KOMODO SURVIVAL PROGRAM

Komodo dragon Conservation Project

Flores Programme

2021 Report

A report of 2021 research and conservation activities by *Komodo Survival Program*:

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In collaboration with

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Direktorat Jenderal Konservasi Sumber Daya Alam dan Ekosistem (KSDAE)

Eastern Lesser Sunda Central Bureau for Conservation of Natural Resources
Balai Besar Konservasi Sumber Daya Alam (BBKSDA) *Nusa Tenggara Timur*

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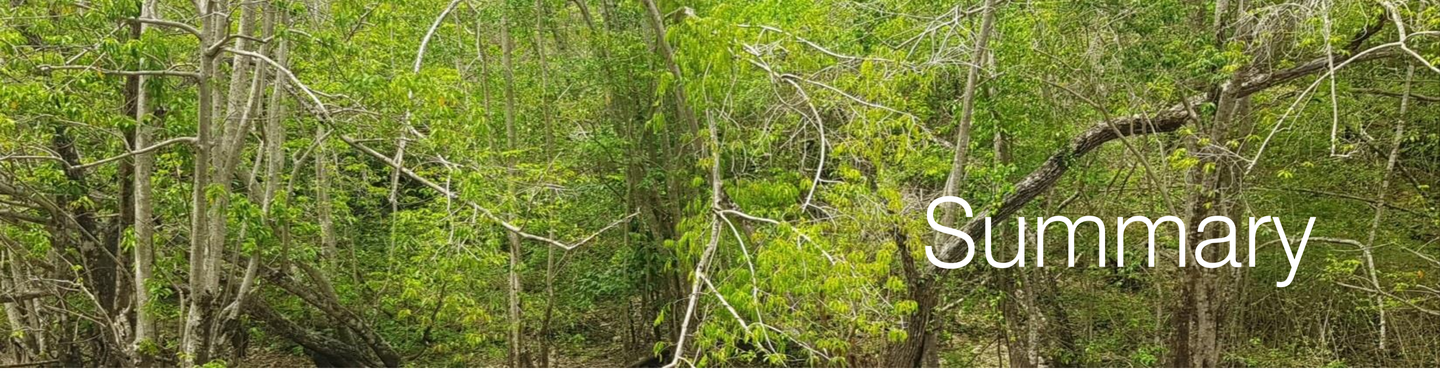


Summary

Population monitoring by means of passive infrared cameras recorded a relatively stable population density in both western and northern Flores. Site occupancy values recorded in 2021 in Pota where slightly lower than 2020 estimates but simlar to 2019 values. In Pota, no dragons were recorded east of the Buntal river, where human expansion and conversion of natural habitats to cultivates represent a main disturbance to extant Komodo dragon populations.

Deer population in Wae Wuul appeared to have maintained a relatively stable density from 2009 to 2019. However, we recorded a sharp decrease in the 2020 and 2021 surveys. These, however, were conducted later than in previous years, probably providing an underestiamte of counts due to accelerated feacal decay rates. Wild pigs trends were in line with previous years while we recorded a relative increase in water buffaloes densities.

Community awareness initiatives were conducted on the Island of Longos and the village of Sambirampas, District of Pota, northern Flores and involved classes on environmental awareness and protection for adults and primary and secondary school kids. Social studies were also implemented whereby local people perception about wildlife, and Komodo dragon in particular, was systematically recorded through in-depth interviews. This initiative aimed at assessing whether people had changed their overall perception of Komodo dragons and willingness to coexist with monitor lizards after the establishment of mitigation of human-Komodo dragon conflicts measures and alternative, sustainable livelihoods. As for 2020, we found an increase of overall positive attitude of people towards Komodo dragons, which were considered for the first time as an asset for economic growth and sustainable development.

The programme also provided training to rangers and technical staff of the Indonesian Department of Forestry (BBKSDA) in wildlife monitoring techniques. Patrolling and surveillance of non-protected areas were conducted in northern Flores, across the Torong Padang peninsula.

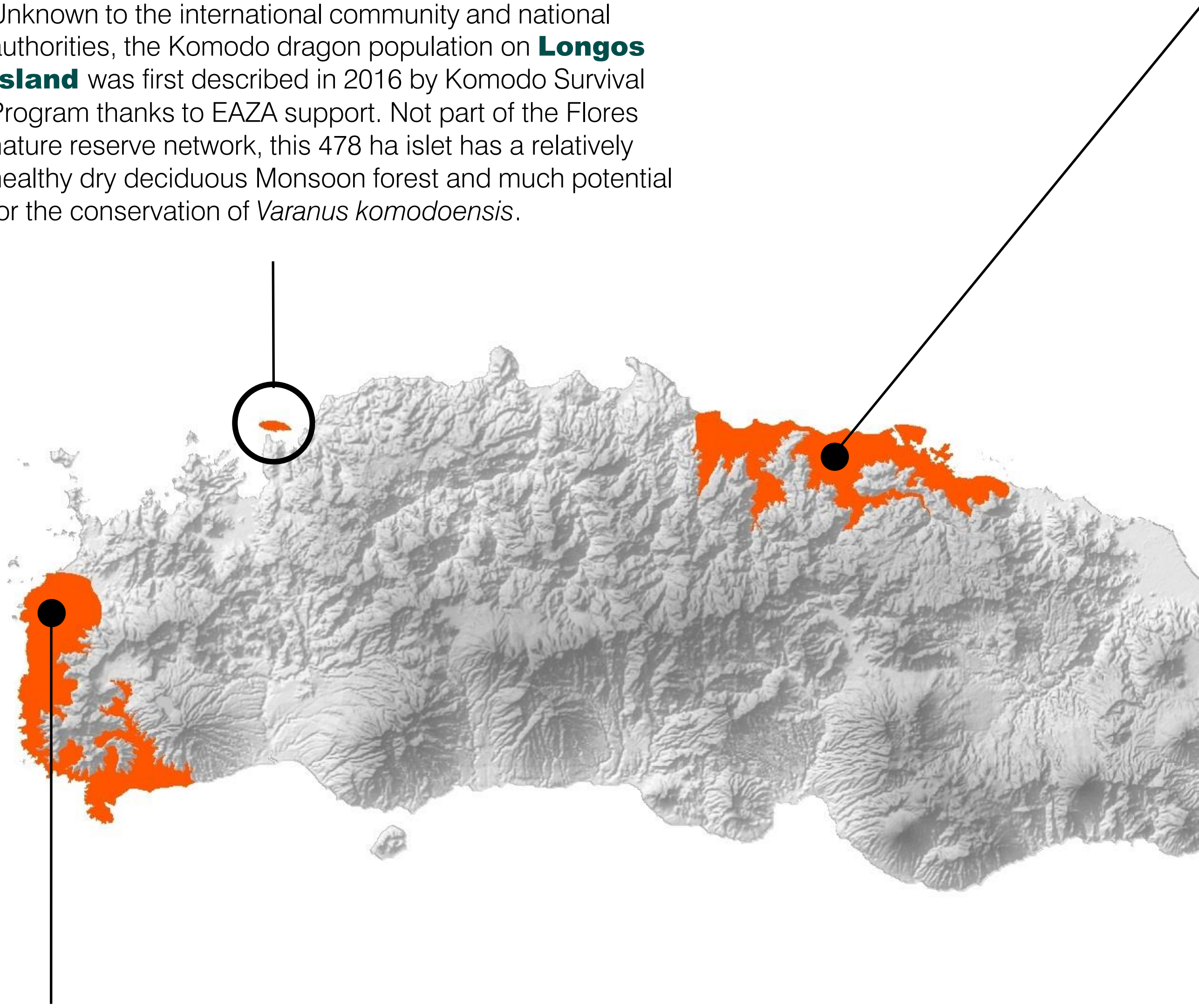
A group of handicraft makers were given the opportunity to present an exhibit on handicraft making and sell their items at the annual Flores Folklore exhibition held in the Ngada Regency and supported by the local government and the Ngada Tourism Board. This was part of the capacity building programme and one sustainable development activity for northern Flores

The dissemination programme in 2021 had a few but quite important agenda items and included a number of meetings with government and local authorities. In particular, these meetings resulted in a common agreement to set the basis for continued collaboration between KSP and BBKSDA for an additional 5 years.

Finally, in 2021, one members of the local community working closely with KSP on the community awareness programme received an appreciation award from the Director General of KSDAE for his dedication to conservation of Komodo dragons.

Project sites

Unknown to the international community and national authorities, the Komodo dragon population on **Longos Island** was first described in 2016 by Komodo Survival Program thanks to EAZA support. Not part of the Flores nature reserve network, this 478 ha islet has a relatively healthy dry deciduous Monsoon forest and much potential for the conservation of *Varanus komodoensis*.

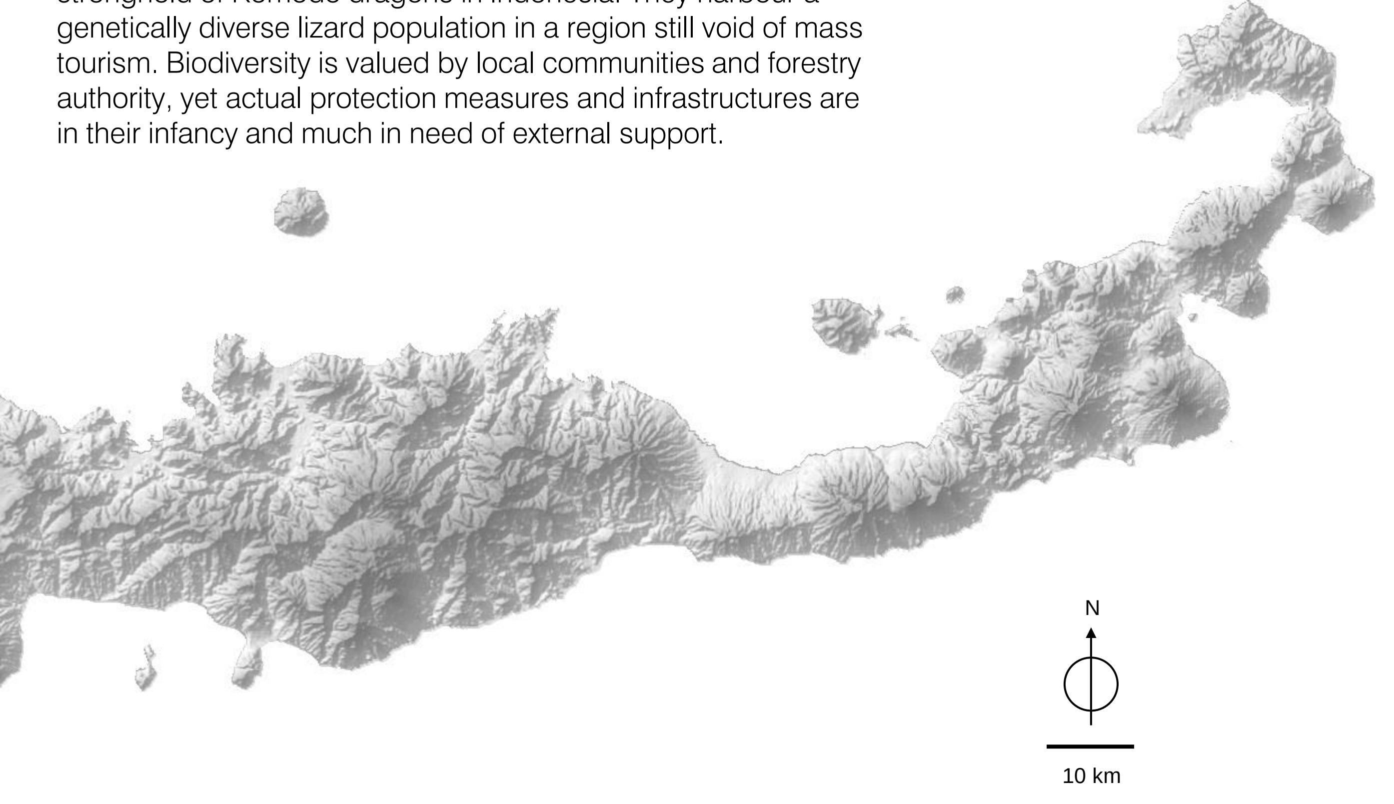


The **Wae Wuul** reserve is both a buffer zone to Komodo National Park and a geographical divide between the populated area of Labuan Bajo and the dry deciduous monsoon forest of southwest Flores. Protection of Wae Wuul is crucial to contain expansion of habitat encroachment and protect the natural habitat of Komodo dragons in western Flores.

