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Restoration Outcomes of the Wugu Wetland in the Erchong Floodway in New Taipei City

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Abstract

Taiwan is surrounded by seas and has diverse soils and landscapes, a temperate climate, abundant rainfall, and longitudinal and transverse valleys and mountain ranges. These conditions afford Taiwan a rich variety of wetland environments on coasts and around its lakes and rivers. On July 3, 2013, the legislature of the Taiwanese government passed the third reading of the Wetland Conservation Act, which took effect on February 2, 2015. The act lists a total of 42 wetlands of international and national prominence and 41 others of regional prominence (provisional designation) across Taiwan. In addition, before the implementation of the act, the Ministry of the Interior reduced the total area of designated wetlands nationwide from the 56,860 hectares established in 2011 to 47,627 hectares. This study investigated the Wugu Wetland in the Erchong Floodway in New Taipei City, a wetland located in a metropolitan area of northern Taiwan that had been partially damaged from misuse, and examined the recent restoration policies for the wetland implemented by the New Taipei City government. A SWOT (strengths, weaknesses, opportunities, and threats) analysis was subsequently conducted to propose feasible strategies for positive restoration outcomes of the wetland.

Keywords: Wetland degradation; Restoration

Introduction

Wetlands are functionally vital and valuable to the health of nature and are one of the most productive ecosystems. Their biodiversity of fauna and flora is conducive to the breeding of new and propagation of valuable species. Being surrounded by sea, Taiwan is fully encircled by a wetland network, in the broad sense of the definition, that spans mudflats, rocks, estuaries, and beaches in and around the coast, marshes, rivers, ponds, rice fields, and other bodies of inland waters, as well as swamp forests, reservoirs, and high mountain lakes in the mountains. With the ecological value of wetlands being increasingly promoted by private and public sectors and nongovernmental organizations (NGOs) at home and abroad, the Construction and Planning Agency of Ministry of the Interior (CPAMI) had been undertaking extensive wetland conservation and restoration measures to fulfill the mandate of the Basic Environment Act [1] before the Wetland Conservation Act (Laws & Regulations Database of The Republic of China, 2015) was legislated. The CPAMI has also formulated measures for wetland conservation and restoration to expedite the construction of a comprehensive ecological network that would extend progressively from nationally prominent wetlands to major ecological habitats (i.e., starting from coasts and moving inward to estuaries, riparian watersheds, and ponds, and up to mountain lakes). To assess and track the ecological conditions of nationally designated wetlands and encourage public participation in their conservation and restoration, the agency has funded regional governments to develop and launch projects that mobilize the local communities and NGOs, [2] as well as private and public organizations, to survey, restore, and reengineer these essential ecological resources [3]. Because of the implementation of such policies, the Wugu Wetland in the Erchong Floodway in New Taipei City has been undergoing restoration.

Literature Review

Previous studies on wetlands were reviewed to investigate wetland development. These studies were collated to elucidate the relevance of previous studies and establish a theoretical framework for the present study.

Overview of wetlands

Completed in 2005, which was 5 years after being initiated, the Millennium Ecosystem Assessment [4] provided a comprehensive evaluation of all types of ecosystems across the globe, highlighting the importance of wetlands in terms of their ecological and economic value. The MA results revealed that more than half of wetland ecosystems worldwide had been ruined throughout the last century and the remainder were already degenerating.

The MA offered the following valuable conclusions. First, wetlands perform diverse ecosystem services that can benefit human wellbeing. Second, based on the comparison between the market and nonmarket benefits of wetlands, the total economic value of no transformed wetlands is often higher than that of transformed ones. Third, nutrient oversupply poses substantial threats to rivers, lakes, swamps, coastal areas, and coral reefs.

Fourth, wetland ecosystem services (e.g., denitrification and flood and cloudburst prevention) have become increasingly essential. Fifth, wetlands, and thus the species thereof, deteriorate and disappear more rapidly than other ecosystems do. Sixth, the combined effect of biodiversity loss, land degradation, and climate change is undermining the capability of wetlands to reduce negative impacts on nature. In sum, the most effective strategy to address the implications of climate change and the changes to the global ecosystem is to implement cross-

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sectoral approaches for wetland management [e.g., integrated water resource management [5] and integrated coastal zone management (Wikipedia)], thereby lessening pressure on wetlands and improving their restorative capability. Such approaches are more effective at promoting wetland sustainability than are sector-specific ones, which are currently widely applied in numerous countries.

International wetland conservation

Approximately 5 decades ago, a group of scientists studying wetland bird species discussed how to effectively manage functional wetlands that support biodiversity and serve as stopover sites for migratory water birds from across the world. In 1962, they had their first meeting in what is currently the Camargue Biosphere Reserve in France, but was then a large wetland at the estuary of the Rhône River. Afterwards, the national governments that advocated this movement, including those of Britain, the Netherlands, Iran, France, and the former Soviet Union, convened their own respective technical meetings. An international treaty was subsequently reached on the basis of legal guidance from the Environmental Law Commission of the International Union for Conservation of Nature (IUCN). The treaty was first ratified by participating nations at a meeting in the city of Ramsar in Iran in 1971, amended in 1975, and came into force that year as the Ramsar Convention [formally the Convention on Wetlands of International Importance, especially as Waterfowl Habitat [6]. The Ramsar Convention soon became universally acknowledged and, in the first 20 years after its ratification, prioritized wetlands upon which water birds ecologically depend. In other words, the convention did not protect waterfowl directly as its formal name suggests; it actually protected wetland ecology. In addition, it did not address concerns of wetland biodiversity until approximately a decade later.

