Danau Girang Field Centre

Tenth Anniversary Report

2008-2018


DANAU GIRANG FIELD CENTRE
DGFC10TH
ANNIVERSARY 2008-2018

Danau Girang Field Centre Tenth Anniversary Report

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Dausip, J.B.: p34, p72 (lower left); Fayle, T.: p56 (upper background, left upper insert); Koh, J.K.: p56 (left lower insert); KOPEL/MESCOT: p58-59; Osman, A.: p55; Parks, T.: p41; Reef Guardian: p69 (middle lower insert); Scubazoo: cover, p18 (upper); Sebastiano, M.: p48 (lower insert); Suarez, J.: p85, p88; Symondson, W.O.C.: p56 (middle insert).

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Danau Girang Field Centre

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The information contained in this report has been prepared by many professionals. These works are cited appropriately in Section VII (Publications).

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Abbreviations

a(α)-LoCoH – Adaptive Local/Localised Convex Hull

bp – Base Pairs

BRB – Biased Random Bridges

CA – Core Area

CART - Classification and Regression Tree

dBBMM – Dynamic Brownian Bridge Movement Model

DBH – Diameter at Breast Height

DGFC – Danau Girang Field Centre

EOB – Expert Opinion Based

GCM – Grill Cell Method

GPS – Global Positioning System

HEC – Human Elephant Conflict

ID – Intensity Distribution

kya – Thousand Years Ago

LiDAR – Light Detection and Ranging

LKF – Lower Kinabatangan Floodplain

LKWS – Lower Kinabatangan Wildlife Sanctuary

LoCoH – Local/localised Convex Hull

MaxEnt – Maximum Entropy

MER – Managed Elephant Range

NPV – Net Present Value

PCA – Principal Component Analysis

RUF – Resource Utilisation Function

SWD – Sabah Wildlife Department

T-LoCoH - Time-Based Adaptive Local/localised Convex Hull

TWR – Tabin Wildlife Reserve

UD – Utilisation Distribution (or home range)

WHGFL – Wildlife Health, Genetic and Forensic Laboratory

WHU – Wildlife Health Unit

Danau Girang Field Centre. Tenth Anniversary Report.

Preface

It was 2001 when I first stumbled upon three empty buildings and a watchtower on the shore of the oxbow lake called Danau Girang in the Kinabatangan floodplain. Back then, I only thought it was a pity such a place was not operational. Five years later, the facilities were still empty and, in general, they were falling apart. It was then when I thought of reviving the place by setting up a research and training centre. Today it gives me pleasure to share it has become much more than that!

The Danau Girang Field Centre (DGFC) was set up in July 2008 intending to gather useful and relevant information regarding the ecological systems and the landscape-level requirements critical for the viable persistence of tropical species in the highly fragmented and oil-palm dominated landscapes of the Kinabatangan floodplain, the largest wetland in Sabah, Malaysian Borneo. Since its establishment, DGFC has provided extensive capacity building opportunities for international and local scientists paired with a close collaboration with the Sabah Wildlife Department and Cardiff University. This has generated true, on-the-ground, targeted research, and informed conservation actions. In ten years we have performed satellite telemetry studies on nine species, some of those have been the first known on their respective focal species in the world and have met with significant success in terms of data quality and conservation potential; we have led the production of five species action plans and generated 112 publications; we also provided higher education opportunities for 14 Malaysian scientists (among many others); we were able to give scientific data useful for the establishment of new forest reserves; and, lastly, we engaged with other conservation and government organisations in Sabah to help safeguard the future of the Kinabatangan floodplain.

This publication is a compendium of works led by or in collaboration with Danau Girang Field Centre. It presents the research projects and conservation efforts accomplished between 2008 and 2018, marking DGFC's tenth anniversary. Section I (Introduction) provides general information on DGFC and on its location: the Lower Kinabatangan Wildlife Sanctuary. Section II (A changing landscape) describes the problematic of land-use change in the Kinabatangan floodplain and possible solutions to those problems. Section III (Understanding wildlife responses to human-driven landscape changes) presents the scientific projects on the flagship model organisms we have focused on, including aims, methods and results (when available). Section

IV (Striving towards sustainability in the Lower Kinabatangan floodplain) focuses on the involvement of DGFC in the governance of the region, mainly on environmental protection actions based on scientific data such as land reclamation and road infrastructure development. Section V (Contributing to scientific knowledge beyond the Lower Kinabatangan floodplain) describes our participation in research projects that provide information at the state level, and on orang-utans throughout their range. Section VI (Conservation in action) marks how we have engaged in the decision-making process in Sabah to apply the knowledge gained into concrete conservation actions, such as the creation of state action plans, as well as in environmental education campaigns. Section VII (Impact on higher education and scientific research) shows how DGFC has contributed to the capacity building of scientists and trained personnel, not only of the region but also at an international level; it also contains information on the scientific publications derived from our research and their impact worldwide. Section VIII (The path ahead) shares the vision for the next ten years of DGFC: to further integrate our research goals with the community's needs in a sustainable way, while taking our knowledge to other geographical areas with similar problematics. Finally, Section IX (Acknowledgements) mentions those who have been involved in our activities since before the centre opened its doors and up to the printing of this publication; these ten years would not have been possible without them. I will take this opportunity to acknowledge the contribution of all of those who have been involved in producing this document.

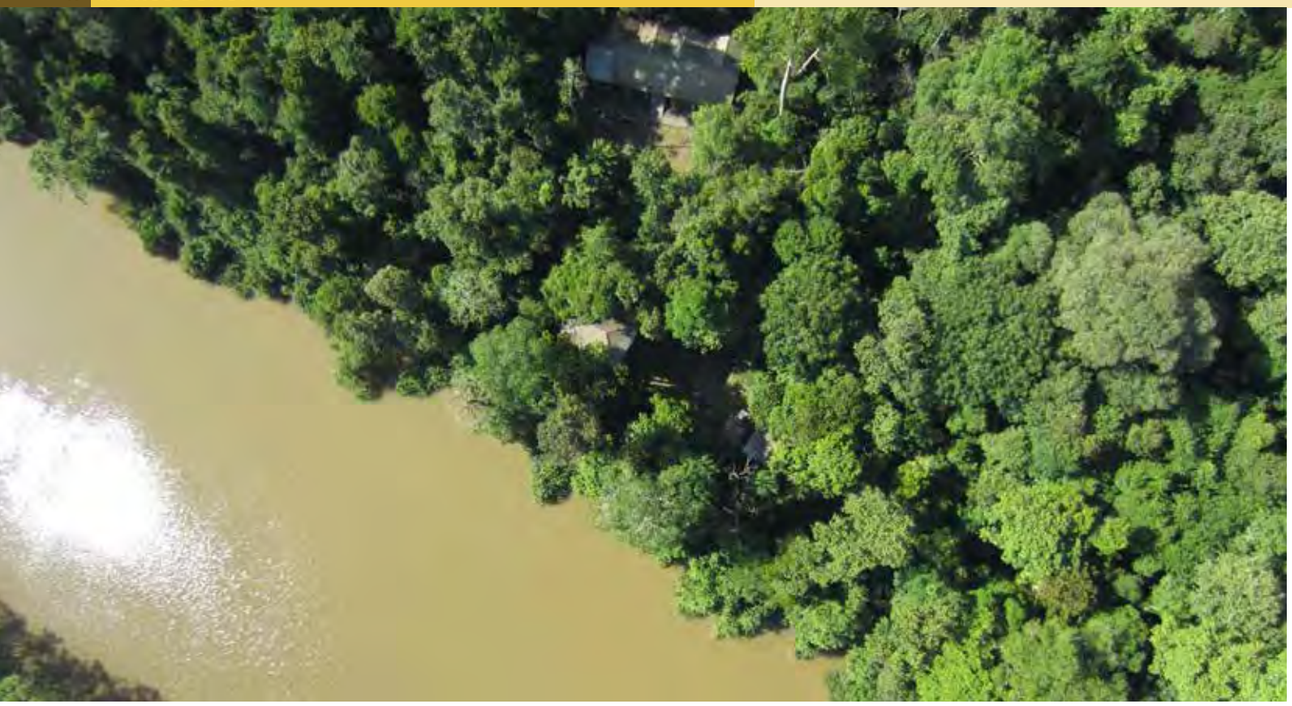
It is the hope of DGFC's members that this report will provide information to all audiences about the scientific and conservation challenges they have faced and investigated, as well as their achievements. For further information, the reader is encouraged to read the publications listed in Section VII, these and more can be found at DGFC's web site (www.dgfc.life).