The **district of Pota** embraces one of the largest non-protected Komodo dragon habitat in Flores. It is crucial to raise community as well as central and local government awareness on the importance of northern Flores for the sustenance of viable populations, and to envisage a protection plan for a wider portion of coastal land where Komodo dragons persist.

The **Torong Padang** peninsula is located east of the Pota district and is a buffer zone to three reserves of Wolo Tadho, Riung and Tujuh belas pulau. This area harbours a relatively stable Komodo dragon population and is pivotal to contain expansion of habitat encroachment from the relatively more populated area of Pota.

The three contiguous conservation areas of **Wolo Tadho**, **Riung** and **Tujuh belas pulau** constitute the eastermost stronghold of Komodo dragons in Indonesia. They harbour a genetically diverse lizard population in a region still void of mass tourism. Biodiversity is valued by local communities and forestry authority, yet actual protection measures and infrastructures are in their infancy and much in need of external support.



Komodo dragon distribution on Flores

Part 1

Komodo dragon population monitoring

Part 1
Komodo dragon population monitoring

Komodo dragon populations on Flores were monitored by means of remote cameras. Camera trapping, by which animals are photographed as they walk past a stand-alone camera, is a widely used methods to assess presence or absence of individuals and describe wildlife population trends, particularly for rare or elusive species. Non-invasive detection of animals is also the most valid alternative to live trapping and capture-mark-recapture studies, whereby individuals are trapped and uniquely tagged for future identification. For the most part, capture-mark-recapture studies via cage trapping seems effective for documenting demographic trends. However, long-term monitoring using capture-mark-recapture methods requires considerable logistical, economic and time efforts and costs. Moreover, animals may become trap-shy and their presence underestimated simply because a lizard won't enter a trap after experiencing a number of consecutive live trapping sevents. A comparison of detection values for Komodo dragons recorded by cage traps and by cameras in Komodo National Park indicated a higher overall detection by camera traps. No significant differences was observed between probability of detection of camera traps paired with cage traps and camera traps alone[1], indicating that detection by camera traps was not affected by animals avoiding locations with cage traps. Moreover, we showed that baited camera traps produced higher site occupancy estimats than unbaited traps whichever the sampling duration[2]. Data collected via camera trapping can be used to estimate site occupancy, whereby the proportion of sites occupied by an animal is assessed based on presence/absence data and can be used to provide estimates of population trends. Species detection probability is also calculated and defined as the probability of detecting at least one individual during a sampling session.

In 2021, we conducted camera trapping sessions in the Wae Wuul nature reserve (West coast of Flores), the Island of Ontoloe (Tujuh Belas Pulau reserve), the Island of Longos (northwestern coast of Flores), and the Pota district along the northern coast of Flores.

We used Bushnell cameras. Each device was attached to a tree approximately 40 cm above the ground and programmed to take three photos each time the animal triggered the sensor. A 15 minute delay was included to prevent repeated photography of the same individual. Baited aluminum boxes were placed in front of each camera in order to attract animals to the trapping site.

[1] Ariefiandy A, Purwandana D, Seno A, Ciofi C, Jessop TS. 2013. Can camera traps monitor Komodo dragons a large ectothermic predator? PLoS ONE. 8:e58800.

[2] Purwandana D, Ariefiandy A, Azmi M, Nasu SA, Sahudin, Dos AA, Jessop TS. 2021. Turning ghosts into dragons: improving camera monitoring outcomes for a cryptic low-density Komodo dragon population in eastern Indonesia. Wildlife Research. https://doi.org/10.1071/WR21057

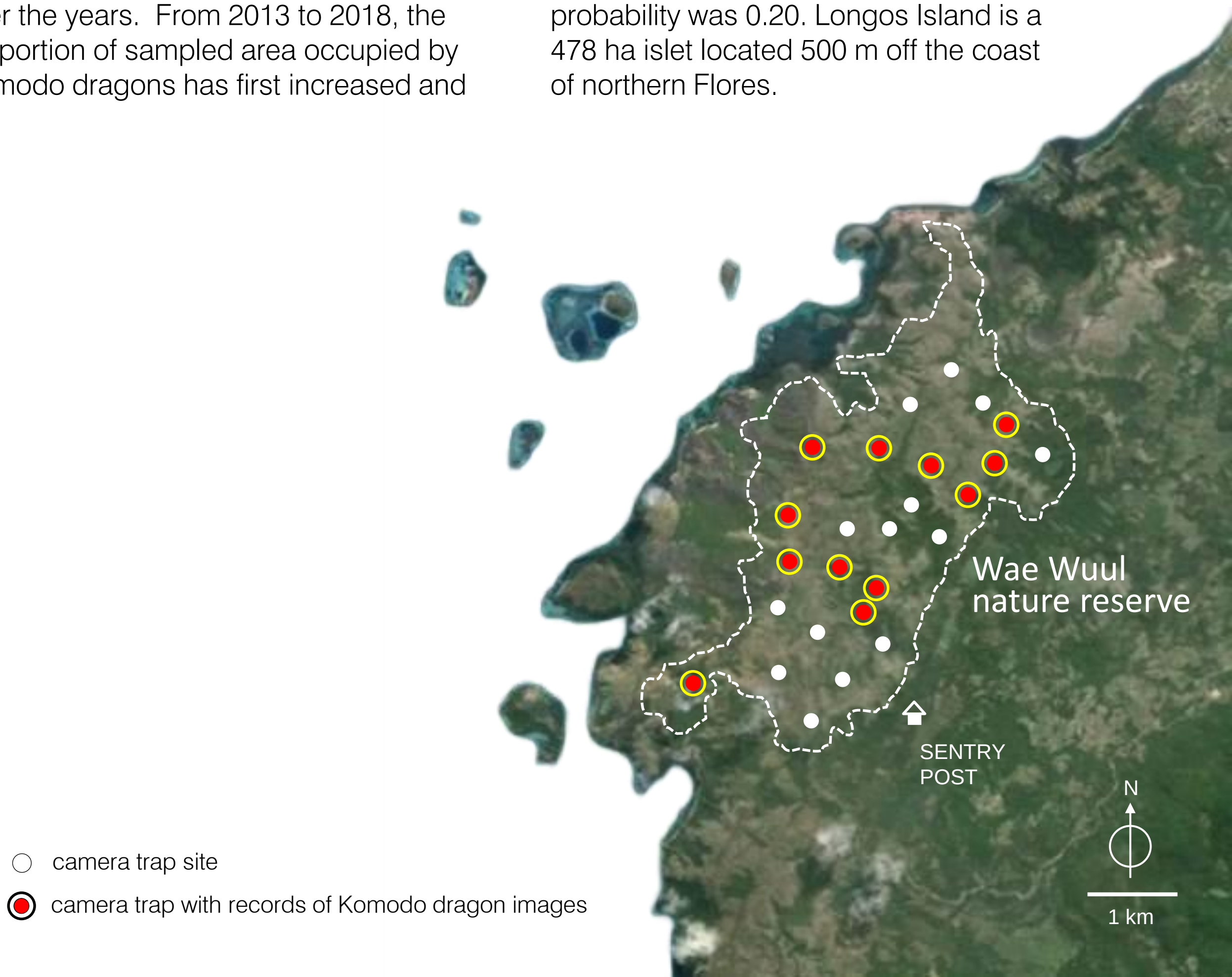
Detection probability (number of animals captured divided by the number of capture events) and proportion of sites (or sampled area) occupied by Komodo dragons based on presence/absence data were assessed using a maximum likelihood site occupancy approach implemented in PRESENCE 12.7.

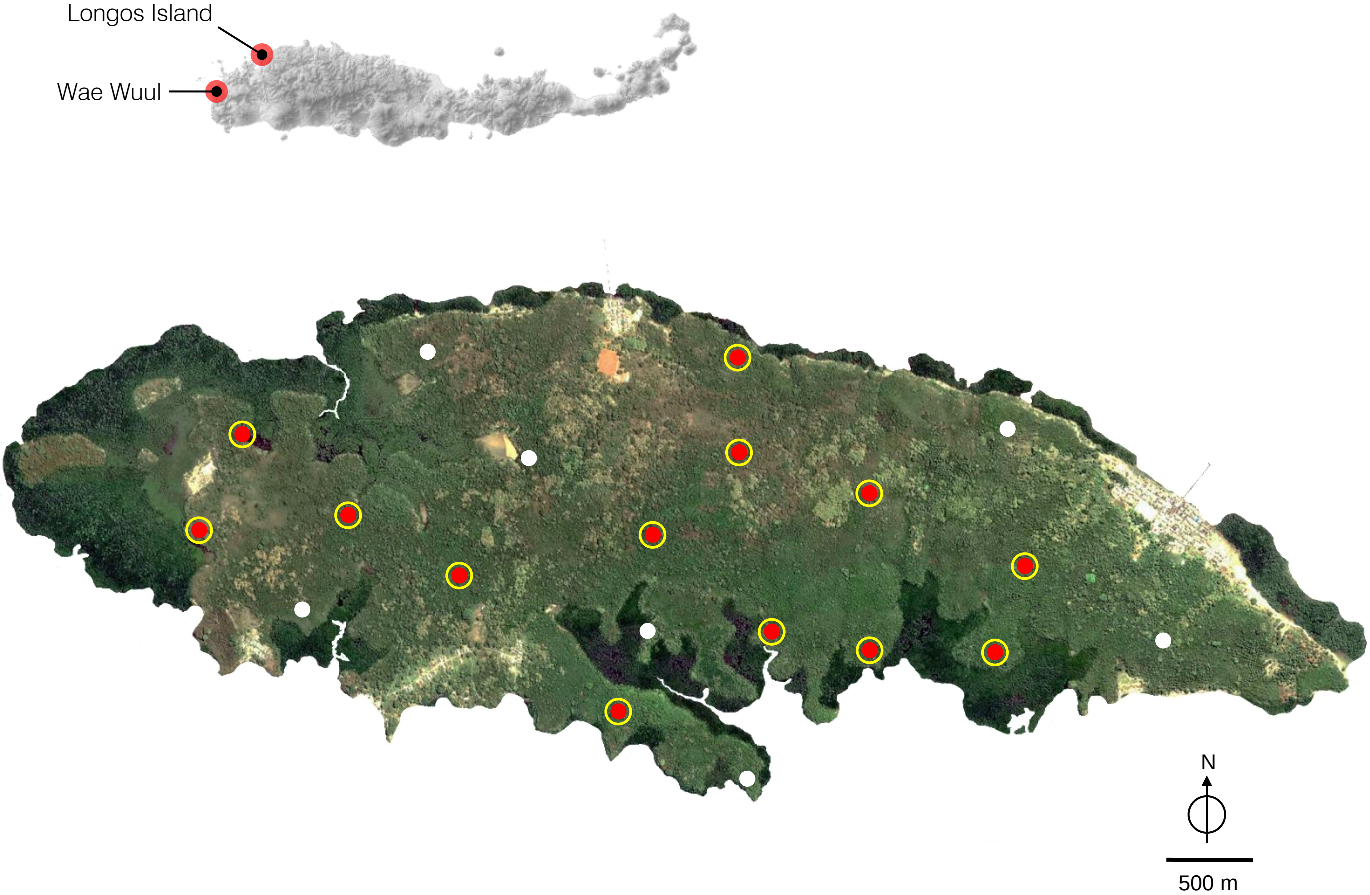
Wae Wuul

In Wae Wuul, a total of 26 camera traps were deployed in deciduous monsoon forest and savannah grassland. We recorded 22 detections at 12 camera trapping sites. Probability of detection and proportion of the Wae Wuul area occupied by dragons were 0.25 and 0.56±0.13, respectively. Site occupancy values showed a somehow variable trend over the years. From 2013 to 2018, the proportion of sampled area occupied by Komodo dragons has first increased and then dropped to relatively low figures. Occupancy then reached an apex in 2019 when for the first time as many as 17 out of 26 trapping sites recorded presence of Komodo dragons in Wae Wuul. Site occupancy has remained relatively stable since then and figures recorded in 2021 confirmed a trend which may well be the result of consistent protection activities and community awareness initiatives carried out on a regular basis by Komodo Survival Program in western Flores.