International conventions on wetland biodiversity that were ratified in the 1970s and 1980s include the World Heritage Convention [7], the Convention on Migratory Species [8], the Convention on International Trade in Endangered Species [9], as well as the Dublin Statement on Water and Sustainable Development, which was applied at the International Conference on Water and Environment in 1992 [10]. Although the final version of the Dublin Statement made no mention of wetlands, its emphasis on effective water management indicated the importance of the wise use of wetlands, which are also considered a water resource. The Dublin Statement also played a part in the World Conference on Environment and Development [11], which was convened in the city of Rio de Janeiro in Brazil 20 years after the 1972 Stockholm conference. At the globally known WCED, three United Nations treaties were approved: The Convention on Biological Diversity [12], the United Nations Framework Convention on Climate Change (UNFCCC), and the United Nations Convention to Combat Desertification [13].

The concept of ecosystems, developed in the 1990s, was first incorporated into the MA as a precursor to the formulation of environmental protection policies. Moreover, "the ecosystem approach," [14] an essential element for the implementation of the Convention on Biological Diversity, was integrated into the development of the MA as a mechanism for managing biodiversity and played a role in international conferences on biodiversity protection and management. Thus, the conceptual framework of the MA was developed with the provisioning, regulating, and supporting, as well as cultural services of the environmental protection system. All these services are intended to benefit human wellbeing [15].

Wetland conservation in Taiwan

To maintain the health and stability of ecosystems, promote the sustainability of the natural environment, and improve the conservation and restoration of wetlands, it is crucial that government organizations at all levels and the public at large properly manage and wisely utilize the natural resources and ecological functions of wetlands to ensure no net loss to these areas.

Types of wetlands in Taiwan: Defined by the formation condition, wetlands can be divided into "natural wetlands (NWs)" and "constructed wetlands (CWs)." NWs can then be dichotomized into coastal and inland wetlands [16]. Coastal wetlands: distributed in and around coastal regions and formed as a result of tidal movements. Coastal wetlands come in different forms:

- Swamps
- Mudflats (located in areas such as the Lanyang Estuary, Zengwen Estuary, and Kaoping Estuary),
- Forest swamps (located in areas such as the Zhuwei Shoreline of the Tamsui River, the Hongmao Port in Hsinchu, and the coastal area in Budai Township in Chiayi),
- Intertidal zones/offshore shoals,
- Lagoons and saline lakes (e.g., the Qigu Lagoon in Tainan),
- Islets (e.g., the Mianhua Islet off the coast of Keelung,

Inward wetlands: wetland systems distributed in and around rivers, lakes, high mountains, and plains. Inward wetlands come in different forms:

- Freshwater swamps/ponds,
- Shrub swamps,
- Peat swamps (e.g., the Menghuan Lake at the foot of the Qixing Mountain in Taipei),
- Lowland broadleaf forests,
- Forest swamps,
- Seasonally flooded grasslands/forests,
- Constructed wetlands (e.g., rice fields, fish ponds, salt pans, reservoirs, and artificial lakes),

Based on the wetland classification proposed in 1975 by the IUCN, wetlands are further divided into the following (available from the Database of Natural Resources and Ecology of Forestry Bureau of Council of Agriculture, [17]):

- Shallow sea bays and straits (less than 6 meters deep at low tide),
- Estuarine waters/estuarine systems of deltas,
- Islets,
- Rocky marine shores and sea cliffs,
- Sandy beaches,
- Tidal flats and mudflats,
- Coastal mangrove swamps,
- Coastal brackish and saline lagoons and swamps,
- Salt pans,

- Fish and shrimp ponds,
- Slow rivers/streams/creaks,
- Fast rivers/streams/creaks,
- Riverside swamp,
- Freshwater lakes with adjacent swamps,
- Swamps and small freshwater ponds (less than 8 hectares),
- Inland saline lakes with adjacent saline swamps,
- Reservoirs (artificial lakes),
- Seasonally flooded grasslands,
- Rice fields,
- Irrigated land,
- Swamp forests and seasonally flooded forests,
- Peat swamps.

Wetland conservation outcomes in Taiwan: It was not until the early 1980s, when public demand for protecting the mangrove forest at the mouth of the Tamsui River spread nationwide, that the Taiwanese society began to appreciate the relevance of wetland protection. Since 1986, the Council of Agriculture has designated the mangrove forest and other NWs as nature reserves in accordance with the Cultural Heritage Preservation Act. It has also designated ecologically rich wetlands (e.g., seas, estuaries, swamps, lakes, streams and brooks, and farmland, which are listed in the implementation guidelines of the Wildlife Conservation Act) as major wildlife habitats and wildlife reserves [18].

There are currently 83 nationally designated nature reserves, major wildlife habitats, wildlife reserves, and protected natural areas, spanning 11.38% of the entire area of Taiwan. Numerous natural resources in the Taiwanese domestic wetlands have accordingly been safeguarded (Tables 1 and 2).

- Wetlands of international and national prominence. Designated on account of their global relevance in the fields of ecology, botany, zoology limnology, and hydrology. This type of nomination is proposed by the competent authority and reported to the executive branch of the Taiwanese government for approval.
- Wetlands of regional prominence. Areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or both, including areas of marine water with a depth at low tide that does not exceed 6 meters, and without any inclusion in the list of wetlands of international or national prominence. The nomination shall be proposed by local governments and reported to the competent authority for approval.