I hope you find it interesting, informative and useful but most importantly that it gives you a perspective of the large amount of work done and the huge efforts made by a team of committed and passionate people: the DGFC's family.

Benoît Goossens

Director

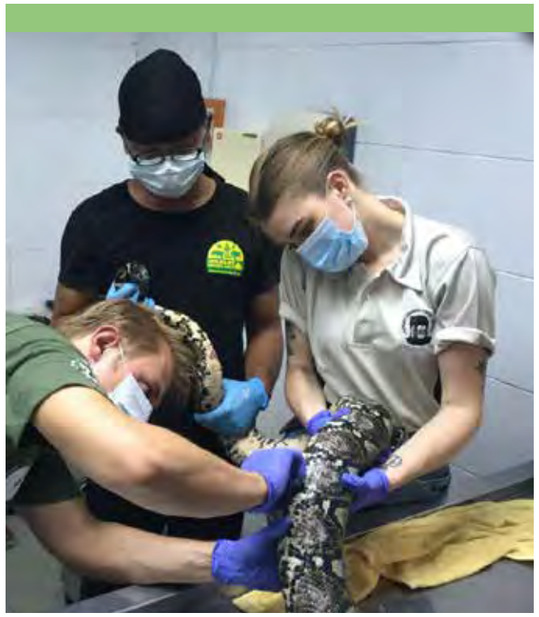
September 2018.



I. Introduction

The Story of Danau Girang Field Centre

In the late 1990s the Sabah Wildlife Department (SWD), with funds from the Federal and State governments, built an education centre on the shore of Danau Girang, an oxbow lake located in lot 6 of the Lower Kinabatangan Wildlife Sanctuary. The centre comprised a main building, a hostel, a studio, and a watchtower. Unfortunately, due to lack of personnel and funds, the SWD was not able to make use of the centre and it quickly fell into disuse.



In 2001, while collecting non-invasive samples for a Darwin Initiative project on orangutan population genetics, Dr Benoît Goossens encountered the abandoned facility. In 2006 the facility was derelict and under threat of collapse; it was then that he approached the SWD with the idea of reviving the facility and converting it into a research and training centre focusing on wildlife responses to landscape degradation. Datuk Patrick Mahedi Andau, then Director of the SWD, and Datuk Laurentius Nayan Ambu, then Deputy Director, were supportive of the project and encouraged Dr. Goossens to seek for funding. Cardiff School of Biosciences was approached with the project and subsequently invested GBP100,000.00 in the renovation of the existing facility and the building of a staff house and a water treatment system.

A two-year Memorandum of Understanding (MoU) was signed on August 2007 between the Sabah Wildlife Department and Cardiff University, and was witnessed by the Sabah Minister of Tourism, Culture and Environment, YB Datuk Seri Panglima Masidi Manjun. It was agreed that a field centre would be established to provide the facilities and resources to:

a) Undertake research projects with the goal of better understanding the mechanisms of degraded forests;

b) Deliver teaching/training programs for Malaysian, UK and other international students.

The Danau Girang Field Centre (DGFC), under the direction of Dr. Benoît Goossens, opened its doors on July 2008 to the first field course organised by Cardiff School of Biosciences. In July 2009, a subsequent MoU was signed by the same parties with the aim of strengthening the collaboration for the management of DGFC. Then in June 2013, an extension to the latter MoU was signed, expressing the wish to continue the collaboration until 2024. Now, ten years after its opening, Danau Girang Field Centre employs more than 30 staff, runs over 10 international field courses per year, has hosted the research projects of 58 higher education students, and is completely self-sufficient.

Mission:

To further scientific research with the aim of contributing to long-term conservation projects in the area, and develop a better understanding of our environment and the living things we share it with.

Vision:

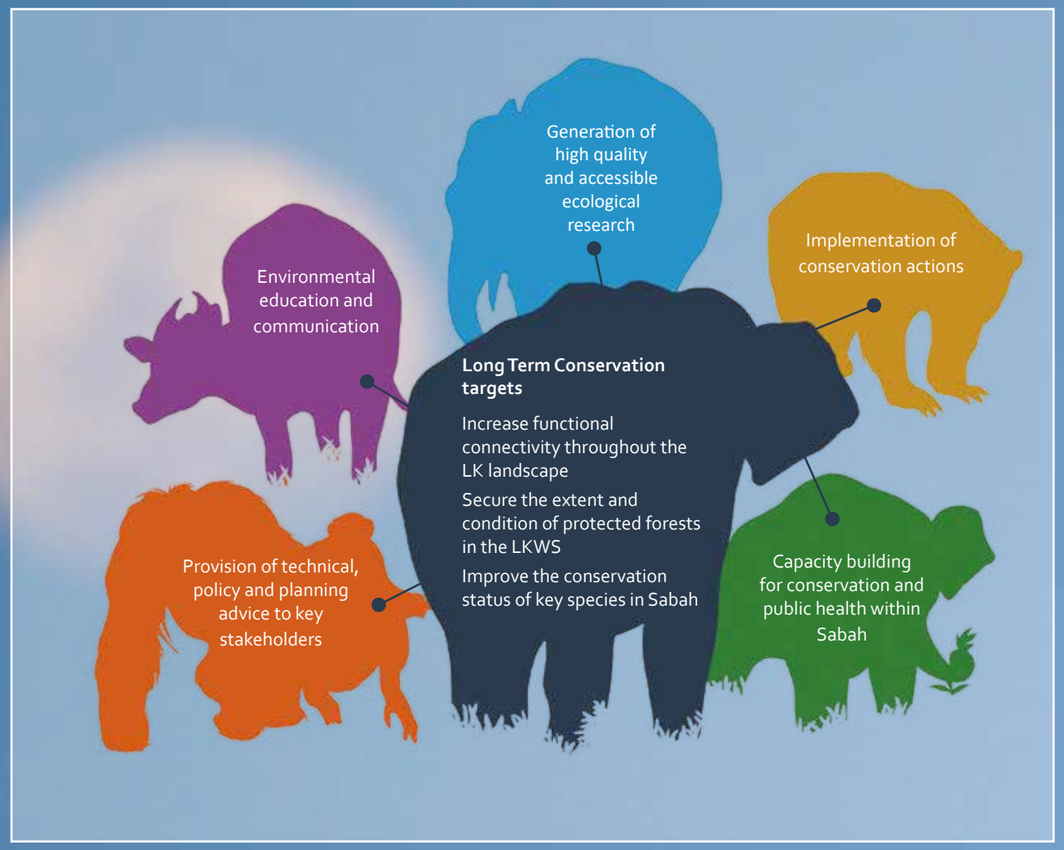
To be a "collaborative research centre for the applied conservation of tropical eco-systems using world class facilities and cutting-edge technological tools for the effective management of wildlife in a fragmented landscape, while providing outreach and awareness programs for multiple stakeholders (local communities, eco-tourism, palm oil plantations) whilst upholding a standard of internationally-recognised expertise and scientific publications".

