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Estimating the Anoa (Bubalus spp.) Occupancy Area and Environmental Factors Effect in Dako Mountain Nature Reserve, Central Sulawesi, Indonesia

Yusuf Sulo, Sri Ningsih Mallombasang, Abdul Rosyid and Shahabuddin Saleh

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1st Yusuf Sulo
Central Sulawesi Natural Resources Conservation Center
Ministry of Environment and Forestry
Palu, Indonesia
sulowesi@gmail.com

2nd Sri Ningsih Mallombasang
Forestry Faculty
University of Tadulako
Palu, Indonesia
email address

3rd Abdul Rosyid
Forestry Faculty
University of Tadulako
Palu, Indonesia
email address

4th Shahabuddin Saleh
Postgraduate Program
University of Tadulako
Palu, Indonesia
email address

Abstract— Anoa, a tiny buffalo endemic to the Indonesian island of Sulawesi (and surrounding offshore islands) is the largest wild terrestrial mammal in Sulawesi. It is protected by the Government of the Republic of Indonesia, categorized as Endangered (EN) based on the IUCN Red List of Threatened Species, and included in Appendix I according to the Checklist of CITES Species. Information about the area occupied by anoa is needed and important for conservation efforts, particularly in dealing with potential threats to the population decline of this animal. This study aims to determine the level of anoa habitat occupancy and environmental factors that affect anoa habitat occupancy in the Dako Mountain Nature Reserve, Tolitoli District, Central Sulawesi, Indonesia. The occupancy area of Anoa was surveyed directly at 10 study sites of ca.400 ha each and indirectly by using six camera traps on 6 sites. The data was analyzed using a species occupancy model while the environmental factors influencing the occupancy area of anoa were analyzed by using the PRESENCE software. From 10 sites of direct surveys, anoa was detected in 7 sites. Meanwhile, from a camera trap method anoa was recorded occupying four of six sites. The three best environmental factors positively correlated with occupancy area indicate that anoa prefers areas that are far from cultivated areas and roads and has extensive primary forest cover. The closest distance between the cultivated area and the road where anoa was detected was 1.329 meters and 2.051 meters, respectively while the minimum forest vegetation cover in which anoa was detected was 22.9%. Therefore, these three factors need attention from stakeholders in the conservation planning of this endemic animal.

Keywords— Endemic buffalo, Occupancy area, Environmental factors, Sulawesi, Species Occupancy Model

I. INTRODUCTION

Anoa is dwarf buffalo, endemic to the Indonesian island of Sulawesi (and surrounding offshore islands), but is the largest wild terrestrial mammal on Sulawesi. Two species are currently recognized, the lowland anoa (Bubalus depressicornis) and the mountain anoa (Bubalus quarlesi) [1]. Solitary life and a smaller body are one form of adaptation of animals in forested habitats with complex geological and physical conditions because it will be difficult for large animals and groups to move freely in forest habitats with varied ecosystem topography [2].

Anoa is an important species for conservation, as the largest endemic wild mammal on Sulawesi island has high biodiversity. Habitat destruction and hunting anoa cause population decline, resulting in the extinction of this animal. The threat of deforestation that causes damage to anoa habitat occurs in Central Sulawesi, including Tolitoli District. Based on data, the deforestation that occurred from 1990 to 2016 in Tolitoli District was 73.223 hectares or an average of 2.816 hectares per year, with a deforestation rate of 1.19% per year [3]. Rejeki et al. [4] stated that Anoa was hunted or captured by as many as 283 individuals in one year. The highest hunting rate was recorded in North Sulawesi Province (34%), followed by Southeast Sulawesi (30%), and then Central Sulawesi (22%); in these provinces, it was identified that certain species were hunted as commodities to generate income.

