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Movement and Home Range of the Translocated Komodo Dragons (*Varanus komodoensis* Ouwens, 1912) in Flores, East Nusa Tenggara, Indonesia

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Abstract

One of the conservation efforts for the Komodo Dragon (*Varanus komodoensis*) is the translocation of the Komodo. Six juvenile captive-bred Komodo Dragons were translocated from Bogor to Wae Wuul Nature Reserve, East Nusa Tenggara Province, on 23rd September 2023. This research aims to calculate and describe home ranges total daily movements and the habitat conditions of Komodo Dragons. The research was carried out at the Wae Wuul Nature Reserve using the radio tracking method for 11 days, as most of the translocated Komodo Dragons could only survive in the short term. Results showed that translocated Komodo Dragons tend to stay near the initial release location. The average total daily movement translocated Komodo Dragons was 424.53 m day^{-1} with an average home range of 34.11 ha and an average core area of 8.20 ha. The habitats used by Komodo Dragons are savanna and monsoon forests dominated by bushes and trees. The presence of feral dogs and vehicle road access have the potential to pose a threat to the translocated Komodo Dragons.

Keywords: komodo dragons, post-released, radio tracking, translocation

1. Introduction

Translocation is the activity of moving live animals from one place to another [1]. Translocation activities are primarily focused on conservation efforts or driven by commercial interests [2]. Animal translocations for conservation efforts include the transfer or release of animals, which aim to improve the conservation status of species locally and globally and restore ecosystem functions in a location [3]. Reintroduction has long been used in conservation efforts for various wildlife species to establish stable populations in their natural habitats [4,5]. Animals released into the wild may come from rehabilitation and captive breeding in conservation facilities [6]. Once animals have been released, their movements need to be monitored, as information on their survival history is required to determine the success of the release [7].

The Komodo Dragon (*Varanus komodoensis*) is an endemic reptile in Indonesia, and its main habitat in Komodo National Park has been designated as a world heritage object by UNESCO. Komodo Dragon is included in the Endangered (EN) category species based on the IUCN red status [8]. Komodo Dragons are mostly distributed in Komodo National Park (especially on Komodo Island, Rinca Island, and Gili Motang Island) [9], but also outside the National Park. Wae Wuul Nature Reserve [10] and a small part of the north and west Flores Island [11]. The natural population of the Komodo Dragons is estimated to be less than 3,000 individuals [12].

The isolated distribution and low level of genetic diversity of Komodo dragons could lead to extinction [13]. The biggest threat to the survival of Komodo Dragons comes from illegal hunting for natural prey in their habitat, such as deer and wild boar, which will lead to the extinction of the Komodo dragons [14]. Other factors that can threaten the survival of Komodo Dragons include habitat destruction, forest fires, illegal hunting and trade [15], and collisions [16]. The limited distribution area of the Komodo Dragons is also a strong reason for the protection and maintenance of the dragon [11].

Considering the limited population and high threats, conservation efforts to translocate Komodo dragons from conservation institutions to their distribution on Flores Island were undertaken. Natural Resources Conservation Center East Nusa Tenggara/*Balai Besar Konservasi Sumber Daya Alam Nusa Tenggara Timur* (BBKSDA NTT), Safari Park Indonesia/*Taman Safari Indonesia* (TSI), and PT SMELTING released Komodo dragons from TSI Bogor on 23rd September, 2023, in the Wae Wuul Nature Reserve. This area is home to the Komodo Dragons, known as *Mbou* by the people of Flores [17]. The Wae Wuul Nature Reserve (1,484.84 ha) consists mainly of savannah, shrub, and secondary dry forest. The Wae Wuul Nature Reserve represents the buffer zone of Komodo National Park (KNP) and is geographically the dividing line between the Labuan Bajo and monsoon forests [18].

To determine the success of translocation efforts, monitoring is required to provide information on the survival of the translocated animals [7]. Bubac et al. [19] also, monitoring is necessary to identify failure trends, biases, and challenges from release activities. Post-release monitoring of the Komodo Dragon movement behavior will be carried out using radio-tracking methods to determine the progress of their survival. According to Ujvari and Korsos [20], radio tracking produces ecological data that cannot be obtained using traditional direct observation methods and makes it possible to measure these data quantitatively. This method uses selected individual wildlife objects to analyze their ecological data [21]. The use of the radio tracking method on Komodo Dragons was carried out by Purwandana et al. [22], but has never been done before on post-released Komodo Dragons.

Thus, this study aimed to calculate and describe the home range of the post-release Komodo Dragons; calculate the total daily movements and describe the movement patterns of the post-released Komodo Dragons; and describe the habitat conditions used by the post-released Komodo Dragons.

2. Materials and Methods

2.1. Study area

The study site was located in Wae Wuul Nature Reserve, specifically in Macang Tanggar Village and Warloka Village, Komodo District, West Manggarai Regency, East Nusa Tenggara Province, and was conducted from January to March 2024. The determination of translocation in Wae Wuul Nature Reserve was based on the results of the blood sample test of the translocated candidate from the zoom by researchers from the National Research and Innovation Agency/*Badan Riset dan Inovasi Nasional* (BRIN). A map of the study site is shown in Figure 1.

