



## Estimating of moluccan megapode (*Eulipoa wallacei*) densities using a fixed-radius point count distance sampling method

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### Abstract

Reliable estimates of bird population (density and size) are urgently needed in conservation efforts of numerous tropical species, including the Moluccan megapode (*Eulipoa wallacei*), mainly due to the lack of quantitative population data. Therefore, this study aims to estimate the density of the Moluccan megapode using a fixed-radius point counts distance sampling method. We used a total of 72 points marked with a distance of 200 m along 13 transects systematically positioned 300 m apart. The observation radius at each point was 30 m, with 15 minutes of observation time at each point. Distance v.7.4 Release 2 software calculates individual encounter rates and population density. A total of 1321 individuals were detected at five locations in the western part of Haruku Island (mean  $n = 164$  individuals), and the number of samples generated by the model used ( $k$ ) was 308 samples with an average detection probability of 93.6%. This study showed that the population density of the Moluccan megapode on Haruku Island is 487 individuals/km<sup>2</sup>, and most of the population was concentrated in forests near their nesting sites in Cape Maleo, such as Cape Maleo Forest, Marunimei Forest, and Lalean Forest. We recommend regular population surveys to monitor changes in the population density of the Moluccan megapode on Haruku Island.

**Keywords:** population size, abundance, density, momoa, maleo, haruku, maluku

### Introduction

The Moluccan megapode (*Eulipoa wallacei*) is only found on a few islands in the central and northern Maluku Islands (Beehler *et al.*, 1986, White and Bruce, 1986, del Hoyo *et al.*, 1994, Dekker *et al.*, 1995, BirdLife Internasional, 2016) [1-5]. Since 1994, the population of Moluccan megapodes was predicted to decrease due to the exploitation of their eggs for consumption, destruction of habitat and nesting sites, and predation of individual chicks and adults (Colar *et al.*, 1994, Dekker *et al.*, 1995, Argeloo and Dekker, 1996, Dekker *et al.*, 2000, Heij and Rompas, 2011, BirdLife International, 2016) [6, 7, 8, 9, 5]. Therefore, since 1994 the Moluccan megapode has been designated as a vulnerable species by the IUCN (BirdLife International, 2016) [5]. Currently, a relatively large population of Moluccan megapodes can be found on Haruku Island and eastern Halmahera Island (Heij *et al.*, 1997, Heij and Rompas, 2011) [10, 9]. In 1991, the bird population size on Haruku Island was estimated at 8000 to 10000 adults, while in 1997, it was estimated at 8400 adults (Dekker *et al.*, 1995, Jones *et al.*, 1995, Heij *et al.*, 1997, Heij and Rompas, 2011) [4, 11, 10, 9]. However, the number of eggs exploited in the last 27 years on Haruku Island showed that the bird population has decreased by 30.70% (Heij *et al.*, 1997, Heij and Rompas, 2011, Simanjuntak *et al.*, 2020) [10, 9, 12]. The bird population on Halmahera Island also showed a declining trend of 9.2% between 2011 and 2012 (Sjafani *et al.*, 2015) [13]. In these earlier studies, population size estimates of Moluccan megapode were based on the number of eggs obtained at their nesting site combined with the number of adult females (Heij *et al.*, 1997, Heij and Rompas, 2011, Dekker *et al.*, 1995, Jones *et al.*, 1995) [10, 9, 4, 11] and the number of individual nests at their nesting site (Sjafani *et al.*, 2015) [13]. Methodologically, the technique in the previous study was not based on direct encounters with individual birds in their habitat, so the population values (density and size) were biased and did not show accurate results.

