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The Estimation of Cuscus Population and Distribution in Teluk Wondama District, West Papua Province, Indonesia

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Abstract

Cuscus is marsgupials endemic to the eastern part of Indonesia. Populations and their habitats are under pressure due to deforestation, land clearing and massive utilization of forest resources. Studies on cuscus ecology have mainly focused on protected habitats or conservation areas. This study aims to identify and analyse populations and predict the distribution of cuscus in production forest area, which is PT Wijaya Sentosa. This study was conducted in November 2020 until January 2021 in several land cover categories. The methods used in this study were literature and secondary data studies, field observations using strip-transect and camera trap techniques, interviews using purposive sampling techniques. This study found nine individual cuscuses from two families, namely Phalanger and Spilocuscus, as well as four species, namely ground cuscus (*Phalanger gymnotis*), spotted cuscus (*Spilocuscus maculatus*), Bohai cuscus (*Spilocuscus rufoniger*) and gray cuscus (*Phalanger orientalis*). Individual encounters were obtained from direct observation with transect lines and two cuscus individuals from camera traps. Ground cuscus (*P. gymnotis*) populations had the highest abundance and density, while spotted cuscus (*S. maculatus*) populations had the lowest values. The population structure was dominated by males and adult age classes, but no females and young age classes were found. Most cuscus was found alone on the observation path and was not found on every path. The distribution pattern of the cuscus population in the production forest of PT Wijaya Sentosa's concession is grouped/aggregated, based on the dispersion index value and the ratio of the value of variance to the mean value. The most common ground cuscus was found in the 2018 and around the 2013 logged-over areas (LOA).

Keywords: Camera trap, Cuscus, Dispersion index, Distribution pattern, Population structure.

1. Introduction

Cuscus are marsupials mammal endemic to Papua, Maluku and a small part of Sulawesi [1]. They are nocturnal [2], and generally live arboreal in various types of habitats [3]. Based on the Minister of Environment and Forestry Regulation Number P.106 of 2018, there are fourteen types of protected cuscus in Indonesia. The grey cuscus (*Phalanger orientalis*) and spotted cuscus (*Spilocuscus maculatus*) are included in the Least Concern category, according to the IUCN Redlist. There are also types of cuscuses that are categorized as critically endangered, such as the Biak spotted cuscus (*Spilocuscus wilsoni*) [4] and black-spotted cuscus (*Spilocuscus rufoniger*) 5. These species with a high risk of threat are thought to be caused by the limited distribution of individuals and populations [4], reduced habitat area due to land cover changes [5], habitat fragmentation, high levels of uncontrolled exploitation activities [3], as well as hunting activities in line with the increasing number and needs of the population and the lack of public knowledge about animal conservation [6].

So far, studies on cuscus ecology have mainly focused on protected habitats or conservation areas and the islands where the cuscus is endemic [7-12]. However, information on the population and distribution of cuscus in production forest still requires further study to achieve the target of sustainable forest management, where one of the indicators is ecological aspects such as animal management.

PT Wijaya Sentosa is one of the national private companies holding business permits for the use of timber forest products in natural forests [13]. Based on the results of the 2018 High Conservation Value (HCV) identification, this production forest concession is known to be the habitat of the Critically Endangered (CR) cuscus species, namely the Black-spotted cuscus (*S.*

rufoniger), as well as three other cuscus species, namely, the grey cuscus (*P. orientalis*), the spotted cuscus (*S. maculatus maculatus*), and the ground cuscus (*P. gymnotis*). Therefore, this study aims to identify, analyse and estimate the population and spatial distribution of cuscus in this production forest.

2. Materials and Methods

The research was conducted in November 2020-January 2021 in several land cover categories, namely, natural forest areas that had not been logged (Virgin Forest), germplasm conservation areas (Buffer zone), areas around water sources (i.e. areas around springs), and former logged (LOA 2013, LOA 2016, LOA 2018, and LOA 2020) in concession of production forest. The equipment used in this study consisted of a compass, GPS, regional map, camera trap, wristwatch, headlamp/spotlight, photo/video camera, meter, tally sheet/notebook, manual, laptop. The object observed was the cuscus population in production forest at Teluk Wondama Regency, West Papua.