Longos

Komodo dragons were also recorded at 13 out of 20 remote cameras deployed on the Island of Longos. Site occupancy was high (0.89±0.20) and detection probability was 0.20. Longos Island is a 478 ha islet located 500 m off the coast of northern Flores.




Longos Island
Wae Wuul
N
500 m


30 °C / 86 °F
28/11/2021 08:22:50
BBKSDA NTT - KSP
37 °C
10-23-2021
15:25:37

It harbours a recently described Komodo dragon population and, although not part of the Flores nature reserve network, it has a relatively pristine dry deciduous Monsoon forest and Mangrove forest habitats. This is advocated by an increase of camera trapping events with respect to 2020 when 6 out of 20 cameras recorded presence of Komodo dragons on Longos.

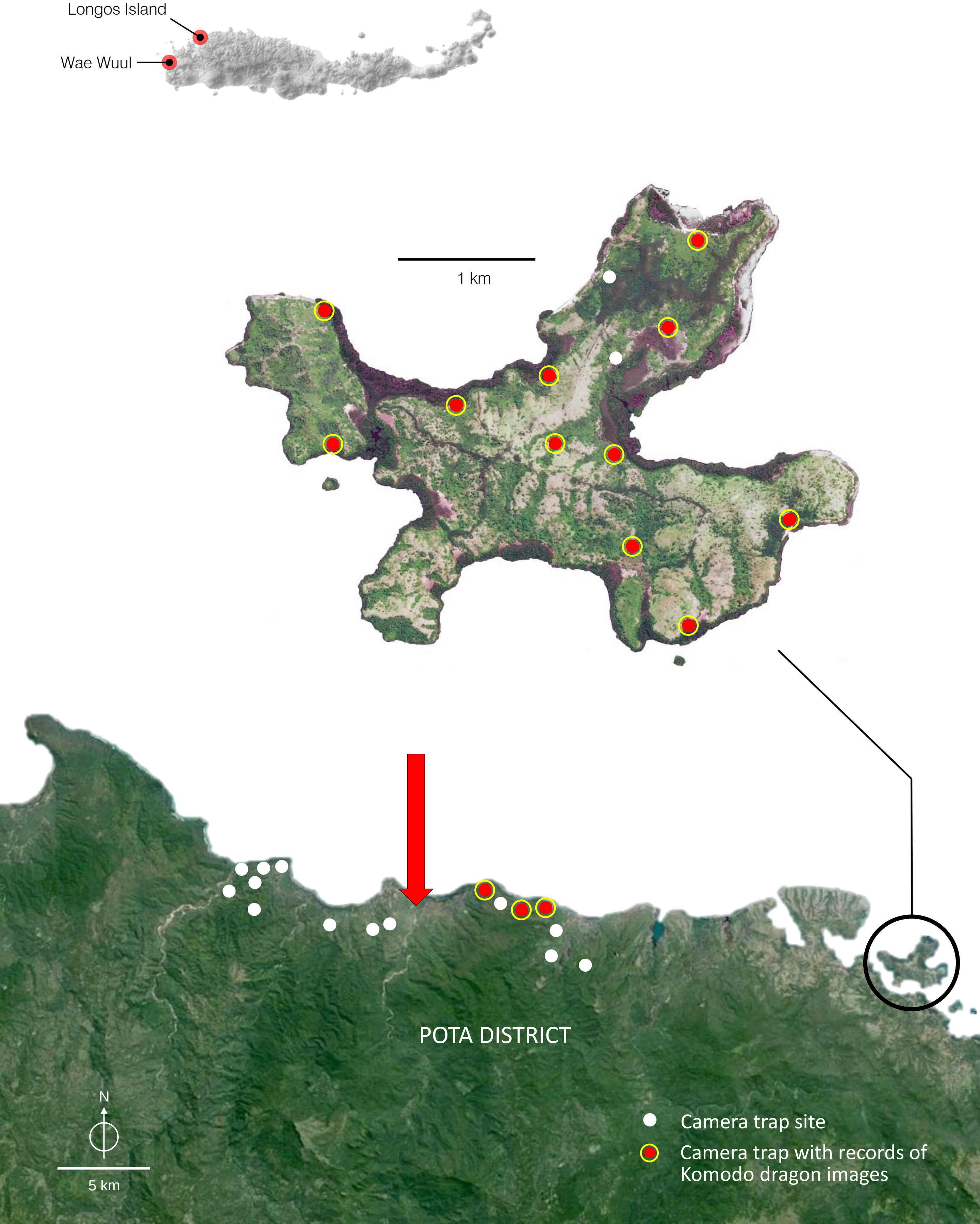
North Flores

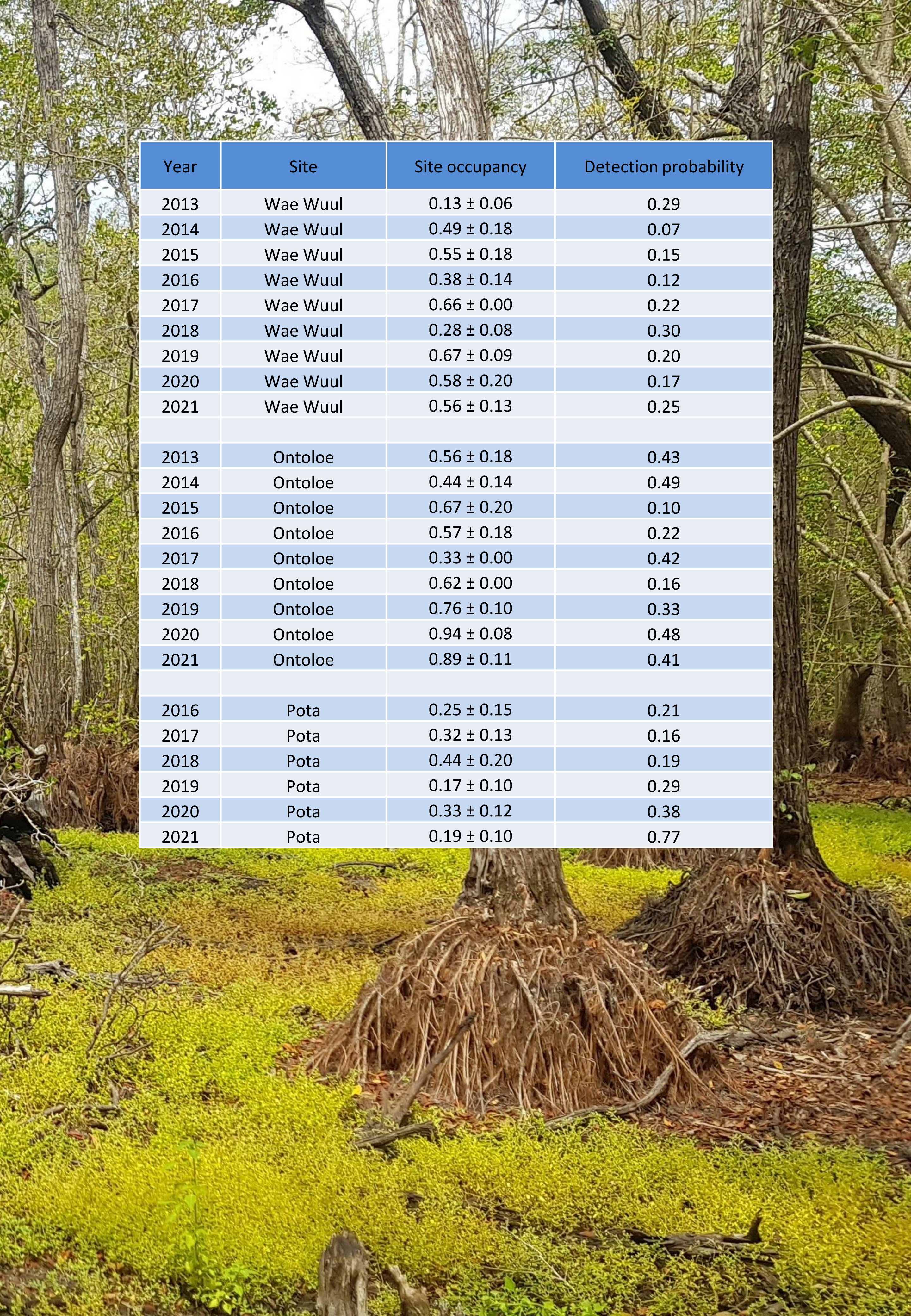
On the Island of Ontoloe, we detected 28 trapping events at 11 out of 13 camera trapping sites. Detection probability and site occupancy were 0.41 and 0.89 ± 0.11. This result advocate a stable population in the protected areas of northern Flores. On the Island of Ontoloe, part of the Tujuh Belas Pulau nature reserve, the proportion of sites occupied by Komodo dragons have remained relatively stable since 2013, with a steady increase in values recorded over the last three years.

Regular conservation measures implemented by KSP in collaboration with the Eastern Lesser Sunda Central Bureau for Conservation of Natural Resources (BBKSDA) have most probably helped maintenance of site occupancy values in the northern Flores reserves. Moreover, Komodo dragons can still be found west of the Tujuh Belas Pulau, Riung and Wolo Tadho nature reserves, particualrly in the Torong Padang pensinusla. This is an area of approximately 850 ha serving as an important ecological corridor for Komodo dragon populations in northern Flores. During a preliminary survey conducted in 2018 we recorded presence of Komodo dragons at 14 distinct trapping sites and advocated the importance of protecting Torong Padang as an area suitable for Komodo dragons and important for dispersal across the three nature reserve located east of the peninsula and the district of Pota to the west of Torong Padang.

In the Pota district, on the other hand, we recorded a total of 14 detections at only three out of 19 camera trapping stations. Detection probability was high (0.77) but occupanccy values were realtively low (0.19 ± 0.10). While we confirmed the occurrence of Komodo dragons in the Pota district in savannah and dry deciduous Monsoon forest, no trapping events were recorded est of the Buntal river, were Komodo dragons were last recorded in 2017. Occupancy estimated in the Pota district have been relatively low since the beginning of the monitoring survey, in 2016, and are currently the lowest with respect to the other study sites in northern Flores, Longos, and the western coast of the Island.

Communities in the district of Pota are expanding and the consequent conversion of natural habitats to cultivates represent a strong disturbance factor to the extant Komodo dragon population. In the Pota district, Komodo Survival Program is conducting regular and intensive community-based work in different villages and hamlets of the Province. Mitigation of human-Komodo dragon conflicts and establishment of alternative, sustainable livelihoods are being developed to minimize anthropic impact on wildlife habitat in Pota and adjacent non-protected areas of northern Flores.