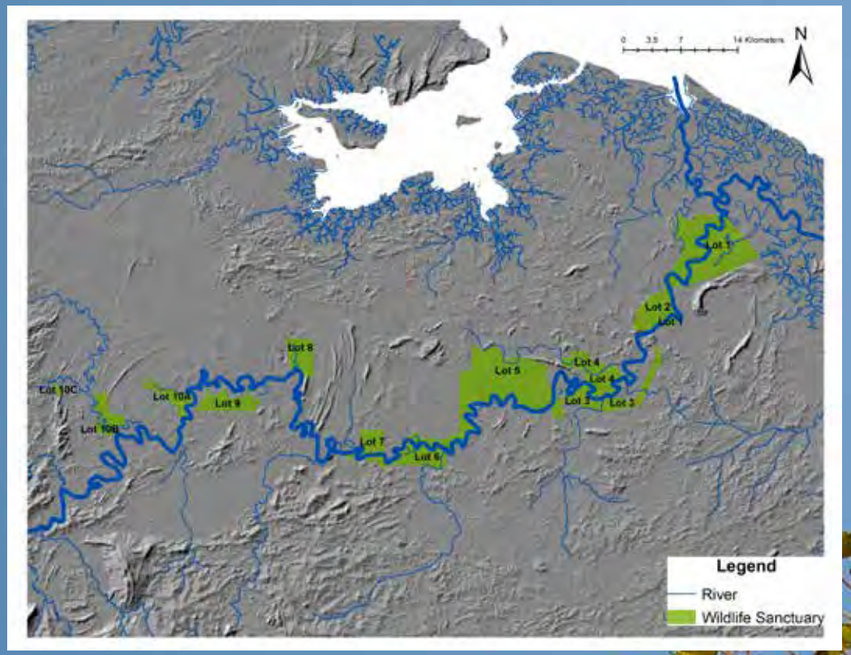
Objectives:

1. To provide facilities and resources for (1) research projects to be undertaken with the goal of better understanding the dynamics of degraded forests and (2) the delivery of teaching/training programmes for Malaysian and international students.

2. Through the utilisation of advanced technologies such as camera traps, GPS collars, drones and molecular tools, to explore the survival mechanisms employed by multiple flagship species, with the aim of developing species action plans and landscape management guidelines for fragmented lowland tropical forests.

Long Term Conservation targets





The Kinabatangan Landscape and the Lower Kinabatangan Wildlife Sanctuary.

Located in the east coast of Sabah, the Kinabatangan River extends for 560 km from the highlands in the interior of the state towards the Sulu Sea. It is a widely meandering river which now has about 30 oxbow lakes scattered along. The original habitat was a mix of riparian, seasonally flooded, swamp and dry (humid) dipterocarp forest, which has been seriously disturbed by both selected logging and oil palm plantations. Sabah lost 39.5% of its forest cover between 1973 and 2010; the Kinabatangan region lost 67% of its forest cover between 1982 and 2014 with the deforestation starting even before 1982. The remaining forest was highly fragmented, spread out into many irregular shaped patches with poor connectivity between them and different levels of disturbance. Some of these forests were classified as protection forest reserves and virgin jungle forest reserves (under the Forest Enactment 1968). However, by 2005 significant areas of forests remained outside the protected areas.

Attempts to create a corridor linking the existing forest reserves with the coastal mangroves and the interior forests started as early as 1999, when the State Government declared the Lower Kinabatangan as a "Gift to the Earth". Following this, in 2005, the Lower Kinabatangan Wildlife Sanctuary (LKWS) was gazetted under Section 9 of the Wildlife Conservation Enactment 1997. The sanctuary consists of ten forest blocks along the river, totalling about 26,000 ha. The forest types represented include lowland dipterocarp forest, forest over limestone, seasonal and tidal swamps, permanent freshwater swamp, and mangroves. These forest types are located within a landscape with significant human impact, including villages, small scale agriculture and oil palm plantations. Other relevant features include the world famous Gomantong cave system, which is an example of the limestone karst system - a strong feature of the landscape in the Kinabatangan floodplain. This matrix landscape is ideal for investigating the influence and interaction of human encroachment on the diversity, behaviour and abundance of the local wildlife.

Biodiversity.

Despite the non-virgin nature of the remaining forest and their lack of connectivity, the Lower Kinabatangan remains an important hotspot for biodiversity. It is estimated to harbour 129 species of mammals, 314 species of birds, 101 species of reptiles and 33 species of amphibians. Besides housing the iconic Bornean orangutan (*Pongo pygmaeus morio*) and the Bornean elephant (*Elephas maximus borneensis*), this is one of the two places in the world where ten species of primate live in sympatry.

References

Gaveau, D.L.A., *et al*. 2014. PLoS One, 9, e101654.

Francis, O. 2017. Cardiff University.

Abram, N.K., *et al*. 2014. PLoS One, 9, e95388.

II. A Changing Landscape

In a mosaic of habitats such as that of the LKF, the impact of human-driven landscape changes can be measured in two ways: by focusing on each individual species, or by looking at the changing landscape.

In terms of landscape, deforestation and land-use conversion present significant challenges for the establishment and maintenance of wildlife corridors. Thus, in-depth landscape knowledge provides one of the best options for effectively re-connecting forest fragments, especially if such actions can be aligned with the interests of the majority of the stakeholders.

Oil palm trees (*Elaeis guineensis*) cover over almost 80% of the LKF. This species is flood intolerant, therefore areas with periodic flooding may become less productive or even unprofitable. Yet, the palm oil industry has sought lowland coastal land, as these fertile areas provide the highest possible palm oil yields. Given the high levels of biodiversity associated with lowland forests, large-scale conversion to agriculture poses a severe threat to the continued functionality of lowland forest ecosystems, as well as the overall biodiversity in the region.

References

Francis, O. 2017. Cardiff University.

Abram, N.K., *et al*. 2014. PLoS One, 9, e95388.

Evans, L.J., *et al*. 2017. For. Ecol. Manage., 401, 159–165.

Understanding the deforestation process

Aims

Focusing on the LKWS, and the surrounding floodplain, the history of land use change in the area was investigated, as well as how it has affected the sanctuary and other remaining forest.

Methods

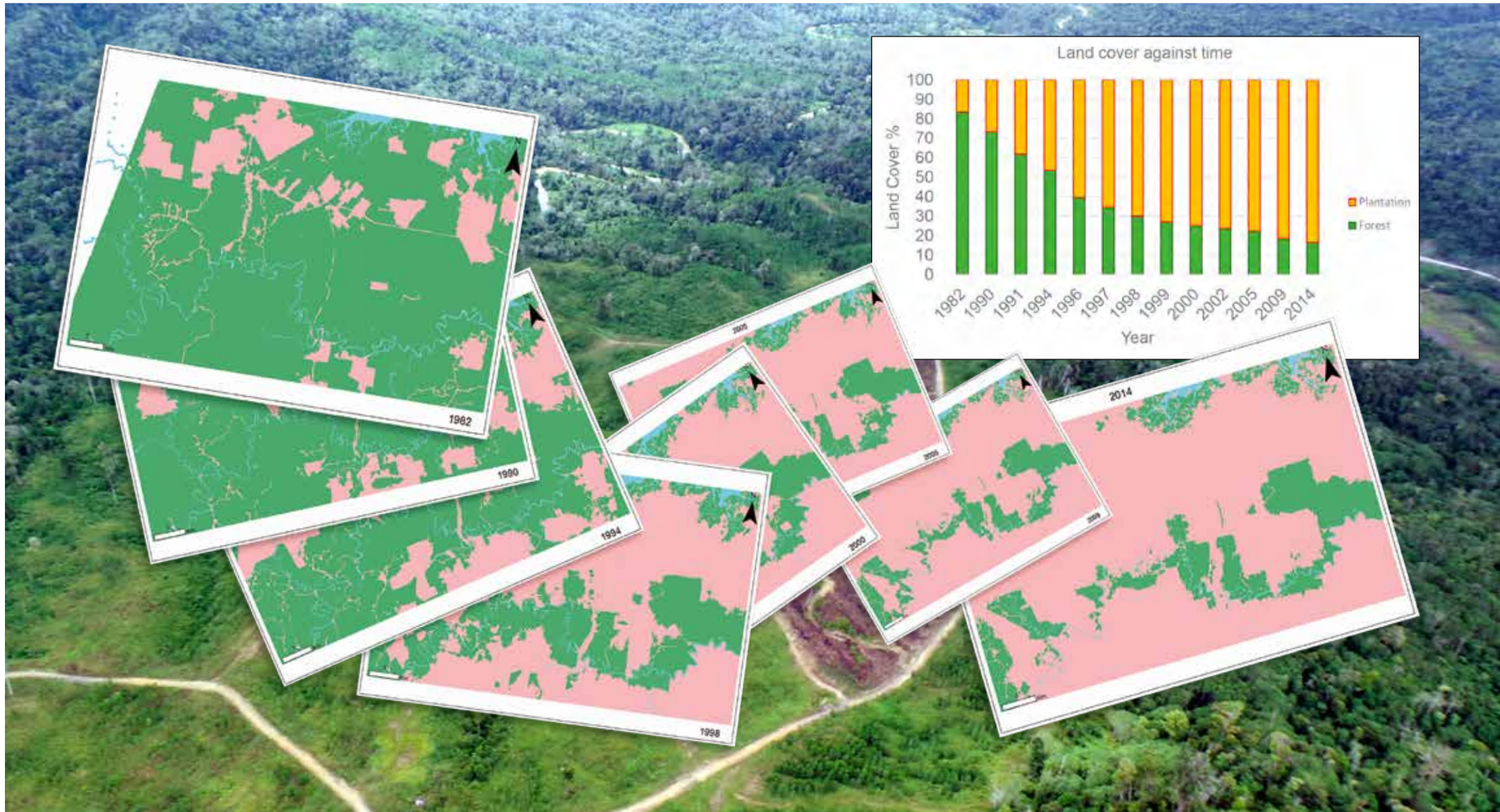
A temporal and spatial record of deforestation and classification of forest was produced using Landsat images (from 1982 to 2014) and the image analysis software eCognition.

