Waterbirds habitat mapping using unmanned aerial vehicle in Belawan Mangrove Ecosystems, North Sumatera, Indonesia

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Abstract. Waterbirds are ecologically dependent on wetlands. Monitoring waterbird species diversity and habitat conditions is very important to protect natural resources from threats and habitat destruction. The use of Unmanned Aerial Vehicle (UAV) technology can overcome survey constraints for preserving mangrove ecosystems, which have difficult access and take a long time. This study aims to identify waterbirds' habitat in mangrove ecosystems in the Belawan Bird Island area of Medan City using Unmanned Aerial Vehicles (UAV). This research was conducted in June-August 2022 in the Bird Island area on the coast of Medan City, North Sumatra Province, Indonesia. The method used in the observation of waterbirds is using the path method. Field surveys for vegetation analysis use the census plot method. Furthermore, aerial photo processing and Object-Based Image Analysis (OBIA) of the mapping results through UAVs are carried out. Image processing with OBIA goes through the stages of segmentation, classification, and accuracy testing. We found 4 bird species found in Burung Island, namely, Egretta garzetta, Egretta alba, Phalacrocorax sulcirostris and Bubulcus ibis. The results of mapping using UAVs obtained a mangrove forest waterbird habitat covering an area of 1,01 hectares. The results of aerial photo identification found that the number of birds in the study area was 23,454 birds with a density of about 2 birds/m2. Vegetation found on bird islands are Avicenia marina, Rhizophora apiculata, and Nypah fruticans. Waterbirds in the Belawan mangrove area are local birds. The accuracy test results of waterbirds' habitat mapping with the OBIA method obtained an overall Overall Accuracy result of 77%. We conclude that the results of UAV mapping of waterbird habitats are reliable for use as final classification results.

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1 Introduction

The presence of birds in coastal areas, especially in mangrove ecosystems, illustrates the condition of the local environment. Coastal areas are one of the habitats for a wide variety of bird species. This area is famous for its diversity of natural resources and natural wealth that can be utilized. Mudflats in coastal areas are productive ecosystems because they act as the origin of nutrients, so mudflats have the meaning of an ecosystem that is very important for living things, one of which is waterbirds. Mudflats are important foraging areas for waterbirds. The diversity of waterbird species is largely determined by the availability of varied wetland habitats [1]. The presence of waterbirds in wetlands is influenced by many factors including the availability, height and quality of water, food availability, shelter and nesting from predators [2].

Bird habitat mapping in wetlands has developed, especially with the increasing use of remote sensing technology. Research by [3] has mapped mangrove ecosystems in areas close to Bird Island in Medan City using Unmanned Aeriak Vehicles (UAV). The study produced a map of the distribution of objects in the mangrove ecosystem with very high resolution in a fast time and low cost. In another study, [4] applied UAV technology to identify plant species in mangrove forests in Belawan, Medan City, Indonesia. With accurate results, UAVs can identify tree species in mangrove forests so that they can be used as a reference for future conservation programs. The study by [5] also mapped mangrove forests using Sentinel 2-A Satellite Imagery in the Mangrove ecosystem in Bali which is very useful for bird habitat conservation in particular.

Currently, there has not been much development of UAV technology for monitoring waterbirds and their habitats. Waterbird and habitat surveys are still conducted through field surveys. This is not easy considering that waterbird habitats are located in wetlands with low access. In addition, the cost and labor of field surveys are relatively more expensive. Therefore, it is necessary to monitor waterbird species to support understanding and increase information on the presence of waterbirds using technology that is more efficient with quality results. Monitoring waterbirds and their habitat conditions is very important to do in order to protect natural resources from threats and habitat destruction (Suciani and Rahmadi, 2019). The purpose of this research is to identify the distribution of waterbirds and identify tree species as habitat for waterbirds in the Belawan mangrove forest area using Unmanned Aerial Vehicles.

2 Materials and Methods

2.1 Study Area

This research was conducted in June-July 2023, starting from research preparation, field research implementation, data processing and presentation of results. The research was conducted in the Belawan Mangrove Forest area, Medan City, North Sumatra. Data processing and analysis activities were carried out at the Forest Resources Conservation Laboratory, Faculty of Forestry, University of North Sumatra. The map of the research location on Belawan Bird Island can be seen in Figure 1.