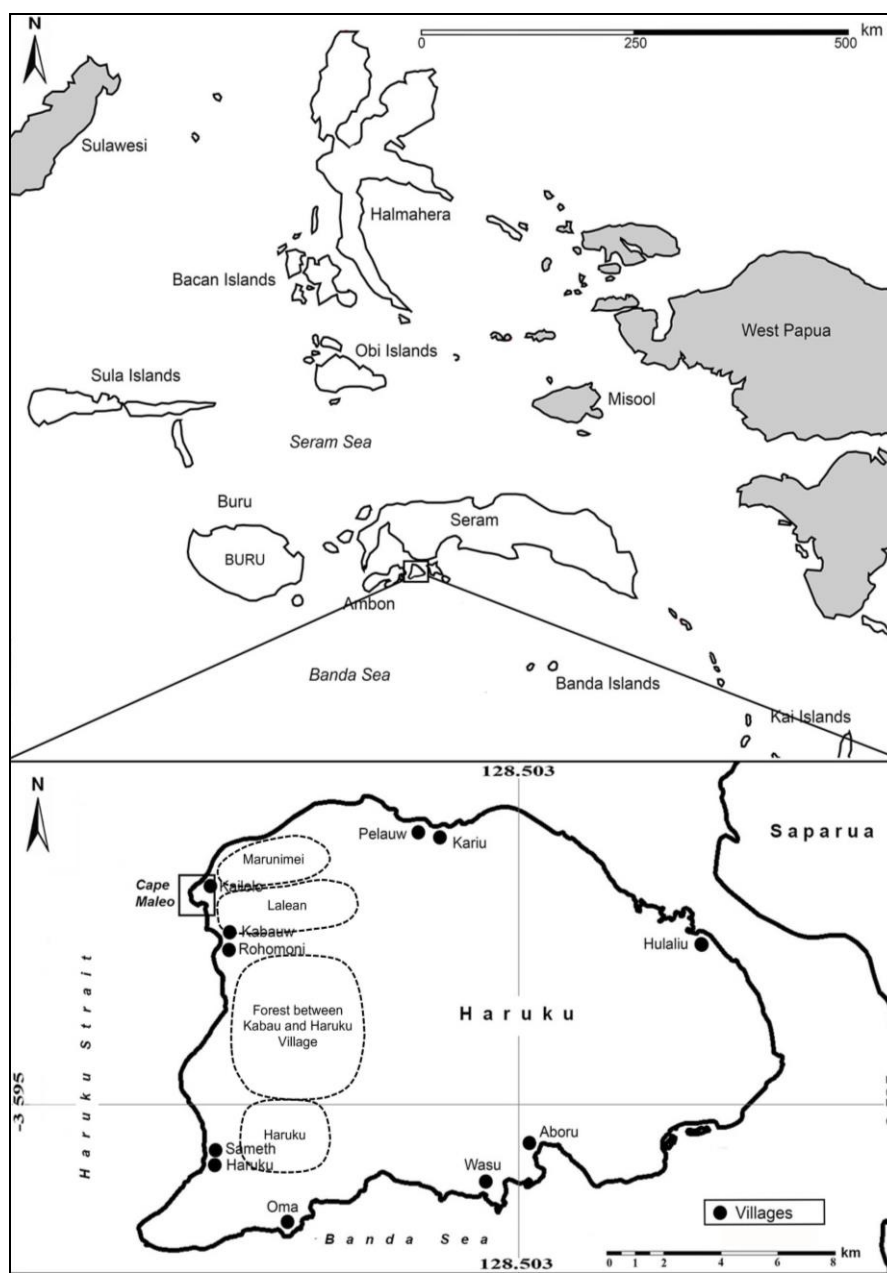
The characteristics of megapodes as terrestrial birds are often obscured by their cryptic nature and the vegetation cover in their habitats, making it challenging to relate information on species encounter rates (sightings or vocal detections) to their abundance, density, or population size (Dekker *et al.*, 2000) [8]. As a result, population studies of the Moluccan megapode and other megapode species were rarely conducted. However, that quantitative data on populations, such as population density and size in a particular area, were essential for conserving these birds (Dekker *et al.*, 2000) [14]. Density estimates, for example, provide baseline data on population abundance that play a role in estimating population size, and these can be monitored over time to assess the suitability of the conservation strategy implemented (Conroy and Lee, 2014, Callaghan *et al.*, 2021, Fensham, 2022) [14, 15, 16]. Understanding changes in population sizes of species targeted for conservation is critical if policies and management plans are to be based on a sound understanding of the status of these species (Sutherland *et al.*,