Undesignated. Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or both, including areas of marine water with a depth at low tide that does not exceed 6 meters.

Wetland conservation measures in Taiwan: To balance commercial environmental and spatial planning with ecological sustainability [19], the CPAMI promulgated the Wetland Conservation Act on February 2, 2015, requiring wetland developers and users to submit wetland-impact statements detailing the damages to major wetlands from their land development and use. The CPAMI formulated guidelines within the act on the verification, dissemination, and public review of the submitted statements, as well as the calculation of off-site compensation and ecological compensation, to minimize the impact of land development and use on wetlands. The measures regarding this objective are detailed as follows:

- Standards and criteria for wetland-impact statements of land development and use within or around major wetlands and implementation guidelines on public participation.
- Implementation guidelines on impact minimization and ecological compensation associated with land development or use within or around major wetlands.
- To facilitate wetland conservation, wetland developers and users are required to contribute specific amounts of their monetary reward toward funds for wetland conservation and restoration and environmental education.
- Guidelines on the application for "wetland badges," calculation of monetary reward, and wetland land management and use certificates. This market mechanism is intended to promote wetland conservation.
- The delineation of the functions of wetland ecosystems, limitation and prohibition of certain actions on wetlands, and management and wise use of them.

Comprehensive comparison of wetlands in Taiwan and other countries: The position of a wetland park is specified by an overall assessment of the features, faunal and floral species, environmental

Northern		Central		Southern		Eastern		Outlying Islands	
Region	Number of wetlands	Region	Number of wetlands	Region	Number of wetlands	Region	Number of wetlands	Region	Number of wetlands
Taipei City	2	Miaoli County	4	Chiayi County	6	Hualian County	3	Lienchiang County	1
New Taipei City	1	Taichung City	3	Chiayi City	2	Taitung County	7	Kinmen County	1
Keelung City	0	Nantou County	5	Tainan City	8			Penghu County	2
Taoyuan City	2	Changhua County	1	Kaohsiung City	12				
Hsinchu City	1	Yunlin County	2	Pingtung County	10				
Hsinchu County	4								
Ilan County	6								
Total: 16		Total: 15		Total: 38		Total: 10		Total: 4	

Table 1: Distribution of wetlands in Taiwan.

Name and Level of Designation	Total Number of Bird Species	Area (Hectare)	Type
International			
Zengwen Estuary Wetland	121	3128	Coastal NW with partial CW
Sicao Wetland	160	547	Coastal NW with partial CW
National			
Menghuan Lake Wetland	Limited	1	Inland NW
Danshuei River Drainage Wetlands			
North-Jetty of Port of Taipei Wetland	Limited	477	-
Wazihwei Wetland	Limited	60	Coastal NW
Danshuei River Mangrove Wetland	Limited	190	Coastal NW
Guandu Wetland	139	394	Combination of coastal NW and CW
Wugu Wetland	Limited	358	CW with partial inland NW
Dahan-Sindian Wetland	101	650	Inland NW
Sinhai Manmade Wetland	Limited	101	CW
Fujhou Manmade Wetland	Limited	129	CW
Daniaopi Manmade Wetland	Limited	76	CW
Chenglin Manmade Wetland	Limited	36	CW
Lujiao River Manmade Wetland	Limited	25	CW
Taoyuan's Reservoir and Canal Wetlands	49	2974	Inland NW with partial CW
Xucuo Harbor Wetland	180	1836	CW
Sinfong Wetland	Limited	165	Coastal NW
Yuanyang Lake Wetland	Limited	374	Inland NW
Siangshan Wetland	277	1600	Officially included in the East-Asian Waterfowl Protection Network at the 1996 Conference of the Contracting Parties of the Ramsar Convention
Xihu Wetland.	Limited	183	-
Cijiawan River Wetland	Limited	7221	Inland NW
Gaomei Wetland	135	701	Coastal NW
Dadu Estuary Wetland	235	4136	Coastal NW
Aogu Wetland	259	512	Coastal wetland behind a seawall, with a partial mudflat outside the seawall
Puzih Estuary Wetland	179	8522	-
Haomeiliao Wetland	93	1171	Coastal NW with partial CW
Budai Salt Pan Wetland	93	721	CW with partial coastal NW
Bajhang Estuary Wetland	93	635	Coastal NW
Jiianan's Reservoir and Canal Wetland	Limited	1383	Inland CW with partial coastal NW
Beimen Wetland	119	2447	Coastal NW with partial CW
Guantian Wetland	Limited	15	CW
Cigu Salt Pan Wetland	121	2997	Coastal NW with partial CW
Yanshuei Estuary Wetland	200	635	Coastal NW
Nanzihsiian River Wetland.	Limited	130	Inland CW
Daguei Lake Wetland	Limited	39	Inland CW
Jhouzai Wetland	Limited	10	CW
Nanren Lake Wetland	Limited	118	Inland CW
Longluan Lake Wetland	Limited	289	Inland CW
Sinwulyu River Wetland	Limited	193	Inland CW
Dapochih Wetland	Limited	41	Inland CW
Beinan Estuary Wetland	98	947	Coastal NW
Siiaoguei Lake Wetland	Limited	18	Inland CW
Hualien Estuary Wetland	Limited	259	Coastal NW
Fataan Wetland	Limited	177	Inland CW
Shuanglian Reservoir Wetland	Limited	17	Inland CW
Lanyang Estuary Wetland	236	2799	Coastal NW
52-jia Wetland	150	299	CW with partial coastal NW
Wuwei Harbor Wetland	140	684	Coastal NW
Nanao Wetland	Limited	200	Inland NW
Chingluo Wetland	Limited	221	Coastal NW with partial CW
Cih Lake Wetland	Limited	188	Inland NW
Cingshuei Wetland.	Limited	12	Coastal NW
Regional			
Jhubei Lianhua Temple Wetland		1	CW