2.2 Material and tools

The tools used are camera, Garmin 64s GPS, stationery, raffia, meter, cellphone, Timestemp Application, Avenza Maps Application, DJI Mavic 2 Enterprise Drone, Personal Computer,

and ArcMap 10.8. The materials used in this study are aerial photography maps from UAVs, bird species data, and mangrove vegetation in the Belawan Pulau Burang (Bird Island) area.

2.3 Data collection

Primary data is data obtained from field observations. The data collected is in the form of identification data of the distribution of waterbird presence points and direct encounters and what vegetation dominates waterbird habitat on Belawan Bird Island. Secondary data is obtained from literature studies from various sources.

2.4 Aerial Photo Acquisition from UAV

Data for mapping come from aerial photo acquisition with flying missions and plotting for vegetation type analysis. The acquisition of aerial photos requires several stages, namely preparation, data acquisition, and data processing. In the preparation stage, identification of the area to be mapped is carried out in the form of a grid, flight path, flight height, overlap, flight speed, and determination of pixel resolution or ground sample distance (GSD). The flight height in data acquisition is 60 with the type of UAV used is DJI Mavic 2 Enterprise. Determination of flight missions for mangrove area identification using Pix4D Capture, an Android and iOS-based application used to estimate area coverage, flight height, overlap, GSD, and flight duration.

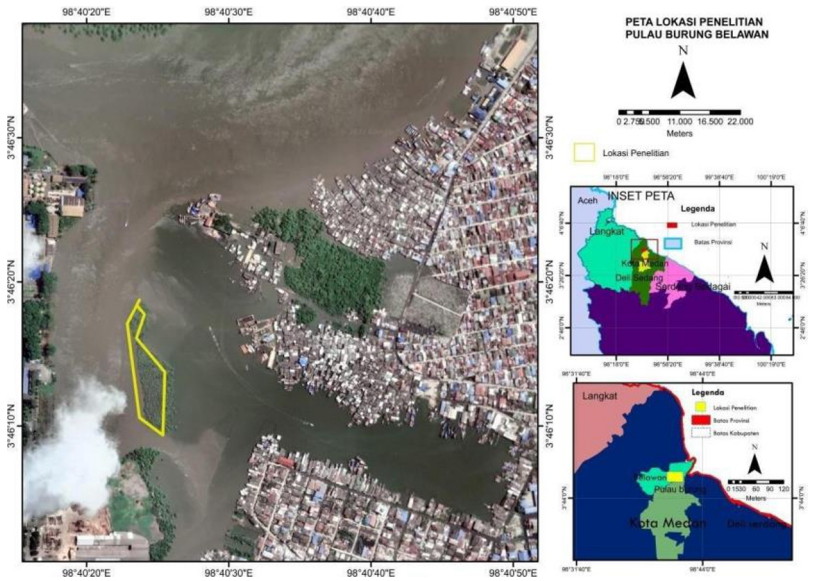

Fig. 1. Study area.

2.5 Waterbids monitoring

The method used in this study is the path method (Figure 2a). In this path method, observations recorded all bird species encountered along the observation path. Observations were made at predetermined points, namely Bird Island in the Belawan mangrove area, observations were made within a period (10-15 minutes) before going to the next point. Each species encountered at each point was recorded and then made a new list again. In addition,

documentation was also carried out Taking photos using a camera aims to identify in detail [6].

The observation path was made with a path length of 100 meters with 4 observation path points, the placement of this path was adjusted to the research location which is a muddy beach in the mangrove area. The map of the waterbird observation path on Belawan Bird Island can be seen in Figure 2a.

Observations were made during the afternoon to evening depending on the tide. Species recording was done on every direct bird encounter including those in flight. Photographs were taken using a camera for detailed identification [6]. Bird species identification was based on a field guidebook [7]. Furthermore, identified bird species were categorized based on protection status based on Law Number 5 of 1990, Government Regulation No.7 of 1999, Minister of Environment and Forestry Regulation Number 20 of 2018, and criteria from the International Union for Conservation of Nature on the website https://www.iucnredlist.org/.