Anoa is protected by the Government of the Republic of Indonesia, categorized as Endangered (EN) based on the IUCN Red List of Threatened Species, and included in Appendix I according to the Checklist of CITES Species. Regarding the abundance of the Anoa population, there needs to be more data or information to accurately measure the abundance of the species at this time. However, Anoa is still relatively widely distributed within the currently known range in Sulawesi. It is estimated that the population sizes of the two anoa species are fewer than 2.500 mature individuals. It is thought no subpopulations exceed 250 mature individuals, even in large protected areas (e.g., Lore Lindu National Park) and other large forest blocks [5][6]. Efforts to protect and preserve the Anoa have been carried out to protect the anoa species from extinction. In addition to designating it as a protected animal, the government also established anoa habitat to be protected as a conservation area. One of Anoa's natural habitats is the Dako Mountain Nature Reserve based on the Decree of the Minister of Forestry and Plantations Number: 238/Kpts-II/1999 dated April 27, 1999, covering an area of 19.590.20 hectares.

II. RESEARCH METHODS

A. Data Collection Technique

This research was carried out from February to November 2021 in the Dako Mountain Nature Reserve, Galang Subdistrict, and Baolan Subdistrict, Tolitoli District, Central Sulawesi, Indonesia. The survey was conducted directly on 10 research grids covering an area of 3.483

hectares, each measuring 2.000 m x 2.000 m (400 ha). In addition, the survey was also conducted with camera traps on 6 research grids that were passed during the direct survey.

Each sample unit/grid with a unique identity is surveyed on foot to look for the presence of the target animal by direct encounter or animal tracks (footprints, droppings, friction (body and horns on trees), food scraps, and others). The survey was conducted by tracing the sample path. Every 1 km traced along the sample path is made a segment. The minimum number of replications in each sample unit or grid is 5 x 1 km. The survey paths follow existing animal paths or topography, such as hill or mountain ridges, to maximize the probability of getting anoa trails or direct encounters.

Wildlife observation techniques are carried out using camera traps for animals that have elusive behavior from humans. The camera operating in the field for large mammals is about ninety days, with the duration between the first camera being installed and the last camera being taken not more than 3 (three) months. This should be done to ensure that the assumption of a temporally closed population is not violated so that the effects of birth/death and immigration can be ignored [7]. Anoa occupancy survey using camera traps in this study considers the number of camera traps available. Therefore, the number of camera units will determine the number of points installed in the field. The survey design with camera traps follows the sample unit (grid) that has been made, where 1 (one) sample unit/grid 1 location of camera traps is installed with a single camera (not facing each other).

The environmental covariates measured were distance from roads, distance from cultivated areas, distance from settlements, presence of water sources, forest cover, and slope and altitude. All environmental covariate variables were analyzed through ArcGIS software to get the closest distance from each grid or sample unit.

B. Data Analysis

The data obtained from the survey activities were then analyzed using the species occupancy modeling method [8][9]. This method is an estimation method using presence or absence data by taking into account the possibility of detecting the proportion of areas inhabited by animals with a detection probability of less than one for analysis of anoa occupancy and the factors that influence it using the PRESENCE application [10]. This study uses single species single-season occupancy modeling because this model is the simplest and most often used.

The proportion of the use of the Anoa area in all sample units (grid) is calculated by calculating the naive occupancy probability value. For example, psi (Ψ) estimation with the assumption that the detection probability (p) is perfect or with a value of "1" is called a naive occupancy estimate, with the following equation:

$$Psi(\Psi) = x/s$$

Description:
Ψ = naive occupancy estimateby animals
x = the number of sample units (grids) where the presence of animals is detected at least once.
s = total of all surveyed grids

III. RESULT AND DISCUSSION

A. Measurement Results of Environmental Covariates Affecting Anoa Occupancy

The measurement results show that the average distance between the closest and furthest roads to the research location is 2.051 meters and 4.809 meters. From the measurement results, it is known that the average distance between the nearest and furthest edges of the cultivated area is in the form of gardens (cloves, cocoa, and other plantation crops), with the research locations detected for signs of Anoa and caught by camera traps, namely 1.533 meters and 4.301 meters. The measurement results show that the average distance between the closest and furthest settlements inhabited by humans is the closest to the research location were signs of Anoa were detected and caught by camera traps, namely 2.853 meters and 5.655 meters. The measurement results show that the average distance between the nearest and farthest water sources from the research location where signs of Anoa were detected and caught by camera traps were 42 and 376 meters. From the area measurement results, it is known that the smallest grid area (sample plot) of the research location (Anoa detected) is 88 hectares or 22.9% of the sample plot area. The widest is 400 hectares or 100% of the sample plot area. In the sample plots of the research location, no signs of Anoa (L3, I3, J1) were detected, namely 67.13 hectares (2.30%), 115.70 hectares (3.03%), and 0 hectares (no forest primary cover). The measurement results show that the average altitude of the lowest and highest places at the study site, which detected signs of anoa presence and caught by camera traps, was 742 meters and 1.686 meters. The average of the smallest and largest slopes at the study site, which detected signs of Anoa and were caught by camera traps, were 18% and 54%. More details can be seen in table 1.