The data types taken in this study included species, number of individuals, sex, age structure, geographical location (GPS coordinate), encounter time, activity, and whereabouts when found, altitude. The methods used included:

1. Literature and secondary data studies were conducted to obtain complementary data from documents in the form of notes or results of previous studies related to the population and distribution of cuscus in Papua and its surroundings, and to support data obtained from field observations and interviews.

2. Field Observation

1. The Strip-transect was carried out by walking on a track 1.000 meters long and 100 meters wide (Figure 1) using spotlights. Repeat times are at 19.00-21.00 (UTC+09:00), 23.00-01.00 (UTC+09:00) and 03.00-05.00 (UTC+09:00) on each transect. Ten strip-transects were determined purposively based on historical data from this forest product company's initial survey findings, information from interviews, and representation of land cover categories.

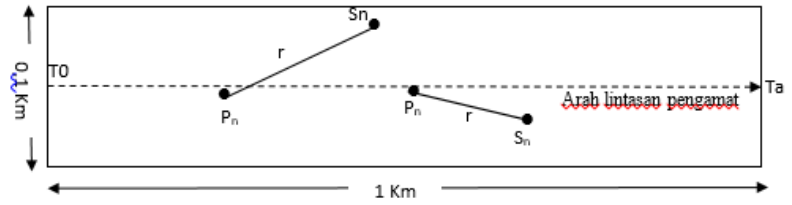

Figure 1. Illustration of observation transect using strip transect method (Adaptation to [14])

2. Ten camera traps were installed in pairs at nine potential locations on tree trunks with a height of 2-5 meters from the ground with a slope of 0º –15º. The distance between cameras was 2-3 meters, set in hybrid mode. Data collection was done in every 7-10 days.
3. Interviews were conducted with unstructured interviews to obtain data on the presence, location indicators of the presence of cuscus that were useful in determining the path for observation and knowing the distribution of the population that might not be found during direct observation. Purposive sampling was applied for the selection of samples or subjects. Respondents selected in this study included staffs and field workers who have met, have knowledge and information about cuscus. Furthermore, people who have met, have knowledge and information about cuscus and have used cuscus for their daily needs.

Data analysis used in this study includes:

1. Population relative abundance

Abundance by transect method is calculated according to the following equation [15]:

$$RA = \frac{ni}{N} x100\%$$

where:

RA = Relative Abundance Index
Ni = number of individual species i
N = total abundance or the total number of individuals of all species.

Abundance is also known by the camera trap method calculated according to the following equation [16]:

$$\mathrm{RAI_I} = \frac{ni}{\sum TN} \text{ x } 100$$

Where:

RAIi = Relative Abundance Index (relative abundance index per 100 trap days)
Ni = Number of videos or pictures independent of species – i
∑TN = Number of days active camera

2. Population Density and Size

Population density is calculated by calculating the number of individuals found on each observation line or transect. The estimation of population density is done by first calculating the density on each path, according to the following King (King Methods) equation [17]:

$$D = \frac{\sum_{i=1}^{n} xi}{2.L.w} \quad \text{or} \quad D = \frac{\sum_{i=1}^{n} xi}{a}$$

Where:

D = Estimated population density (ind/km2 or ind/ha)
Xi = the number of individuals found in the i-th contact
L = Strip-transect length (m)
a = area of each strip-transect (km2 or ha)
w = strip-transect width left or right (m)

The overall population size of the observation area is determined by following the following equation [17]:

$$\bar{P} = \frac{\sum_{i=1}^{n} xi}{2\sum_{j=1}^{k} Lj.Wj}.A \quad \text{or} \quad \bar{P} = \frac{\sum_{j=1}^{k} Dj}{k}.A$$

Where:

P = estimated population size (individuals)
K = number of observation strip-transects
A = total area of study
Dj = population density in the j-th observation transects (ind/km2 or ind/ha).