2.6 Vegetation survey

Square plots measuring 10 x 10 meters were taken at each location. The plot size was adjusted to the Sentinel-2 resolution of 10 meters. Transect lines were drawn perpendicular to the shoreline or river inland. The vegetation observation box used covered the entire 1 ha area modified from [8]. Vegetation observations were conducted across the 1 ha area to determine the function and utilization of habitat for birds in each study site (Figure 2b).

2.7 Aerial Imagery Processing

Processing aerial imagery into ortho mosaic using Agisoft Metashape software with steps such as importing photos and reconstructing flight paths, Aligning photos, merging Dense Point Clouds, construction, texture modeling, DEM development, Orthophoto development, and exporting ortho mosaic in GeoTIFF format.

2.8 Object-based image analysis

Image classification that serves to map mangrove composition using Object-Based Image Analysis (OBIA). The OBIA approach used is superior to pixel-based classification because it considers not only spectral but also spatial aspects. The OBIA method is a classification method developed by segmenting and analyzing objects or image classification processes based on their spatial, spectral, and temporal characteristics to produce image objects or segments which are then used for classification.

The segmentation algorithm used is the multiresolution segmentation (MRS) algorithm. This algorithm starts with a single pixel and combines neighboring segments until the heterogeneity threshold is reached. In the segmentation process with the MRS algorithm, there are three important parameters, namely shape, compactness and scale. The classification object-based image processing procedure is performed using eCognition Developer software.

2.9 Accuracy test

Overall accuracy is used to determine the accuracy of calculations from maps with ground check data. Accuracy determination uses the principle of a confusion matrix. Segmentation results were compared with field survey data. The formula to determine overall accuracy follows the following formula :

$$Procedure\ accurancy = \frac{X_{ii}}{X_{+1}}\ x\ 100$$

$$User\ accurancy = \frac{X_{ii}}{X_{i+}}\ x\ 100$$

$$Overall\ accurancy = \frac{\sum_i^r X_{ii}}{N}\ x\ 100$$

Where:
Xi : The diagonal values of the i-th row and i-th column of the contingency matrix
X+i: Number of pixels in the i-th column
Xi+: Number of pixels in the i-th row
N : Number of pixels in the sample

The accuracy calculation in this study is based on the guidelines for processing satellite image data. In the guidelines for land cover classification from satellite imagery, the accuracy value used is no less than 75%.

3 Results and Discussion

3.1 Bird Species Identification and Conservation Status

Observations of water birds on Belawan Bird Island found 4 species of water birds namely Phalacrocorax sulcirostris, Bubulcus ibis, Egretta alba, Egretta garzetta (Table 1). The following table shows the bird species found in the Belawan Bird Island area. The most dominant bird species observed on Belawan Bird Island is Egretta alba and the least common is Bubulcus ibis. Bird activities observed during the study were flying, perching and foraging. Waterbird activities during the observation were dominated by perching activities. This indicates that Belawan Bird Island provides a variety of food sources and good resting places. The availability of food plays an important role for animal life, breeding success, habitat selection, and migration [9].

Table 1. Bird species found in the Belawan Bird Island area.

	Species	Conservation Status			
Local name	Species name	IUCN	CITES	D/GA	Activities
Pecuk Hitam	Phalacrocorax sulcirostris	LC	-	UP	1,2
Kuntul Kerbau	Bubulcus ibis	LC	-	UP	1,2,3
Kuntul Kecil	Egretta garzetta	LC	-	P	1,2,3
Kuntul Besar	Egretta alba	LC	-	P	1,2

Remark 1 : Flying, 2 : Perch 3 : Foraging
Conservation Status: Appendix CITES (2012), IUCN Red list (2016). D= Decree, GA : Government Agreement P: : Protected Birds, UP: Unprotected Birds, LC: Least Concern

Some of the bird species found on Belawan Bird Island are included in the list of protected species based on IUCN, CITES, and Indonesian laws and regulations. 4 bird species that are included in the IUCN low threat status, namely Egretta alba, Egretta garzeta, Phalacrocorax sulcirostris and Bubulcus ibis, have a low risk status (LC). For the CITES Appendix list, there are no bird species that are threatened by trade, while there are 3 bird species that are protected in legislation (Law No. 5 of 1990 and Government Regulation No. 7 of 1999), therefore the existence of these birds is an interest and priority for the Indonesian government to protect from the threat of hunting, trade and habitat destruction.