Table 1. Measurement Results of Environmental Covariates that Affect Anoa Occupancy

Kovariat	Grid									
	G4	G5	G6	I4	I5	L3	I3	J1	J2	K3
Distance from road to animal trail finding (m)	2051	3195	4809	2526	3826	1137	0	0	3826	3814
Distance from cultivated area to animal tracks found (m)	1533	2676	4301	1608	2907	620	0	0	3783	3163
Distance from settlement to animal discovery (m)	2853	4026	5655	3713	4713	1892	1254	852	3826	4281
Distance from water source/river to animal trail finding (m)	126	166	376	291	290	348	50	2	374	42
Primary forest cover (ha)	275.22	392.82	400.00	376.81	400.00	67.13	115.70	0	88.00	352.97
Altitude Where Animal Footprints are Found (m asl)	742	1029	1626	1100	1686	652	407	40	701	708
The slope of the place where animal tracks were found (%)	21	29.2	21.4	43.5	18	46	45	25	27	54

B. Anoa Habitat Occupancy

Anoa directly survey on 10 grids (G4, G5, G6, I4, I5, L3, I3, J1, J2, and K3) with 5 replications and a total of 46 replications, Anoa was found in 14 replications. Most often, Anoa was found in Grid G5 and G6 because it was found in 4 replications. In addition, the results of anoa occupancy analysis in the Dako Mountain Nature Reserve from a direct survey (abandoned animal signs) can be seen:

- Naive occupancy/naive occupancy in the form of a percentage of sample plots/locations detected anoa sign. For example, from 10 grids (sample plots), anoa marks were detected in 7 grids resulting in a naive occupancy of 0.7000 or 70% of the study area.
- Psi (occupancy probability)/ occupancy rate of Anoa in the Dako Mountain Nature Reserve is estimated at 0.85 or 85% (SE ± 0.1992). This data shows that Anoa inhabits about 85% of the entire Dako Mountain Nature Reserve research area.
- Anoa's detection probability value (p) is estimated at 0.3519 or 35.19% (SE ±0.0958) for each replication because there is no sampling covariate.

Replication in the survey using camera traps was the active day of camera trapping, so there were 90 replications in total. Out of 540 camera trap days, Anoa was detected on 17 days in 4 of 6 camera locations. Most often, Anoa was found in Grid I5 because it was found in 8 replications. The results of anoa occupancy analysis in the Dako Mountain Nature Reserve from a survey with camera traps can be seen:

- Naive occupancy/naive occupancy is the percentage of sample plots/locations that detected anoa signs. For example, 6 grids (sample plots) detected anoa marks in 4 grids resulting in a naive occupancy of 0.6667 or 66.67% of the study area.
- Psi (occupancy probability)/occupancy rate of Anoa in the Dako Mountain Nature Reserve is estimated at 0.6759 ± 0.1954 or 67.59% (SE ± 0.1954). This data shows that Anoa inhabits about 67.59% of the entire Dako Mountain Nature Reserve research area.
- Anoa's detection probability value (p) was estimated at 0.0466 ± 0.0114 or 4.66% (SE ± 0.0114) for each replication because there was no sampling covariate.