Longos Island
Wae Wuul
1 km
POTA DISTRICT
N
5 km
Camera trap site
Camera trap with records of Komodo dragon images



Year	Site	Site occupancy	Detection probability
2013	Wae Wuul	0.13 ± 0.06	0.29
2014	Wae Wuul	0.49 ± 0.18	0.07
2015	Wae Wuul	0.55 ± 0.18	0.15
2016	Wae Wuul	0.38 ± 0.14	0.12
2017	Wae Wuul	0.66 ± 0.00	0.22
2018	Wae Wuul	0.28 ± 0.08	0.30
2019	Wae Wuul	0.67 ± 0.09	0.20
2020	Wae Wuul	0.58 ± 0.20	0.17
2021	Wae Wuul	0.56 ± 0.13	0.25
2013	Ontoloe	0.56 ± 0.18	0.43
2014	Ontoloe	0.44 ± 0.14	0.49
2015	Ontoloe	0.67 ± 0.20	0.10
2016	Ontoloe	0.57 ± 0.18	0.22
2017	Ontoloe	0.33 ± 0.00	0.42
2018	Ontoloe	0.62 ± 0.00	0.16
2019	Ontoloe	0.76 ± 0.10	0.33
2020	Ontoloe	0.94 ± 0.08	0.48
2021	Ontoloe	0.89 ± 0.11	0.41
2016	Pota	0.25 ± 0.15	0.21
2017	Pota	0.32 ± 0.13	0.16
2018	Pota	0.44 ± 0.20	0.19
2019	Pota	0.17 ± 0.10	0.29
2020	Pota	0.33 ± 0.12	0.38
2021	Pota	0.19 ± 0.10	0.77

North Flores

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Part 2

Komodo dragon prey population survey

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Komodo dragon prey population survey

Komodo dragons prey mostly upon Timor deer Rusa timorensis, and rely to a minor extent on the wild pig Sus scrofa and the water buffalo Bubalus bubalis. Annual trends in population abundance of these species are therefore of significant importance to assess availability of food resources for extant Komodo dragon populations on Flores. Here, direct counts of prey species are best conducted from vantage points in savannah habitats but are difficult to implement in Monsoon forest. Other direct survey methods (e.g. distance sampling) are also inappropriate, for both deer and wild pigs are quite elusive and difficult to spot through the vegetation.

On Flores, we used an indirect methods to assess prey population density based on faecal pellet group counts as an index of relative abundance of the main prey species of Komodo dragons. The relationship between this index and known densities of preys has been widely evaluated and generally has shown that pellet group density is positively correlated with prey density2. Moreover, the survey is conducted in the late dry season in the near absence of rain for several months, so that faecal decay rates are presumed very low, providing a long-term index of prey availability.

Surveys were conducted since 2009 in Wae Wuul, in the Pota district and on the Island of Ontoloe, part of the Tujuh Belas Pulau nature reserve, where Komodo dragon prey species did not appear to have experienced drastic changes in population density. In 2021, we conducted our survey in west Flores only. A table of random numbers was used to locate start points across grid referenced digital maps for 42 linear transects across the Wae Wuul nature reserve.

The 150 m long transects consisted of thirty 3.14m2 circular plots (i.e., a radius of 1 m) at 5 m intervals. The plots were thoroughly searched and the total number of deer pellet groups or intact faeces of wild pigs and buffaloes were recorded on each plot. A density index based on average number of pellet groups or faeces per transect (which covered an area of 94.2 m2) was calculated by dividing the number of pellet groups (or faeces) found along each transect by the number of transects.

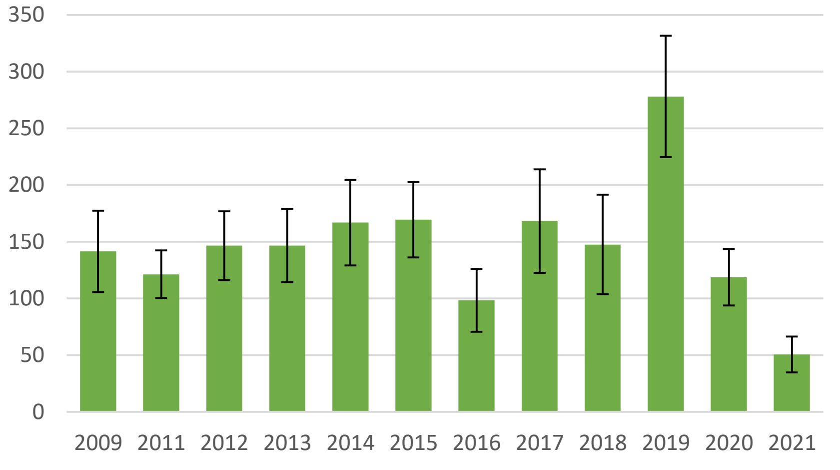
In Wae Wuul, the 2019 survey recorded a sharp increase in mean Timor deer pellet group density with respect to previous years. That was an average density of approximately 275 pellet groups per ha compared to 150 and 170 pellet groups per ha recorded in 2018 and 2017, respectively. In 2020, however, deer pellet group densities were approximately 120 per ha and in the latest 2021 survey down to 55 groups per ha.

[2] Ariefiandy A, Purwandana D, Coulson G, Forsyth DM, Jessop TS. 2013. Monitoring the ungulate prey of the Komodo dragon *Varanus komodoensis*: distance sampling or faecal counts? Wildlife Biology. 19:126–137.

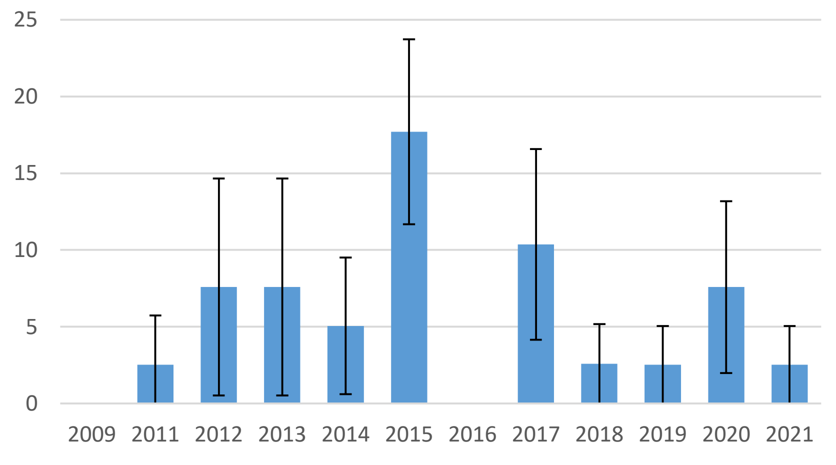
This sharp decrease in deer density might be due to late surveys that were conducted at the onset of the rain season in 2020 and 2021. This probably accelerated the feacel decay rates and therefore provided an understiamte of the actual counts. Deer population in Wae Wuul appears to have maintained a relatively stable density from 2009 to 2020. This is an indication of consistent resource availability for Komodo dragons. Regular implementation of community awareness initiatives and patrolling in Wae Wuul by Komodo Survival Program in collaboration with the local branch of the Indonesian Department of Forestry has also helped maintaining a viable deer population and a regular pattern of prey-predator interactions. However, the significantly low figure recorded in 2021 needs careful consideration and will have to be evaluated along with the density estimates which will be recorded in the upcoming survey planned for 2022.

Similarly. wild pigs had an avergage scat density of 2.5 faeces per ha, a lower figure with respect to 2020 but similar to values recorded in 2019. The general population trend of *Sus scrofa* appears variable over the years. Wild pigs move quite long distances during the 24 hours and this may affect differences in pellet densities recorded across years. As for the deer density estimates, values recorded in 2021 will have to be evaluated along with upcoming 2022 numbers in order to determine whether boar are decreasing in western Flores.

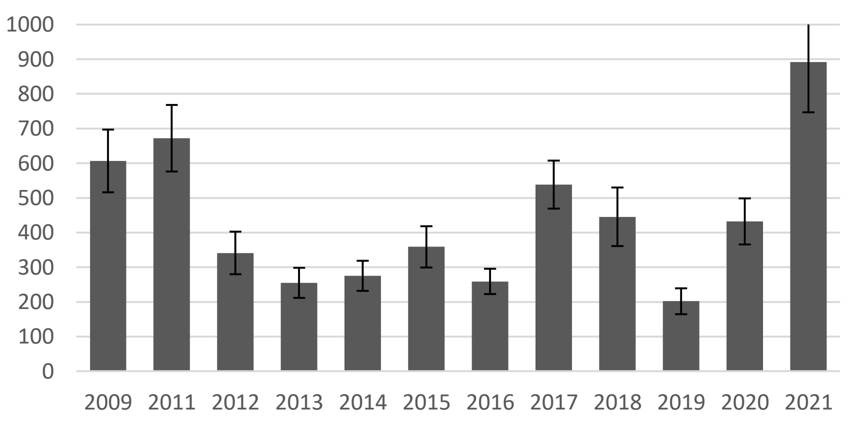
A increase in average scat densities was instead recorded in 2021 for water buffaloes. Since 2009, we recovered a relatively stable trend for the Wae Wuul populaiton of *Bubalus bubalis*, with a sharp increase reported by the latest survey. In Wae Wuul, water buffalos are mainly part of tamed herds owned by people from nearby villages. Members of the local community mark animals with ear tags and let them graze in the Wae Wuul reserve. Water buffalos represent an alternative, valuable prey for Komodo dragons in Wae Wuul. Lizards prey upon *B. bubalis* less frequently than they do upon deer and rely mainly on weak or ill individuals, which are easier to ground. The figures reported by the 2021 survey may reflect an increased in reproductive rate or simply in the number of new heards brought to Wae Wuul. Either ways, the increase in buffalo density represent an increment in the diversity of preys available to Komodo dragons.



