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Water bird habitat suitability analysis in an urban coastal wetland (case study: Lantebung mangrove ecotourism area)

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Abstract. Water birds are significant wildlife in mangrove ecosystem. These aquatic birds have prominent roles for the integrity of the ecosystem. This research aimed to analyse water birds habitat suitability level at Lantebung Mangrove Ecotourism Area in Makassar, South Sulawesi, Indonesia. Geography Information System (GIS) and remote sensing approaches were employed in this study. Eight parameters were used for water bird habitat suitability assessment: land type, food class, water level, human disturbance, salinity, pH, dissolved oxygen, and temperature. All data parameters other than land type were interpolated using Inverse Distance Weighted Interpolation (IDW) in ArcGIS 10.5. Meanwhile, land types were digitized on-screen using Landsat 8 imagery (acquisition October 2018), based on GPS field tracking. The suitability assessment was done by weighted overlay analysis, based on the scoring and weighting of each layer. The results showed that the area suitable for water bird habitat at Lantebung Mangrove Ecotourism Area was approximately 44 ha or 51.2% from the total area. The majority of suitable area consisted of mangrove forest, mudflat in front of mangrove forest, and mudflat behind mangrove forest. Further sustainable effort is needed to manage the available habitats, so that water bird population can be conserved.

1. Introduction

The dynamics of mangrove wetlands, particularly in tropical coastal urban areas are highly impacted by urbanization and human activities [1]. The degradation of this type of wetland has resulted in deterioration of wetland ecosystem services and the biodiversity that depends on these wetlands [2]. Water birds are a significant wildlife component in tropical mangrove wetlands. These birds are an important part of mangrove wetland ecosystems, because they have ecological role in mangrove forest dynamics [3]. Water birds are able to oxygenate the soil while eating, and release nutrients into the water body through their faeces and leftovers [4]. Water birds, particularly wading egrets and herons [5], and migratory shore birds [6] are known to occupy even highly disturbed mangrove ecosystems which can often still provide them with important habitat. Therefore, conservation efforts to preserve both water bird species and their habitat are much needed in order to sustain equilibrium in

ecosystems, especially in urban areas where anthropogenic pressures are at their highest. In such cases, habitat suitability assessments should be done as an essential step towards conservation.

Water birds habitat suitability assessments using remote sensing and Geographic Information System (GIS) approaches have been conducted in several types of wetland ecosystem, including freshwater wetlands [7–9], archipelagic wetlands [10], semi-arid wetlands [11], and tropical non-urban wetlands [12]. However it appears that these tools have not yet been used for water bird habitat suitability assessments in tropical urban mangrove wetlands, even though this habitat is very prone to loss. Therefore, this research aimed to analyse water bird habitat suitability level using a remote sensing and GIS approach. The study site was the Lantebung Mangrove Ecotourism Area, a tropical urban mangrove wetland area located in a suburb of Makassar City, Indonesia.

2. Research Method

2.1. Research Design

Geographical Information System (GIS) and remote sensing approaches were employed in this study. Eight parameters were used for water bird habitat suitability assessment, i.e., land type, food class, water level, human disturbance, salinity, pH, dissolved oxygen, and temperature. All of the data parameters except land type, were collected in the field, input to the GIS and interpolated using Inverse Distance Weighted Interpolation (IDW) in ArcGIS 10.5. Meanwhile, land types were digitized on-screen using Landsat 8 imagery (acquisition October 2018), based on GPS field tracking. Suitability assessments were done by weighted overlay analysis, based on the scoring and weighting of each data layer.

2.2. Study Time and Area

This study was conducted from May to November 2018, at the Lantebung Mangrove Ecotourism Area, Lantebung Village, Tamalanrea District, Makassar City. This area is surrounded by fishponds, fishing settlements, and industrial warehousing areas. The mangrove forest extends for around 11 ha, stretched along 1.5 km of shoreline (Figure 1).