Ecological Park of Toucian River		492	-
Jhunan Manmade Wetland		9	Coastal CW
Siiangtian Lake Wetland		3	Coastal NW with partial CW
Danan Lake Wetland		9	Inland NW
Dongshih Manmade Wetland		4	Inland NW (planned to be rebuilt as CW)
Caonan Wetland		2	Inland NW
Shinjie Cold Spring Wetland		50	-
Twin Lakes Wetland		12	-
TouSher Basin Wetland		13	-
Caodi Wetland		2	Inland NW
Chenglong Wetland		171	Coastal CW with partial NW
Yiwu Wetland		1857	Coastal NW with partial CW
Mituo Wetland		30	Inland NW
Bajhang River Mid-Stream Wetland		363	Inland NW
Baihe Elementary School Manmade Wetland		0.4	CW
Chianan University of Pharmacy and Science Manmade Wetland		1	CW
Wetland of the National Kaohsiung University		5	-
Jiading Wetland		171	CW with partial coastal NW
Yongan Salt Pan Wetland		133	Coastal CW
Dashu Manmade Wetland		177	CW
Niaosong Wetland		4	CW
Linyuan Manmade Wetland		50	CW
Yuanjhong Harbor Wetland		39	Coastal CW
Banping Lake Wetland		12	CW
Fongshan Reservoir Wetland		118	Inland CW
Linluo Manmade Wetland		3	-
Wuluo River Manamde Wetland		15	CW
Kanding Wetland		153	-
Pingtung University of Science and Technology Manmade Wetland		56	CW
Sihchong Estuary Wetland		25	-
National Museum of Marine Biology and Aquarium Manmade Wetland		5	CW
Shihlinger Mountain Wetland		2	-
Dongyuan Wetland		112	-
Guanshan Manmade Wetland		2	CW
Luanshan Lake Wetland		4	CW
Jinlong Lake Wetland		5	CW
Lioushihdan Mountain Wetland		6	Inland NW
Jhuan Wetland		1417	Coastal NW with partial CW
Caiyuan Wetland		82	Coastal NW with partial CW
Undesignated			
Changhua Coast Wetland		21152	Coastal NW
National Taiwan University Wetland		-	-
Fubow Wetland		30,000 (approx.)	-
Hanbao Wetland		3800	-
Puzih Estuary Wetland		-	-
Dajia Wetland		-	-
Neiweipi Wetland (a.k.a. Kaohsiung Museum of Fine Arts Wetland)		-	-
Yanshuei Estuary Wetland		-	-
Jhongdou Wetlands Park		-	-
Love River Wetland		-	-
Shezihlinpi Wetland Park		-	-
Linyuan Manmade Wetland		-	-
Baoan Wetland Park		-	-
Benhe Village Flood Retention Pond		-	-
Baoye Village Flood Retention Pond		-	-

"-" denotes data unavailability from the CPAMI. (Source: Compiled by this study).

Table 2: Classification and distribution of wetlands in Taiwan.

conditions, geographical location, development goals, and specified functions of the wetland in the park. This assessment determines whether the wetland is characteristic of the park and makes it capable as a model for other wetland parks in the local region or nationwide [20].

Case comparison

Wetlands of national prominence from three countries were compared (namely, the Wugu Wetland and Wuwei Harbor Wetland in Taiwan, the Sungei Buloh Wetland Reserve in Singapore, and the Kushiro Shitsugen National Park in Japan). Table 3 presents the comparison results [21].

Recommendations for wetland construction and management

The comparison of these four cases yielded the following suggestions for organizations involved in the construction and management of wetland habitats:

- Identify the characteristics of wetland habitats. A wetland should be developed on the basis of the characteristics and distribution of ecological resources in the wetland park, as well as the integrity of natural and cultural landscapes, managerial convenience of the park, and reasonable planning of wetland use.
- Formulate specific conservation objectives. The functions of a wetland should be specified in accordance with the ecological characteristics and dependence on ecological processes of the species listed for protection. Thus, the ecological characteristics of the wetland can be maintained and the protection of endangered faunal and floral species can be prioritized.
- Build partnership and integrate ideas. Public and private sectors should cooperate to develop relevant policies, as well as exchange and synergize ideas on regional development topics.
- Focus on the local environment. To facilitate its management, a wetland should have its functions specified in accordance with the attributes, characteristics, and immediate environs of fauna and flora inhabiting the ecological area. This is to ensure correspondence between the indigenous animals and plants and their immediate environs.
- Seek resources from the society. Through integration and dissemination, societal resources can be exploited to the greatest extent possible.