Timor deer



Wild pigs



Water buffaloes

Part 3

Habitat protection Community awareness and Education

Part 3

Habitat protection, Community awareness and Education

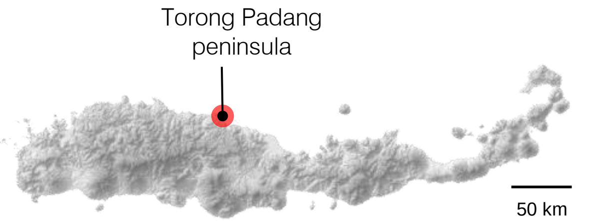
Patrolling activities

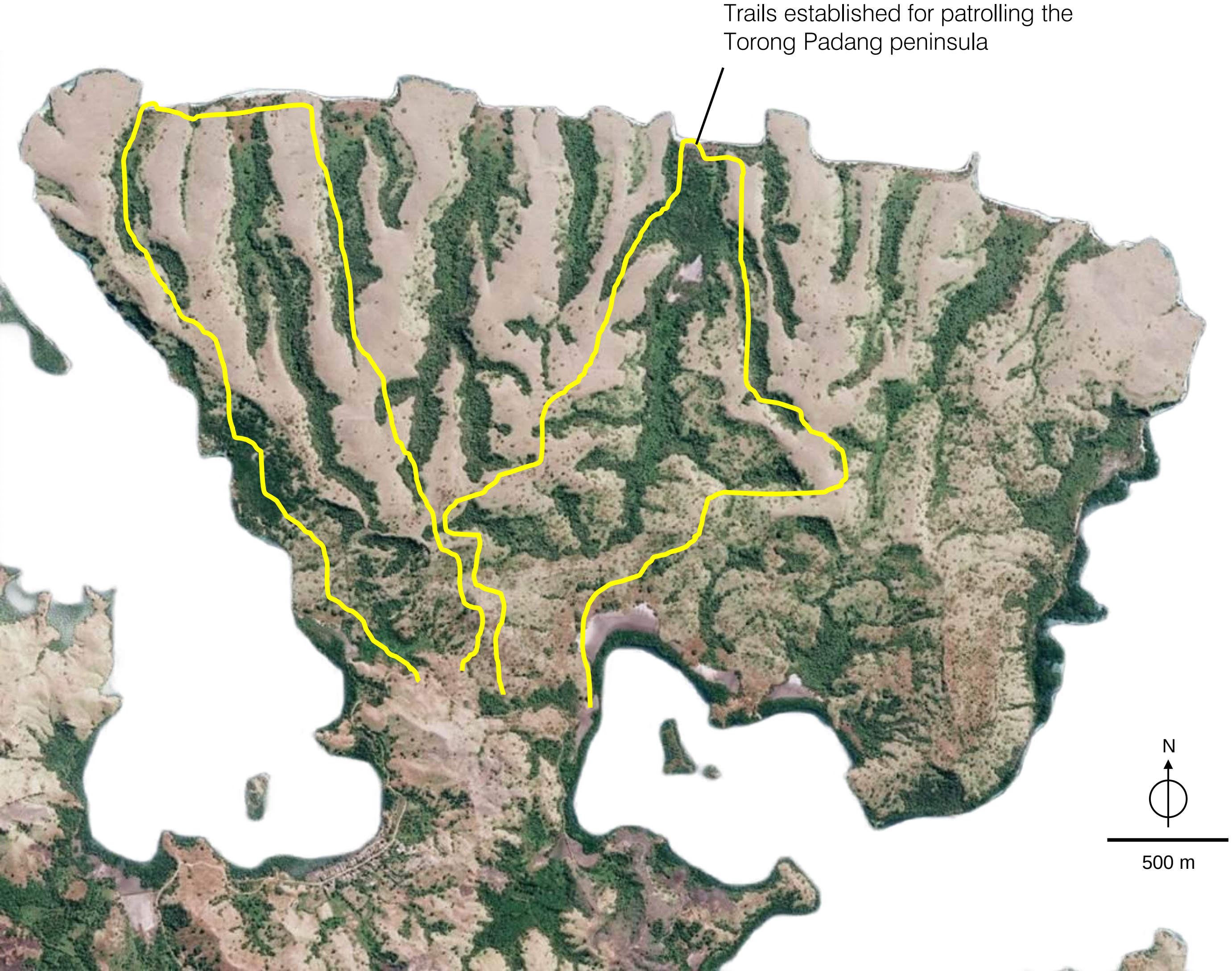
In 2021, we conducted patrolling activities across Torong Padang peninsula, off the western borders of the Tujuh belas pulau nature reserve, northern Flores. Patrolling and surveillance included the involvement of local staff of BBKSDA, local police and Masyarakat Peduli Api (MPA), a task force made of 10 people from local villages living close to the nature reserve and the Torong Padang peninsula. The MPA was first established in 2014 and helps BBKSDA staff in patrolling protected areas.

Patrolling activities consisted in regular hiking along established trails to prevent or spot and extinguish bushfires, discourage illegal hunting of deer and wood harvesting. This initiative was conducted twice a month during the dry season in full agreement with local government authorities. Weekly briefings provided opportunities for staff of BBKSDA to discuss team rotations and solutions to problems encountered during surveys conducted with the local community. Patrolling trails on Torong Padang were established along two main paths covering key areas of the peninsula. The starting and ending point of each path were set along a white road in the southern part of the area. Patrols were conducted from 7 am to 11 am and then again from 4 pm to 6 pm. Field schedule was followed pretty regularly with no major inconveniences.

Patrolling activities were conceived in accordance to Spatial Monitoring and Reporting Tool - SMART protocols (https://smartconservationtools.org), which will be fully implemented in 2022 to collect, store and subsequently evaluate data on patrol efforts, patrol results, and threat levels. In the Torong Padang peninsula, in particular, we experiment SMART in order to map data from systematic surveys of Komodo dragon habitats and understand species and habitat changes over space and time, if any, as well as factors responsible for the changes. At the same time, we plan to use SMART to maintain records of local staff participation in patrolling events, manage the maintenance schedules for field equipment, and track incidences of habitat encroachment and possible human-wildlife conflict around the peninsula.

Patrols found no particular issues during their walks, apart from a few instances of illegally cut wood, harvested most probably to set fireplaces for cooking. No wild fires, snares or poaching were recorded. This is most probably the result of an agreement signed in 2019 to protect the peninsula and limit deer hunting to just a single annual event conducted using traditional spears.


Torong Padang
peninsula
50 km


Trails established for patrolling the
Torong Padang peninsula
N
500 m

Community awareness

In 2021, community awareness activities were conducted on the Island of Longos and the village of Sambirampas, District of Pota, located on the northern coast of Flores. Awareness sessions were led by staff members of the NGO Komodo Survival Program (KSP) to reiterate sustainable use of natural habitats habitats, emphasize the importance of minimizing levels of encroachment to monsoon forest and savannah habitat, as well as the beneficial, long-term effect of preventing intensive poaching on Komodo dragon prey species, and restate the commitment of national and international sponsors in sustainable development program. Activities involved first a preliminary meeting with local religiuos leaders and autorities. The team conducting community awareness sessions included staff of the Indonesian Central Bureau for Conservation of Nature Resources (Balai Besar Konservasi Sumber Daya Alam – BBKSDA) and KSP. Sessions were attended by religious leaders (mainly Muslim), village chiefs and community members. Staff from BBKSDA and KSP gave presentations on the importance of nature reserves and law enforcement activities in protected areas. The awareness programme also included initiatives similar to those conducted in 2019 and 2020, namely on local people perception about wildlife.

Habitat encroachment and occasional illegal hunting on Komodo dragon preys have recently resulted in Komodo dragons getting closer to the forest edge adjacent to human settlements, therefore increasing frequency of human-wildlife conflict events often spurred by depredation of Komodo dragons (and often feral dogs) upon livestock.

Rounds of prelimnary interviews were conducted to describe the general attitude of people towards Komodo dragons and their perception of monitor lizards as a possible asset for sustainable development. As for past surveys conducted in the Pota District, compehensive description of the species life habits, mitigation measures undertaken in nearby villages and examples of how Komodo dragon protection can be linked to ecotourism activities, led to a general increase in positive attitudes towards Komodo dragons and a perceived higher intention to coexist with lizards. As for previous surveys, the 2021 programme showed a clear potential to change local communities attitude towards Komodo dragons, also thanks to the capacity building initiatives regularly conducted on the northern coast of Flores. This is particularly relevant when considering responses by livestock owner from Sambirampas. First interviews revealed an overall negative attitude towards Komodo dragons, which were then seen as a possible asset by the very same people following mitigation measures which KSP has been conducting in 2016 and then again from 2019 onwards.

Education

Community awareness and education activities were also conducted in primary schools on the island of Longos and the village of Sambirampas in the Pota district. We held both classes for children and seminars for teachers in collaboration with staff members of BBKSDA. The general aim was to give pupils a general background knowledge on the terrestrial biodiversity and assess whether education activities can be of an importance for kids' perception and attitude toward biodiversity conservation. In Longos, classes were held at Kapung Baru elementary school with 31 students attending classes. Documentaries and educational cartoons on Komodo dragons were shown to kids prior to engage in interactive classes.

In Pota, we provided with educational material and gave lectures on Komodo dragons and biodiversity conservation to 24 students from the Mataram student association (located east of the Pota district) and 14 undergraduate students from Yogyakarta Muhammadiyah University who were visiting the area. A similar programme to the one implemented in Longos was presented to 20 students from the Sambirampas Catholic Youth Organization.

Environmental education classes were given to students visiting the Pota district at the Pota Komodo dragon information center (a facility build thanks to EAZA funds) by a local community member who has been involved with KSP in Komodo conservation since 2012. This is a particularly imporatant example of how knowledge transfer can help establish local expertise to foster regular environmental education which in turn can help conservation of wildlife and natural habitats in northern Flores.

Part 4

Capacity building and Dissemination

Part 4

Capacity building and Dissemination

Handicraft production and exhibition

Since 2016, community based initiatives are in place whereby selected members of the local community who have shown specific wood carving skills are encouraged to produce and sell handicrafts. These are handicraft characters resembling local wildlife, in particular Komodo dragons in different postures, including male combats. Other wildlife such as deer and buffaloes are also carved. As for Komodo National Park, handicrafts are meant to be sold directly to tourists and shops and airports throughout Indonesia. Wood carving activity, based on sustainable and strictly monitored wood harvesting, is one remunerative activity for people living within the boundaries of Komodo National Park and has the potential of developing in a similar sustainable activity in northern Flores. In the first editions of the initiative, Muksim Gantong, a local carpenter from Sambinasi village, North Flores, was trained in making wooden handicraft in Komodo village (Komodo National Park). After learning how to improve his skill in wood carving, he returned to Sambinasi village and became himself the trainer of other local community members. Muksim Gantong has now six apprentices and together are now part of a carpenter group named “Baar tribe Komodo dragon wood carvers” at Marotauk village.

In 2021, this group of handicraft makers were given the opportunity to present an exhibit on handicraft making and sell their items at the annual Flores Folklore exhibition held in the Ngada Regency and supported by the local government and the Ngada Tourism Board. Practical workshop sessions were held by the Baar tribe Komodo dragon craftsmen who demonstrated the different steps involved in the making of wooden Komodo dragon characters. Participants did sell their products and had the opportunity to participate to roundtables set up to define strategies for fostering production and selling products to a wider audience nation-wide. We believe such grassroots initiatives to be very important and will likely pave the way for additional alternative likelihoods plans aimed at protecting and conserving extant Komodo dragon populations in northern Flores.

Training

Capacity building programme included training of staff members of BBKSDA in wildlife monitoring techniques. This is a long-standing initiative that has been successfully conducted for more than 10 years and has involved a large number of BBKSDA technical staff. Training sessions included lectures, class and field training in the use of monitoring devices, including GPS and passive infrared cameras to assess presence/absence and trends of Komodo dragon populations. We provided background knowledge on ecological methods for assessing animal population abundance and density based mainly on camera trapping and the use of dedicated software for site occupancy data analyses. Training sessions were held in Labuanbajo in November 2021, and included practical session on the use and deployment of camera traps, sampling design and data analyses using the software PRESENCE 12.7. Teaching material included a copy of the software to be installed on personal computers, handbooks, printouts and teacher guides. In 2021, the workshops were attended by 10 BBKSDA rangers and technical staff from the Lessere Sunda Region.

Dissemination

The dissemination programme in 2021 had a few but quite important agenda items and included a number of meetings with government and local authorities and recognition awards to KSP. Meetings with authorities are necessary for reinforcing current collaboration efforts for the implementation of wildlife monitoring, community awareness, capacity building and infrastructure development initiatives. An evaluation meeting was first held at BBKSDA offices in Kupang, West Timur, in order to disseminate 2020 and 2021 results of the 5-year collaboration project to the Director of BBKSDA, local authorities and stakeholders.

These meetings also resulted in a common agreement to set the basis to continue the current collaboration between KSP and BBKSDA for an additional 5 years. Both parties agreed that a renewal of the agreement should emphasize the involvement of local community in the protection and conservation of Komodo dragons also beyond the current protected areas on western and northern Flores. The programma should also foster current capacity building of BBKSDA staff, including the possibility of enrolling in higher education programs in Indonesian Universities and by increasing knowledge transfer on Komodo dragon research in order to continue creating expertises among local authority employees.