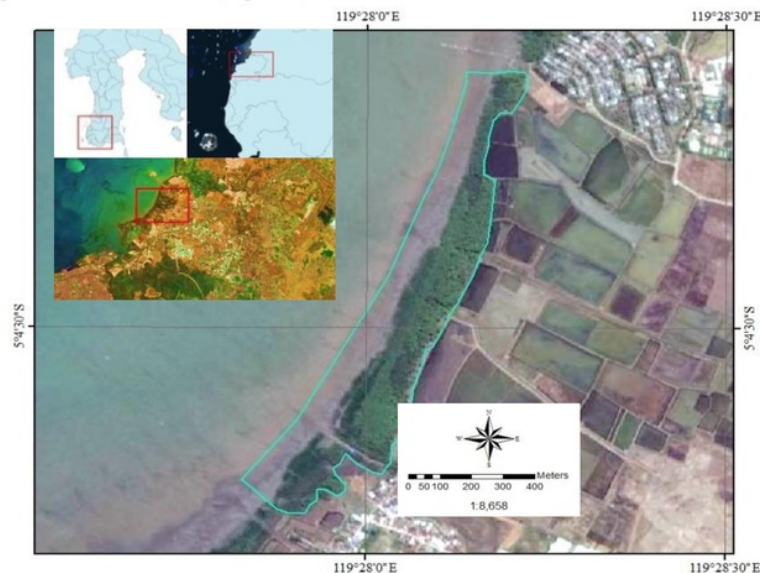


Figure 1 Research Location: the Mangrove Ecotourism Area, Lantebung, Tamalanrea District, Makassar City

Based on previous study data, there are 18 water birds species (wading birds and shore birds) the live in this area, with an average visitation rate of 339 birds per day. Three of these water birds are protected by the government based on the Regulation of the Environment Minister issued in 2018.

2.3. Data Sources

Landsat images (acquisition October 2018) were downloaded from the United States Geological Survey (USGS) site <https://glovis.usgs.gov>. Food class was identified by point sampling using a core sampler, duplicated at 15 points which were evenly distributed along the area. Human disturbances were identified by on-site observation; if two people were conducting the same activity, it was considered as one activity. Data on the physical and chemistry characteristics of the water (salinity, pH, and temperature) were measured using a Water Quality Checker (WQC) unit. Water depths were calculated using a water level meter. Water was collected for Dissolved Oxygen (DO) analysis using a Winkler bottle sampler at each of the 15 sampling points, and calculated using *in situ* Winkler titration. Additional data collected on site were photographs of land types and GPS tracking data.

2.4. Data Processing

Landsat images were pansharpened to increase the spatial resolution. Multispectral imagery were pansharpened with Panchromatic band (Band-8 on Landsat 8 OLI), using “Create Pansharpened Raster Dataset” in the ArcMap 10.5 toolbox and natural colour channels selected. For all images, georeferencing was set to UTM WGS 1984 Zone 51 S. Images were specifically cropped to the study area (Lantebung Ecotourism Area) and spectral display was adjusted. A land types map was created based on GPS tracking data and on site observation, using on-screen digitation in ArcGIS 10.5. Distribution maps of each parameter were created using the on site point sampling data for each attribute. These data were interpolated for each attribute using Inverse Distance Weight Interpolation (IDW) in ArcGIS 10.5 Geostatistical Wizard. The value of power and search neighbourhood were adjusted to get the lowest RMS (root mean square) value. Each attribute was then classified based on the determined range value.

2.5. Data Analysis

Raster data results from IDW interpolation were reclassified to give a score attribute to each layer. Suitability analysis was done using weighted overlay analysis of every parameter layer. Each data layer was input to Weighted Overlay tools in ArcGIS, and given a determined weighting value. Table 1 shows the weighting and scores used for each parameter.

Table 1 Habitat suitability parameters influencing water bird abundance and diversity [12] (modified from various sources)

Suitability parameter	Criteria	Score	Weight	Source
Human Disturbance	0	3	20	[8,12]
	1 type	2		
	> 1 type	1		
Food Class	4 classes	3	20	[12,13]
	3 classes	2		
	1-2 classes	1		
Land Types	Mudflat	3	15	[12] modified based on field condition
	Mangrove	2		
	Active Fishponds	1		
Water Level	0-50 cm	3	15	[14]
	50 cm – 90 cm	2		
	>90cm	1		