The following calculations determine the estimation of the size of the cuscus population [17]:

$$\overline{Dj} = \frac{\sum_{j=i}^{k} Dj}{k} \qquad S^2 = \frac{\sum D_j^2 - (\sum D_j)^2 / k}{k-1}$$

$$S_{\overline{D}} = \sqrt{\frac{S^2}{k}} \qquad S_D = A.S_{\overline{D}}$$

Where:
Dj = average estimated population density of all observation strip-transect (ind/km^2 or ind/ha)
S^2 = variant
S_D = standard deviation of population observations
A = sample population size (area of observation/area of each observation point)

The results of these calculations are then used to estimate the population size interval for the entire area studied, based on the following estimated values [17]:

$$P = \left[\overline{D} \pm t_{a/2;db} S_D\right] \quad \text{or} \quad P = \left[\overline{D} \pm \left(t_{a/2;db} . S_{\overline{D}}\right)\right] A$$

3. Population structure

The parameters that make up the population in this study are known based on sex (male/female) and age class (Adult/Young/Infant). The analysis was carried out by using ratios and data grouping.

4. Population Distribution

Estimating the shape of the population distribution pattern with the dispersion index (ID) value approach [18]:

$$(\mathrm{ID}) = \frac{\sigma^2}{\bar{x}} \quad \text{Where,} \quad \bar{x} = \frac{\sum x.F(x)}{N} \quad \text{and} \quad \sigma^2 = \frac{\sum x^2.F(x) - ((\sum x.F(x))^2/N)}{N}$$

Where:

ID = Index of Dispersion
σ^2 = variance
$\overline{X}$ = the average number of cuscuses in the sample plot
x = the number of individuals in the sample plot
F(x) = the frequency of occurrence of x-numbered individuals in the sample plot
N = total number of research plots

The conclusion to determine the spatial distribution pattern of cuscus with the dispersion index (ID) value approach follows the following criteria:

1. If ID = 1, then the distribution pattern is random (Poisson distribution)
2. If ID < 1, then the distribution pattern is uniform (positive binomial)
3. If ID > 1, then the distribution pattern is clumped (negative binomial).

Determination of the shape of the spatial distribution pattern can also be done using the variance ratio method with the mean value, as a comparison from the dispersion index (ID) value approach, with the criteria for concluding as follows:

1. If $\sigma^2 = \bar{x}$, then the shape of the scattering pattern is random
2. If $\sigma^2 < \bar{x}$, then the shape of the distribution pattern is homogeneous
3. If $\sigma^2 > \bar{x}$, then the shape of the distribution pattern is in clusters

In addition, the distribution of cuscus at the production forest was also mapped using direct encounter coordinate data and camera traps.

3. Results and Discussion

3.1. Cuscus Population

3.1.1. Relative Abundance, Density and Population Size

Based on direct observations using the Strip transect method, nine individuals of four species of cuscus were found in the concession area of PT Wijaya Sentosa. Therefore, the absolute and relative abundance of the cuscus population in this production forest can be seen in Table 1.

Table 1. Absolute and relative abundance, and density of cuscus population

No	Species	Scientific Name	ni	RA (%)	Density (D) (individual/Ha)
1	Common Spotted Cuscus	*Spilocuscus maculatus*	1	11	0.05
2	Black-Spotted Cuscus	*Spilocuscus rufoniger*	2	22	0.2
3	Ground Cuscus	*Phalanger gymnotis*	4	44	0.4
4	Northern Common Cuscus	*Phalanger orientalis*	2	22	0.2
	Total		9	100	0.85

Note: ni = Number of individuals of the species found; RA = Relative Abundance

The species of Common spotted cuscus (*S. maculatus*) has the lowest abundance index and density value. It is influenced by individual encounters level, which is also the least because its activity was high in the canopy strata B to A (± 20 meters) when found, so the opportunity to be observed by the observer was also low. It is similarly to the habitat of the Common spotted cuscus on Numfor Island, which also dominated by vegetation types with height of about 24-42 meters which are included in the category of canopy strata A [19]. Cuscus usually nests in a tree at a height above 20 meters from the ground [20].

Ground cuscus (*P. gymnotis*) has the highest abundance and density value, presumably due to the ability and behaviour of nesting in rocks and not limited to arboreal, as well as more diverse feed preferences, causing Ground cuscus to have an ecological niche that is not very specific and wider than other cuscus species found in the region of PT Wijaya Sentosa. That is a supporting factor for the sustainability of the ground cuscus population, as well as reducing competition between animals or species in the same habitat at the same time because of the availability of feed and nesting places that have differences with other animals [21], so that their daily movements are different.