Awards & Recognitions

In 2021, KSP received an award from the Preparatory Committee of the Fifteenth meeting of the Conference of the Parties to the Convention on Biological Diversity (COP15), UN-CBD Secretariat, as one of 108 "Noteworthy Practices" for long-term multidisciplinary efforts for the protection of Komodo dragons in Flores. The award was given as a recognition of the ongoing collaborative work between the Indonesian government (BBKSDA NTT) and KSP, particularly for the continued involvement of local community members as one of the main actors in Komodo dragon conservation in non-protected areas on the Island of Flores.

During the last three years, KSP successfully changed people perspective and attitude towards Komodo dragons. If monitor lizards were considered pests which preyed upon livestock, they were later regarded as an asset, a practical mean for sustainable development to be conserved along with its natural habitat. This change in perspective was also the result of KSP mitigation progamme whereby a signficant decrease in the number of human-wildlife conflicts and Komodo dragon killings were recorded.

An additional award was granted to Arsyad, a member of the local community from northern Flores, by the Director General of Nature Conservation and Ecosystem of the Ministry of Environment and Forestry for his dedication in helping KSP activities in the District of Pota, Tujuh Belas Pulau Reserve and the Torong Padang peninsu, and particularly for his overall support as a local community member of the education program in northern Flores.


KEMENTERIAN LINGKUNGAN HIDUP DAN KEHUTANAN
DIREKTORAT JENDERAL KONSERVASI SUMBER DAYA ALAM DAN EKOSISTEM

PIAGAM PENGHARGAAN

Nomor : PI.380/KSDAE/SET.3/PEG.7/6/2021

Diberikan Kepada :

Arsyad

Tokoh Muda Pecinta Lingkungan

Atas kegigihan dan peran aktifnya dalam mendukung pengelolaan konservasi sumber daya alam dan ekosistem melalui aksi penyelamatan satwa dilindungi Varanus komodoensis dan sosilisasi kepada masyarakat sejak tahun 2012

Jakarta, 26 Juni 2021
Direktur Jenderal,

Ir. Wiratno, M.Sc.
NIP. 19620328 198903 1 003

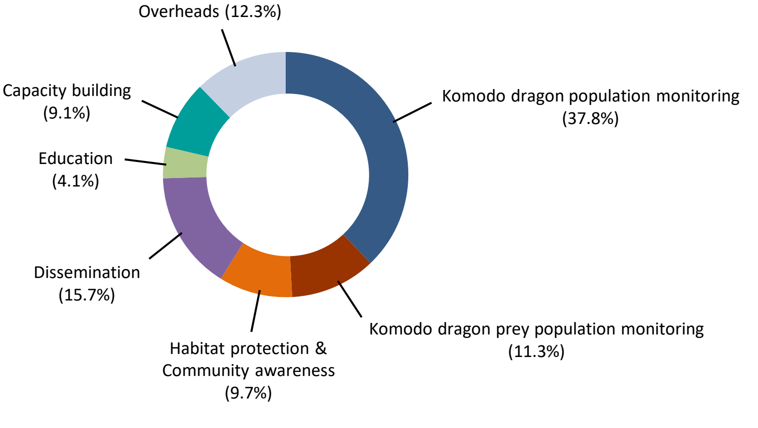
Road To HKAN 2021

"Harmony Ring Of Beauty With 3A"
(Aparigraha, Ahimsa, Anekanta)

2021 BUDGET BREAKDOWN

Indonesian Rupiah

KOMODO DRAGON POPULATION MONITORING		
Fieldwork expenses and equipment	Rp	177,631,483
Indonesian staff stipends	Rp	53,000,000
Total Expenses	**Rp**	**230,631,483**
KOMODO DRAGON PREY POPULATION MONITORING		
Field work expenses	Rp	57,000,000
Indonesian staff stipends	Rp	12,000,000
Total Expenses	**Rp**	**69,000,000**
HABITAT PROTECTION & COMMUNITY AWARENESS		
Local transportation and accomodation	Rp	2,652,000
Community awareness meetings	Rp	12,939,008
Coordination meetings	Rp	7,500,000
Indonesian staff stipends	Rp	12,000,000
Operational costs	Rp	24,000,000
Total Expenses	**Rp**	**59,091,008**
CAPACITY BUILDING		
Community awareness meetings	Rp	12,939,008
Training and capacity building programs	Rp	18,282,287
Indonesian staff stipends	Rp	24,000,000
Total Expenses	**Rp**	**55,221,295**
DISSEMINATION TO GOVERNMENT AUTHORITIES		
Coordination and dissemination meetings with BBKSDA in Kupang	Rp	32,763,825
MoU between KSP and BBKSDA	Rp	23,605,942
Dissemination meeting with Directorate General KSDAE in Jakarta	Rp	7,148,300
Dissemination meeting with local Government in Longos	Rp	20,000,000
Indonesian staff stipends	Rp	12,000,000
Total Expenses	**Rp**	**95,518,067**
EDUCATIONAL ACTIVITIES AT POTA EDUCATION CENTER		
Educational materials	Rp	11,120,000
Field assistant stipends	Rp	14,000,000
Total Expenses	**Rp**	**25,120,000**
OVERHEADS		
KSP 2021 overheads	Rp	75,000,000
Total Expenses	**Rp**	**75,000,000**
GRAND TOTAL EXPENSES	**Rp**	**609,581,853**



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Turning ghosts into dragons: improving camera monitoring outcomes for a cryptic low-density Komodo dragon population in eastern Indonesia

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Abstract

Context. Detection probability is a key attribute influencing population-level wildlife estimates necessary for conservation inference. Increasingly, camera traps are used to monitor threatened reptile populations and communities. Komodo dragon (*Varanus komodoensis*) populations have been previously monitored using camera traps; however, considerations for improving detection probability estimates for very low-density populations have not been well investigated.

Aims. Here we compare the effects of baited versus non-baited camera monitoring protocols to influence Komodo dragon detection and occupancy estimates alongside monitoring survey design and cost considerations for ongoing population monitoring within the Wae Wuul Nature Reserve on Flores Island, Indonesia.

Methods. Twenty-six camera monitoring stations (CMS) were deployed throughout the study area with a minimum of 400 m among CMS to achieve independent sampling units. Each CMS was randomly assigned as a baited or non-baited camera monitoring station and deployed for 6 or 30 daily sampling events.

Key results. Baited camera monitoring produced higher site occupancy estimates with reduced variance. Komodo dragon detection probability estimates were 0.15 ± 0.092–0.22 (95% CI), 0.01 ± 0.001–0.03, and 0.03 ± 0.01–0.04 for baited (6 daily survey sampling events), unbaited (6 daily survey sampling events) and long-unbaited (30 daily survey sampling events) sampling durations respectively. Additionally, the provision of baited lures at cameras had additional benefits for Komodo detection, survey design and sampling effort costs.

Conclusions. Our study indicated that baited cameras provide the most effective monitoring method to survey low-density Komodo dragon populations in protected areas on Flores.

Implications. We believe our monitoring approach now lends itself to evaluating population responses to ecological and anthropogenic factors, hence informing conservation efforts in this nature reserve.

Keywords. population monitoring, effective sampling, protected areas, apex predator, reptiles, *Varanus komodoensis*.

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Introduction

Large terrestrial predators are most often at risk from human actions and increasingly require effective conservation actions to ensure population persistence (Gittleman and Harvey 1982; Prowse *et al.* 2015; Penjor *et al.* 2019). The key requirement to establish effective conservation actions for apex predators is to accurately monitor population trends and status (Karanth *et al.* 2011). However, because apex predators are often rare or averse to capture or detect, non-invasive monitoring methods are routinely used to evaluate the effects of threatening processes or conservation actions on their populations (Karanth *et al.* 2004; O'Connell *et al.* 2010). Similarly, the increasing use of hierarchical models such as site occupancy and n-mixture models, which account for imperfect detection, are now among the most common techniques used to provide population-level inference for apex predators (MacKenzie *et al.* 2002, 2006; Royle 2004; Kéry *et al.* 2005). Indeed, these methods are often well suited for threatened predator population studies (du Preez *et al.* 2014; Tan *et al.* 2017; Penjor *et al.* 2019; Searle *et al.* 2020), because threatened predators often persist at low densities where individual-based recapture or resighting probabilities can be too low to allow for the alternate population estimates using mark–recapture type models (Williams *et al.* 2002; Kéry and Schmidt 2008; Couturier *et al.* 2013; du Preez *et al.* 2014; Tan *et al.* 2017; Searle *et al.* 2020).

Non-invasive monitoring techniques such as camera trapping are now increasingly used for monitoring terrestrial reptiles, a taxon with over 11 000 primarily predatory species (Ariefiandy *et al.* 2013; Jessop *et al.* 2013; Welbourne *et al.* 2015; Adams *et al.* 2017; Moore *et al.* 2020). Nevertheless, the use of cameras, as measured by the capacity to achieve adequate detection for robust population-level estimates, remains variable within and among reptile species because of the effects of body size, species habits and environmental factors (Ariefiandy *et al.* 2013; Welbourne *et al.* 2015; Richardson *et al.* 2017; Einoder *et al.* 2018). In the case of large reptiles, lower population densities, greater daily movement capacity, the effects of seasonal climatic variation, and smaller skin surface to ambient air temperature differences can all influence camera-based population monitoring effectiveness (Ariefiandy *et al.* 2013; Jessop *et al.* 2013; Welbourne 2013; Richardson *et al.* 2017; Hu *et al.* 2019). Furthermore, human activities can often disproportionately threaten large-bodied reptiles, causing their populations to be at much lower densities than normal and thus more difficult to monitor (Todd *et al.* 2010; Tingley *et al.* 2019). Thus, addressing these factors by modifying camera sampling designs to increase detection probability is a key consideration to monitor threatened reptile populations effectively. Under such circumstances, there may be compelling reasons to improve camera-based detection using baits or lures (i.e. attractants) to increase detection probability (O'Connell *et al.* 2010; Long *et al.* 2012; Read *et al.* 2015).

Multiple studies have reported that the use of baits or lures as attractants can vastly improve predators' detection sensitivity (du Preez *et al.* 2014; Austin *et al.* 2017; Comer *et al.* 2018). This result is especially important in predator populations where individuals can be cryptic or persist as low-density populations. Hence, attractants or baits may be essential to increase detection to prevent poor quality estimates of population-level parameters (Thompson 2013). For this reason, baited camera traps deployed during appropriate weather conditions can be advocated to optimise large-reptile detection probability (Jessop *et al.* 2013). Although, it is important to note that these benefits may need to consider how baits can affect a species' movement behaviour and create potential biases in any arising population-level estimates (Stewart *et al.* 2019).

The Komodo dragon (*Varanus komodoensis*) is the largest lizard and has an important ecological role as an apex predator (Jessop *et al.* 2006, 2019, 2020). The current distribution of Komodo dragons is restricted to five islands located in Komodo National Park and several fragmented populations on Flores Island (Jessop *et al.* 2007, 2018; Purwandana *et al.* 2014*a*; Ariefiandy *et al.* 2015; Jones *et al.* 2020). Populations on Flores Island have decreased because of anthropogenic activities and are now increasingly reliant on a small number of reserve areas to ensure their persistence (Ariefiandy *et al.* 2015, 2020; Jones *et al.* 2020).