Suitability parameter	Criteria	Score	Weight	Source
pH	7-8.5	3	10	[13,15,16]
	5.4-6.9 and 8.6-9	2		
	<5.3 and >9	1		
Salinity (ppt)	<34	3	10	[13,15]
	34-50	2		
	<2.5 and >40	1		
Temperature (°C)	28-32	3	5	[13,15,17]
	2.5-28 and 32-40	2		
	>50	1		
DO (ppm)	>5	3	5	[13,15,16]
	3-5	2		
	<3	1		

3. Results and Discussion

Distribution maps (Figure 2) of human disturbance, food class, land types, and water level are displayed in Figure 2. The types of human disturbance observed on site were fisherman in boats in front of the mangroves, visitor activities near mangroves, and people working in fish ponds. The area with no human disturbance was 16 ha or 18.6% of the total area; one type of human disturbance occurred in 67 ha (77.8% of the total area), and more than one type of human disturbances occurred in 3 ha or 3.49% of the total area (Figure 2A).

Food classes found in the Lantebung Ecotourism Area were: Polychaeta (sea worms), Bivalvia (shellfish), Gastropoda (sea snails), Maxillopoda (barnacles), and Pisces (fish). The areas which were considered 'suitable' (with 3 food classes) covered \approx 40 ha or 46.5% of the total area (Figure 2B).

Land types in the Lantebung Ecotourism Area comprised mudflats in front of and behind the mangroves (20 ha or 23.3% of the total area); Mangroves (\approx 11 ha (12.8%)), while active fish ponds covered 11 ha (12.8%), salt ponds 31 ha (36%), and inactive fish ponds 13 ha (15.1%) (Figure 2C). In terms of water level, suitable water bird habitat (with water levels of 0- 30 cm) extended for \approx 39 ha or 45.3% of the total area (Figure 2D).