2004, Nijman and Menken, 2005, Buckland *et al.*, 2008) [17-19]. Information related to changes in population size is also needed to manage populations of endangered species such as megapodes, especially to measure the impact of egg exploitation pressures and habitat destruction on changes in the bird population (Dekker *et al.*, 2000, Blanco *et al.*, 2022) [8, 20]. Therefore, this study was conducted to estimate the population density of the Moluccan megapode based on encounters rates with individual birds using a fixed-radius point count distance sampling method. The study results are expected to provide up-to-date data on the status of the Moluccan megapode population in the Maluku Islands.

## Materials and Methods

### Study area

The Moluccan megapode population survey was located on Haruku Island, Indonesia (3.567°S, 128.483°E). Haruku Island is one of their primary habitats in the Maluku Islands, which has an area of 174 km<sup>2</sup>. The island's topography is hilly, and the highest point is 554 m above sea level. Haruku Island is one of the main habitats for the Moluccan megapode in the Maluku Islands (Heij *et al.*, 1997, Heij and Rompas, 2011) [10, 9]. Population sampling was carried out at five forest sites in the western part of Haruku Island, between their two nesting areas on Cape Maleo and the coast of Haruku Village: Cape Maleo forest, Marunimei forest, Lalean forest, Kabau and Haruku border forest, and Haruku forest (Fig. 1). Cape Maleo is the largest nesting site in the Maluku Islands, while the coast of Haruku Village is a small nesting site with relatively few nests.



Description: Dotted line circle indicates the sampling location

**Fig 1:** Map of sampling locations for the Moluccan megapode (*Eulipoa wallacei*) population in the western part of Haruku Island, between their two nesting areas on Cape Maleo and the coast of Haruku Village: Cape Maleo forest, Marunimei forest, Lalean forest, Kabau and Haruku border forest, and Haruku forest.

### Bird survey

The sampling method of fixed radius point distance is used to survey the population, especially to detect bird species that are cryptic and difficult to detect. The basic assumption of this method is that every bird is visually visible at every observation point (Hutto *et al.*, 1986, Bibby *et al.*, 2000, Thomas *et al.*, 2002, Gibbons and Gregory, 2006, Buckland *et al.*, 2008) [21-24, 19]. Point transects were marked with a distance of 200 m along transects systematically positioned at each location. A total of 13 transects were set at 300 m with 72 observation points. Distance intervals between points and transects were assumed to reduce the potential for re-observing and re-counting individual birds at each point. The observation radius at each point was 30 m, the farthest viewing distance for detecting the presence of birds visually using binoculars because of the vegetation that camouflages the birds when they are active on the forest floor and the small size of the birds. Meanwhile, the observation time at each point was 15 minutes, continued to the next point and thereafter to the last point. The transfer time between observation points was also 15 minutes. We repeated this procedure three times every two weeks. The bird survey started at 07:00 Eastern Indonesia Time until it finished. The points were approached silently, and any birds detected moving from near the survey point on recorder arrival were counted over the counting period, and the distance from the bird's initial position to the center of the point was estimated. Birds flying to the point after the counting period started or birds flying above it were excluded following the recommendations of Marsden (1999) [25]. The radial distance to the nearest meter was estimated from the survey point to each bird contact (visual) over a 15-minute counting period, and the length was estimated to the center of the observation point. The accuracy of distance estimates for bird detection was improved through pre-survey training and previous experience in distance estimation.