Komodo dragon populations on Flores persist at much lower population densities ($<$1 dragon km^{-2}) than those observed in Komodo National Park ($\sim$10 dragons km^{-2}; Laver *et al.* 2012; Purwandana *et al.* 2014*a*; Ariefiandy *et al.* 2015, 2020). Multiple field methods have been used to estimate population trends of Komodo dragons (Ariefiandy *et al.* 2013, 2014). However, these can vary considerably in their monitoring effectiveness (Jessop *et al.* 2007; Ariefiandy *et al.* 2013, 2014; Purwandana *et al.* 2014*a*, 2015). On Flores, low densities and trap-wary behaviour of Komodo dragons favour wildlife cameras over direct trapping methods as a more effective population monitoring methodology (Ariefiandy *et al.* 2015). However, optimising camera monitoring design is still necessary to allow conservation managers to improve the data used to evaluate these most vulnerable populations (Jones *et al.* 2020). Here, we compare the effect of baited and unbaited camera sampling on the estimates of Komodo dragon detection probability and site occupancy, alongside other measures of monitoring efficacy and project running costs within the Wae Wuul Nature Reserve of Flores. Finally, we discuss the implications of our results for managing Komodo dragons within this protected area and, more broadly, for other populations distributed on the island of Flores.

Materials and methods

Study area

The Wae Wuul Nature Reserve comprises a protected area of 14.84 km^2 located on the western coast of Flores in eastern Indonesia (Fig. 1*a, b*). The reserve was established in 1985, aiming to increase protection of Komodo dragons beyond Komodo National Park. The climate is highly seasonal, dominated by a long dry season from March to November and a short wet season. Annual rainfall is less than 2000 mm (Monk *et al.* 1997). The study area comprises a hilly coastal landscape covered in multiple distinct vegetation communities. The two most common vegetation communities are savanna grassland (common species include *Eulalia leschenaultiana* and *Setaria adhaerens*) and savanna woodland (common species include *Borassus flabellifer* and *Zizyphus horsfeldi*) that cover $\sim$80% of the study area (Auffenberg 1981). In valley floors holding permanent or ephemeral watercourses, drier vegetation communities are replaced by open deciduous monsoon forest ($\sim$20% of the study area; dominant species include *Tamarindus indica*, *Schleichera oleosa* and *Cassia javanica*) or bamboo forest. These land cover types are representative of those found across the lowland coastal areas of major islands in this region of eastern Indonesia, including the adjacent Komodo National Park (Auffenberg 1981).

Study design

Twenty-six camera monitoring stations (CMS) were deployed within the Wae Wuul Nature Reserve. These CMS were placed within all key vegetation communities, including deciduous monsoon forest and savanna woodland. A minimum of 400 m separated all sites to improve data independence obtained from cameras (Ariefiandy *et al.* 2013, 2014). This 400-m distance between monitoring sites was based on the radius of the mean home-range area for Komodo dragons (Jessop *et al.* 2018; Purwandana *et al.* 2021). At the commencement of the study, each site was randomly assigned as a baited (n = 13) or non-baited (n = 13) camera monitoring station to ensure equal replicates within each camera method treatment. After the initial sampling period at each station, the assigned camera method

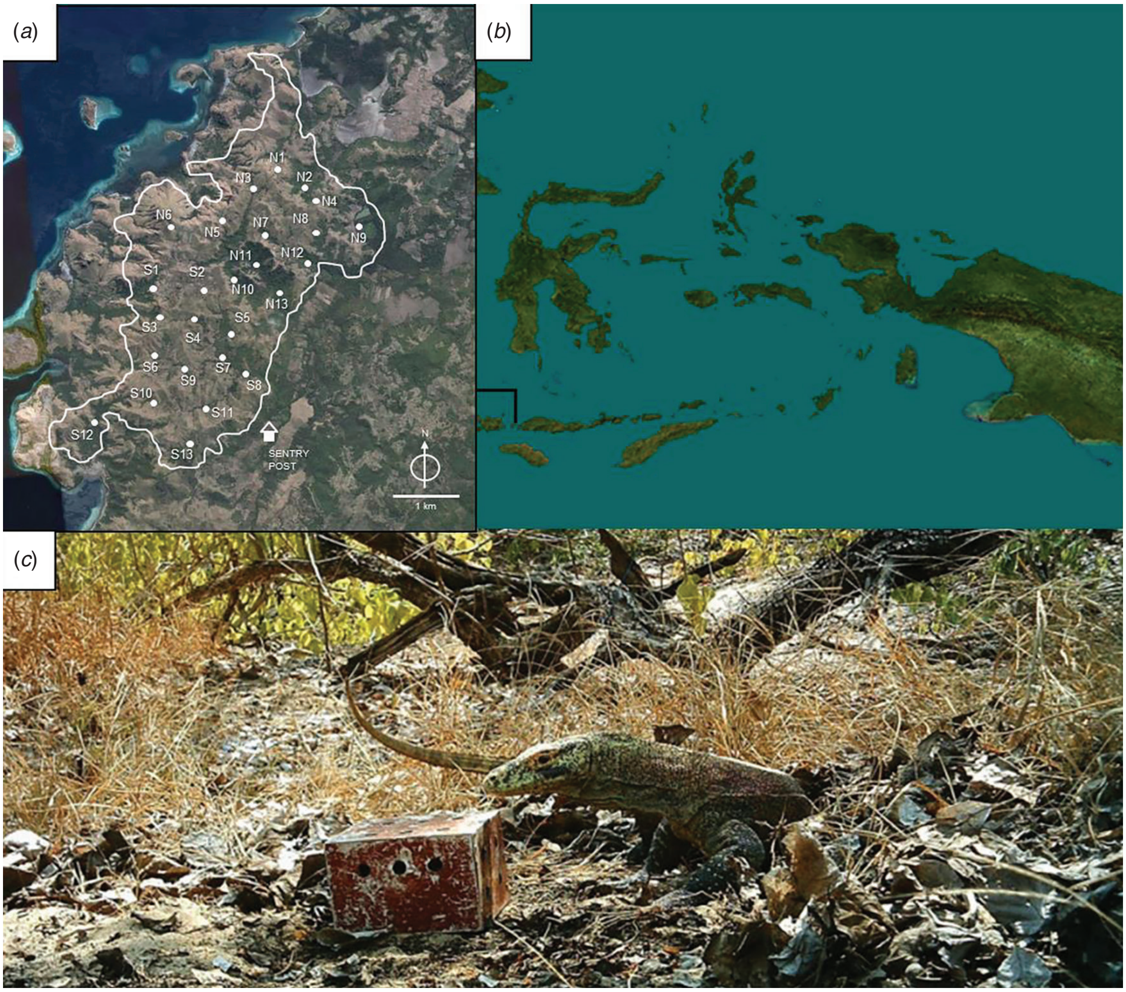

Fig. 1. The study evaluated the effect of bait attractant on Komodo dragon detection probability and site occupancy estimates by using camera monitoring stations deployed across (*a*) the Wae Wuul Nature Reserve located (*b*) on the western coast of Flores in eastern Indonesia. (*c*) An image of a Komodo dragon inspecting the meat attractant contained within a metal bait box.

was reversed to the alternate method to compare estimates of Komodo dragon detection probability and occupancy obtained for each method at each site. The study was conducted during June and July 2017 in the mid-dry season when environmental temperatures permit Komodo dragons to exhibit normal daily diurnal activity patterns and, hence, pending abundance, the potential for good detection probability (Harlow *et al.* 2010*a*, 2010*b*; Jessop *et al.* 2013).

Camera monitoring design

At each CMS, a single outward facing Bushnell camera (Model Trophy Cam HD 119678) was attached to a tree (40 cm above the ground) as described elsewhere (Ariefiandy *et al.* 2013, 2014). Cameras were programmed to take three photos and a 1-min video each time an animal triggered the device. At installation, all cameras were tested to confirm normal functioning. For CMS allocated to the bait treatment, we used two scent lures that comprised a small aluminium box (25 × 15 × 15 cm; L × W × H) and a suspended plastic bag, each containing goat meat that was placed 4 and 2 m in front or above the camera respectively. Baited and unbaited CMS were deployed for 6 and 30 days of monitoring respectively. The uneven durations between treatments reflected our belief that baited cameras would require considerably less sampling effort to produce higher detection probabilities than those obtained from unbaited cameras. As Komodo dragons have been observed to investigate baits at traps for several minutes before entering traps or moving elsewhere, we also used a 30-min camera delay to prevent repeated photography of the same individual lizard (Ariefiandy *et al.* 2014). In addition, a 3-day non-monitoring period was used immediately after the transition from baited to unbaited sites. This waiting period was implemented to remove a potential carry-over bait effect that could have attracted Komodo dragons and inflated detection probability at sites then monitored with unbaited cameras. This research abided by the journal's guidelines on ethical standards.

Estimating detection and site occupancy estimates

We modelled the detectability and occupancy of Komodo dragons by using a single-season occupancy model, using the

Table 1. Model selection results testing effects of baited and non-baited cameras for influencing detection probability (p) and site occupancy (Ψ) of Komodo dragons within the Wae Wuul Nature Reserve in West Flores

K, the number of estimated parameters; logLik, logliklihood; AIC, Akaike information criterion; ΔAIC, the difference in value between AIC of this model and the most parsimonious model; and AIC weights (w_i), a measure of relative model support

Model	K	logLik	AIC	ΔAIC	w_i
Ψ(.) p(bait vs no-bait))	3	365.43	371.43	0.00	0.71
Ψ(bait vs no-bait)) p(bait vs no-bait))	4	365.21	373.21	1.78	0.29
Ψ(.) p(bait vs no-bait))* daily survey variation	62	302.17	426.17	54.74	0.00
Ψ (.) p (.)	2	424.44	428.44	57.01	0.00

software Presence (Hines 2006). Site occupancy models use patterns of detection and non-detection over multiple surveys (sampling occasions) of a sampling unit (CMS) to estimate detection probabilities (p) and, thus, produce unbiased estimates of occupancy (ψ) (MacKenzie *et al.* 2002). We modelled the effect of baits on both the detection probability (p) and ψ relative to those cameras without baits (i.e. p. ψ). We partitioned the unbaited CMS detection probability data into two datasets, given the sampling duration differences between baited and unbaited CMS. One dataset comprised the first six, and the other the full 30 daily sampling events. Models were ranked using AIC, and we considered the effect of bait provision at CMS to be influential if the model AIC was >2 units below that estimated for the null model (Burnham and Anderson 2004).

Detection probability curves, probability of site absences and survey design costs

To assess the expected reduction in sampling effort provided by using baits at CMS, we produced detectability curves for CMS with and without baits. Detectability curves represent the cumulative probability (i.e. rate of increase) that Komodo dragons will be detected after a given number of sampling occasions in a site where the species is present (Wintle *et al.* 2005). Cumulative detection probability curves were estimated as $pk = 1 - (1 - p)^k$, where p is the species' per-survey detection probability within a given treatment and k is the given number of sampling occasions (MacKenzie and Royle 2005).

Next, we estimated the minimum number of sequential sampling occasions, with no detection required to be 95% certain (i.e. $\alpha = 0.05$) that Komodo dragons were absent from a surveyed site by using baited and unbaited cameras (Wintle *et al.* 2012; Ferreras *et al.* 2018). The probability (with $\alpha = 0.05$) of not detecting Komodo dragons after N sampling occasions at a given site is estimated by the formula

$$N > \frac{\log\left(\frac{\alpha}{1-\alpha}\right) - \log\left(\frac{\Psi}{1-\Psi}\right)}{\log(1-\mathrm{p})}$$

Here, values of p and ψ are specific to baited and unbaited CMS site occupancy estimates derived from the 6-day sampling period.

Finally, we compared the costs of sampling for baited and unbaited camera trapping methodology to achieve a similar monitoring outcome (i.e. $\alpha = 0.05$) by calculating protocol-specific costs of each technique, beyond common costs associated with camera purchases, as such we estimated

$$C(m) = \sum (C_d + C_r + C_b \times S_d + C_{bb} \times S_d + C_{cb} \times S_d)$$

where $C(m)$ = method specific survey cost, C_d = cost of camera deployment, C_r = cost of camera retrieval, C_b = cost of bait (US\$0.26 per camera per survey day (S_d)), C_{bb} = cost of bait boxes (US\$10.00 per camera), C_{cb} = cost of camera batteries (US\$0.20 per camera per survey day).