The analysis shows that the occupancy rate of Anoa inhabits around 67.59% to 85% in the Dako Mountain Nature Reserve research area. The high occupancy rate of Anoa in the Dako Mountain Nature Reserve indicates that the anoa habitat in the Dako Mountain Nature Reserve is still good for finding food, looking for water, sheltering, and breeding to maintain their lives. Habitat selection by Anoa is strongly influenced by the quality and availability of resources in it. Anoa habitat preferences are shown in locations far from human reach, namely in safe and undisturbed habitats. Preferences for non-forest habitat types are less preferred or tend to be avoided by Anoa [11]. Anoa is a diffident animal and is very sensitive to various types of disturbances. These animals have a very sensitive sense of smell (olfactory system). Therefore, the slightest disturbance to their habitat will cause Anoa to avoid looking for a safer place [12]. Grid Map, Finding Anoa Traces and Location of Camera Traps in the Dako Mountain Nature Reserve, Tolitoli District, Central Sulawesi as shown in Figure 1.

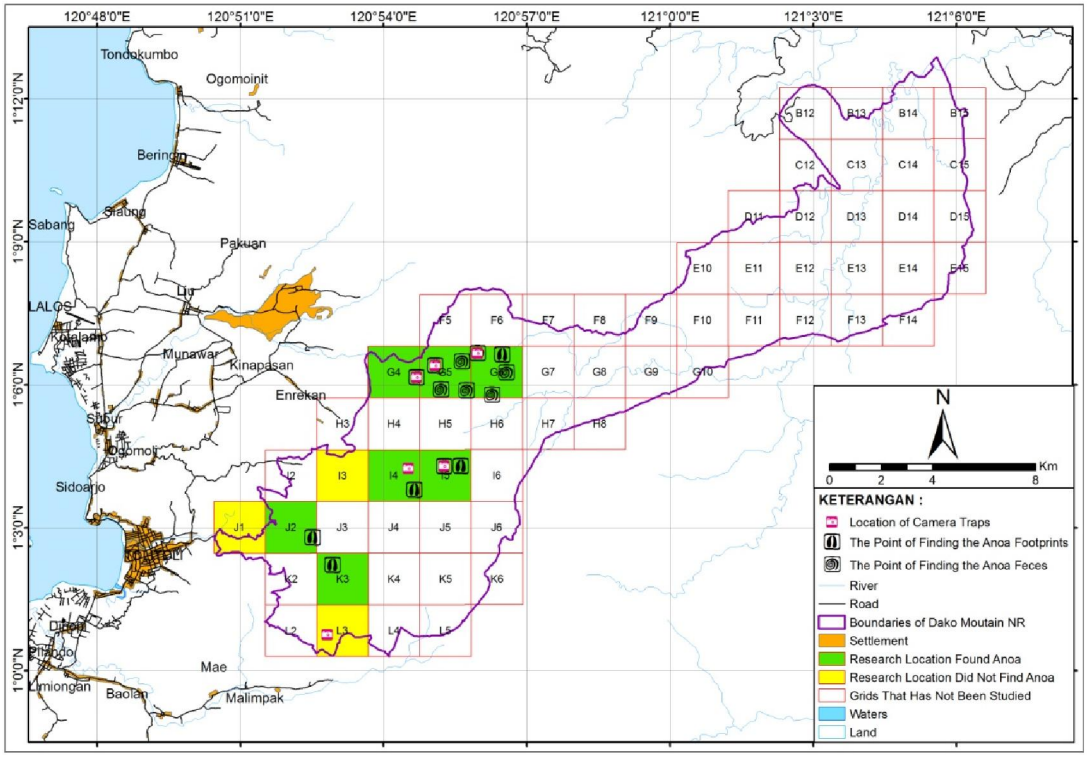

Fig. 1. Grid Map, Finding Anoa Traces and Location of Camera Traps in the Dako Mountain Nature Reserve

C. The Effect of Environmental Covariates on Anoa Occupancy

There are seven environmental covariates that are thought to affect the occupancy and presence of Anoa, namely the distance from the road (Road), the distance from the cultivation area (Plantation), the distance from the settlement (Village), the presence of water sources (River), forest cover (Cover), altitude (Elevation) and slope (Slope). The results of the analysis of the occupancy model that show the role of environmental covariates on anoa occupancy in the Dako Mountain Nature Reserve are as shown in table 2.