Item \ Wetland	Wugo Wetland (Waterfowl Reserve)	Wuwei Harbor Wetland (Waterfowl Reserve)	Sungei Buloh Wetland Reserve	Kushiro Shitsugen National Park
Protection Range	Within the Erchong Floodway in New Taipei City, Taiwan	Between the villages of Aozaijiao and Dakengu in the southeast of the Lanyang Plain in Ilan, Taiwan	The northwest shore of Singapore	The east of the island of Hokkaido, Japan
Area (hectare)	177	102	130	26,861
Designation Year	1900	March 1993	January 2002	1890
Formation	The mountain pass of Shizitou in the narrowest part of the estuary of the Tamsui River was blasted to expedite the flow of the river into the sea. However, this subsequently caused seawater intrusion into many areas of agricultural land, turning them into swamps.	Because a channel through which the Xincheng River used to empty into the Pacific Ocean was deposited, the River shifted to the north, leaving the channel to become a swamp.	Naturally formed	Naturally formed
Relevance	The floodway in which the Wugo Wetland is located stems floodsto minimize property loss.	A crucial waterfowl wintering site in the northeast Taiwan.	The only mangrove forest left in Singapore, a major stopover for migratory birds flying to East Asia, and a critical wintering site for black-faced spoonbills.	Maintains the health of and promotes the restoration of natural environments, facilitates the use of agricultural land and the development of agriculture, and contributes to the local region.
Feature	CW with partial inland NW.	Hosts waterfowl flocksduring winter.	A regenerated wetland	Restores the ecosystem and natural landscape in the park.
Water Level Control Mechanism	Natural tidal	Artificial control and natural tidal	Artificial control and natural tidal	Natural tidal
Objectives of Management	Restoration, protection, education, preservation, and public participation.	Restoration, protection, education, preservation, and community participation.	Restoration, protection, education, recreation, and research	Restoration, protection, education, preservation, and citizen participation
Management Characteristics	The local residents, conservation groups, and government cooperate on conservation and water quality improvement.	The local residents, conservation groups, and government cooperate on conservation and conflict resolutionof economic interests of land use.	The government leads the management of the reserve and works with the local schools, conservation groups, andthe private sector on environmental restoration.	The local residents, conservation groups, and government cooperate on environmental conservation.
Challenges	The impact of human activity and human-made facilities.	The requirement for more land, water pollution from metro areas and industrial activity, and coastal road development.	Pollution from the north of Malaysia.	Regulating the flood control capacity of the wetland to prevent the inflow of sand sediments caused bysoil self-regulation.

(Source: Compiled by this study).

Table 3: National wetlands in Taiwan versus those in Singapore and Japan.

Case Study of the Erchong Floodway and the Wugu Wetland

Erchong floodway

Located in a metropolis area of Taipei in northern Taiwan, the Erchong Floodway travels north–south, with its western and eastern embankments bordering the districts of Luzhou, Sanchong, Wugu, Taishan, and Xinzhuang in New Taipei City. Emptying into the Tamsui River and measuring 7.7 kilometers in length and 450 to 750 meters in width, the floodway was previously used to prevent floods as part of a flood control project implemented in Taipei and later extended to afford recreation and ecological protection. It is a 424-hectare high riverbank lying in the boundary of the Taipei Basin and includes an extensive green space approximately 16 times the size of Daan Forest Park (one of the largest parks in Taipei) and times the size of Central Park in New York City.

The Erchong Floodway is an ecological corridor that links with major waterways in several cities of a conurbation. Located in a wetland site where fresh and saltwater bodies intersect, it appeals to diverse bird species, creating an environment conducive to the existence of Mortonagrion hirosei, an endangered insect. Its expansive hinterland provides optimal conditions to improve the ecosystems of urban areas.

A part of the estuarine system of the Tamsui River and located near the low-lying Taipei Basin, the Erchong Floodway serves as the confluence of three major tributaries (Dahan Creek, Xindian Creek, and Keelung River) of the river, which typically surges during typhoons. The floodway provided the source of farmland irrigation during the Japanese colonial period in the nineteenth century. Following the retrocession of Taiwan from Japan in 1945, the Nationalist government erected levees in Taipei to prevent residential areas from floods, although this measure intensified flooding in the neighborhood of the Erchong Floodway. In 1961, the government ordered that the mountain pass of Shizitou at the estuary of the Tamsui River be blasted to quicken the flow of the river into the sea. However, this subsequently caused seawater intrusion into numerous areas of agricultural land in the Wugu istrict, turning them into swamps. Afterwards, levees were erected in four phases as floodways for this region to stem floods and minimize property loss.

Wugu wetland

Situated at the Erchong Floodway in Wugu District (a low-lying, southwestern region of the Taipei Basin) in New Taipei City in Taiwan (25° 5' 19.7016" N, 121° 26' 3.084" E) and penetrated by the Un-A Channel, the Wugu Wetland spans the north end of the Erchong Floodway, borders the Guandu Wetland on the north, the National Highway No. 1 (a.k.a. the Sun Yat-sen Freeway) on the south, the Shuhong 1st Road (County Highway 59 on the north) on the east, and the western levee of the floodway on the west, and is approximately 177 hectares in area. The wetland was built as a CW with partial NW because some of its area is subject to the tidal influence of the Tamsui River. It has been listed by the CPAMI as a wetland of national prominence, managed by the High Riverbank Construction Management Office of New Taipei City Government, and adopted by the Society of Wilderness (SOW), although the adopter has no legal power.

The formation of the Wugu Wetland dates back to the mid-seventeenth century. As policies were increasingly implemented to accommodate a growing population in the local region, it evolved from a fertile, arable soil to a tidal, ecologically rich swamp and ended up as a turf-blanketed sporting park, with its ecological functions undermined throughout all these major changes. The transformation of the wetland can be divided into five periods:

Before 1960: Farmland: During this period, the predecessor of the Wugu Wetland was a major farming site in Greater Taipei that yielded bountiful rice, citrus fruits, and taros. With populations growing and buildings being developed on the Taipei Basin and the surge of the Tamsui River increasing in frequency, the once fertile field degenerated into an infertile, highly saline swamp, encroaching on the lives and properties of the public at large.