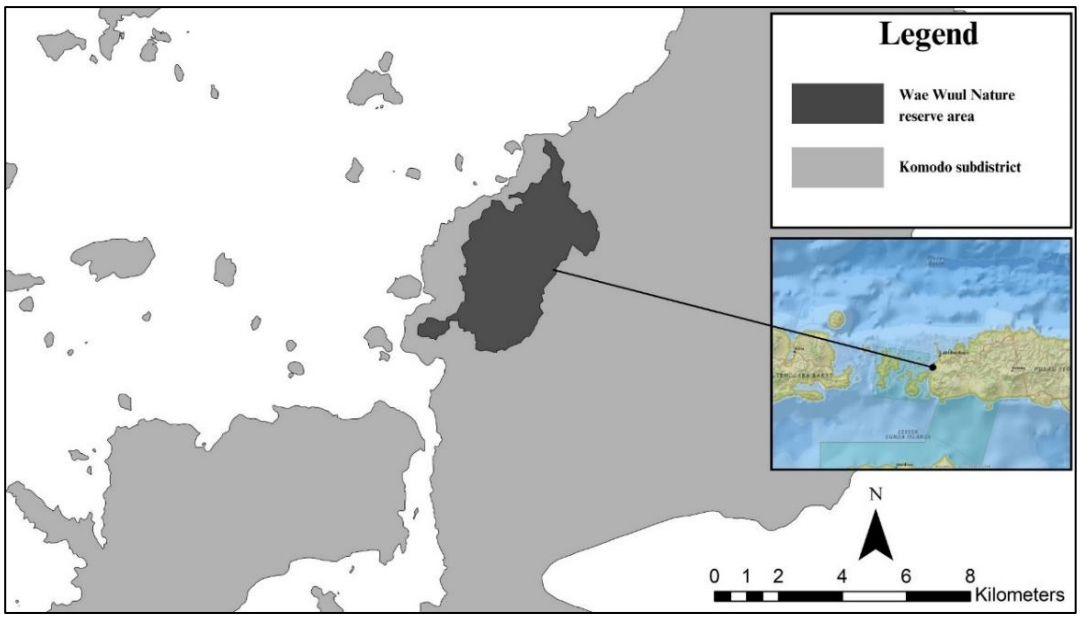

Figure 1. Map of the Wuul Nature Reserve Area in Flores, Indonesia.

2.2. Research Subject

The Komodo Dragon studied six individuals released into the wild by BBKSDA NTT, TSI, and PT SMELTING since 23rd September 2023, in the northern part of Wae Wuul Nature Reserve. These reptiles came from captivity in Taman Safari, Indonesia, Cisarua (Bogor). The Komodo Dragons were transported from Cisarua to Labuan Bajo, East Nusa Tenggara, on August 16, 2023, and immediately placed in one habituation cage (size 250 m^2) in the northern area of the Wae Wuul Nature Reserve. The acclimatization process was conducted from 16th August 2023 to 22nd September 2023. All Komodo Dragons were fed live food (free-range chicken) once a month in the morning to train their hunting instincts, trees to train their climbing abilities, and limited direct encounters with humans. The conditions of the habituation cage and Komodo Dragons in the habituation cage are shown in Figure 2.

Figure 2. Conditions of the habituation cage (A) and TSI Komodo dragon in the habituation cage (B). Image source: BBKSDA NTT.

Each Komodo Dragon was given a special name and color code to distinguish one individual from another. The color code can be distinguished by the color of the pouch attached to each Komodo Dragon. The six tagged Komodo Dragons were 3 years old (juvenile age class), male, weighed more than 3.5 kg and ranged in length from 127 to 137 cm. Six juvenile Komodo Dragons fitted with transmitters were released simultaneously at 12:00 WIT on 23rd September 2023. The release location was outside the habituation cage at 119°50'13.61 E and 8°33'30.90 S. The dragons were released by opening a cage door and letting them out.

2.3. Movement and Home Ranges

Post-released Komodo Dragons were monitored using GPS tracking techniques to minimize stress on animals because researchers are not close to or interact directly with the animals being studied [23]. We used a Q4000ER GPS (*radio transmitter*) and a Q4000ER *base station* (*radio receiver*) from *Telemetry Solutions*. The transmitter was set to send data every 3 hours, and active battery power was expected to last until September 2024. The transmitter signal is captured by the base station (receiver) in the form of data, that is, coordinates (longitude and latitude), date, time, battery status (volts), and temperature conditions (°C). Furthermore, data on each individual Komodo Dragon captured by the base station can be downloaded via a laptop. Data collection was carried out twice a day at 09.00 and 16.00 by flying the base station attached to the DJI Mavic 3 Pro drone for 10–15 minutes near habituation cage (**Error! Reference source not found.**). These data were used to determine t he daily movements and home ranges of each individual Komodo Dragon.

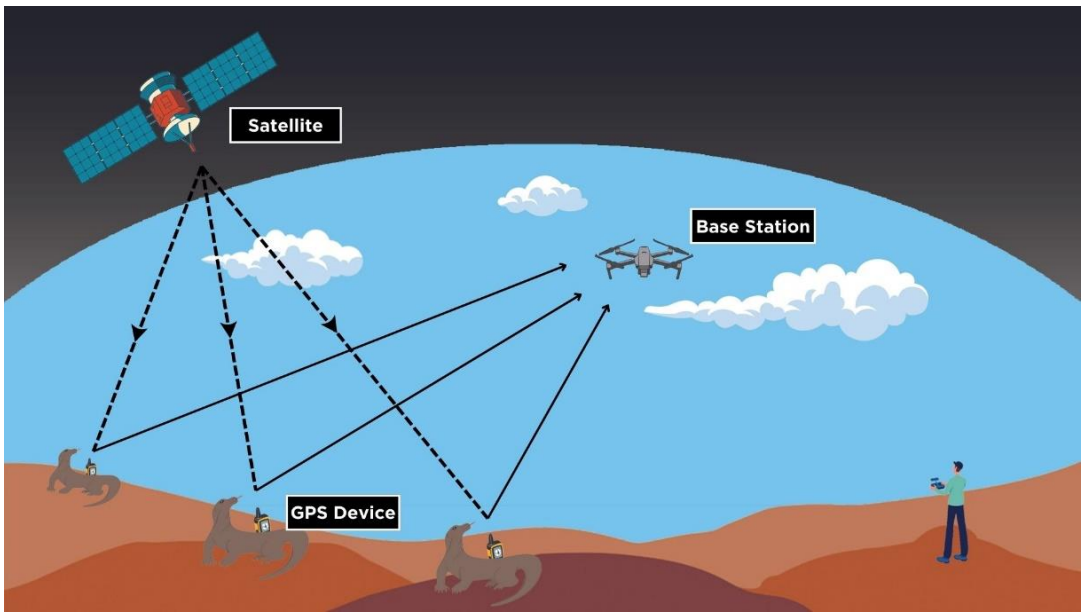

Figure 3. Illustration of the data collection process using GPS tracking equipment