Table 2. Results of Occupancy Model Analysis Showing the Role of Environmental Covariates on Anoa Occupancy in Dako Mountain Nature Reserve

	Model	AIC	ΔAIC	AIC wgt
1	psi(Plantation),p(.)	56.02	0.00	0.3027
2	psi(Road),p(.)	56.02	0.00	0.3027
3	psi(Cover),p(.)	56.31	0.29	0.2618
4	psi(.),p(.)	60.00	3.98	0.0414
5	psi(Cover+Road+ Plantation),p(.)	60.02	4.00	0.0410
6	psi(Village),p(.)	62.53	6.51	0.0117
7	psi(River),p(.)	62.53	6.51	0.0117
8	psi(Slope),p(.)	62.53	6.51	0.0117
9	psi(Elevation),p(.)	62.53	6.51	0.0117
10	psi(Cover+River+ Plantation),p(.)	66.53	10.51	0.0016
11	psi(Village+Road+ Plantation),p(.)	66.53	10.51	0.0016
12	psi(Cover+River+ Elevation+Slope),p(.)	68.53	12.51	0.0006

From the table above, it can be seen that the model by including the environmental covariates distance from the cultivation area (Plantation) and distance from the road (Road) is in the top order of psi (Plantation), p(.) and psi(Road), p(.) . This model ranks at the top with AIC value = 56.02. The smallest AIC value indicates that the model is the best model of all the models that are run with the support of 30.27% (AIC weight = 0.3027). This also shows that this model is the best model in explaining the anoa occupancy pattern in the Dako Mountain Nature Reserve, Tolitoli District, Central Sulawesi. The second and third best models, namely psi(Cover),p(.), and psi(.),p(.) have low support of 26.18% and 4.14%, respectively. The combination model by including more than one environmental covariate is at the top of the other combination models, namely psi(Cover+Road+Plantation), p(.) which has a very low support of 4.10%.

From the results of compiling data on the presence of Anoa both by direct surveys and surveys with camera traps and compiling data on measuring distance, height, slope or area of environmental covariates, the results of the analysis of anoa occupancy probability using environmental covariates can be seen in Table 3. it can be seen that the probability of anoa occupancy in the Dako Mountain Nature Reserve is estimated at 71.29 (SE ± 0.12) to 80% (SE ± 0.00). While the probability of detection (p) of Anoa is estimated at 36.84% (SE ± 0.0783) to 40.51% (SE ± 0.0859) for each replication because there is no sampling covariate as shown in Table 4. The value of probability of detection (p) of Anoa more than 0.3 (30%) so that the anoa occupancy rate is classified as good. A good estimate for the occupancy value, if the detection probability> 0.3 (30%) [13].

Table 3. Results of Anoa Occupancy Probability Analysis Using the Top-Order Environmental Covariates (Plantation, Road, Cover)

Site			Individual Site estimates of <psi>			Individual Site estimates of <psi>		
			Plantation and Road			Cover		
			estimate	S.E. 95%	conf. interval	estimate	S.E. 95%	conf. interval
Psi	1	G4	1	0	0 - 1	0.9935	0.0334	0.0059 - 1
Psi	2	G5	1	0	0 - 1	0.9971	0.0168	0.0032 - 1
Psi	3	G6	1	0	0 - 1	0.9971	0.0168	0.0032 - 1
Psi	4	I4	1	0	0 - 1	0.9953	0.0255	0.0046 - 1
Psi	5	I5	1	0	0 - 1	0.9971	0.0168	0.0032 - 1
Psi	6	L3	1	0	0 - 1	0.3167	0.2781	0.036 - 0.8519
Psi	7	I3	0	0	0 - 1	0.4649	0.32	0.0653 - 0.9153
Psi	8	J1	0	0	0 - 1	0.0602	0.1382	0.0005 - 0.885
Psi	9	J2	1	0	0 - 1	0.3148	0.2776	0.0356 - 0.8513
Psi	10	K3	1	0	0 - 1	0.9922	0.0389	0.0068 - 1
Average			0.8	0		0.7129	0.1162	

Table 4. Results of Anoa Detection Probability Analysis Using the Top-Order Environmental Covariates (Plantation, Road, Cover)