Black-spotted cuscus (*S. rufoniger*) and Northern common cuscus (*P. orientalis*) had the same relative abundance and density values. The location of the encounter of the two types of cuscuses also has almost the same characteristics, namely in the riverine forests. However, the distance between the encounter locations of both species was not close. Based on the concept of ecological niche theory, if two or more species of animals have similarities related to a series of use of habitat resources such as food, water, and shelter, but in a geographical area or the different biotic communities are called 'niche counterparts' and the species occupying them called 'ecological equivalents' [21]. Based on the same theory, the geographic range, and the ecological range and the adaptability of the animal species determined the ecological niche of an animal species.

The cuscus population density in this study was lower than the other study on Obi Island, which found that the cuscus density of the phalanger genus on the island was 25 individuals/ha [22]. Another research on cuscus populations in the Arfak Mountains Nature Reserve, whinch also stated higher densities for the Northern common cuscus (*P. orientalis*), the ground cuscus (*P. gymnotis*) and the common spotted cuscus (*S. maculatus*), spesifically with a density value of 67 individuals/ha, 17 individuals/ha, and 11 individuals/ha [23]. The different results study on Numfor Island also revealed that the density for the common spotted cuscus species in that area was 0.31 individuals/ha. This lower value in this study presumably was due to the logging activity in this concession area and the openness of the forest area. Mammals are more likely to find the open forest edges area due to abundance of various feeding type [24]. Unfortunately, this can lead to the increase of hunting activity and decreasing number of wildlife population.

(a) (b) (c) (d)

Figure 2. The first individuals (a and b) and the second individuals (c and d) of the female common spotted cuscus (S. maculatus) caught on camera traps, (a and c) side and back view, (b and d) left side and abdomen.

Based on the visual data from the images and the videos captured with camera traps, there were 36 images and videos managed to record individual animals from the total catch, and only two individuals had obtained about one species of cuscus, namely the adult female of common spotted cuscus (*S. maculatus*) (Figure 2). The number of active days of the camera trap installed was 19 days, and the number of videos or independent pictures of the cuscus species was two captured images. Thus, the relative abundance for this type of cuscus was 10,53%. The cause of the low number of video captures or independent images was due to the arboreal nature of the cuscus so that the chance of capturing individuals by camera traps was relatively small. However, camera traps successfully captured individuals of the common spotted cuscus (*S. maculatus*) mounted at KM 7 on a fig tree (*Ficus pungens*) bearing fruit at the time of installation. Based on the level of palatability, cuscus species tend to consume food in the form of ripe fruit, because in addition to the sweet taste favored by cuscus, ripe fruit also has high wat1er content, making it easier for cuscus to eat and digest such as *Ficus sp*. [25].

Table 2. Density on each observation transect

No	Species	Transect									
		1	2	3	4	5	6	7	8	9	10
1	*S. maculatus*	1	0	0	0	0	0	0	0	0	0
2	*S. rufoniger*	0	1	1	0	0	0	0	0	0	0
3	*P. gymnotis*	0	0	0	0	0	0	0	1	3	0
4	*P. orientalis*	1	0	0	0	0	0	0	0	0	1
Density of each transect (Dj)		0.10	0.05	0.05	0.00	0.00	0.00	0.00	0.05	0.15	0.05
Population Size in the Observation Area (P)											4,50

The density distribution in each observation path is as shown in table 2, which shows that the highest density is owned by transect nine, with a transect density value of 0,15 individuals/ha. Three individuals of Ground cuscus species were found in transect nine (Figure 3a, 3b, and 3c). Some paths have a density of 0 individuals/Ha because no individual species of cuscus was found during direct observations on that transect. In addition, several paths have the same density value of 0,05 individuals/Ha, but there are differences in species found in other transects. That shows that not all types of cuscuses were found in every transect (Figures 4). This presumably was due to the difference characteristics of vegetation structures, environment and canopy openness in each transects. Environmental differences that can lead to increased species richness at the edge through resource mix and inter-habitat overlap, as different environments tend to have different sets of species and resources leading to "ecotonal effects" [26,27].

(a) (b) (c)

Figure 3. Ground cuscus (P. gymnotis) found in transect 9, (a) the first individual, (b) the second individual, (c) the third individual.