The transmitter on each Komodo Dragon was installed using a pouch attached to the back near the tail. The pouch stores the Q4000ER GPS and its battery, with a total weight of 120 g, according to the load ratio criteria, namely, not exceeding 5% of the animal's body weight by others study [24] (Figure 4). Each Komodo dragon is equipped with a GPS tracking device. Although we have no animal ethical clearance, the released Komodo Dragon is a project initiated by BBKSDA NTT with TSI, as stated in *Surat Keterangan* No. KT.80/K.5/BIDTEK/KSA/9/2023, dated 10th September 2023. Thus, the GPS tracking equipment was set up under the supervision of a veterinary team from Taman Safari Indonesia to ensure safety.

Figure 4. Released Komodo with a transmitter installed on its back

2.4. Microhabitat Characteristics

Microhabitat data, including air temperature, humidity, canopy density, dominant vegetation, altitude, and proximity to water sources, settlements, and roads, were collected at the initial, 24-hour, and final release sites for each Komodo Dragon. Air temperature was recorded directly from the dragon's transmitter, while humidity was estimated using the

Normalized Difference Moisture Index (NDMI) from image analysis [25]. Canopy density was assessed using the CanopyApp, a smartphone application that automatically calculates canopy coverage from photographs.

Canopy density uses the criteria developed by Ayuningrum [26], namely, the categories of very dense (81–100%), dense (61–80%), somewhat open (41–60%), open (21–40%), and very open (0–20%). Elevation data were derived from GPS measurements. The dominant habitat recorded was the vegetation mostly found at the observation site. The recorded habitat types included trees, shrubs, bushes, herbs, and undergrowth. The distance to the water source was used to determine water availability at the release site. The distance from settlements and roads determines the potential for conflict between humans and the post-released Komodo Dragons. Distance variable data were derived from the distance between the coordinate points of the Komodo Dragons and the coordinate points of the nearest settlements, roads, and water sources. The microhabitat characteristics data will be used to describe the habitat conditions used by post-release Komodo Dragons and determine the possibility of conflict between humans and Komodo Dragons, which could affect the success of reintroduction efforts.

2.5. Data Analysis

Komodo Dragon's movement was calculated using the Straightness Index which shows the movement tendency value [27] based on a comparison value between the total displacement and total movement of each individual Komodo Dragon. This index is used to indicate that the Komodo Dragons moved far from the initial release point or tended to stay near the initial release point. In addition, daily movements are shown as mean ± standard deviation. Komodo Dragon's movement patterns are depicted in maps created using ArcMap 10.8 and Google Earth Pro.

We analyzed the home ranges of Komodo Dragons using the ((MCP) in RStudio version 2023.12.1, using the "adehabitatHR" [28] and "maptools" [29] packages. However, the "maptools" package is no longer available in RStudio as of 2023, so a replacement package with similar functionality, "sf," was used for data analysis. MCP is a wildlife home-range estimation technique that uses the outermost points of animal detection to form a convex polygon [30]. The core area was described using 50% of the MCP calculation results, whereas the home range was described using 95% of the MCP calculation results (5% observation points for outliers) as a model for the entire home range. The Komodo Dragon's home range and core area are shown on an ArcMap map.

The microhabitat characteristics were analyzed by providing quantitative values for the identified habitat variables. This was calculated from the field data in the form of percentage canopy cover, altitude, distance from settlements, distance from roads, and distance from water sources (springs and dead streams/waterholes). Temperature data were recorded at the base station. The dominant vegetation data at the data collection site were the descriptive explanatory data. In addition, moisture data were obtained through the normalized difference moisture index (NDMI) image analysis approach using an equation calculated using a raster calculator in ArcMap 10.8. The equation to obtain the NDMI is NDMI = (Band 5 − Band 6) / (Band 5 + Band 6). The satellite used was Landsat 8 (Path:133; Row:66) in October to December 2024. All these habitat variables were used to describe the habitat conditions used by Komodo Dragons after release and to determine the potential for conflict between humans and Komodo Dragons, which could affect the success of reintroduction efforts.

3. Results

3.1. Daily Movement of Komodo Dragons

Post-release monitoring results showed that the six Komodo Dragons moved for 6–11 days. There were 3 individuals (KD-01, KD-05, and KD-06) were found dead after 6–10 days, one individual (KD-03) was reported missing, and two individuals (KD-02 and KD-04) returned to the habituation cage after 9–11 days. An explanation of the movements and Straightness Index values of each individual Komodo Dragon is given in Table 1.