Site			Individual Site estimates of <P[1]>			Individual Site estimates of <P[1]>		
			Plantation and Road			Cover		
			estimate	S.E. 95%	conf. interval	estimate	S.E. 95%	conf. interval
P[1]	1	G4	0.3684	0.0783	0.2318 - 0.53	0.4051	0.0859	0.2529 - 0.5779
P[2]	1	G4	0.3684	0.0783	0.2318 - 0.53	0.4051	0.0859	0.2529 - 0.5779
P[3]	1	G4	0.3684	0.0783	0.2318 - 0.53	0.4051	0.0859	0.2529 - 0.5779
P[4]	1	G4	0.3684	0.0783	0.2318 - 0.53	0.4051	0.0859	0.2529 - 0.5779
P[5]	1	G4	0.3684	0.0783	0.2318 - 0.53	0.4051	0.0859	0.2529 - 0.5779

Based on the estimated value of the Beta covariate coefficient (Beta's), the overall Beta coefficient is positive, indicating that the overall environmental covariate, both single and combined covariates, is positively correlated with

anoa occupancy in the Dako Mountain Nature Reserve. From the most influential covariates, namely the distance from the cultivated area and the distance from the road and primary forest cover, it can be seen that the positive correlation value is 2.24 with a standard error (SE) of ±0.652 and 2.66 with SE. ±0.631 and 0.86 with SE. ±0.788 as shown in Table 5. The positive correlation of the most influential covariates indicates that Anoa prefers areas far from cultivated areas and also far from roads and extensive primary forest cover. And vice versa, the chance of the area being inhabited by Anoa is low.

In Bogani Nani Wartabone National Park (BNWNP) the current preference for anoa habitat is shown in locations far from human reach, namely in safe and undisturbed habitats [11]. Anoa is a shy animal and is very sensitive to various types of disturbances. These animals have a very sensitive sense of smell (olfactory system). Therefore, the slightest disturbance to their habitat will cause Anoa to avoid looking for a safer place [12]. In line with this study, the most influential environmental covariates inhabited by Anoa are habitats that are far from plantations (cultivated areas) and far from accessibility (roads). In the Dako Mountain Nature Reserve, the closest distance to the study site (Anoa was detected) from the community cultivated area in the form of gardens (cloves, cocoa and other plantation crops) is 1,329 meters, while the farthest distance is 4,870 meters. The closest distance to the research location (detected Anoa) from the road is 2,051 meters, while the farthest distance is 5,388 meters.

Habitat selection by Anoa is strongly influenced by the quality and availability of resources in it. Primary forest vegetation is a good and preferred habitat for Anoa because it provides a place to find food, drink, shelter and breed. Primary forests include coastal forests, swamp forests, lowland forests, and mountain forests. In the Dako Mountain Nature Reserve, the sample plots of the research site contain at least 22.9% to 100% primary forest vegetation of the sample plot area. Meanwhile, in the sample plots of the research location, there was no primary forest cover, nor were there any signs of Anoa detected.

Table 5. The Results of the Analysis of the Probability of Anoa Detection Using the Top Order Environmental Covariates (Plantation, Road, Cover)

Model		A	B
		(ß-coefficient ± S.E.)	p(ß-coefficient ± S.E.)
1	(Plantation),p(.)	2.2424 ± 0.6519	-0.5389 ±).3362
2	(Road),p(.)	2.6601 ± 0.6314	-0.5389 ±).3362
3	(Cover),p(.)	0.8605 ± 0.7881	-0.3844 ±).3565
4	(.),p(.)	1.7343 ± 1.5623	-0.6107 ±).4202
5	(Cover+Road+Plantation),p(.)		
	Cover;	5.5251 ± 10.000	-0.5389 ±).3362
	Road;	2.5508 ± 10.000	
	Plantation;	2.1503 ± 10.000	

IV. CONCLUTION

Anoa inhabits about 67.59% to 85% in the Dako Mountain Nature Reserve, Tolitoli District, Central Sulawesi, Indonesia. The best model in explaining anoa occupancy patterns in the Dako Mountain Nature Reserve, is in the first to third order, namely the distance from the cultivated area, the distance from the road and the primary forest vegetation cover with the support of 30.27%, 30.27%, respectively and 26.18%. The three environmental covariates are positively correlated, indicating that Anoa prefers areas far from cultivated areas and also far from roads and extensive primary forest cover.

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