Bird Island is one of the islands located in the Belawan mangrove forest area, with an area of approximately 1 hectare. The interesting thing about Bird Island is that it is nicknamed Bird Island by the local community because the island is inhabited by thousands of birds by various types of water birds.

In their daily activities, waterbirds utilize various vegetation found in the Belawan Bird Island area to support their activities, 3 types of vegetation are often used and support the presence of birds in the bird island area, namely Avicenia marina, Rhizophora apiculata, and Nypa fruticans. Mangrove vegetation on Bird Island also provides space for water birds to make nests. Migratory birds also utilize mangrove roots as a place to rest during high tide, the availability of mudflats in mangrove habitats is a suitable place to find food [10].

3.2 Mapping of habitat and waterbirds distribution.

Bird distribution mapping in the 1-hectare research area using aerial photography from UAV. Processing of aerial photos that produce orthomosaics is then analyzed using Object Based Image Analysis (OBIA) to produce object classification. The results of aerial photo mapping using UAVs produce aerial images with a spatial resolution of 1,41 cm/pix. Very high spatial resolution produces excellent images for object analysis, especially birds.

Aerial photo maps of waterbird habitats in the Mangrove ecosystem on Belawan Bird Island are presented in Figure 2a and Figure 2b. Based on Figure 2, it can be seen visually that bird objects are seen in white color that covers green vegetation. The gray and gray colors are water areas and reddish gray are objects in the form of water taken from aerial photographs from flying missions. The mapped area of this Bird Island is 1.01 hectares.

This classification method can provide accurate results with a relatively short processing time. The classification was performed on two classes: waterbirds and mangrove vegetation. The classification process was carried out using a sample-based classification method with the maximum likelihood algorithm. The map of waterbird distribution classification results using OBIA is presented in Figure 3.

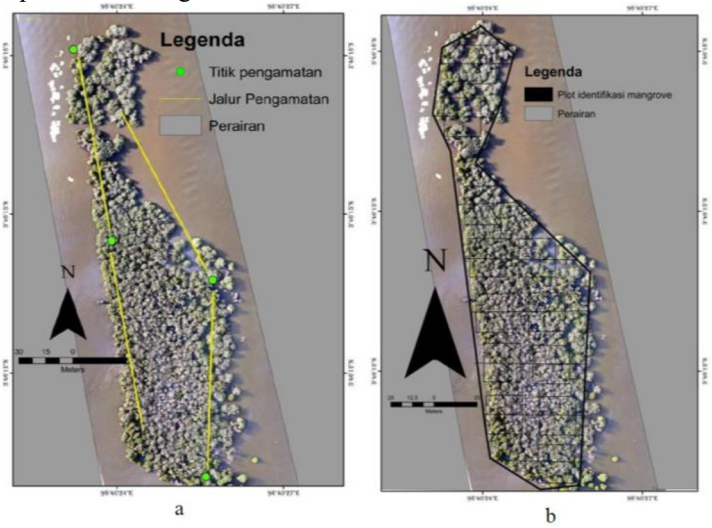

Fig. 2. Bird Island Aerial Imagery Map with waterbird observation paths (a) and vegetation observation plots (b).

In the classification results in Figure 3, waterbirds gather more in the northern region. This is because the area is slightly higher than the other areas, and during high tides the area is safer for perching and sheltering. The vegetation growing in the northern area is Avicenia marina and Nypa fruticans. This suggests that waterbirds like to roost in this vegetation. Observations in the field showed that waterbirds use the vegetation only for perching and not for nesting. Mangrove vegetation is the vegetation used by waterbirds as nest building

material. The selection of trees for nesting has a tree structure that is considered safe enough during the breeding season because it is an important factor affecting breeding success [11].