Table 1. Summary of movement results and Straightness Index values for post-release Komodo Dragons

Map Code	Total Movement (m)	Mean daily movement ± SD (m day^{-1})	Highest daily movement (m)	N days of movement	Total coordinate point	SI	Note
KD-01	3,534.07	504.87 ± 320.59	1,071.64	7	38	0.59	Died d-7
KD-02	3,954.21	395.42 ± 273.36	750.41	11	57	0.10	Recaptured d-11
KD-03	4,818.20	481.81 ± 439.83	1,591.10	10	46	0.32	Lost d-10
KD-04	4,148.10	518.51 ± 352.40	1,116.91	9	31	0.08	Recaptured d-9
KD-05	1,584.87	264.14 ± 248.88	689.28	6	38	0.30	Died d-6
KD-06	3,823.85	382.38 ± 275.84	732.00	10	57	0.41	Died d-10
Total mean	3,643.88	424.53 ± 318.49	991.89	8.83	44.50	0.30	-

Komodo Dragon KD-03 exhibited the greatest overall movement (4,818.20 m), while KD-05 displayed the least (1,584.87 m). KD-04 had the highest average daily movement (518.51 ± 352.40 m), and KD-03 recorded the furthest single-day movement (1,591.10 m). Despite these variations, the released Komodo Dragons generally remained close to the initial release site, as indicated by an overall straightness value of 0.30. Figure 5 provides a visual representation of their movement patterns.

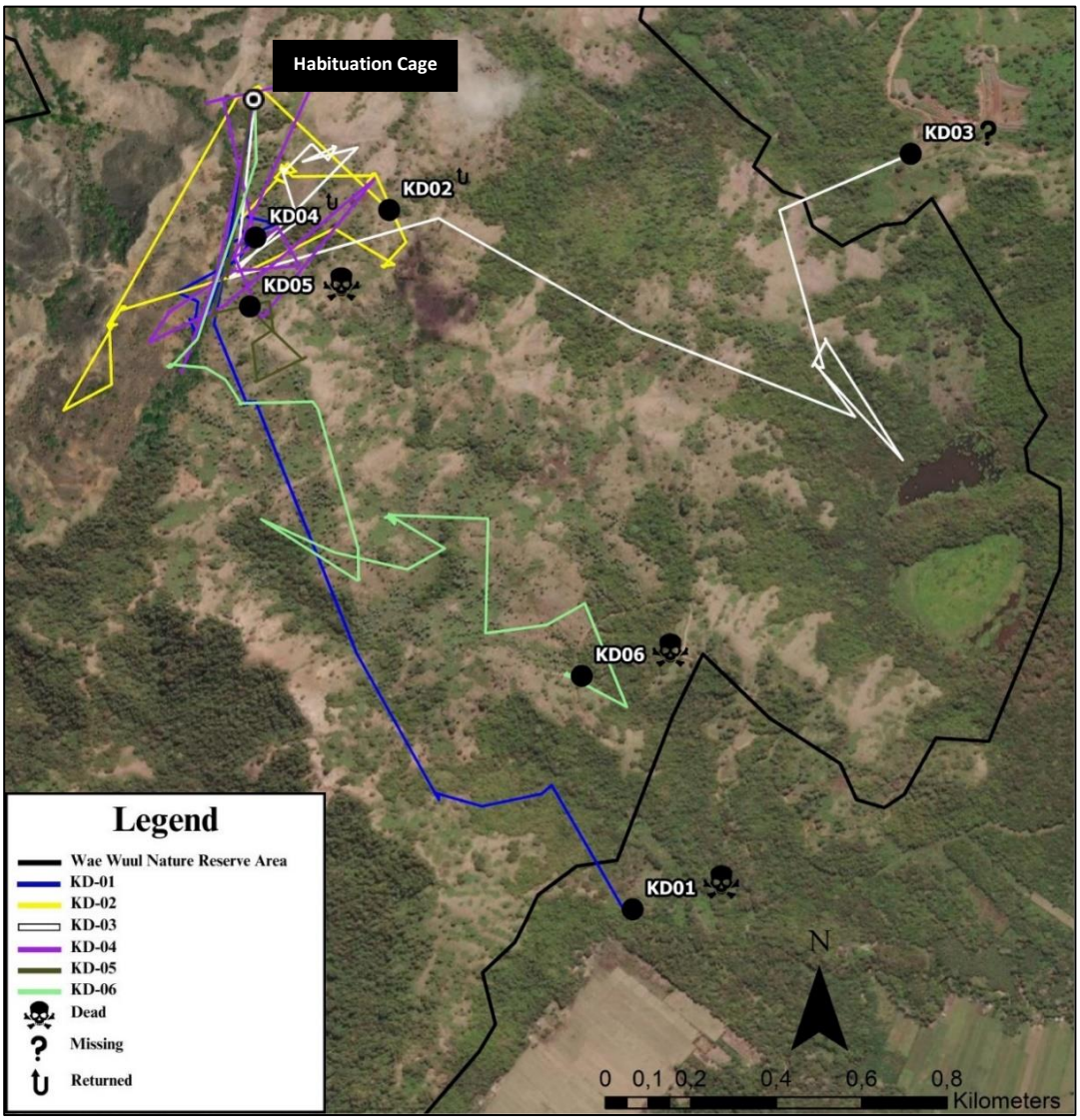

Figure 5. Movement patterns of translocated Komodo post-release in the Wae Wuul Nature Reserve

Three Komodo Dragons—KD-01, KD-03, and KD-06—moved away from the initial release site, while the others remained relatively close. KD-01 and KD-03 ventured outside the Wae Wuul Nature Reserve into residential areas. Unfortunately, KD-01, KD-05, and KD-06 perished at the following locations: 119°50'42.47 E, 8°34'31.85 S; 119°50'13.44 E, 8°33'46.24 S; and 119°50'38.60 E, 8°34'14.18 S, respectively. KD-03 was last recorded at 119°51'3.54 E, 8°33'34.69 S before it was reported missing. KD-02 and KD-04 were successfully returned to the habituation cage from their last known locations: 119°50'24.00 E, 8°33'38.93 S and 119°50'13.88 E, 8°33'41.00 S, respectively.