Most of cuscus individuals found were close to a water source in the form of a river or located along the riverbank. That shows that besides feed, water sources are also very influential on the presence of cuscus. There were many riparian habitats also found during observation in transects. Water resources are crucial component in wildlife habitats. A place should have three basic components to be an animal habitat, namely a source of feed, shelter (cover), and water – as a source of life that plays an important role in species life [28].

The results of the calculation of the overall size of the cuscus population in the observation area were 4,5 individuals. The estimated population size was 0,45 ± 5,109 individuals/ha. Cuscus are mammals with a small territory of about 4 individuals/ha in good forest conditions. The conditions of wildlife populations were also influenced by environmental factors such as food availability, space and habitat [19].

(a) (b) (c) (d)

Figure 4. The individual species of cuscus found in transect 1, (a) Common spotted cuscus (S. maculatus), (b) Northern common cuscus (P. orientalis). Black-spotted cuscus (S. rufoniger) found indirect observation, (c) in transect 2, (d) in transect 3.

3.1.2. Population Structure

The study considered that each individual of the same cuscus species (Phalangeridae) found by the transect method and by camera trapping was included in one population. Table 3 shows that from direct observation and camera traps, the number of cuscus individuals in the adult age group is more than the number of individuals in the adolescent and infant age groups.

Table 3. Number of individual cuscuses per species for each age structure

No	Species	Number of Individual Cuscus Per Species Each Age Structure					Total Number
		AM	AF	YM	YF	I	
1	*S. maculatus*	1	2	0	0	0	3
2	*S. rufoniger*	1	0	1	0	0	2
3	*P. gymnotis*	2	1	1	0	0	4
4	*P. orientalis*	1	0	1	0	0	2
Percentage		45,00%	27,00%	27,00%	0,00%	0,00%	100,00%

Note: AM = Adult Male; AF= Adult Female; YM= Young Male; YF = Young Famale; I= Infant.

However, only individuals of the adult age group were found, both male and female, and young with male sex, while the young age group female and puppies were not found (Figure 5), which was thought to be due to the parenting pattern of the cuscus in the parent's abdominal pouch. The period for breastfeeding or keeping baby in an abdominal pouch by an individual adult female parent is quite long, which can reach 6 months [29]. Based on the sex ratio in the overall population found in this study regardless of species (Figure 5), the number of male individuals was more common than female individuals. The sex ratio of male and female individuals in the adult age group is almost 2:1.

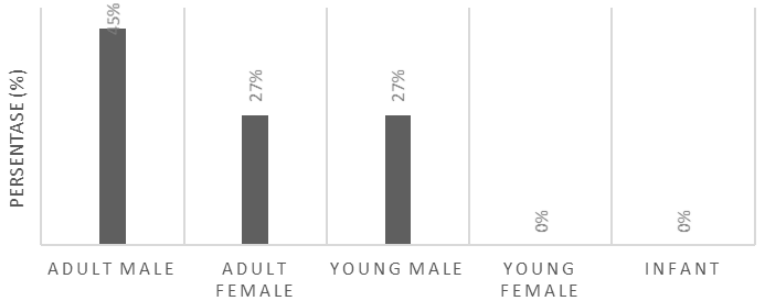

Figure 5. The structure of the cuscus population at PT Wijaya Sentosa

The population structure based on the type of cuscus found (Figure 6) shows that all species found in the adult age class are male, while the female adult age class is only found in Ground cuscus (*P. gymnotis*) and for the young age class, it is in males, only common spotted cuscus (*S. maculatus*) was not found. Then, there were no individuals of all types in the female, young, and infant classes either from direct observations or camera trap recordings.