Results

Classifications of the Lower Kinabatangan floodplains show that the deforestation began before 1982 and to 2014 plantations covered 83% of the study area. Within that lapse the area lost 137,992.6 ha of forest (67%). The deforestation occurred at its fastest rates between 1991 and 1997 with 28% of the deforestation occurring in this time. The greatest yearly loss happened between 1990 and 1991 with 16,989 ha or 9.6% of the forest cleared. The rates of deforestation decrease after 1997 with a loss of 18% occurring in the years since compared to a loss of 49% prior to 1997. Despite the official gazetting of the wildlife sanctuary in 2005 deforestation is still ongoing but at a lower rate.

References

Francis, O. 2017. Cardiff University.



The impact of rapid land use change on river dynamics.

As a meandering river, alterations to the Kinabatangan's dynamics may lead to accelerated loss of agricultural land, damage to infrastructure, and increased sediment loading that would have severe consequences downstream. The assumption that total forest conversion along river boundaries will maximise profitability leaves little incentive to maintain riparian reserves within plantations.

Aims

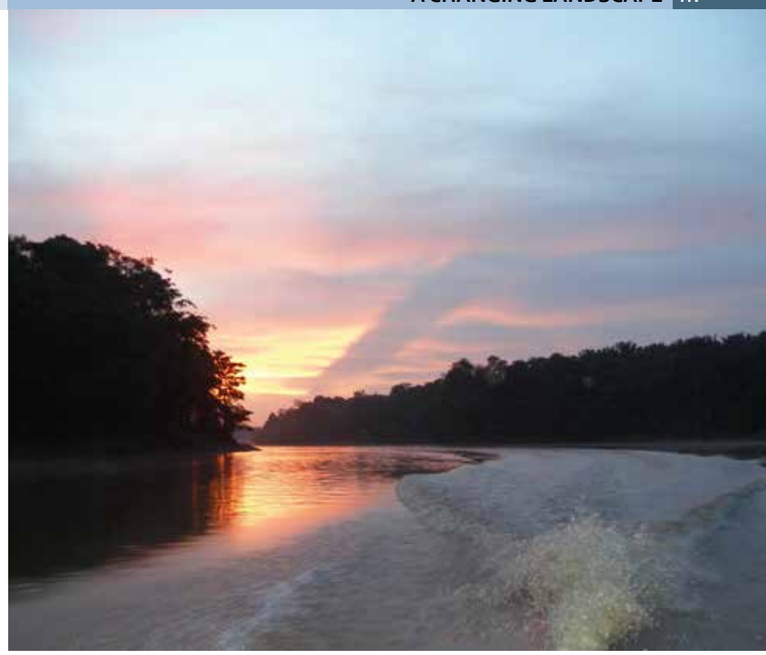
To assess the role of trees in controlling rates and patterns of riverbank erosion, by comparing rates of channel migration between forested river sections, and sections of the river cleared of riparian cover.

To quantify the effects riparian forest reserves along these unprotected reaches could have on expected yield from oil palm cultivation adjacent to the river.

Methods

Using Landsat imagery (1989-2014) four meandering reaches (67 river sections) were selected to provide examples of riverbanks with varying degrees of land-cover alteration and to ensure observations of river meandering unhindered by geological (e.g., bedrock outcrop) or engineering (e.g., riverbank revetment) controls.

A numerical model of river meander migration was used to simulate future channel planform position given different scenarios for forest removal in sections of unprotected riparian forest marked for future conversion. We assess the impact that riparian buffers along these unprotected reaches could have on expected yield from oil palm cultivated adjacent to the river.



Results

For the period between 1989–2014, sections along the Kinabatangan River that had been cleared of riparian forest show rates of channel migration (riverbank erosion) >23% greater on average than those sections that remained forested, suggesting a key role of forests in the stability of meandering rivers.

Additional results suggest that, under certain conditions, preservation of riparian buffers can enhance profitability of adjacent plantations by slowing land loss (while also reducing carbon emissions, maintaining forest connectivity, and supporting ecosystem biodiversity), and that the optimum width of a riparian reserve depends upon the horizon of economic return.

References:

Horton, A. J. 2017. Cardiff University.

Horton, A. J., *et al.* 2017. Geology, 45, 511-14.

Horton, A. J., *et al.* 2018. Earth's Future, d.o.i 10.1029/2018EF000874.

Possibilities for habitat connectivity

Aims

To understand spatial and economic variation of forest conversion to oil palm in a riverine system.

To examine whether allowing secondary forests to regenerate naturally on abandoned oil palm plantation could provide a cost-effective method of enhancing habitat connectivity for Bornean elephants.

Methods

Oil palm and forested landscapes were mapped (using object-based-image analysis, classification and regression tree analysis and on-screen digitising of high-resolution imagery) and economic modelling was undertaken. CART analyses were used to predict suitable and unsuitable areas for oil palm outside the protected areas.

An area of natural forest regrowth, previously cleared for agriculture and abandoned due to high levels of flooding was identified. The structural regrowth of this forest after a 17-year period was assessed, and its efficacy as corridor habitat for Bornean elephants examined.

References:

Abram, N.K. *et al.* 2014. PLoS One, 9, e95388.

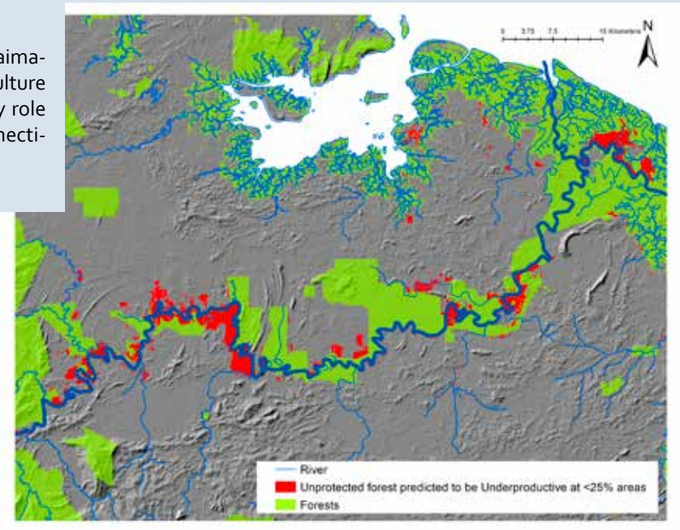
Evans, L.J. *et al.* 2017. For. Ecol. Manage., 401, 159–165.

Results

64% of unprotected forest is allocated for future oil palm. However, it is estimated that 54% of these forests are unsuitable for this type of crop. Also, of the area cultivated with oil palm (within the study region), 20.5% is under-producing; moreover, 6.3% is commercially redundant (NPV range -$299/ha^{-yr} to -$65/ha^{-yr}).

Under-productive oil palm can be reclaimed and, without restoration, can provide suitable corridor habitat for endangered Bornean elephants.