3.2. Post-Released Komodo Dragons Home Range

Each Komodo Dragon established a unique home range and core area. KD-03 exhibited the largest home range (50.91 ha, 95% MCP) and core area (17.84 ha, 50% MCP). Overall, home ranges varied from 8.57 to 50.91 ha, and core areas ranged from 1.01 to 17.84 ha. KD-05 had the smallest home range and core area. Table 2 provides a detailed breakdown of these spatial metrics for each Komodo Dragon. Figure 6a illustrates the home ranges of the released Komodo Dragons.

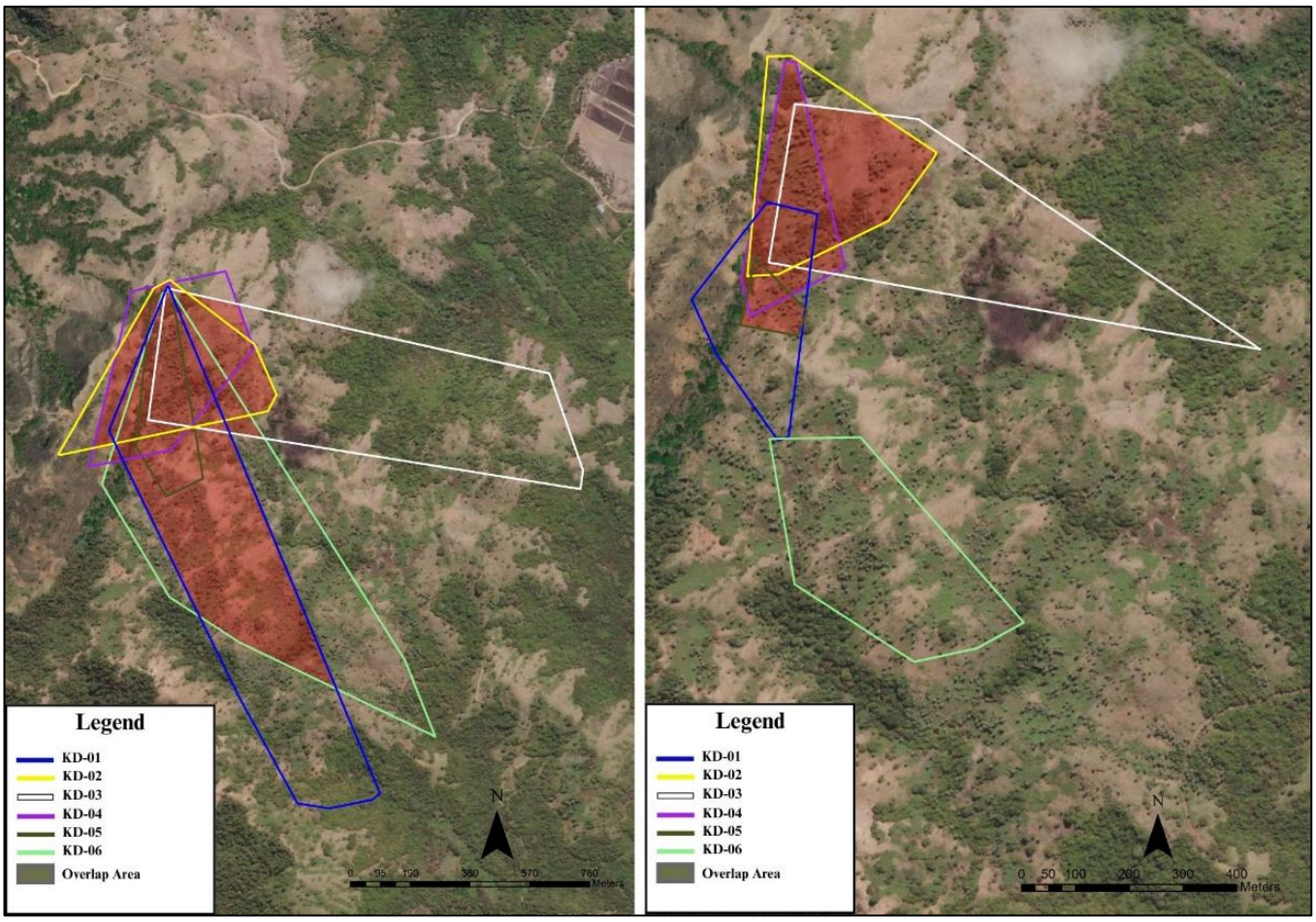

Figure 6. (a) (left) MCP calculation results for 95% of the Komodo Dragon's home ranges after release in Wae Wuul Nature Reserve and (b) (right) MCP calculation results for 50% of the Komodo Dragon's core areas after release in Wae Wuul Nature Reserve.

There were overlapping areas in the home ranges of the released Komodo Dragons (red polygons). The total home range area overlapping the MCP 95% was 48.62 ha. Six released Komodo Dragons shared this area. The core areas of the released Komodo Dragons are shown on the map in Figure 6b. There were also overlapping areas within the core areas of the released Komodo Dragons. The total core area that overlapped with the MCP 50% was 5.93 ha. KD-01 shared this area with KD-05. The core area of KD-06 did not overlap with those of the other five individuals.

