands as well as coastal main land in Sarasota Bay. Dredging and filling for land development for

residential and commercial uses caused wetland and habitat loss to a large extent. Dredge material was moved to mangroves and shallow water bay bottoms to create upland areas. The most active land development began in 1945, and the development accelerated to the most extensive status in the 1950s and 1960s (Antonini, 1999). Population increases and the extensive development around Sarasota Bay between 1930 and 1990 caused detrimental impacts on seagrass habitats and wetlands. According to Sarasota Bay National Estuary program, 2,495 acres of tidal wetlands were destroyed between 1950 and 1990 by intensified coastal and bay development with dredge-and-fill activities. Intensified waterfront development created concrete sea walls, changed shorelines, and destroyed seagrass beds and wetlands.

For example, Bird Key, one of the largest seagrass beds in Sarasota Bay, was totally changed to subdivided single-family community with five miles of interconnected canals. Concrete sea walls during development of waterfront communities in Sarasota Bay changed natural shoreline habitats, and dredge-and-fill activities altered and destroyed wetlands. The dredging and filling for coastal land development were also designed for human benefit without considering ecosystem. It tried to maximize land development without how dredging and filling activities for land development interact with ecological system. Ignorance about degraded quality of Sarasota Bay ecosystem continued until the early 1970s when public started to concern about its impact on ecosystem from dredging and filling activities. However, 26 percent of mangroves and 92 percent of salt marsh had been already destroyed in

Sarasota Bay at that time (Antonini, 1999).

2-3. Loading nitrogen to Sarasota Bay from land development

Moreover, the increased development created nitrogen pollution from wastewater and stormwater runoff directly to Sarasota Bay. Degraded Sarasota Bay ecosystem, affected by the disturbance on freshwater wetlands, salt marsh, and mangrove, lost ecosystem function to filter stormwater and to prevent extensive runoff from the intensified development from barrier islands and the two counties. Also, increased impervious surface from intensified land development increased stormwater runoff.

According to the U.S. Environmental Protection Agency, nitrogen loadings were three times higher than the nitrogen levels prior to increased development of Sarasota Bay areas. Water quality in Sarasota Bay was also impacted by wastewater and stormwater from the Sarasota Bay watershed which includes Manatee and Sarasota Counties. Nitrogen loads in Sarasota Bay changed extensively from 191,419 kg TN/year in 1890 to 905,386 kg TN/year in 1988 (Tomasko, *et. al.*, 2005). Excessive wastewater and stormwater runoff to Sarasota Bay from increased development is the largest source of nitrogen loading in the bay. Overabundance of nitrogen caused algae blooms, and it reduced oxygen levels in the bay. Eventually, it resulted in turbid water and loss of seagrass from opaque water status that sunlight cannot reach underwater grasses. Wetlands and seagrass are critical indicators of quality of ecosystem because these are sources of food and shelter for coastal habits.

One of important ecosystem function includes

Table 1. Disturbance and its impact on Sarasota Bay ecosystem from the 1980s to 1970s

Time	Disturbance	Description	Resiliency Loss
1890s	Channelization of the Gulf Intracoastal Waterway	- Created a waterway across Sarasota Bay	- Seagrass beds loss - Wetland loss
1920s	Large scale drainage projects	- Drained 100,000 areas of freshwater marsh to initially create agricultural use	- Bay bottom structure modification - Water circulation change
1950s to 1970s	Intensified coastal and Bay development	- Hundreds of acres of Bay bottom were dredged to produce waterfront lots and subdivisions, - Drained saltwater marshes were converted to residential neighborhoods	- Nitrogen loads - Less oxygen - Algae blooms - Turbidity - Redundancy loss

providing habit for marine and bird wildlife. Extensive nitrogen loads also affected marine and bird species that were provided nutrients from the seagrass beds. Direct damages to seagrass in Sarasota Bay have been caused from channelization of the Gulf Intracoastal Waterway, dredging and filling activities including dredging of canals, filling of the bays for coastal development, and boat propellers. In addition to the direct damage on seagrass ecosystem, nitrogen loads by wastewater and stormwater runoff to Sarasota Bay from increased coastal development has resulted in indirect damages to seagrass. Seagrass in Sarasota Bay declined by 39 percent between 1880s and 1990.