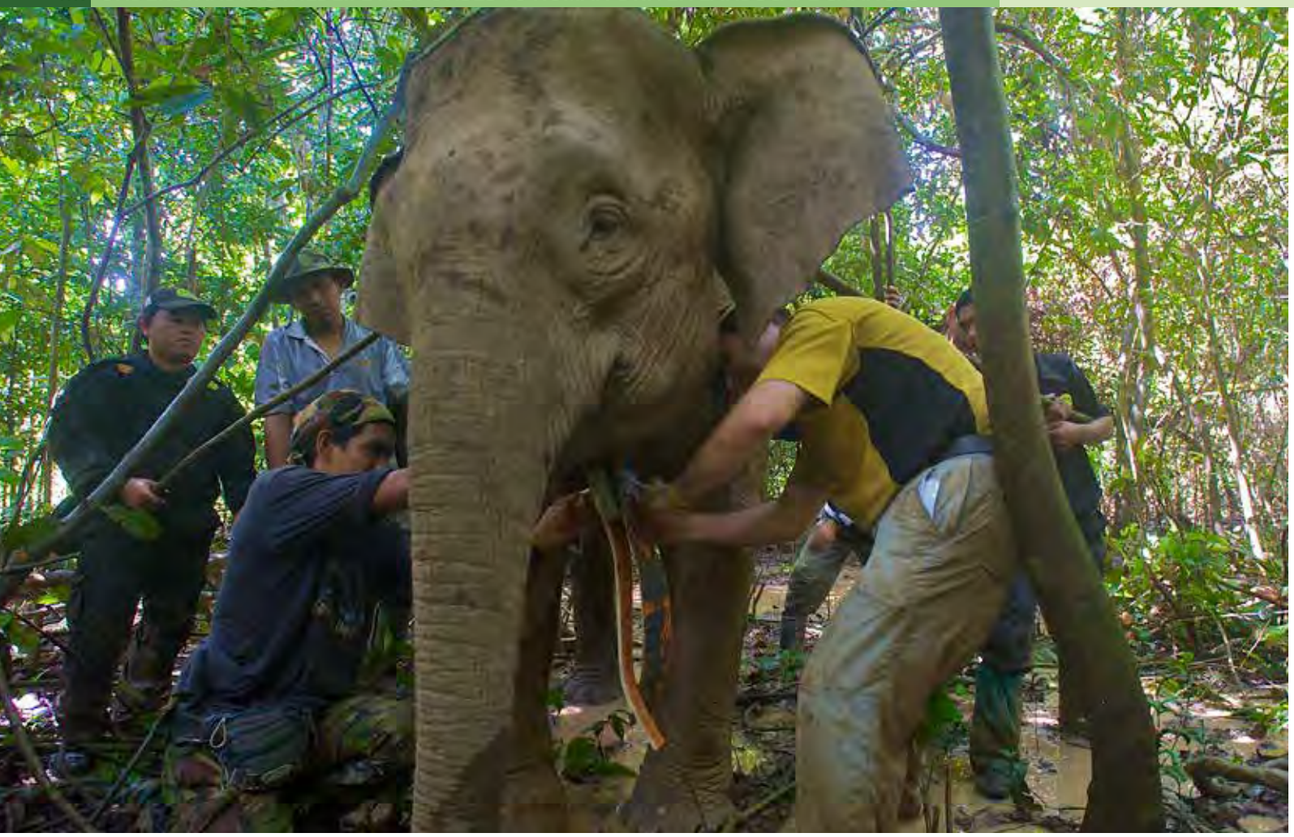
Natural regeneration of reclaimable, underproductive agriculture has the potential to play a key role in lowland tropical forest connectivity.



III. Understanding wildlife responses to human-driven landscape changes

An assumption of fragmented landscape studies is that the remaining original habitat is appropriate for all species in the area whereas the reality is that habitat a is species specific concept. Fragmentation affects some species more than others because it is unlikely that any given fragment is suitable for all animals and it is also improbable that areas of connectivity will be used by all species equally. In this context, we have focused on 15 animal models within the LKF to better understand their requirements for future conservation efforts. Information has been collected mainly on their spatial ecology, habitat use, behaviour and health.

This section contains the project aims, methods and results achieved within the area of the LKF. However, for some of these species, the research is still ongoing and only preliminary results are available.



Bornean elephant (*Elephas maximus borneensis*)

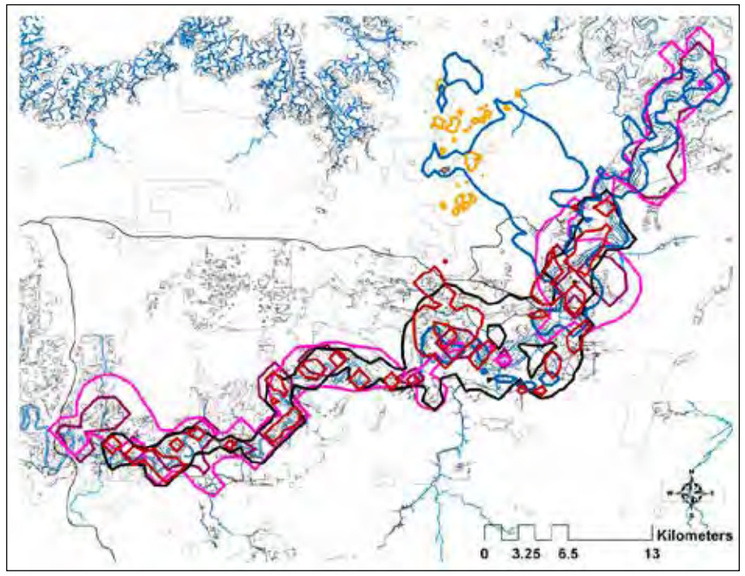
Movement/Spatial Ecology

Projects and Aims

The first GPS satellite tracking program to investigate the movement of wild Bornean elephants in Sabah was initiated in 2005. The home range size for the Bornean elephant had never been investigated and the study focused on a region of fragmented forest (LKF) and one of non-fragmented forest (Tabin Wildlife Reserve, TWR). Starting in 2010, the work on the LKF was expanded with the following objectives: 1) to calculate and map the utilization distributions (UDs) and core home range areas (CAs) used by elephants within the LKF in the flooding and non-flooding seasons, and 2) to elucidate which environmental variables best explain the UDs and CAs of elephants.

Methods

The 2005 study determined the home range size and movement patterns of one individual in the LKF and of four individuals in TWR. This intensive study in the Kinabatangan used GPS data from six individuals collected between 2011 and 2014. The UD analysis was restricted to months within the main flooding season and the main non-flooding season and was determined by Dynamic Brownian Bridge Movement Modelling (dBBMM) and the data was used to determine whether the size of the home range (UD) and the CA were explained by individual identity and season. CART analyses were implemented to predict which variables determined both the core and the home range of elephants in different seasons.



Home ranges (UD areas) of six individual elephants, each represented by a different colour, during the flooding season.

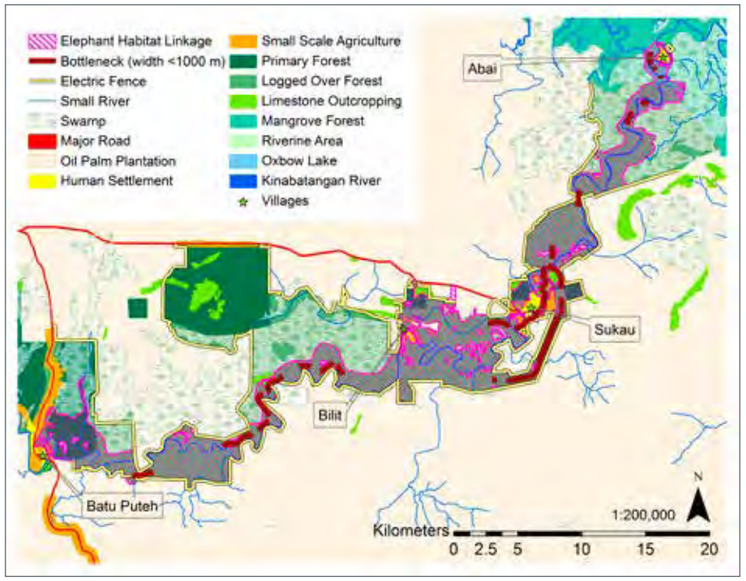
Results

The first movement ecology study suggested a home range of 600 km² in the Kinabatangan. The home range and the movement rate were influenced by the degree of habitat fragmentation. However, the more detailed study determined a home range between 77 - 276 km² while the core area size varied between 3.9 - 53.8 km². In both seasons, elephants were observed to maintain their UD close to the river. In the flooding season elephants were less selective in their space use and were more predictable in their movements. Unlike the flooding season when physical features mostly influenced the elephants' UD, during the non-flooding season the elephants' UD was determined largely by anthropogenic factors.