1960-1980: Seawater intrusion and wetland formation: Excessive land development, groundwater overexploitation, and flood control implementation caused land subsidence along the Un-A Channel, making the Wugu Wetland one of the most severely subsiding sites in the Taipei Basin. In addition, the riparian location of this field was within tidal reach of the Tamsui River that, because of discharged bottlenecks at the mountain passes of Guandu and Shizitou, used to flood into low-lying areas, causing seawater intrusion into the districts of Wugu and Luzhou, and eventually turning fertile fields in the regions of the modern Wugu Wetland. Formed by chronic flooding, the Wugu Wetland now nourishes animals and plants, making it one of the major bird-watching sites in northern Taiwan and one of the top 12 wetlands nationwide.

1980-2000: Booming economy, declining environment: To meet the flood planning prevention requirements of the greater Taipei area, the construction of the Erchong Floodway took most of a 20-year period to complete. During this construction, the residents of the Wugo Wetland were forced to relocate and the local culture and history were completely eradicated. Additionally, the wetland area shrank by almost half as its environmental wellbeing continued to be deteriorated by the construction of soil disposal and waste dumping sites in the Wugu Industrial Park. It was further damaged by industrial effluents from a cluster of factories upstream, as well as by private plantations and use, resulting in ecological degradation.

2000-2004: Green space establishment and the Wugu wetland conservation movement: Between 1997 and 2001, the Taipei County Government (predecessor of the New Taipei City Government) undertook a revitalization project to build green areas, sports fields, and many other facilities along the entire Erchong Floodway. However, this project caused the disappearance of riparian vegetation downstream the Un-A Channel, threatening the ecological environment of the Wugu Wetland. In 2002, the SOW led other NGOs to establish a Floodway Ecological Conservation Alliance, which launched a movement for the conservation of the wetland, giving rise to the establishment of the Wugu Wetland Ecological Park.

2004-present: Adoption and management of the Wugu wetland by the society of wilderness: To increase the area of green land in the densely populated, highly urbanized Taipei region by utilizing idle spaces, the government initiated a 5-year construction project, establishing a 420 hectare multiple-function recreational park. Because the development of the recreational park along the floodway focused on providing sporting fields, the SOW applied to the government to adopt the Wugu Wetland in November 2004 and build an ecological park for it. The SOW has since conducted projects in ecological education and wetland maintenance on a 3-year basis.

Conservation of the Wugu wetland

Geographical and climate characteristics of the Wugu wetland: Geography: Located in the lowest-lying region of the Taipei Basin

and penetrated by the Un-A Channel, the Wugu Wetland serves as the confluence between the Keelung River and the major tributaries of the Tamsui River. These characteristics impede water discharge for the Wugu Wetland, which is further aggravated by the influence of the Guandu mountain pass. The wetland was the main agricultural area in the Greater Taipei, but tidal influence, flood surges of the Tamsui River, and human activity gradually made it barren and turned it into the largest reed cluster in northern Taiwan. It was subsequently reserved as a habitat for Mortonagrion hirosei, an endangered insect.

- Climate: The Wugu Wetland is in a warm and humid climate with annual and monthly average temperatures of 22.6°C and 15-28°C respectively, annual and monthly average precipitation amounts of 2325.2 mm and 136-337 mm respectively (the rainfall on the wetland is typically the highest in June, August, and September and lowest from November to January), and a relative humidity of 75-80%.

Conservation sites of the Wugu wetland: The SOW, the adopter of the Wugu Wetland, has divided the wetland into five conservation sites (Table 1):

- Shuhong Ecological Park: comprises a ditch, a swamp, a tidal pond, high grass, and recreational turf in an area of 30.4 hectares and is designated for ecological education and as a waterfowl habitat.
- Ecological Pond: comprises a tidal pond, a mudflat, and barren land in an area of 15 hectares and is designated as a waterfowl habitat.
- Reed Cluster: comprises a tidal reed cluster and land in an area of 22.6 hectares and is designated as a reserve and habitat for Mortonagrion hirosei.
- Shuhongzhenbian Park: comprises a freshwater pond, a partial tidal pond, and high grass in an area of 33.3 hectares and is designated as a freshwater ecological site, insect ecological site, and partial habitat for Mortonagrion hirosei.
- Shuhong Swamp Park: comprises a swamp, a freshwater pond, and high grass, in an area of 75.7 hectares and is designated as a reserve that can be used as a water purification park.

Conservation strategies and development goals for the Wugu wetland: The Tamsui River wetlands vary in formation and pattern depending on geographical location and provide either biological conservation or water purification in accordance with the immediate ecosystem. The Wugu Wetland is a riparian CW that can be developed to purify water, conserve Mortonagrion hirosei, and rehabilitate on-site biodiversity. To achieve this end, the immediate surroundings of the wetland, which span the Wugu Industrial Park, commercial and residential areas, and green parks, can be used.

Challenges

- The wetland borders industrial zones and has chronically lacked a protective monitoring mechanism for industrial wastewater and wetland water quality.
- Despite its expansiveness, the wetland is prone to disturbance from frequent anthropogenic activity. The extent of disturbance to the wetland from such activity and the use of human-made facilities should be investigated.
- The life of fauna and flora inhabiting the wetland is threatened by fertilizer pollution from illegally established vegetable gardens.