III. Thresholds

Walker and Salt described that thresholds are levels in controlling slow variables (Walker, *et al.*, 2006). In Sarasota Bay ecosystem, seagrass loss from channelization, dredging and filling activities, and increased nitrogen loads from

coastal development is a slow variable that explains how the ecosystem changed from a phase to another phase in adaptive cycle.

Seagrass loss became apparent slowly after several decades. As a latent variable, the seagrass loss reached to the threshold without attentions to restore seagrass before it reached to carrying capacity, and crossed to alternate regimes. (Table 2) shows Sarasota Bay Estuary Program seagrass coverage and targets in acres. Seagrass target levels of the table are threshold of seagrass coverage for each bay segment.

IV. Adaptive Cycle

According to Walker and Salt, adaptive cycle describes how an ecosystem organizes itself and how it responds to a changing world (Walker, *et al.*, 2006). In order to understand internal connection of Sarasota Bay ecosystem, it is meaningful to analyze its adaptive cycle. It would help understand how Sarasota Bay has been responding to disturbance, changing from phase

Table 2. Sarasota Bay estuary program seagrass coverage and targets (unit: acres)

Bay Segment	Historical(1950)	1988	2004-2006 Average	Seagrass Target
Palma Sola	1,031	1,111	1,015	1,031
Sarasota	7,269	6,323	7,041	7,269
Roberts	283	334	348	348
Little Sarasota	883	533	702	702
Blackburn	273	411	447	447
Total	9,739	8,712	9,552	9,997

to phase toward its resiliency, and how social systems and social-ecological systems change through times (Walker, *et. al.*, 2006).

The adaptive cycle has two models with opposite characteristics. The fore loop consists of the rapid growth phase (r Phase) and the conservation phase (k phase). The back loop consists of the release phase (Ω phase) and the reorganization phase (α phase). The fore loop is slow compared to the back loop, and change is incremental and predictable. The back loop is explained by uncertainty, novelty, and experimentation (Walker, *et. al.*, 2006).

In Sarasota Bay ecosystem, the r phase could be explained by channelization of the Intracoastal Waterway and dredging and filling for land development. Gunderson and Holling explained that the progression in the ecosystem cycle starts from the rapid growth phase and it slowly proceeds to the conservation phase (Gunderson, *et. al.*, 2002). The channelization of the Intracoastal Waterway began in 1895 and was completed in 1967, and the dredging and filling activities for coastal land development started the early 1900s and intensified during the 1950s to 1970s. These two variables have impacted on Sarasota Bay ecosystem slowly over several decades.

In addition to the two variables, rapid

population increase adjacent to Sarasota Bay area and extensive impervious surfaces from land development would be applied to the rapid growth phase. In the rapid growth phase, humans started to affect ecological systems for their economic benefits without considering ecological resiliency. Since the r phase proceeds slowly to the K phase, it is hard for humans to recognize disturbance on the ecosystem resiliency.

The K phase, the conservation phase, represents the status of maximizing dredging and filling activities for coastal development in Sarasota Bay ecosystem. Eventually, the detrimental impact on Sarasota Bay ecosystem extended to a maximum extent, and it reached to the threshold from the conservation phase to the release phase. In this phase, the ecosystem's carrying capacity was influenced by the disturbance. For example, maximized dredging and filling activities have disturbed wetlands, seagrass beds, the bay bottom structure and the shorelines. From this disturbance, the carrying capacity of the wetland decreased, and it lost its ecosystem function of self-filtering distressed water to Sarasota Bay. It started to lose its resiliency of Sarasota Bay ecosystem. Like the systems as a Ball-in-the Basin Model, Sarasota Bay ecosystem was getting closer to the threshold separating alternate basins

Table 3. Adaptive cycle of Sarasota Bay ecosystem

α phase	K phase
<ul style="list-style-type: none"> - Sarasota Bay ecosystem management plans - Interconnected system - Seagrasses/ Wetlands restoration - Wastewater/ Stormwater management - Marine/ Bird habitat management - Monitoring and Research 	<ul style="list-style-type: none"> - Maximization coastal land development
r phase	Ω phase
<ul style="list-style-type: none"> - Channelization of the Intracoastal Waterway Dredging and filling for land development - Population increase / Land use Change 	<ul style="list-style-type: none"> - Nitrogen Loads - Seagrasses/wetlands loss - Algae Blooms / less oxygen level - Redundancy loss

(Walker, *et. al.*, 2006).