### Data analysis

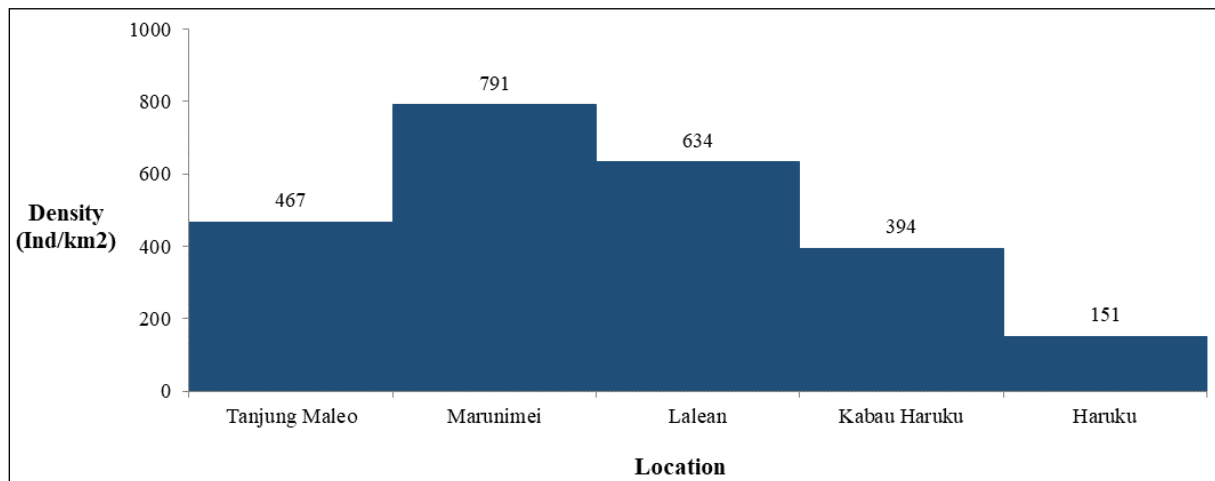
Abundance estimates that include density (individuals per transect point) and density estimates (individuals/km<sup>2</sup>) were calculated using Distance v.7.4 Release 2 software (distancesampling.org) (Buckland *et al.*, 1993, Buckland *et al.*, 2001, Thomas *et al.*, 2010) [26-28]. The first step in the distance sampling analysis was to model the probability of detection as a function of the distance from the point/transect. The assumptions used were (1) all individuals at zero distance (i.e., at the point) were detected, and (2) the detection usually decreases with increasing distance from the line or point. Individual points were used as sampling units for the distance analysis and detection from visits to observation points (Buckland *et al.*, 1993, Buckland *et al.*, 2001, Thomas *et al.*, 2010) [26, 27, 30].

### Results

A total of 1321 individuals were detected at five locations in the western part of Haruku Island (mean  $n = 164$  individuals), and the number of samples generated by the model used ( $k$ ) was 308 samples. The highest number of individuals was observed in Lalean forest ( $n = 696$ ), while the lowest was in Haruku forest ( $n = 59$ ). Although the highest number of individuals was observed in Lalean forest, the highest density of the Moluccan megapode population was in Marunimei forest ( $n = 362$ ), presumably due to the difference in area between the two forests. During 15 minutes of observation at each point, the probability of detection of individual birds on average was 93.6%, indicating that the number of individual birds was large on Haruku Island. The detection probability reached 100% in the Marunimei forest, Lalean forest, and the border of the Kabau – Haruku forest, whereas the lowest detection probability of 78.3% was in the Haruku forest (Table 1). Most individual birds were detected at a distance of 20 to 30 meters from the center of the observation point due to their sensitivity to the presence of humans at a very close distance. The results of the population density analysis based on the presence and probability of detection show that the highest population density of the Moluccan megapode on Haruku Island was in Marunimei forest, reaching 791 individuals/km<sup>2</sup> (Table 1 and Fig. 2). From the five locations on Haruku Island, the average population density value was 487 individuals/km<sup>2</sup> (Table 1).

**Table 1:** Population density (individuals/km<sup>2</sup>) of the Moluccan megapode (*Eulipoa wallacei*) in five locations on Haruku Island (Distance v.7.4 Release 2).