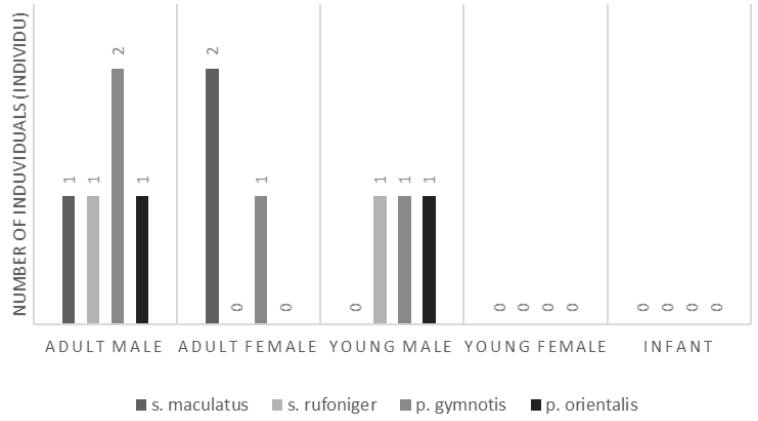

Figure 6. Population structure of each species based on gender and age class

3.2. Distribution of cuscus

3.2.1. Cuscus Presence

Data of cuscus presence in this study were obtained based on the results of primary and secondary data, found as many as 30 points of encounter with individual cuscus, with a total of 31 individuals. Based on the type and source of data, the findings of cuscus in PT Wijaya Sentosa are divided as in Table 4.

Table 4 The direct encounters of cuscus at PT Wijaya Sentosa

Species	Fo	CT	ST	HP PT WS	Bg	Total Number
Spilocuscus maculatus	2	2	1	1	2	8
Spilocuscus rufoniger	-	-	2	1	-	3
Phalanger gymnotis	-	-	4	5	-	9
Phalanger orientalis	4	-	2	4	1	11

Note: Fo = Field officer, CT= Camera Trap, ST = Direct Observation with Strip Transect, HP PT WS = Historical point PT Wijaya Sentosa, Bg = Research results from Manokwari Research and Development.

The presence of cuscus at PT Wijaya Sentosa was also marked by indirect findings in the form of traces of its feed. Feeding signs of cuscus were on the matoa (*Pometia pinnata*) fruit (Figure 7). Traces of the feed were found around transect three in KM 1. In this transect also found individuals of the Black-spotted cuscus (*S. rufoniger*) doing their movement (mobilization) on the branches of matoa (*P. pinnata*) trees. That indicates that the cuscus individuals spread spatially following the availability of feed resources. Various types of feed vegetation in a habitat have a significant effect on the existence of the spotted cuscus population on Numfor Island [19].

(a) (b)

Figure 7. Traces of cuscus feed on matoa (P. pinnata) fruit.

3.2.2. Cuscus Distribution Pattern

Based on observation, the frequency of encounters with individual cuscus, amounting to 1 individual in 1 transect at a time of replication, is the highest, while encounters with individual cuscus, amounting to 3 individuals in 1 transect at a time of replication, is the lowest frequency of encounters. That shows that cuscus is more often found in solitary activity. Cuscus are solitary because it is not always in pairs or clusters [30].

By the frequency of the encounters, it is known that based on the dispersion index (ID) approach, the shape of the spatial distribution of cuscus in PT Wijaya Sentosa is in groups/aggregates because the dispersion index (ID) value of 1.37 is included in the criteria for drawing conclusions ID>1, then the form of the distribution pattern is to group/aggregate. The exact form of distribution pattern is also obtained from the results of calculations based on the method of variance ratio with the median value because it is included in the criteria for concluding the value of variance (σ^2) is greater than the mean value (x), with a variance value of 0.41 and a mean value of 0.3. Thus, the cuscus at PT Wijaya Sentosa spatially has a clustered/aggregate distribution pattern. Distribution patterns in groups or aggregates are common in nature, both in animal and plant species [31].

3.2.3. Cuscus Distribution Map

The map of the distribution of cuscus from the encounter data, both obtained from direct observations, camera trap recordings, historical data from PT Wijaya Sentosa and research results from the Manokwari Forestry Research and Development Agency, is shown in Figure 7. Several factors influence the presence of animals in a habitat. The presence of cuscus on Obi Island was influenced by the availability of food, predators, and habitat conditions [22]. Cuscuses are more often found to be solitary, because cuscus is a species of animal that is active at night (nocturnal) which is solitary, not always in pairs or groups [30]. The clustered

spatial distribution pattern shows that animals have specific preferred or suitable habitat preferences to support their survival and sustainability. Animals that spread in groups can be caused by the heterogeneity of habitats, especially in areas with abundant food availability to support the lives of these animals [32].