Gunderson & Holling stated that resources become divided to separate uses (Gunderson, *et. al.*, 2002). In Sarasota Bay ecosystem, the ecosystem resources were degraded by maximization of land development. Also, the ecosystem function for marine and bird species had to be divided to different function of land development for humans.

The back loop consists of the release phase (Ω phase) and the reorganization phase (α phase). The conservation phase proceeds very rapidly to the Ω phase, the release phase. Once the ecosystem's threshold or carrying capacity is exceeded in the K phase, the ecosystem goes to the release phase. The transition from the conservation phase to the release phase is very rapid. As Gunderson & Holling said, the tight connections are broken and feedback regulatory controls weaken in the release phase (Gunderson, *et. al.*, 2002).

In Sarasota Bay, the release phase refers to seagrass and wetland loss, algae bloomed, and decreased water quality by nitrogen loads. Maximization of coastal development in the K phase exceeded the threshold that Sarasota Bay ecosystem holds. Nitrogen loads from wastewater and stormwater runoff from the coastal development caused algae to bloom. It connectively caused seagrasses and marine habitat loss.

The uncertain release phase proceeds quickly into the reorganization and renewal phase (α phase). The reorganization phase refers to the Sarasota Bay ecosystem management strategies by different levels of societies towards the ecosystem resiliency. Gunderson & Holling stated that in the reorganization phase is comparable to one of innovation and restructuring society such as

practical attention for social transformation (Gunderson, *et. al.*, 2002).

The first public concerns on Sarasota Bay ecosystem in the 1970s would be an example of the release phase. Moreover, the Sarasota Bay comprehensive conservation and management plan for the Bay in 1995 is a good example of the reorganization phase. The conservation and management plan suggested six action items to restore the destroyed Sarasota Bay ecosystem. These action items are wastewater treatment and reclamation, stormwater treatment and prevention, freshwater and saltwater wetlands, fisheries and other living resources, recreational use, and bay monitoring and research (Alderson, *et. al.*, 1995). Until today, different levels of social systems are involved in the Sarasota Bay towards its resiliency. Currently, Sarasota Bay ecosystem is located in the reorganization phase.

V. Feedback between ecological and social components of the system

Holling stated that the ecosystem and the social system should be analyzed simultaneously as a linked system. The cycles of adaptation to their changing ecosystem should include ecological and social system components together (Walker, *et. al.*, 2006). Beatley mentioned that a resilient community refers to one with strong social systems and networks (Beatley, 2009). Especially, resilience in recovery and reconstruction depends on how this social system works well with ecological system. Also, different spatial and temporal scales should be considered to understand how the ecosystem functions and sustains its

Table 4. Social components of Sarasota Bay ecosystem

Time	Social components	Description
1972	Public	Started to pay attention to water quality and disturbance on Sarasota Bay
1986	Mote Laboratory	Explored how to conserve Sarasota Bay with local government officials
1987	Sarasota Bay Scientific Information Symposium	Interaction of different levels for knowledge
1989	Sarasota Bay National Estuary Program	Initiated 10 major studies and a series of early-action demonstration projects.
1993	A science-based Draft management plan by the National Estuary Program	Proposed to restore Sarasota Bay from Anna Maria Sound south to Venice Inlet.

resiliency without crossing carrying capacity. Toward resilient ecosystem, it is critical to consider how social components interact with their ecosystem rather than to ask how humans affect ecological system (Alberti, *et. al.*, 2008).

In the fore loop of the Sarasota Bay ecosystem adaptive cycle, there were not strong interactions and feedbacks between ecological and social components. Until the early 1970s, public did not pay much attention to how humans affected the ecosystem. As the extensive disturbance caused detrimental impact on the ecosystem, human started to realize that the ecosystem was interconnected to social component, and feedback between ecological and social component started to arise. (Table 4) describes how social component of the ecosystem were added to sustain resiliency of the ecosystem from the 1970s to the 1990s.