Sampling Location	Detection Probability (%)	Population density ( $D$ ) (ind/km <sup>2</sup> )	Number of observed objects ( $n$ )	Number of samples ( $k$ )	% CV	95% Confidence Interval	Akaike Information Criterion (AIC)
Cape Maleo	89.6	467	129	114	5.11	1.02	823.00
Marunimei Forest	100	791	362	305	3.13	1.12	2372.80
Lalean Forest	100	633	696	760	2.35	0.87	4414.90
Forest between Kabau and Haruku Village	100	394	75	200	10.60	0.30	462.44
Haruku Forest	78.3	151	59	160	11.44	0.29	378.04
Average	93.6	487	164	308	6.53	0.72	1690.24



**Fig 2:** Comparison of population densities (individuals/km<sup>2</sup>) of the Moluccan megapode (*Eulipoa wallacei*) in five locations on Haruku Island.

The study results show that most of the Moluccan megapode population on Haruku Island was concentrated in the forests near their nesting grounds in Cape Maleo: Cape Maleo forest, Marunimei forest, and Lalean forest. Furthermore, bird population density decreased with increasing distance from nesting grounds in Cape Maleo, such as in the forest between Kabau Village and Haruku Village, as well as in the forest of Haruku Village (Table 1 and Fig 2). The average value of the coefficient of variation obtained from the use of the model was relatively small (% CV = 6.53), implying that the data used have a good level of homogeneity for estimating the population density of the Moluccan megapode. In addition, the narrow range of confidence interval (95% confidence interval = 0.72) signifies that the value obtained has good accuracy. The model selection was based on comparing the relative suitability of this detection model using the Akaike Information Criterion (AIC) value, where a lower AIC value indicates a more robust estimation model. The average AIC value of the model used in this study was 1690.24, with the smallest AIC value derived from the estimation model in the Haruku forest.

## Discussion

Haruku Island is known as one of the main habitats for the Moluccan megapode in the Maluku Islands. Their nesting site in Cape Maleo has given special attention to the bird population on Haruku Island to assess the status of eggs exploited by local communities and estimate their population (density and size). For population estimation (density and size), the approach was not based on direct encounters with individual birds using sampling techniques for terrestrial birds but on the number of eggs, individual females laying eggs (Dekker *et al.*, 1995, Jones *et al.*, 1995, Heij *et al.*, 1997, Heij and Rompas 2011) <sup>[4, 11, 10, 9]</sup> and the nest inventory (Sjafani *et al.*, 2015) <sup>[13]</sup>. As a result, it can cause a bias toward the estimation results obtained. Population estimation applying this indirect approach has a weakness as it does not describe the condition of the actual population of birds in their habitat. This study becomes the first attempt to estimate population based on encounters with individual birds directly in their habitat. Studies on the population (density and size) of megapodes on several islands in the Pacific region have also applied several population sampling techniques for cryptic terrestrial birds, such as point transect (Fancy *et al.*, 1999, Amidon *et al.*, 2011) <sup>[29, 30]</sup>, direct count (Goth and Vogel, 1995) <sup>[31]</sup>, and playback (Goth and Vogel, 1995) <sup>[31]</sup>. Methods that have the potential to provide good results for estimating the population of cryptic terrestrial birds include spot mapping, triangulation, distance sampling (using line transects and point counts), and camera traps. of the four methods, the distance sampling method was considered a reliable method for making estimates of bird populations (Thunhikorn *et al.*, 2016) <sup>[32]</sup>. Distance sampling was increasingly used in various bird population studies and was generally seen as an efficient and reliable approach to density estimation. Point transect distance sampling was the most frequently used density estimation method for multi-species surveys in tropical forests (Martin-Schwarze *et al.*, 2021) <sup>[33]</sup>. Meanwhile, the distance sampling method with fixed-radius point counts was one of the reliable methods for detecting cryptic and difficult-to-detect bird species (Buckland *et al.*, 2008, Lee and Marsden, 2008, Marsden, 2008, Thunhikorn *et al.*, 2016) <sup>[19, 34, 35, 32]</sup>, such as the Moluccan megapode.