References

Alfred, R., *et al.* 2012. PLoS One, 7: 31400.

Othman, N. B. 2018. Cardiff University.



In the Kinabatangan, elephant dispersal is limited by both man-made and natural barriers. For example, electric fences, settlements and swamps contribute to the formation of bottlenecks for movements.

References

Estes, J. G. *et al.* 2012. PLoS One, 7: e44601.

Landscape ecology

Foraging site and plant Recursion

87 foraging sites (55% of recursion).

Areas of recursion: riverine/ open grass areas along forest margins

Plants of recursion: 77% were grasses

Prefered species: *Phragmites karka* and *Dinochloa scabrida*

References

English, M., *et al.* 2014. Curr. Zool., 60, 551–559.

English, M., *et al.* 2014. J. Trop. Ecol., 30, 371–379.

Aims

To identify the quantity and configuration of suitable elephant habitat in the LKF and to demonstrate the importance of incorporating both landscape permeability and the natural disturbance regime into elephant habitat estimates for this area. To compare elephant density with different habitat carrying capacity estimates using the most recent Kinabatangan elephant population numbers. Finally, to identify bottlenecks impeding efficient connectivity in the landscape.

Methods

Expert opinion-based (EOB) least-cost analyses were conducted to model the quantity and configuration of suitable elephant habitat termed Elephant Habitat Linkage (EHL). A team of experts provided the weighting of four factors) land cover, linear barriers, swamps, and level of protection) and the suite of classes within them to create the EOB Habitat Suitability Model (HSM). In addition to the EOB model, 21 other HSMs, cost-distance grids, and least-cost corridors were created using biologically plausible alternatives. These alternative models were used to conduct uncertainty analysis on the final EHL design for suitable habitat..

Results

The estimate of available habitat was 54% smaller than the one used in the State's Elephant Action Plan for the Lower Kinabatangan Managed Elephant Range. During high flood levels the available habitat can be reduced to only 61 km². Twenty bottlenecks less than one km wide were found throughout the EHL have the potential to further reduce access to suitable habitat. Eighty percent of all bottlenecks, and 92% of total bottleneck length, were caused at least in part by human landscape features such as oil palm plantations and human settlements.

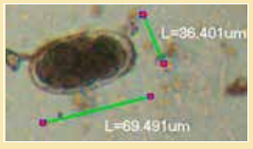
Health

Endoparasitological survey.

Areas: LKF and TWR

Most prevalent parasite: Strongyle nematodes.

Differences between sites: Prevalence and load were higher in the fragmented landscape (LKF)



References

Hing, S., *et al.* 2013. Endanger. Species Res., 21, 223–230.

Behaviour

Aims

This was the first attempt to understand Bornean elephant behaviour using movement data. Human activities and environmental features were used to explain the changes of motion variance and speed in a fragmented landscape. It was also the first longitudinal analysis of the activity budget of adult female elephants in oil palm plantations, freshwater swamp and riparian habitats adjoining the Kinabatangan River, with the goal of understanding how elephant behaviours vary in relation to habitat, time of the day, season and group size.

Methods

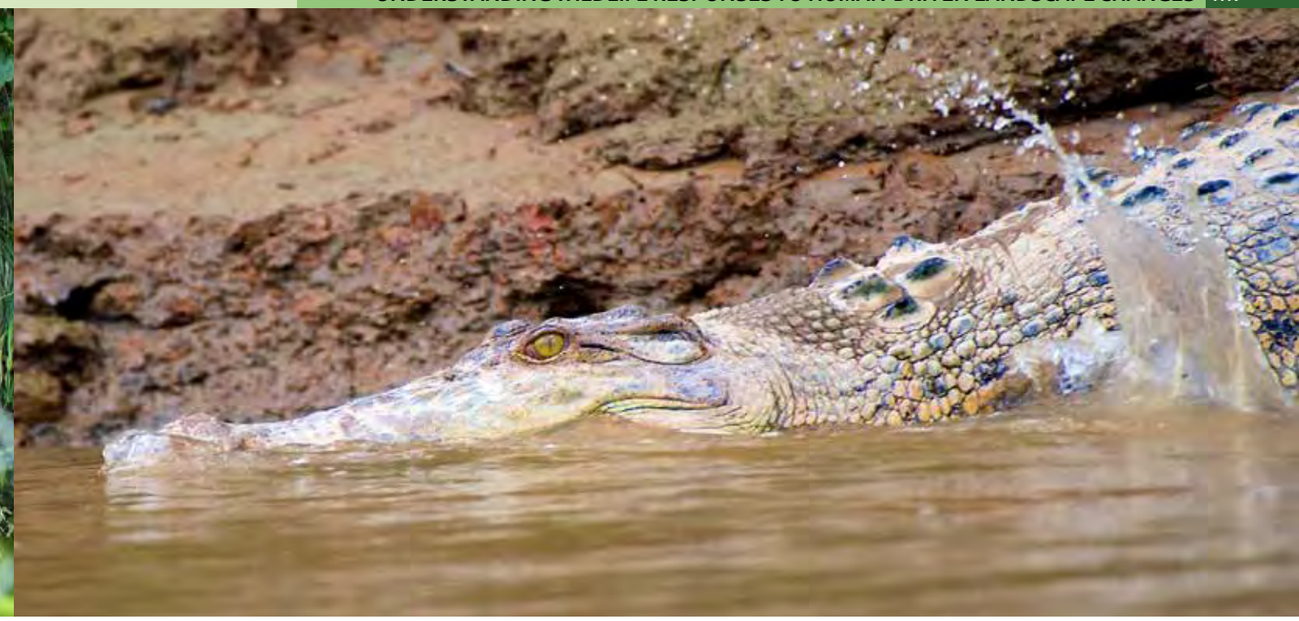
A dBBMM was used to understand the relationships between variation of motion (referred to as "motion variance") and various predictor variables. In addition, movement speed was analysed to examine how the behaviours of 40 individually-identified adult female elephants (primarily feeding, moving, resting, bathing, social interactions, and vigilance) varied in relation to time of the day, season and group size, in the major habitat types within this landscape.

Results

Elephant movement dynamics and speed showed significant temporal (diurnal and seasonal) and spatial (between habitat) variation. Elephants primarily fed in the morning and evening, and rested in the middle of the day. In oil palm plantations, elephants were observed to associate in smaller groups, to feed and socialize less, and to be more restless, vigilant and mobile compared to in riparian habitats. A similar comparison between semi swamp and riparian forest showed significantly higher feeding and vigilance behaviour in freshwater swamp forest but no significant difference in resting and moving, confirming that riparian and seasonal freshwater swamp habitats play an important role as a social arena for Bornean elephants in the LKF, as well as providing food resources and connectivity for movement of elephants across this landscape that is increasingly fragmented by oil palm plantations and other human infrastructure such as roads and bridges.

References

Othman, N. B. 2018. Cardiff University.



Estuarine crocodile (*Crocodylus porosus*)

Spatial ecology of nesting

Aims

To identify nests within a specific region of the Kinabatangan River hoping to establish baseline data for crocodile nesting in a tropical freshwater ecosystem.