Results

The most parsimonious occupancy model (Ψ (.), p (bait vs no-bait), model weight = 0.71) indicated that the effect of baits placed at CMS vastly improved Komodo dragon detection probability compared with the null model (ΔAIC = 57.01; model weight = 0.00; Table 1). Detection probability estimates for baited cameras (6 daily sampling events) were 15 and 5.5 times higher than those estimated for unbaited (6 daily sampling events) and long-unbaited (30 daily sampling events) camera sampling durations (Fig. 2*a*). Similarly, baited cameras produced 2.3 and 1.3 higher Komodo dragon site occupancy estimates at the equivalent and long-unbaited camera sampling durations (Fig. 2*b*). A goodness-of-fit test on the most parameter-rich model demonstrated that our data were not over-dispersed (i.e. $\hat{c} > 1$).

Effects of bait attractants on monitoring considerations

Baited cameras improved sampling efficacy and reduced monitoring costs compared with sampling using unbaited cameras. First, it was evident that based on cumulative detection probabilities, baited cameras, if deployed sufficiently long enough, could achieve perfect detection at sites with Komodo dragons, with much less survey effort than with unbaited cameras (Fig. 3). Compared with unbaited cameras, baited cameras reduced the sampling effort duration from 184 to 21 days to be certain (with α of <0.05) that Komodo dragons were absent from a site. Finally, because of the much-improved detection probability achieved with baited cameras, it reduced the overall study costs from US\$580.20 to US\$547.60, to obtain similar camera-based detection levels within the study area.

Discussion

The choice of an appropriate sampling method for monitoring threatened predator populations depends on interactions among the program objectives, scale and resources and a species's detection probability (Kéry and Schmidt 2008). We demonstrated that using baited-camera compared with unbaited-camera monitoring greatly improved estimates of Komodo dragon detection probability and site occupancy in the Wae

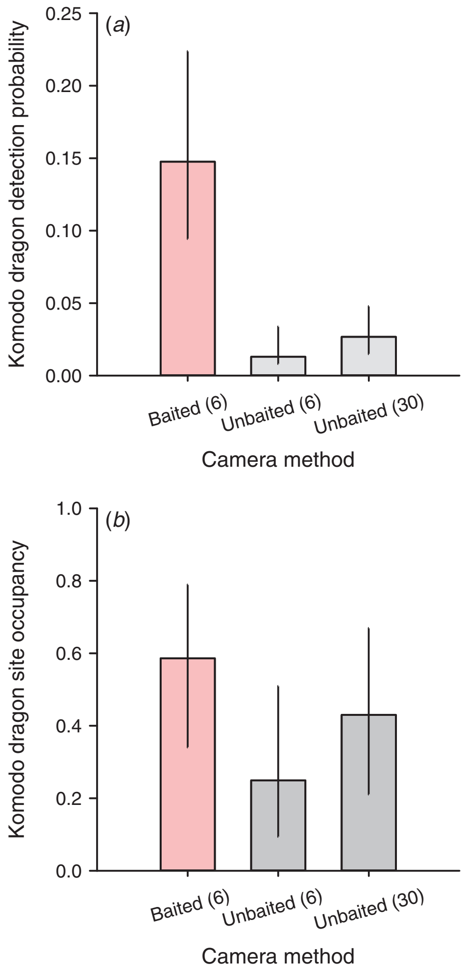

Fig. 2. Komodo dragon (*a*) detection probability and (*b*) site occupancy estimated from baited or unbaited cameras deployed for 6- or 30-day sampling events respectively. The bars report the mean estimate, and the upper and lower 95% confidence intervals are indicated by the error bars.

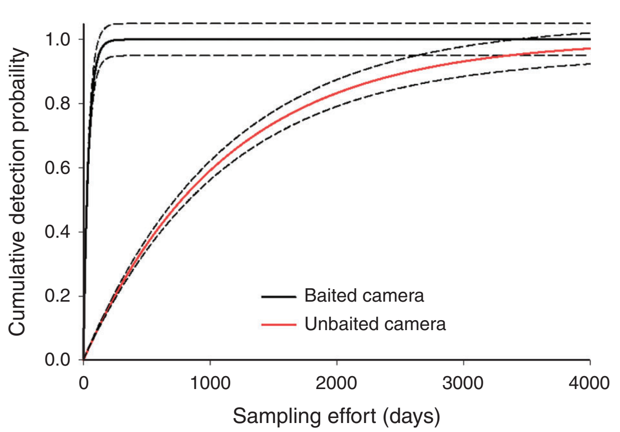

Fig. 3. The cumulative detectability curves for Komodo dragons estimated from baited and unbaited camera occupancy models. These curves represent the probability that Komodo dragons will be detected at least once with each treatment after sequential 1-week sampling period at each camera trap where Komodo dragons are present. The lines report the mean estimate and the dashed upper and lower lower lines are the 95% standard error of the mean.

Wuul Nature Reserve on Flores Island. Indeed, several clear advantages were evident from using baited cameras, including a reduced sampling effort and, ultimately, a more cost-effective monitoring design.

Obtaining a high detection probability is a key requirement to improve site-occupancy estimates for large predators that persist at low density (MacKenzie *et al.* 2006). Such sampling designs should aim to achieve a detection probability exceeding 0.15, so as to allow for better occupancy estimates for predators (O'Connell *et al.* 2010; Otto and Roloff 2011). With camera-based monitoring, there are several ways to increase species detection probability, including increasing the number of cameras deployed for longer survey periods or by also placing cameras in areas that increase detection opportunities of the focal species (e.g. along game trails; O'Connell *et al.* 2010; Geyle *et al.* 2020; Wysong *et al.* 2020). However, the use of attractants such as baits or lures is another common means to improve camera-based detection probability, but their use should be assessed to ensure improved efficacy (Read *et al.* 2015).

It was evident that bait attractants at camera monitoring stations greatly improved Komodo dragon detection probability by 3.5–5 times over similar or extended durations of unbaited camera monitoring. This finding is consistent with those of other studies that indicate similar benefits of using baits or lures at camera monitoring stations (du Preez *et al.* 2014; Austin *et al.* 2017; Tarugara *et al.* 2019). Importantly, these gains in detection probability alongside higher and more robust estimates of site occupancy offset the increased daily sampling costs owing to the purchase of goats as the bait source (Thorn *et al.* 2011).

Another key benefit of baited cameras was the considerable reduction (i.e. 5-fold) in the survey effort needed to achieve adequate Komodo dragon detection within the study area. Reducing survey effort without compromising detection probabilities has many obvious advantages (MacKenzie and Royle 2005). Most importantly, saved survey effort can be allocated into additional sites, survey visits or additional study areas in different ways (Sewell *et al.* 2012). From our perspective, the biggest advantage is that reduced survey effort can be invested into additional camera monitoring activities for more broadly assessing the conservation status of Komodo dragon populations. For example, we have recently used baited camera monitoring surveys beyond this study area to evaluate the distribution of the Komodo dragon across Flores (~400 monitoring stations across 1200 km of coastline; Ariefiandy *et al.* 2021). This feat would not have been possible without using baited cameras to achieve high Komodo dragon detection relative to their survey effort requirements.

It is argued that the use of attractants to increase a species detection must be considerate of any effects on monitoring estimates and arising inference (du Preez *et al.* 2014). For example, if increased estimates of detection at baited cameras arise because of bait effects on animal space-use or daily movements, it could bias parameter estimates. In the case of baited cameras, baits could increase residency times or attract animals beyond their normal home-range area to inflate estimates of detection probability and site occupancy (Stewart *et al.* 2019). This problem could be especially acute if individual animals, particularly those in low-density populations, are detected at multiple camera stations beyond their home range.

Consequently, ensuring spatial independence for camera data is a crucial aspect of monitoring design (Meek *et al.* 2014; O'Connell *et al.* 2010; Geyle *et al.* 2020). We know that the independence of data among camera monitoring sites is largely met for Komodo dragon, because our prior mark–recapture-based studies using traps with similar inter-site distances resulted in a <10% within-study recapture rate of individuals (Ariefiandy *et al.* 2013, 2014).

This study also indicated that estimates of Komodo dragon site occupancy recorded within the Wae Wuul Nature Reserve are significantly lower than those generally recorded for populations in the adjacent Komodo National Park (Purwandana *et al.* 2014*b*; Ariefiandy *et al.* 2015). Adult Komodo dragons, as apex predators, mainly prey on ungulates, particularly Rusa deer (*Rusa timorensis*), wild pig (*Sus scrofa*), and, in some locations, water buffalo (*Bubalus bubalis*; Auffenberg 1981; Bull *et al.* 2010; Purwandana *et al.* 2016). Thus, we attribute this lower occupancy estimate to be in part associated with the commensurate reduction of large ungulate prey availability on Flores (Ariefiandy *et al.* 2011, 2015, 2016; Jessop *et al.* 2020). Reduced prey is a presumed consequence of historical and increasingly contemporary human-mediated processes (e.g. fire, poaching, invasive predators) affecting Komodo dragon habitats on Flores (Ariefiandy *et al.* 2020).

Here we advocate that protected-area enhancement actions and community conservation approaches are needed to address the current threats to Komodo dragons on Flores. For example, unlike Komodo National Park, the Wae Wuul Nature reserve is comparatively under-resourced in staff and logistical resources. Thus, aside from ongoing monitoring of Komodo dragon populations, it is necessary to ensure that integrative conservation actions are used to ensure prey and predator persistence in this reserve (Ariefiandy *et al.* 2015, 2020). Thus, this reserve could benefit from additional infrastructure (e.g. ranger posts) and increased patrolling and surveillance measures that would benefit both Komodo dragons and their ungulate prey (Hilborn *et al.* 2006; Ariefiandy *et al.* 2015, 2020). However, as human activities increasingly modify the habitats that directly border this reserve, community-based conservation actions must also be implemented in neighbouring communities (Ariefiandy *et al.* 2015, 2020). For example, implementing conservation awareness meetings in local communities to inform and discuss the value of protecting natural values within this reserve are deemed essential (Kamil *et al.* 2019). Furthermore, working with communities to reduce rates of incursions of village dogs or livestock and stopping villagers from setting fire to habitats within or adjacent to the reserve could be important steps to promote the conservation of Komodo dragons in this key protected area on Flores (Ariefiandy *et al.* 2020).

In conclusion, our study demonstrated that optimising camera survey methods using baits compared with unbaited cameras can provide a better method for estimating Komodo dragon occupancy. This result was particularly important in this study because we aimed to effectively monitor a very low-density population in a key protected area on Flores. We believe our baited camera monitoring approach now lends itself to understanding population responses to ecological and anthropogenic factors, hence informing conservation efforts in this nature reserve (Ariefiandy *et al.* 2015).

Conflicts of interest

The authors declare that they have no conflicts of interest.

Author contributions

Study design and fieldwork: DP, AA, MA, SAN, MS and TSJ; data analysis: TSJ; writing: TSJ.

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Luas: 1.484,84 Hektar
Terima Kasih Untuk Tidak :
MENGERJAKAN/MENGGUNAKAN/MENDUDUKI, MERAMBAH,
MENEBANG POHON, MEMBAKAR, MENGEMBALAKAN TERNAK,
MENGAMBIL/MERUSAK TUMBUHAN,
MENANGKAP/MELUKAI/MEMBUNUH SATWA/TELUR SATWA
/SARANG SATWA DAN MENGAMBIL BENDA-BENDA LAINNYA
DARI DALAM KAWASAN INI
THERE'S A DRAGON ON MY BACK