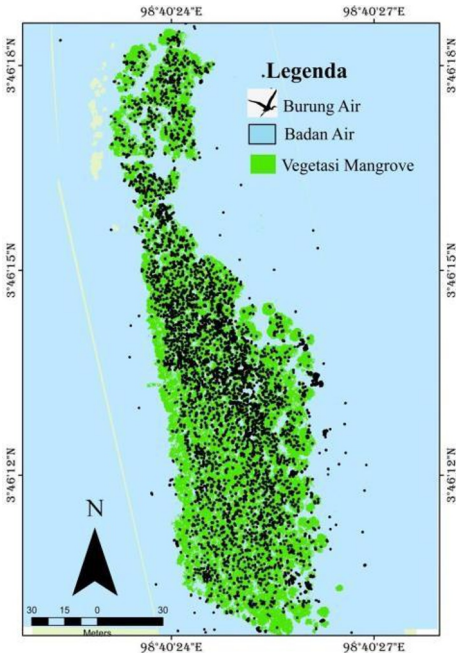

Fig. 3. Waterbirds distribution map of Belawan Bird Island from UAV imagery through OBIA.

The calculation of the number of waterbirds obtained in the classification results of waterbird distribution in Table 2 is known to be as many as 2 individuals/m^2 of the total distribution of bird species in the study site. The following table shows the calculation of the distribution of waterbirds found on Belawan Bird Island.

Table 2. Calculation of Waterbird Distribution.

Birds number (individuals)	Habitat area (Hectares)	Kerapatan (individuals/m^2)
23.454	1,01	2

The number of birds obtained in the classification of waterbirds using OBIA is not the actual number of birds found in the field. The OBIA approach technique only distinguishes color hues, so when distinguishing bird colors, errors can occur in some polygons that can exceed 1 bird. According to Nugroho (2019), the OBIA method is the process of segmenting an image into homogeneous segments or objects according to its parameters. [9] states that an object or segmentation in an image is a set of pixels with the same spectral and spatial values.

An example of a calculation error, for example, individuals in the field, for example, there is more than 1 object gathered and the objects have the same color so that when viewed and analyzed the image can be combined into the same class. According to Ref. [12], there is an error in separating bird objects from mangroves, namely the possibility that bird objects have the same morphology as the objects around them.

To determine the vegetation condition in the waterbird habitat area, mangrove vegetation classes were identified using the OBIA method with the multiresolution segmentation (MRS) algorithm shown in Figure 4. Three vegetation types were identified from the analysis of aerial photographs from the UAV. Table 2 shows that the area of mangrove species present on Bird Island has different areas, namely for vegetation cover Avicenia marina covers

62.68% with an area of 0.636 ha, Rhizophora apiculata covers 8.84% with an area of 0.089 ha and Nypa fruticans covers 28.48% with an area of 0.289 ha (Table 3).

Table 3. Mangrove Species Identification Results Using OBIA.

Mangrove species class	Area (Hectares)	Area (%)
Avicennia marina	0,63	62,68
Rhizophora apiculata	0.08	8,84
Nypa fruticans	0,28	28,48
Total	1,01	100