The feedback has extensively activated in the back loop of the adaptive cycle, especially in reorganization phase, which is corresponding to the current status of the ecosystem. Linked social network of individual, local, regional, institutional components participate to restore resiliency of the ecosystem. For example, Sarasota Bay Estuary Program depends on different levels of social network such as cities, counties, state, federal levels as well as volunteer based individual participants towards resiliency of the ecosystem.

Continuous public involvement with academic institutions, leaders, and media promote social resiliency in the Sarasota Bay ecosystem. These different scale of social network are linked together and are aware of that resiliency of the ecosystem comes from the feedback and interaction between ecological and social components. For example, feedback between ecological and social component regarding to fishery and ecotourism creates benefits to both ecosystem and humans by restoring fishery habitat as well as creating economic benefits.

VI. Conclusions

Although Sarasota Bay ecosystem is currently in the reorganization phase, and social-ecological components of the system is also considered to understand the ecosystem, the ecosystem still confronts and deals with disturbances on the ecosystem. In order to maintain resiliency in the system or some desired state, different types of policy and management strategies are required.

As population in Sarasota and Manatee counties is projected to increase, land use changes from land development happen to come along. The more land development means the more impervious surfaces and stormwater runoffs to Sarasota Bay, impacting on the resiliency of the ecosystem. In order to

decrease its impact on water quality and the ecosystem function of Sarasota Bay, it is highly recommended to implement low impact development strategies, such as green infrastructure. Green infrastructure (GI) refers to interconnected green space that mimics ecosystem function, such as filtering runoffs or preventing flood damages. Converting impervious surfaces to pervious pavements is a good example that ecosystem management policy providing for the resilient ecosystem. To reduce stormwater runoff from land development, implementation of green infrastructure helps maintain resiliency in the ecosystem. Tax and financial incentives could be effective tools for people to implement green infrastructure.

As climate changes and sea level rises, Sarasota Bay confronts another disturbance in the future. Sea level rises would be another slow variable for adaptive cycle that Sarasota Bay ecosystem will change through the four phases. A policy for preparedness for sea level rises disturbance would be recommended. Sea level rises will cause detrimental impacts on the existing ecosystem as well as social resiliency in Sarasota Bay. Therefore, management plans and tools for minimizing its impacts from sea level rise for waterfront communities are important aspect for the resiliency of Sarasota Bay.

Another recommendation is quantifying economic value of the ecosystem and measuring the degree of ecosystem resiliency. Because ecosystem provides different type of functions, it is hard to measure its value and level of resiliency. Quantification of the ecosystem value and resiliency indicators would help different levels of social system

understand its value. Eventually, it will provide a good management plan toward resiliency of Sarasota Bay ecosystem, and will restore and sustain its resiliency without reaching to the threshold of the ecosystem and crossing to a different regime.

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생태계 탄력성 관리를 통한 재난방지 대책에 대한 연구

– 미국 플로리다 주, 사라소타만에 대한 사례분석 –

국문초록 이 연구는 미국 플로리다 주의 사라소타 만에 생태환경의 탄력성 조사를 기반으로 재난 발생 시 자연적으로 복구 가능한 생태계의 범위 및 관리시스템에 대한 고찰을 다룬 논문이다. 자연재해 발생 후 생태계가 자연적으로 복구할 수 있는 탄력성을 갖기 위해 필요한 정책적 준비 및 제도적 장치가 필요한지에 대한 연구를 통해 보다 지속가능한 개발방향에 대해 기술하고 그 필요한 재원에 대해 분석한다. 생태학적 탄력성에 대한 연구는 최근 들어 많은 관심을 받는 주제이지만 이에 대한 자연재해와의 연관성에 대한 연구는 이론적으로나 실증적으로 분석된 부분이 아직까지 많지 않은 상태이다. 따라서 본 연구에서는 생태계의 자연탄력성에 대한 이론적 고찰을 통해 이를 활용한 자연재해 극복 및 대비 방법에 대해 알아보고 그 필요성에 대한 학문적 뒷받침을 제시하여 추후 실증적인 연구가 필요할 경우 그 방향성 및 필요 결과물에 대한 제시를 통해 자연 생태계와 재난방지 분야에 대한 하나의 기준점을 제시한다.

주제어 : 생태계 탄력성, 재해방지, 생태계 관리, 사라소타만 플로리다

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