Conservation strategies

- Establish a long-term water quality monitoring mechanism to reduce the impact of water pollution from industrial zones.
- Implement a facility reduction plan to reduce the disturbance to waterfowl inhabiting and roving the wetland from the use of human-made facilities and human activity.
- Undertake a comprehensive development plan for the ecological conservation space by persuading the owners of illegally established vegetable gardens to relocate their gardens to the upstream area of wastewater and irrigate them through soil treatment, thereby improving the water quality and wetland conservation of the space.
- Evaluate the wastewater purification effectiveness of the CW as a reference for determining the requirement to retain and expand eco-purification sites of other CWs for future waterfront projects, or to change their functionality (Figure 1).

Translations in the textboxes, from top to bottom, left to right: Shuhong Ecological Park -> Ecological Pond -> Shuhong Swamp Park -> Reed Cluster -> Shuhongzhenbian Park.

Development orientation and management objectives

To fulfill the aforementioned conservation strategies and development goals for the Wugu Wetland that focus on water quality improvement and wetland conservation, the development orientation for the wetland, as well as the approaches thereof, was proposed in consideration of the proximity of the Tamsui River watershed to the Taipei metropolitan area and the development potentials associated with the advantageous geographical location of the river.

Maintaining wetland biodiversity

Potential habitats for focal species should be protected and developed to create an ecologically rich habitat environment. Habitats

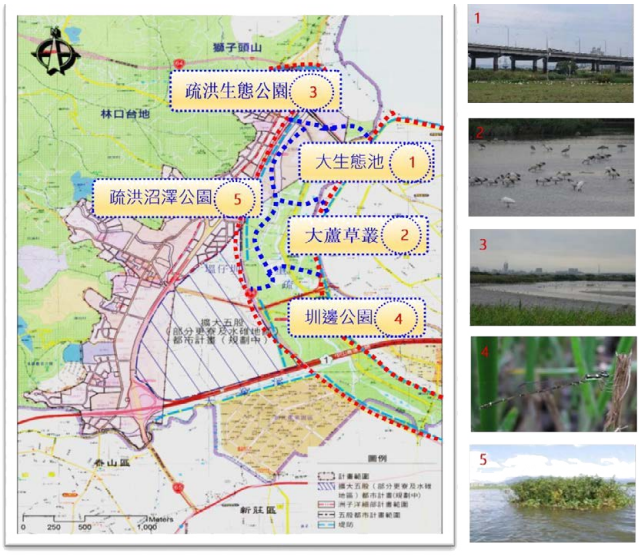

Figure 1: The five conservation sites and the distribution of wetland resources of the Wugu Wetland (source: plotted by the researchers).

for different species should be regenerated and expanded to build diverse biotopes that facilitate the growth of marine life, provide food supplies and habitat for seabirds, serve as stopover sites for migratory birds, and ensure the coexistence of these substantive habitats.

Implementing ecological monitoring

Ecological surveys and education should be conducted periodically. A database that records ecological changes to the wetland on a long-term basis should be developed. Short- and long-term plans should be established to manage ecological reserves effectively and an ecological monitoring system that enables a long-term observation and a regular review of management strategies should be installed.

Controlling the source of water pollution to improve water quality

The source of water pollutants into the Erchong Floodway, which hinder the growth of vegetation in the Wugu Wetland, should be limited to improve the structure of the wetland and increase its purification efficiency. An educational system should be implemented to develop effective maintenance and monitoring mechanisms.

Undertaking wetland conservation and control

Human activity has hindered the growth of the Wugu Wetland ecosystem and reduced the population of the indigenous mammal species. To safeguard its ecosystem against such impacts, functional requirements, spatial configurations, and personnel control should be planned for dividing the Wugu Wetland Ecological Park into core, protected, and transition ecological zones.

Restricting visiting time and visitor numbers to the ecological park

Multiple noise sources, as well as habitat deterioration associated with human activity, have hindered the population growth of species living in the ecological park. Thus, the visiting time and visitor numbers to the core ecological zone of the park should be restricted to maintain the ecological wellbeing of the wetland.

Regulating visitor activity through zone designation

A buffer area should be established between the protected area and visitor routes. In addition, the ecologically sensitive zone should be divided into non protected and ecologically recreational areas to regulate visitor activity.

Protecting rare species in the wetland ecological environment

To sustain the habitats of rare species in the Wugu Wetland, habitat conservation and the development of potential habitats should be undertaken and diverse habitats be established. This would improve ecological abundance and the capability of peripheral habitats to interlock with each other to maintain the integrity of the ecological environment of the wetland.

Providing wetland education

Guided tours and interpretive facilities should be provided at the Wugu Wetland to disseminate information on how the planning and design of the wetland enables the Tamsui River to cleanse water and neutralize miasma. Moreover, because this wetland boasts species diversity, it allows urban residents to come into close contact with animals and waterfowl without having to travel far.

Imposing land use regulations

Human activity should be strictly prohibited within 50 meters of the Wugu Wetland and areas within 100 meters outside of the embankment of the wetland watershed should be designated as parks or green spaces. Such regulations would establish ecological buffer zones to protect the core and ecologically sensitive zones and minimize the impact of recreational activity on the wetland.