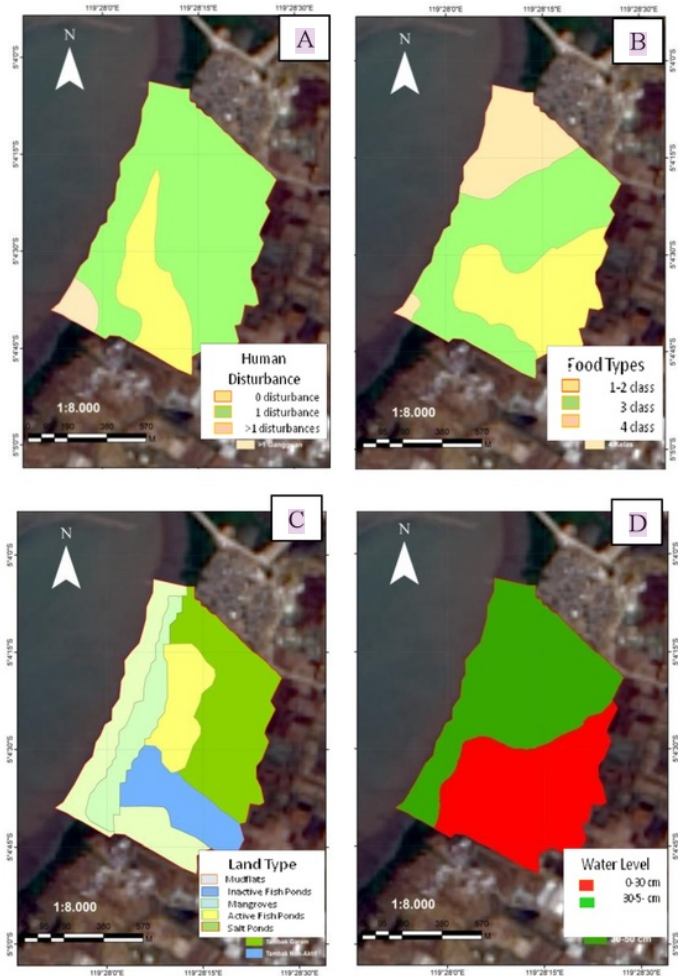
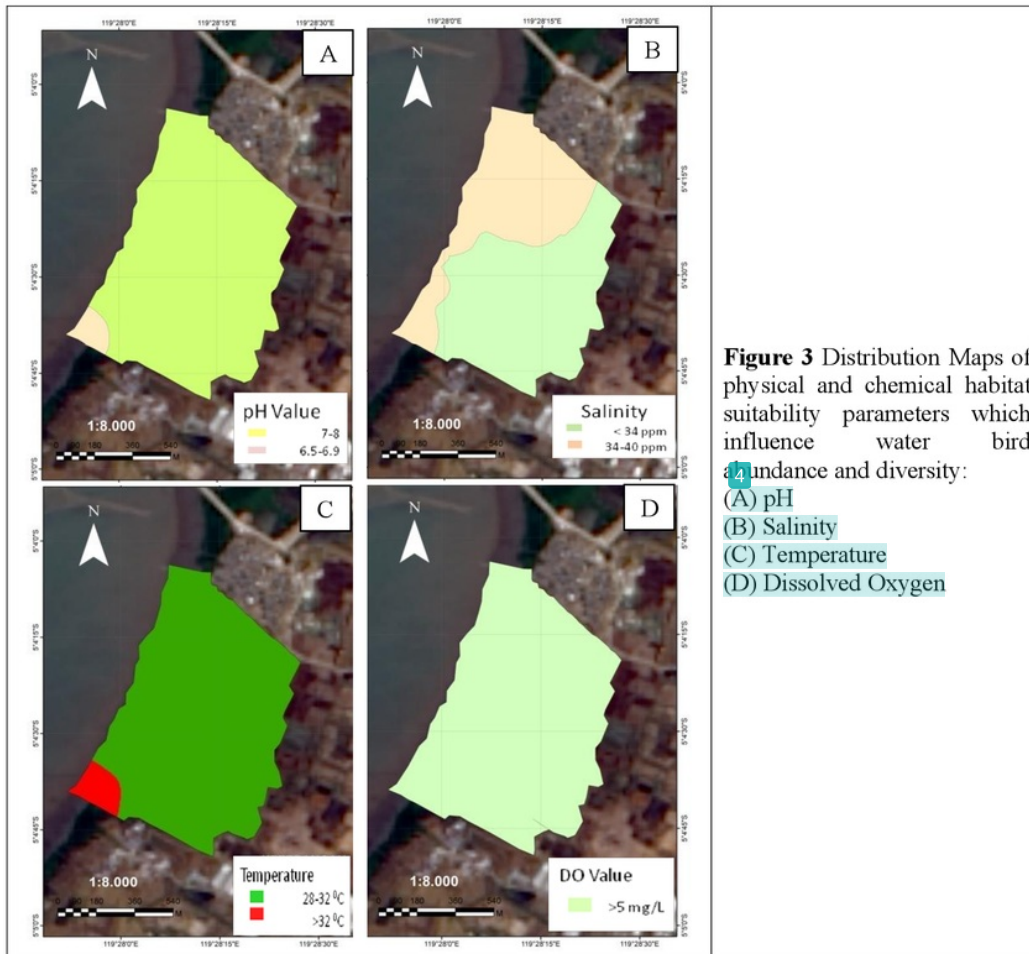


Figure 2. Distribution Maps of four habitat suitability parameters which influence water bird abundance and diversity:
 (A) Human Disturbance
 (B) Food Classes
 (C) Land Types
 (D) Water Level

Physical and chemical factors (water, pH, salinity, temperature, and dissolved oxygen) the distribution of which influences water bird habitat suitability, can be seen in Figure 3. The distribution map of water pH at Lantebung Mangrove Ecotourism Area (Figure 3A) shows that habitat with suitable pH (pH 7-8) covered 83 ha or 96.5% of the total area. Suitable salinity for water bird habitat (below 34 ppt) extended for 51 ha, or 59.3% of the total area (Figure 3B). Temperatures most suitable for water birds habitat (28-32°C) were recorded in 82 ha or 95.3% of the total area (Figure 3C). Dissolved oxygen (DO > 5 ppm) was found all over Lantebung Mangrove Ecotourism Area (Figure 3D).



The map of water birds habitat suitability obtained from overlaying all parameters distribution maps is shown in Figure 4. The result of the spatial analysis to determine habitat suitability classes for water birds based on habitat components in the Lantebung Mangrove Ecotourism Area, showed two classes: 1) suitable, the highest score indicating optimum components, and 2) unsuitable, a feeding ground used when the mudflat was not exposed and habitat components were less optimum. Suitable habitat for water birds in Lantebung Mangrove Ecotourism Area extended for 44 ha or 51.2% of the total area. Meanwhile, the unsuitable area was 42 ha or 48.8% of the total area.