Table 2. Microhabitat characteristics of post-release Komodo Dragons in Wae Wuul Nature Reserve

Variable	Initial Release	24-hours of dead Komodo (K01, K05, K06)	End of points of dead Komodo (K01, K05, K06)	24-hours of recapture Komodo (K02 and K04)	End of points of recapture Komodo (K02 and K04)	24-hours of lost Komodo (K03)	End of points of lost Komodo (K03)
Dominant vegetation	Grass	Trees and Bushes	Trees and Bushes	Trees and Bushes	Trees and Bushes	Bushes	Bushes
Canopy (%)	0	0–85.57	44.08–84.92	24.9–82.39	0–87.02	0	26
Distance from settlement (m)	994	1,018–1,188	159–1,272	1,164–1,175	1,183–1,184	1.186	401
Distance from road (m)	513	605–886	508–897	729–871	597–751	828	95
Distance from spring (m)	368	463–723	766–1,134	592–734	502–620	694	40
Type of spring	Spring 1	Spring 1	Spring 1 or Dolat Lake	Spring 1	Spring 1	Spring 1	Adesco Farm's Spring
Distance from puddles or dead river (m)	22	3–35	1–8	5–7	8–72	15	7
Temperature (°C)	35.79	32.40–39.83	23.47–36.18	37.88–38.01	33.96–35.33	35.27	35.72
Ground surface moisture (NDMI)	Dry	Moist-dry	Moist-quite dry	Moist-dry	Quite dry	Quite dry	Quite dry
Elevation (m)	179	181–188	19–195	181–182	183–214	181	60

3.3. Characteristics of Post-released Komodo Dragons Microhabitats

In general, the released Komodo Dragons used habitats with savanna and monsoon forest land cover conditions. The initial release site had savanna land cover conditions dominated by Bermuda Grass (*Cynodon dactylon*), with a canopy cover of 0% (very open). The temperature recorded at the start of the release was 35.79 °C. After 24 h, the six individuals Komodo Dragons used a habitat with savanna land cover conditions dominated by bushes (*Eupatorium inulifolium*) and a monsoon forest dominated by Walikukun Trees (*Schoutenia ovata*). The habitat used by the six individuals Komodo Dragons after 24 h had an average canopy cover percentage of 42.72% (slightly open).

The final habitat used by the six individuals Komodo Dragons has land cover conditions in the form of a savanna dominated by bushes (Eupatorium inulifolium) and a monsoon forest dominated by Walikukun Trees and Kedaleng Trees (*Bauhinia malabrica*). The final habitat used by the six Komodo Dragons had an average canopy cover percentage of 53.33% (slightly open). Overall, post-release Komodo Dragons used habitats at 19–214 m above sea level with temperatures ranging from 23.47–39.83 °C. In addition, the results of the NDMI analysis showed that post-release Komodo Dragons used habitats with moist to dry soil surface moisture conditions. Table 2 shows the microhabitat characteristics of the post-release Komodo Dragons.

In general, the location of post-released Komodo Dragons was, on average, 964.41 m from settlements, 670.84 m from the road, 630.92 m from the spring, and 15.15 m from the nearest dead pool or river. The closest settlements to the Wae Wuul Nature Reserve were Kampung Jaga, Adesco Farm, and Farmers' Settlement. Permanent water sources were found during the survey, namely Springs in the Wae Wuul Nature Reserve area (Spring 1), Lake Dolat, and the spring belonging to Adesco Farm. However, the Adesco Farm Spring is outside the Wae Wuul area. A vehicle access road ± 1.2 km long and 8 m wide also entered the Wae Wuul area.

4. Discussion

4.1. Daily Movements and Home Ranges of Post-Released Komodo

Initial post-release tracking data revealed that the Komodo Dragons exhibited sedentary behavior, with limited movement within their immediate area. Over 11 days observation period, individuals displayed varying average daily movements, totaling 424.53 m day^{-1} on average. As no prior research on Komodo Dragon movements has been conducted in the Wae Wuul Nature Reserve, a direct comparison is unavailable. However, Imansyah et al. [31] studied wild juvenile Komodo Dragons in Loh Liang, Komodo Island, providing a relevant reference point.

Imansyah et al. [31] reported that the average total daily movement of six individual Komodo Dragons was 129.13 m day^{-1}. These results showed that the average daily movement of post-release Komodo Dragons was relatively greater than that of wild juvenile Komodo Dragons. The difference in the movement results between the research of Imansyah et al. [31] and this research was due to the differences in the conditions of the Komodo Dragons, the length of observation time, the number of coordinate points/samples, and the methods used to determine home ranges. This study had a shorter observation period (6–11 days) and a smaller number of coordinate points/samples, whereas the study by Imansyah et al. [31] had a longer observation period (7–56 days) and a larger number of coordinate points/samples. The study's lower number of coordinate points/samples was caused by various conditions in which the radio transmitter could not send latitude and longitude data to the base station. According to the Q4000ER User Manual [32], the radio transmitter cannot transmit coordinate data when the animal to which the device is attached is underground, underwater, in tree holes, or blocked by hills.

Movement is the effort of individuals or populations to obtain resources to survive and reproduce offspring [33]. Fryxell and Sinclair [34] also argued that animals tend to move due to the availability of food and water and the threat of predators in their habitat. Jessop et al. [9] explained that movement in Komodo Dragons can describe the use of activity areas and behavioral development and represent the ability of Komodo Dragons to disperse. Several factors influence movement in Komodo, including age class, body mass, prey preference, and sex. Purwandana et al. [22] explained that adult Komodo Dragons, which had a larger body mass, tended to move farther when searching for larger prey such as Timor deer (*Rusa timorensis*) or water buffalo (*Bubalus bubalis*). In contrast, young Komodo Dragons only moved around nests or trees for small prey, such as insects or birds. Juvenile Komodo Dragons can climb trees to find food and avoid adult Komodo Dragons that engage in cannibalistic behavior [35]. Cannibalistic behavior in the Komodo Dragons is caused by hunger because they do not find prey [36].