This study results revealed that the population of the Moluccan megapode on Haruku Island was relatively high for an island covering an area of 174 km<sup>2</sup>. As a comparison, based on the number of female individuals, Heij *et al.* (1997) <sup>[10]</sup> estimated that there were only 48 females per square kilometer on Haruku Island, while Dekker (1991) <sup>[36]</sup> estimated 46 – 58 females per square kilometer. Compared to the number of eggs collected from the nesting grounds in Cape Maleo, which reached 21,707 eggs per year (Simanjuntak, 2020) <sup>[12]</sup> or an average of 1,809 eggs per month, it is estimated that each female adult produces about 38 eggs per month. This result contradicts the statement of previous studies that the clutch size of Moluccan megapodes only ranges from 10-12 eggs per year (Heij *et al.*, 1997, Heij and Rompas, 2011) <sup>[10, 9]</sup>. This contradiction causes the results of population estimates to be inconsistent with predictions of possible population size based on the total clutch number of the Moluccan megapode population on Haruku Island. Most of the Moluccan megapode population was estimated to

be the inhabitants of Haruku Island because the results of radio tracking conducted in 1997 by Heij *et al.* (1997)<sup>[10]</sup> showed that of the nine individuals tracked, as many as six individuals remained on Haruku Island (67%) while three individuals (33%) migrate to Seram Island which is about 20 km from their nesting site on Cape Maleo. The size of the Moluccan megapode population on Haruku Island is influenced by local communities' maintenance of their nesting sites, the ability to live on several types of land cover, and the absence of hunting or capturing of adult birds (Heij *et al.*, 1997, Heij and Rompas, 2011, Dekker *et al.*, 2000, Simanjuntak, 2020)<sup>[10, 9, 8, 12]</sup>. The role of the socio-cultural aspect is related to the community's belief that the Moluccan megapode eggs were gifted from their ancestors to be used so that people do not hunt or catch adult birds (Heij *et al.*, 1997, Heij and Rompas, 2011)<sup>[10, 9]</sup>. Another study on the population density of the Moluccan megapode was on Halmahera Island using the number of nests in their nesting grounds. Based on their nesting holes, the population density of Moluccan megapode at several nesting grounds on Halmahera Island was as follows: 670 – 667 individuals/km<sup>2</sup> for Uwo-Uwo Beach, 1368 – 1370 individuals/km<sup>2</sup> for Tiabo Beach, and 222 individuals/km<sup>2</sup> for on Denamabobane Beach. Overall, the population of Moluccan megapods on Halmahera Island was estimated at 5,000.60 ± 5.90 individuals in 2012 (Sjafani *et al.*, 2015)<sup>[13]</sup>. The high population density on Halmahera Island is suspected to be caused by the area of Halmahera Island, which reaches 17,780 km<sup>2</sup>. Estimates of bird populations (density and size) are a crucial aspect of bird conservation. Information about populations allows us to identify important areas for conservation, measure changes in population size over time, and eventually analyze the impacts of habitat loss, pollution, or harvesting (Buckland *et al.*, 2008)<sup>[19]</sup>. Population estimates can also be used to assess whether isolated populations can survive and to determine the effectiveness of conservation management actions (van Rees *et al.*, 2021, Blanco *et al.*, 2022)<sup>[37, 20]</sup>. Meanwhile, population abundance is one of the cornerstones of the IUCN Red List classification scheme (Vie *et al.*, 2008, IUCN, 2012, Santini *et al.*, 2019)<sup>[38-40]</sup>. Population estimates are urgent for tropical forest bird species, the most threatened species such as the Moluccan megapode, especially where quantitative population data are sparsely available.

### Conclusion

The estimation of the Moluccan megapode population using a fixed-radius point counts distance sampling method in this study was the first attempt to use a terrestrial bird sampling method which was cryptic and challenging to survey to estimate their population density. Based on population estimates, the population density of the Moluccan megapode on Haruku Island was 487 individuals/km<sup>2</sup>, with a detection probability of 93.6%. Most of the Moluccan megapode population on Haruku Island is concentrated in forest areas adjacent to the nesting grounds in Cape Maleo, which was the impetus to make Haruku Island a bird conservation area, considering that this bird is threatened and endemic to the Maluku Islands.

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