Training the locals as guides and promoting ecological education

Training programs that involve long-term observation of environmental problems and increase environmental awareness should be offered to cultivate local interpretive guides and volunteers. In addition, environmental education on the wetland and water resources should be provided through printed and electronic media to the general public, thereby achieving the management of the wetland watershed and sustainable management of ecological resources.

Expected outcomes

A conflict between economic development and environmental protection has always existed because the latter is achieved by invoking environmental responsibility and ethical concerns in many cases and diminishing economic activity in some. However, environmental conservation, which promotes the "wise use" of natural resources and the environment, is encouraging the shift in the "rivalry" between environmental and economic concerns toward a "partnership." To facilitate this change in the environment–economy relationship, the government should seek to cooperate with environmental activists and resolve this long-term conflict.

Thus, wetland conservation in Taiwan should be undertaken by the society as a whole to create value for ecological systems. The government can establish a market mechanism to promote wetland conservation, rather than create a clash between conservation practices and the market. Such a mechanism is referred to as "mitigation banking (Table 4).

Strengths–weaknesses–opportunities–threats analysis of the restoration of the Wugu wetland

Current observations indicate that most ecological characteristics of the Wugu Wetland have been constantly changing since 2004, when reservations were first established. Purified water, increased species populations, and an improved ecological landscape have given the wetland a combination of natural, cultural, and scenic values, suggesting its potential to develop ecologically. Thus, the restoration outcomes of this degraded urban wetland indicate that its ecological characteristics have improved.

Damages	Restoration outcomes
Area wassubstantially reduced, accelerating the rate of loss	Decreased in wetland area, increasing the restoration area restoration
Ecosystem structure and habitatswere degraded	Habitats were expanded throughecosystem structure integration
Biodiversity declined	Biodiversity was increased
Soil and water pollution	Quality of soil and water was improved

Table 4: Restoration outcomes for the Wugu Wetland.

The restoration outcomes of the Wugu Wetland, as listed in Table 4, are results of required improvements. To develop viable approaches to improving the restoration of the wetland, all the internal and external conditions of the wetland's ecological characteristics were identified through a SWOT analysis (Table 5).

Conclusion

An ecological characteristic description summarizes the current status of a wetland, providing technical support for wetland management. An analysis of ecological characteristics reveals the threats to these characteristics. This analysis method applies to the protection of not only wetlands of international and national prominence but undesignated ones and can be conducted at any temporal points depending on the objectives or requirements of wetland management.

Although the Wugu Wetland is isolated in an urban environment,

SW / OT		Internal Strengths				Internal Weaknesses			
		•Ecological landscape resources	•Aquatic faunal and floral diversity	•Diversity of protected insects	•Links with the Tamsui River watershed, houses abundant faunal and floral species	•Disturbance of human recreation to fauna and flora	•Hindered vegetation growth caused by water pollutants	•Weakened faunal and floral activity on ecological zonescaused by excessive human-made facilitiesnearby	•Shrunken habitat area due to widened walking paths
External Opportunities	•Promotes ecological education	Prioritizes ecological education over scenic education	Promotes wetland waterfowl conservation	Promotes theprohibition of hunting protected insects	Promotes ecological protection and environmental education	To improve visitors' ecological awareness			
	•Policy-promoted reengineering of ecological landscape	To reengineer the ecological landscape on the basis of the reduction principle and ecological engineering method	To reduce bird-watching facilities		To reduce bird-watching facilities	To reduce the impact of recreational activities ion the ecosystem	To establish a management mechanism for water quality	To determine whether to reduce human-made facilities	
	•Growing public acceptance of wetland conservation	To secure the characteristics of the wetland	To promote the ecological management and conservation of habitats	To use resources beneficial to ecological characteristics	To fulfill the ecological functions of the wetland	To create ecosystem management plans	To establish a monitoring system to secure the growth of ecological environment	To reduce recreational parks and expand ecological habitats	To mend the biosphere
External Threats	•Bustling activity on weekends and holidaysnear the wetland caused by its proximity to the transportation hub of Taipei	To implement effective control plans for the protected zones		To reduce the traffic outside of street blocks and designate traffic areas to lessen the traffic volume within the blocks	To build parking spaces outside of the wetland	To control ecological zones close to public roads and conduct this control plan in accordance with the recreational functions of these zones	To strictly limit the discharge of water pollutants		To narrow biking and walking paths and limit access to them
	•Wetland development limited by the recreational focus of habitats	To rearrange recreational facilities in activity zones		To maintain biodiversity				To limit human activity near protected areas	
	•Habitats disturbed by visiting routes		To maintain biodiversity	To encourage recreational activities that have less impact on the ecosystem		To designate protected and buffer zones			
	•Weak cooperation mechanisms between the general public and local educational institutions	To establish facilities for promoting ecological education and introducing ecological resources			To provide ecological education for visitors of all ages	To establish a stable monitoring and education mechanism			

(Source: Compiled by this study)

Table 5: SWOT matrix of the Wugu Wetland restoration outcomes.

its degraded ecosystem has undergone comprehensive restoration to accommodate social, economic, and natural requirements. Improvements in water purification, species population size, and the ecological landscape have contributed toward restoring the wetland environment and water bodies, increasing species diversity, and improving soil quality (that facilitated the restoration of native helophytes). The aforementioned restoration outcomes confirmed the feasibility of the ecological restoration practice in restoring the function of damaged urban wetland ecosystems according to the structural characteristics of the ecology. Such practice is an effective measure for restoring damaged urban wetlands, improving the water quality, and managing wetland conservation.

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