Figure 7. Individual KD-05 (blue arrow) was captured on a camera trap while climbing the tree

The released Komodo Dragons were three years old, placing them beyond the juvenile phase but not yet in the adult category. Thus, they were still able to climb the trees (Figure 7). The Straightness Index (SI) value showed that the results of comparing the Komodo dragon's movement distance with the total movement ranged between 0.08–0.59 (average total less than 0.5). The straightness index values indicate that released Komodo dragons in the Wae Wuul Nature Reserve area tend to stay at the original release site. Although the released Komodo Dragons moved away from the initial release site, towards the last day of observation, they tended to return to the initial release site.

Komodo Dragons, in nature, tend to settle in one place because they are homebodies capable of exploring long distances but prefer to stay put [37]. In their natural habitat, Komodo Dragons move solitarily to search for prey, water, mates, and nests to lay eggs [38]. As solitary animals, Komodo dragons are found only in groups in one area when they enter the mating season. The research showed that released Komodo Dragons naturally moved away from other released individuals and were never found together. However, the home range analysis revealed overlapping areas in the home ranges and core areas of the released Komodo Dragons. This overlap occurred particularly during the first few days of release. This could indicate some interaction between individual Komodo Dragons at the beginning of the release.

In solitary animals, such as the Javan Gibbon (*Hylobates moloch*), overlapping home ranges can increase the likelihood of agonistic activity [39]. Sastrawan et al. [10] explained that agonistic behavior in Komodo could be divided into aggressive agonistic behavior and submissive agonistic behavior. Aggressive agonistic behavior can be observed in attacking prey and competition between Komodo dragons for mates and shelter. Submissive agonistic behavior occurs when Komodo Dragons fear encountering larger Komodo Dragons. This study did not examine interaction behavior, so whether antagonistic interactions occur between released individuals when home ranges overlap is unclear.

There were differences in the home range and core area size of each Komodo released into the wild. Differences in home range and core area size are well-known in reptiles and are often associated with increased resource use [40–42]. The size of an animal's home range and core area may change with age, size, or even season, but these factors still depend on the availability of resources in the habitat [43]. Carnivores generally have larger home ranges than herbivores and omnivores [44]. Komodo Dragons are carnivores that have no specific prey [11]Furthermore, individual Komodo Dragons found dead had larger home ranges and core areas than the two individuals who eventually were recaptured.

The Wae Wuul Nature Reserve area is directly adjacent to the coastline, and the furthest distance from the area is ± 2 km. This habitat is suitable for the Komodo Dragon [45]Komodo is typically found in savannas, monsoons, and mangrove forests. The Labuan Bajo Regional Conservation Resort Office's monitoring results of Komodo using the capture-marking-recapture-release (CMRR) method in 2011–2016 estimated that the population of Komodo Dragons in Wae Wuul nature reserve was 5–14 individuals.

The released Komodo Dragons primarily utilized savanna and monsoon forest habitats at elevations between 19 and 214 meters above sea level. These areas exhibited temperatures ranging from 23.47 to 39.83 °C, varying soil moisture levels (NDMI), and a relatively open canopy cover (44.33%). These habitat conditions align closely with those found in the natural range of Komodo Dragons [35,46]. However, Komodo Dragons are rarely observed in higher elevations (exceeding 600 m) or at distances greater than 6 km from the coastline [45]. Given the Wae Wuul Nature Reserve's coastal proximity and maximum inland distance of approximately 2 km, these habitat characteristics appear suitable for the released Komodo Dragons.

The presence of bushes and different types of trees is important for the Komodo Dragons because this vegetation provides shelter [10]. Savanna and monsoon forest habitats allow Komodo Dragons to nest, forage, and thermoregulate [47–50]. There were overlapping areas in the home ranges and core areas of released Komodo. Each Komodo shared the overlapping areas in the savanna and monsoon forests. This area was also used by other animals such as Wild Boar, Water Buffalo, Long-tailed Monkeys, Timor Deer, and Bali Cattle to obtain

resources. There were many rocks and holes in the monsoon forest area. The presence of rocks and holes plays an important role in juvenile Komodo Dragons, as juveniles usually use these places for shelter or hiding [31].

During the observations, several dead pools and streams were found in the savanna and monsoon forest areas of the Wae Wuul Nature Reserve. These puddles and dead streams were not permanent water sources. During the rainy season, the puddles and dead streams are filled with water. When the dry season arrives, the puddles and dead creeks dry up or have little water left. The largest puddle in the northern part of the Wae Wuul Nature Reserve is in the monsoon forest area. According to BBKSDA NTT officials, this waterhole was often used by Wild Boar, Water Buffalo, and Timor Deer to walk, making it easier for the Komodo Dragons to find prey. Apart from that, there were permanent water sources that can be found in the northern part of the Wae Wuul Nature Reserve, namely The Springs in the Wae Wuul Nature Reserve area (Spring 1) and Dolat Lake. Apart from that, there were several animals that have the potential to become prey for Komodo in Wae Wuul nature reserve, such as Wild Boar, Timor Deer, Water buffalo, Long-tailed Monkeys, Partridges, Gosard Birds, and Bali Cattle.

4.2. Implications for Management

The Komodo Dragon (*Varanus komodoensis*) is listed as an endangered (EN) category in the IUCN Red List of Threatened Species [8]. The Komodo Dragon population in the Wae Wuul Nature Reserve was smaller than the population in Komodo National Park [18]. Small populations are more vulnerable to extinction [51]. The greatest threat to the existence of Komodo Dragon came from humans. It is feared that the illegal hunting and trade of Komodo Dragons, as well as the hunting of Komodo Dragon's prey, such as Timor Deer and Wild Boar, could lead to their extinction of Komodo Dragons [14,15]. This appeared to be the basis for releasing the six Komodo dragon individuals.