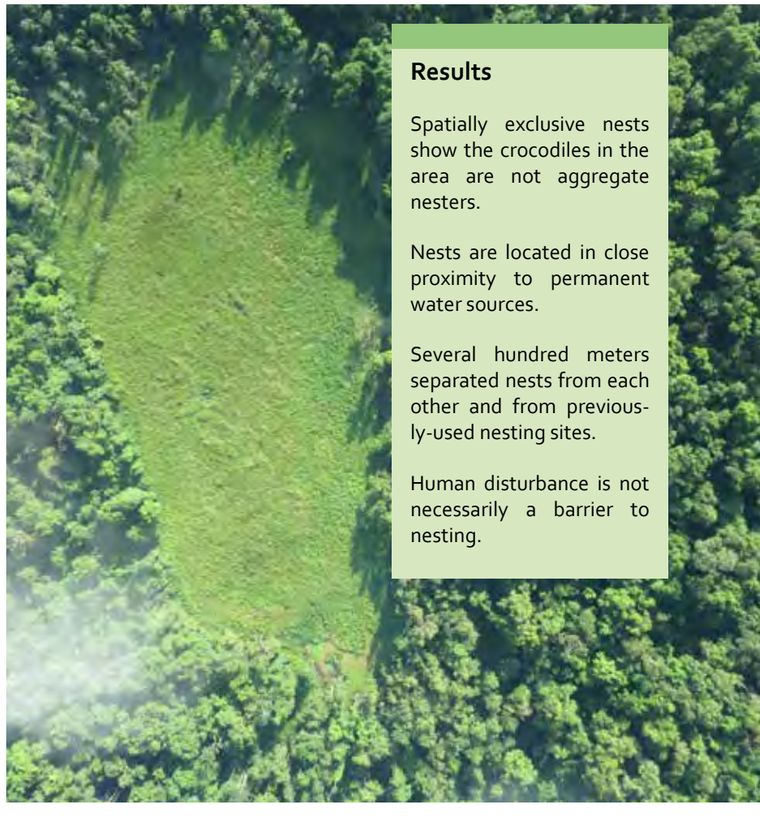
Methods

A 35 km stretch of the Kinabatangan River was selected for the high numbers of both adult and juvenile crocodile individuals present. Aerial surveys were conducted using two drone systems: Bormatec Maja™ (2013) and Skywalker™ (2014). A "fuzzy overlay" model was produced to predict suitable nesting sites as well as a binomial GLMM to define the factors of greatest importance for determining a nesting location.

References

Evans, L. J., *et al.* 2015. Herpetol. Conserv. Biol., 10, 90–98.

Evans, L., *et al.* 2016. Sensors, 16, 1527.



Results

Spatially exclusive nests show the crocodiles in the area are not aggregate nesters.

Nests are located in close proximity to permanent water sources.

Several hundred meters separated nests from each other and from previously-used nesting sites.

Human disturbance is not necessarily a barrier to nesting.

Population surveys

Crocodiles aggregate in forested areas.

Hatchlings were found in close proximity to settlements.

The farther from the village, the larger the crocodiles.

Reference

Evans, L. J. 2011. Cardiff University.

Movement and behaviour ecology

Aims

The study sought to explore, in more detail, site use and activity patterns, both over the short- and long-term, in estuarine crocodiles. It was also meant to determine the use of riparian vegetation during hunting, and to assess and quantify the relationship between crocodile resting sites and hunting behaviours. Within this line, the resting habitat choices of both crocodiles and long-tailed macaques were examined to assess the importance of riparian vegetation in maintaining cryptic hunting behaviours.

Methods

GPS Tags were all attached at the nuchal plate in both male and female crocodiles ranging from 2.12 m up to 5.18 m. Different Local Convex Hull (LoCoH) analyses were tested with the Adaptive (α) LoCoH regarded as the most suitable method to determine home ranges based on biological accuracy and boundary plasticity.

High-resolution airborne LiDAR data and GPS telemetry on animal movement were also combined to identify the repeated use of nocturnal resting sites by adult estuarine crocodiles.

Differences in vegetation between resting and random sites were assessed to examine the factors that affected the presence or absence of macaques during the field surveys.

Results

Data was available from 7 animals (5 males, 2 females).

All individuals were more active at night than during the day, and most exhibited peak activity at dawn, dusk, or both. The females spent large periods of time residing within their core (50%) home range with only brief excursions to areas farther afield. The males, on the other hand, displayed markedly different strategies: site-fidelic and nomadic.

No direct correlation between surrounding habitat and home range size was found, with the exception of the formation of man-made barriers. Despite not providing a physical barrier, the large bridge located at the local village appeared to provide an impassable barrier to four individuals residing in its vicinity who made no attempt to pass under it.

The crocodiles assessed seemed to show clear territorial behaviour, as well as an established dominance hierarchy. Two males and one female held exclusively main river territories. Larger males are preferentially selecting stretches of main river as territories.

Crocodiles were found to be actively selecting overhanging vegetation; the protrusion of trees from the tree line was key to site selection by crocodiles, as well as influencing both the presence and group size of sleeping macaques.

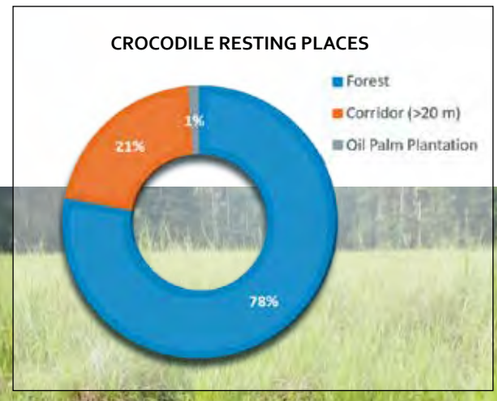
Crocodiles were found to heavily reutilize sites with a high level of tree protrusion, showing preferences for particular locations, especially in forested habitats.

Population genetics

Three genetically distinct populations were identified within approx. 200 km of the Kinabatangan River. They appeared to be evenly distributed throughout the sampling range, suggesting that spatial exclusion does not play a role in the locations they occupy. Equal spatial distribution of individuals from each of the three populations identified also indicate that movement of females and transient males are key in mate-selection and in ensuring that populations are retained.

Reference

Evans, L.J. 2016. Cardiff University



References

Evans, L. J., *et al.* 2015. Herpetol. Conserv. Biol., 10, 90–98.

Evans, L., *et al.* 2016. Sensors, 16, 1527.

Proboscis monkey (*Nasalis larvatus*)

Movement and landscape ecology

Movement ecology data: Is any method a good analysis method?

Aims

Few studies have examined the suitability of new home range estimation methods for primate ecology or conservation using multiple individuals. Therefore, with a high quality GPS collaring data set collected from 10 proboscis monkeys, the aims were to: 1) compare home range estimates generated by the Grill Cell Method (GCM - most commonly used in primatology), with three alternative methods designed for large and/or temporally correlated data sets; 2) evaluate model performance with known physical barriers for a species which recurrently utilises forest edges; and 3) test which of the models is the most versatile and robust by simulating less intense sampling regimes resulting from technological limitations or failures.

Methods

Collaring locations: >2 km apart or on opposite sides of the river, in protected forests (six individuals) and in unprotected forests (two individuals).

Individuals collared: six males and four females.

Data collected: Collars fitted in 2011 – 2014, data obtained for 109 – 401 days.

GPS data: Only 8.3% of points removed prior to analysis (data removed: i) fixed by > four satellites; or ii) further from both the previous point and subsequent point than an animal is able to travel in the elapsed time).

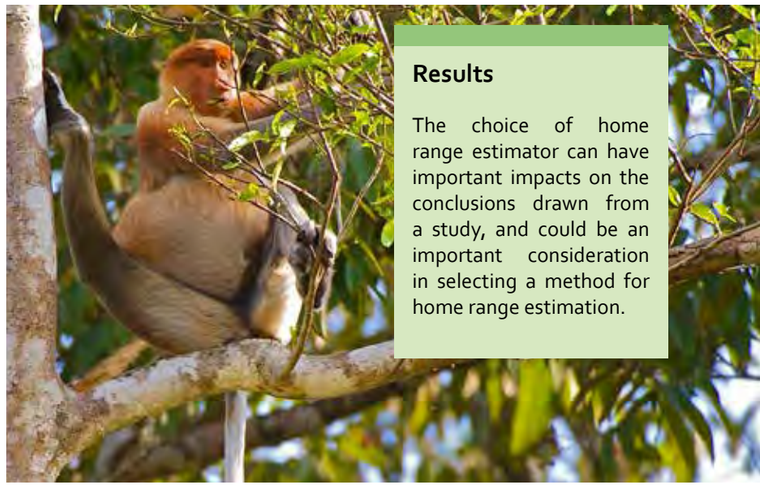
Home range estimates: comparison between the whole dataset and on two subsets of the data that simulated lower fix frequency or higher fix error rates.