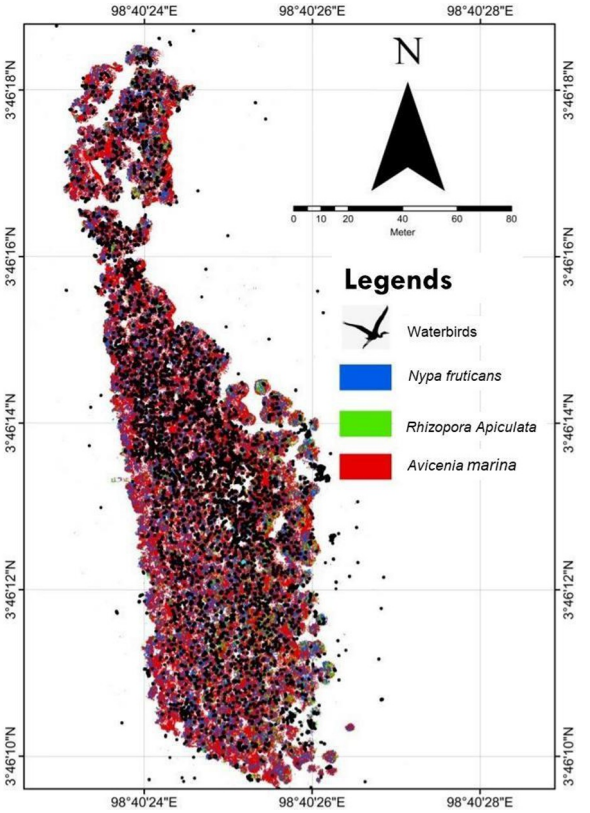

Fig. 1. The Map of Mangrove Species Classification of Belawan Bird Island.

3.3 Accuarcy Test

The results of the accuracy test carried out using Confusion Matrix, to find out how much the level of correctness of the classification carried out using the OBIA classification method with the results of field surveys. The accuracy test is done by taking sample points of objects on the bird island map that is used as a reference, the samples taken are all objects that are classified. Mangrove species classification accuracy test table can be seen in Table 4.

Table 2. Confusion Matrix of mangrove species classification.

Classes of the OBIA Classification	Class of Field Survey			Total	PA
	1	2	3		
1	50	4	10	64	78,12
2	2	7	7	11	63,63

3	5		20	25	80,00
Total	54	11	32	100	
UA	87,71	63,63	62,50		
OA	77,00				

Remarks
Class of mangrove species: 1 = *Avicenia marina*, 2 = *Rhizophora apiculata*, 3 = *Nypa fruticans*
Accuracy test : OA = Overal accuracy, UA = User Accuracy, PA = Producer Accuracy

The Overal Accuracy result is 77% which indicates that the classification results are suitable for use as the final classification results of the study (Table 4). According to [13], the accuracy of land cover classification that is allowed is an average of above 75%. Mapping using UAV technology is very well used in mangrove ecosystems, especially in analyzing the ecological aspects of mangrove ecosystems [4]. This study can show that it can be seen in detail the dominant types of mangroves and other types that can be utilized as a source of seeds, food and habitat for water birds. [14] found that manual and semi-automated analysis of UAV imagery is more appropriate for small bird colonies. In bird habitats with large colonies an automated analysis approach is more appropriate and efficient.

This study is helpful in habitat conservation and wildlife management programs if developed with some considerations. Bird habitat mapping using UAVs needs to consider the flight height. In this research, the flight height was taken as 60 m because it considers the number of bird colonies that reach thousands. At a height of 60 m, objects look more detailed so that it can be easier to separate between water birds and other objects. Research by [15] showed that UAVs can be more precise in detecting individuals and mating pairs of Herring Gulls and Lesser Black-backed Gulls than field surveys. Drone safety needs to be considered by using attachments on the drone to avoid collisions between the UAV and birds. The use of thermal sensors on the UAV will also improve the accuracy of detecting bird objects. As done in the research of [16] who used thermal drones and deep learning for freshwater bird population estimation which resulted in an accuracy of up to 89.2%. Thermal sensors can also detect other objects in bird habitats that have certain temperatures.

4 Conclusion

There are 4 species of water birds found in Belawan Bird Island, namely Egretta alba, little egret Egretta garzeta, Bubulcus ibis and Phalacrocorax sulcirostris. The results of mapping using Unmanned Aerial Vehicles found that the bird habitat covers 1.01 hectares, the number of birds is 23,454 birds and the bird density is 2 birds/m2. Waterbirds in Belawan Bird Island mostly roost on Avicenia marina vegetation types. Vegetation identified in the study area are Avicenia marina, Rhizophora apiculata and Nypa fruticans. The vegetation is utilized by waterbirds for shelter, nesting, and roosting. The results of the accuracy test show that the classification results are feasible to be used as bird habitat mapping results in the vegetation type class. The use of drones for waterbird population and habitat detection needs to consider the suitability of flight height and more sensitive sensors.

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