The TSI veterinarian at the Regional Conservation Resort Office brought three dead individual Komodo dragons (KD-01, KD-05, and KD-06) to the Labuan Bajo Regional Conservation Resort Office for processing and dissection of the carcass of everyone (necropsy). Necropsy results showed that the suspected deaths of KD-01 and KD-05 were caused by stray dogs, pronounced by scratch marks and dog bites. Meanwhile, the death of KD-05 was suspected to have been caused by humans and was pronounced by scars from sharp object cuts. The cause for the disappearance of KD-03 remains unknown. However, the greatest possibility of KD-03's disappearance was caused by humans, as KD-03's last location was very close to Adesco Farm. In addition, KD-01 and KD-03 moved out of the Wae Wuul Nature Reserve area into residential areas. The surviving individuals (KD-02 and KD-04) were recaptured, turned into habituation cages, and later released into the wild on Ontoloe Island, 17 Island Marine Nature Tourism Park.

Several factors are thought to influence the success of release programs. The released Komodo Dragons were not born in the wild but at Taman Safari Indonesia in Cisarua, Bogor. The behavior of these animals at the Indonesian Safari Park is unclear, but their movements and home ranges are believed to be restricted. After the transfer, the Komodo Dragons were placed together in an acclimation cage at the Wae Wuul Nature Reserve, which was limited in size and food. As a result, the released Komodo Dragons had overlapping home ranges at the time of release. Given that the Komodo Dragons are solitary by nature, it is recommended that everyone be housed in separate temporary enclosures during reintroduction to the wild. After release, the Komodo Dragons tended to approach BBKSDA NTT or TSI officers, suggesting they remained associated with humans and had not yet learned to recognize humans as potential threats.

The process of releasing wild animals from captivity usually occurs at several stages. Although reptiles are different from mammals, the release process in mammals has always been thorough and rigorous. Lessons learned from the release of orangutans can be applied to the release of the Komodo dragons. In a case study of orangutan reintroduction in Bukit Tigapuluh National Park conducted by Santosa et al. [52], the orangutans underwent several stages before release, including identifying potential threats in the habitat and acclimation. The failure to identify predators or threats led to the release of Komodo Dragons, unaware

of wild dogs' presence in the Wae Wuul Nature Reserve. During the observations, several packs of wild dogs, each consisting of 2–4 individuals, were found near the last release sites of KD-01 and KD-06. Blower et al. [53] reported that wild dogs seriously threaten the Komodo dragons on Padar Island, Komodo National Park. Wild Dogs can prey on juvenile Komodo dragons and actively hunt in packs; therefore, the presence of Wild Dogs has direct and indirect impacts on Komodo Dragons [18]. These statements strengthen evidence that the presence of Wild Dogs can threaten Komodo dragons.

Another threat to the Komodo dragons is the presence of roads. Based on observational data, the range of released Komodo Dragons was quite close (average total of 670.84 m) to vehicle access roads entering the Wae Wuul nature reserve area. The presence of roads made it possible for Komodo Dragons and other animals to be hit by passing vehicles. Based on the information provided by BBKSDA NTT officials, a Komodo dragon in the Wae Wuul nature reserve area has never been hit by a vehicle. However, Azmi et al. [16] reported a case of a Komodo dragon being hit by a vehicle in Watu Pajung, Flores. This does not rule out the possibility of something similar in the Wuul Nature Reserve area.

Based on the information provided by the Head of the Labuan Bajo Regional Conservation Resort, this road is included in a special block arrangement that allows national strategic development. This road connects Kampung Jaga. From an ecological point of view, this road hurts wildlife in the Wae Wuul Nature Reserve. Various studies have shown that the presence of roads hurts wildlife [54,55] due to animal deaths from being hit by vehicles or facilitation of hunting and resource extraction [56]; therefore, measures are needed to reduce the negative impact of roads on wildlife. Several studies have suggested adding animal crossing routes (tunnels and water culverts), installing signs/warning boards, creating eco-passages, and constructing fences to prevent animals from climbing onto roads [57–59]. Other threats to Komodo include illegal hunting and trade of Komodo and its prey, habitat destruction, and forest fires [14,15,18]. Therefore, to ensure the success of komodo reintroduction in the Wae Wuul Nature Reserve area, the population must be regularly monitored, access permits to the area limited, stray dogs eradicated, and patrols and education increased.

5. Conclusions

This research shows that Komodo Dragons originating from the Conservation Institute (Taman Safari Indonesia), after being released into the Wae Wuul Nature Reserve, tend not to move far from the release location. The average daily movement of the released Komodo dragons was 424.53^{-1} m day, with the longest daily movement distance recorded at 1,591.10 m. The released Komodo dragons have an average home range area of 34.11 ha and an average core area of 8.20 ha based on Minimum Convex Polygon (MCP) calculations. Overlapping areas exist in the range and core areas of the released Komodo dragons. This shows that the area was used simultaneously by every individual Komodo dragon released into the wild. The habitat used by the released Komodo dragons in the Wae Wuul Nature Reserve is a savannah and monsoon forest dominated by bushes and trees. The habitat was 19–214 m above sea level, with temperatures ranging from 23.47–39.83 °C, moist to dry soil surface humidity (NDMI), and slightly open canopy cover (average 44.33 %). The necropsy results of individual Komodo dragons found dead indicated a conflict between humans and the released Komodo dragons. In addition, the presence of wild dogs and vehicle road access can seriously threaten the survival of the Komodo dragons in the Wae Wuul Nature Reserve.

Author Contributions

TMDR: Conceptualization, Methodology, Software, Investigation, Writing - Review & Editing; **MDK, YA, AM**: Conceptualization, Writing - Review & Editing, Supervision.

Conflicts of Interest

There are no conflicts to declare.

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