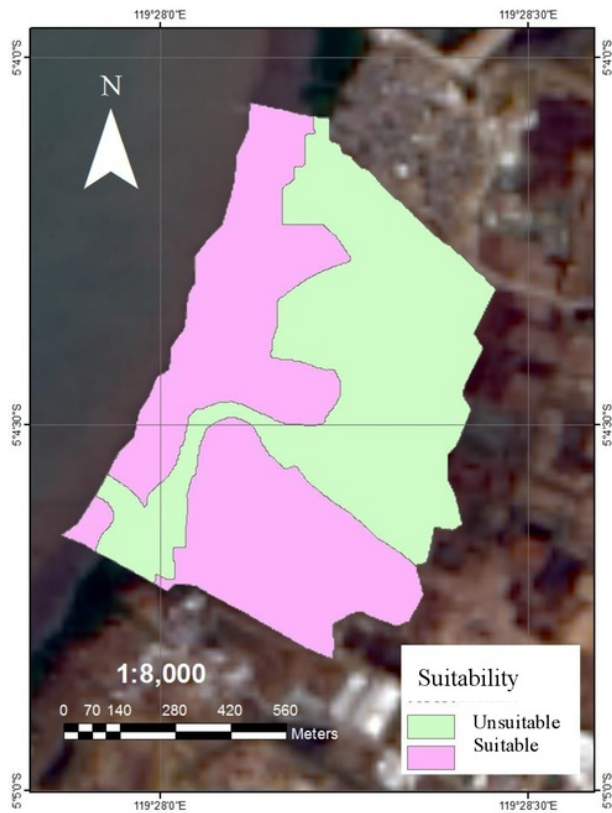


Figure 4 Water Bird Habitat Suitability Map for Lantebung Mangrove Ecotourism Area, Makassar City.

The suitable class comprised areas of mudflats, mangroves, and inactive fish ponds. Suitable areas where foods are available in a higher variety need to be protected from human disturbance. The choice of habitat by water birds in wetlands is strongly influenced by the availability of food sources and the ease of getting food according to the daily needs of each water bird species foraging in a particular area [18].

The presence of human activities in an ecosystem affects the presence, distribution and abundance of animals. Human activity is a form of disturbance that can affect the population dynamics of water birds, affecting their behaviour, abundance and/or distribution. The responses of birds to human presence are varied. They may shorten the time spent in searching for food and may fly away when humans are close to them. Therefore, the existing ecotourism should consider the spatial aspects of bird habitat and the distance between water birds and tourists. This is important when deciding on areas for facilities such as visitor paths and bridges

Generally water birds have a tendency to approach feeding locations that are rich in food sources and migratory birds often visit the same feeding site from year to year [19]. Migrant beach birds tend to always use the same stopover sites every year as places to rest and obtain food. In addition, in this case the accessibility or ease of obtaining food is influenced by water height, further affecting the abundance and diversity of water birds [14].

The distribution and abundance of water birds are also influenced by physical-chemical factors. Changes in physical, chemical and biological factors can have a significant impact on the overall wetlands which are the habitat of aquatic communities. So that in turn these factors will also affect

organisms that depend on wetland habitat (including water birds and their food sources), affecting in turn the attributes of the ecosystem, such as species richness, distribution, and density [20].

Since most water birds have a narrow breeding distribution and habitat meeting their requirements is increasingly restricted, they are often considered as endangered. Therefore, existing ecotourism activities should be able to accommodate water bird habitat conservation efforts. As urban wetlands tend to be highly pressured by human population and activity, the way in which visitor activities are managed will have a significant (positive or negative) impact on water bird habitat. Land conversion of urban wetlands may also reduce the availability of mudflats and inactive fishponds which are important for water birds as foraging areas. Therefore, policies and measures should be taken to manage and control existing water bird habitat.

4. Conclusions

The suitability analysis of water bird habitat in Lantebung Mangrove Ecotourism Area found 44 hectares of suitable land (51.2%) and 42 hectares of unsuitable land (48.8%). These data can be used to support water bird biodiversity conservation and proper management of an existing urban mangrove ecotourism area under increased pressure from human population growth and potential disturbances.

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