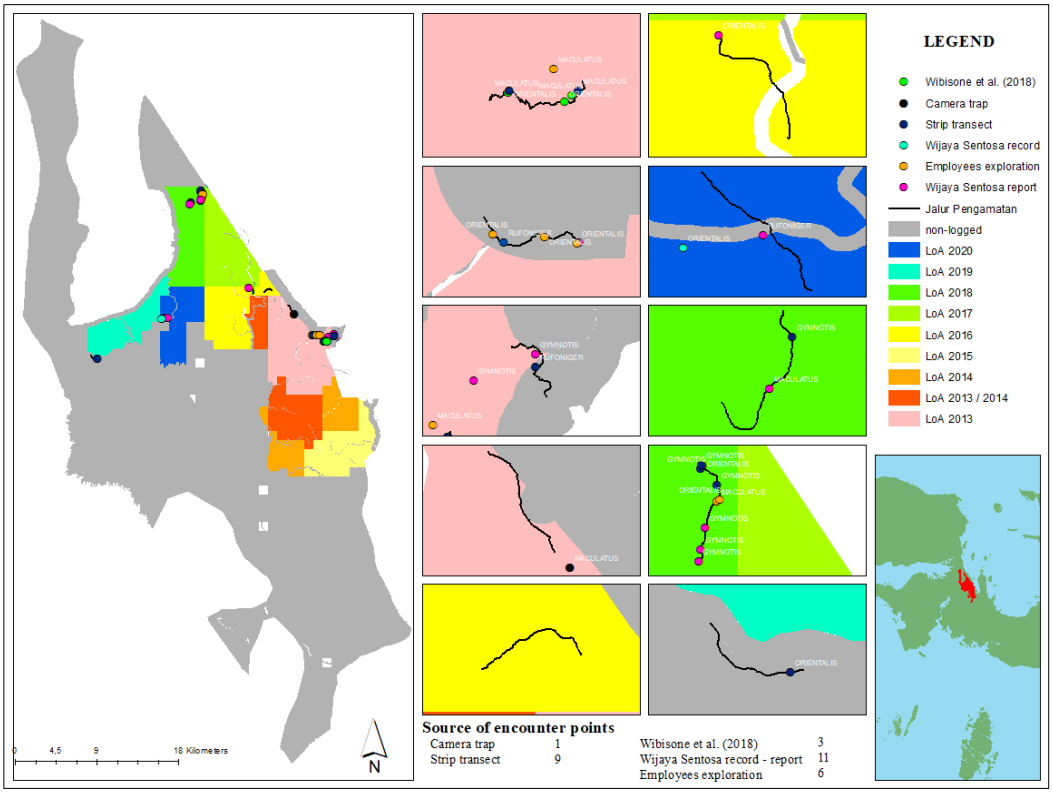

Figure 8. Map of cuscus distribution at PT Wijaya Sentosa

5. Recommendation

Based on this study, it is proven that the existence of endangered cuscus species exists in this production forest concession area. Thus, proper wildlife management is needed to support the protection and conservation of these animals. The role of high conservation value areas can influence and become one of the conservation efforts and increase the cuscus population in this concession area.

In addition to that, there is still a need for studies on the carrying capacity of habitats, as well as studies on the rate of loss of forest or habitat canopy to see how this population affected by the forest production- logging and/or forest clearing activities in this concession. Furthermore, there needs to be cooperation between several parties (KPH or BKSDA) for translocation or rescue mechanisms. Because it does not rule out the possibility that some wildlife species will come out of their habitat.

6. Conclusion

The cuscus population in the PT Wijaya Sentosa HPH showed that *P. gymnotis* has the highest abundance and population density. Meanwhile *S. maculatus* was the lowest. The adult age group was the most dominant. The ratio of males to females was 2:1. Only female species of common spotted cuscus (*S. maculatus*) were recorded by camera trap. Traces of bite marks were found on matoa (*P. pinnata*) fruit. The shape of the spatial distribution pattern of cuscus in this area was clustered. Based on the distribution map, the greatest number of individual cuscuses was found in LOA 2018, while the highest number of species was found in LOA 2013.

Author Contributions

NRF: Writing – original draft, Investigation, Methodology, Formal analysis; **NS**: Supervision, Conceptualization, Methodology, Writing - Review & Editing; **DAR**: Supervision, Conceptualization, Methodology, Writing - Review & Editing

Conflicts of interest

There are no conflicts to declare.

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