Method	Strengths	Weaknesses	Requirements	Suitability
GCM	• Comparable to other studies • Identifies areas of importance • High AUC • Computationally simple	• Sensitive to sample size • Cannot handle barriers well • Largely biased by cell size selected • Interpretation is sensitive to intervals displayed • Time not a factor	• Knowledge of group spread, locational accuracy • Use <100% points (i.e. 90%)	• Supplement other estimators to look at finer detail in high use areas
a-LoCoH & T-LoCoH	• Identifies complex barriers or inaccessible areas • Incorporates time (T-LoCoH) • Robust area estimate with changing sample size or sampling frequency	• Underestimates home range area • No allowance for location uncertainties • Low and variable AUC • User-controlled process in selecting output	• Large dataset • High temporal correlation (T-LoCoH) • Knowledge of natural barriers	• Conservation planning to identify barriers or predator avoidance • Range overlap between groups/ species • Core areas along sharp barriers
BRB	• Incorporates time • High AUC • Robust area estimates with fix failures • Accounts for location uncertainties • Area robust in variation of parameters selected (T_{max} and L_{min})	• Reduced barrier detection as barrier complexity increases • Cannot detect behavioural or biological barriers • Sensitive to decreased sampling frequency	• Species-specific knowledge, locational accuracy • High temporal correlation • Knowledge of natural barriers • At least 200 locations	• Area estimates • Home range for species living along definite habitat edges • Studies with less precise records and more irregular fix success

Summary of the strengths and weaknesses of the home range estimators examined in this study: grid-cell method (GCM), adaptive local convex hull (a-LoCoH), adaptive time local convex hull (T-LoCoH) and biased random bridges (BRB).

UD: estimated by four approaches i) GCM, ii) a-LoCoH), iii) T-LoCoH, and iv) BRB. GCM and a-LoCoH are location-based estimators, whereas T-LoCoH and BRB incorporate time i.e. are movement-based. The UDs were based on the 90th percentile for overall home range size and 50% for the core area.

Home range: compared in two ways: i) the overall dissimilarity between the utilisation distributions, and ii) specific characteristics of the range estimates (e.g. area).



Results

The choice of home range estimator can have important impacts on the conclusions drawn from a study, and could be an important consideration in selecting a method for home range estimation.

References

Stark, D. J., *et al*. 2017. PLoS One, 12, e0174891.

Stark, D. J. 2018. Cardiff University.

Home ranging and resource utilisation

Aims

It is likely that different primate species will respond differently to habitat loss or other anthropogenic activities according to differences in their ecological traits. Home ranging and other detailed ecological responses are crucial given the functional roles primates play in their ecosystems. Therefore, it was vital to identify the resources important to proboscis monkeys and how the proximity of human- made edges (i.e. plantations) or limited forest availability may impact their ranging and resource use as well as to obtain a more accurate depiction of the habitat use and ranging patterns of proboscis monkeys in a degraded forest landscape.

The study focused on gaining insights on how proboscis monkeys utilise a degraded forest landscape across timescales varying from daily, through monthly to annually; examining changes in movement associated with: 1) environmental factors and 2) proximity to forest edges.

Methods

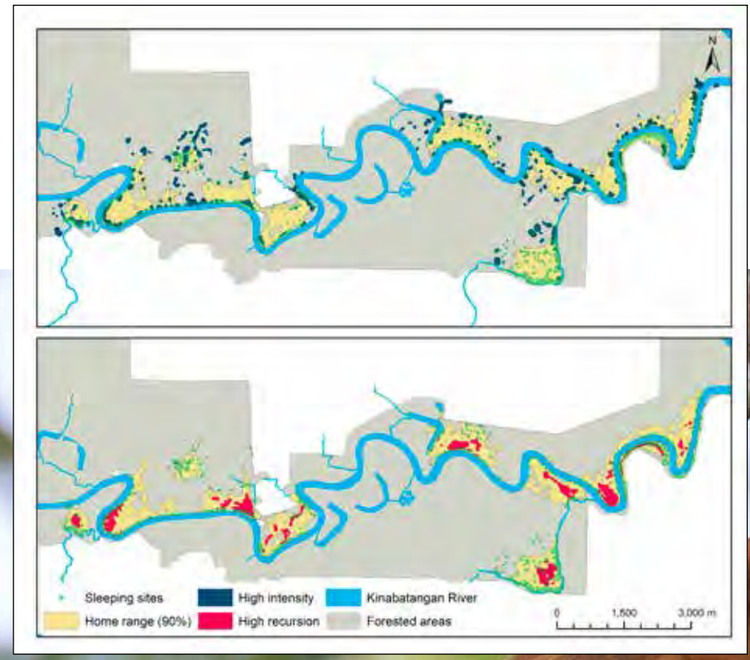
GPS-collar tracking data from 10 proboscis monkeys were used. Collars provided data for 241 (± 33) days; positions were recorded hourly between 05:00 and 19:00. The UD, the high intensity (ID) and the high recursion (RD) sites were determined using BRB. Tracking data also focused on four variables: daily path length (DPL), movement speed, straightness index (SI), and turning angles (TA). DPL and speed are descriptors of the travel effort (how far and how fast), whereas SI and TA describe how individuals move through the habitat (i.e. directed or tortuous).

Landscape structure (e.g. forest area, proximity to forest edge) was analysed using GIS and high-resolution LiDAR data was used to quantify forest structure (20 variables covering three main forest descriptions). A Principal Component Analysis (PCA) was used to resolve the relationships between the LiDAR variables and to select a subset of distinct variables representative of each principal component. Resource Utilisation Functions (RUFs) based on the PCA variables were estimated to quantify differences in proboscis monkey resource use between the UD, ID and RD.

Phenology data in 34 botanic plots (20 m x 20 m) each of a single habitat type were recorded in addition to the GPS and LiDAR data. These data were used to: 1) examine the seasonal variation in the availability of different plant parts (young leaves, flowers or fruit), 2) examine the role played by rainfall, 3) regress movement patterns onto monthly average rainfall and phenology, 4) test whether movement patterns changed in the vicinity of forest edges, both along the river and next to oil palm plantations.

References

Stark, D.J. 2018. Cardiff University.



Within a home range (UD; yellow) the areas most intensively used (ID, high intensity; navy blue) did not necessarily overlap with those most visited (HR, high recursion; red). Sleeping sites (green) were not restricted to river banks.

Results

Most heavily used areas = mean tree heights in the range of 20-25 m, close to rivers (<200 m) or farther away from oil palm plantations (>2 km).

Habitat use peak: around 60-110 m from rivers and lakes yet areas reaching as far inland as 1.2 km were also important habitats.

DPL = 937 m (average); 1.7% of DPL exceeded 1800 m, with a maximum of 3037 m

More rainfall =

less distance travelled

less "straight-line" movements

more fruits and flowers available

Forest-plantation edge = quicker and "straight-line" movements

Inside ID patches = slower and tortuous movements

Riparian forests are important and an area of at least 200-300 m along the river is required instead of the legal minimum of conserving 20 m of forest along the main river and 5 m along tributaries.

Disturbance and forest area appeared to have little effect on ranging behaviour. ID and HR also become more similar in size when less forest is available.

Social and/or ecological factors may influence ranging patterns.

Sleeping site selection

Aims

To test both the 'antipredation' and 'potential food abundance' hypotheses, and also the association of sleeping sites with 1) environmental factors (i.e., rainfall, moon phase) and 2) proximity to forest edges.

Methods

Recorded daily rainfall, temperature and moon phase.

Used GPS data (1900 hr fixes) of collared proboscis monkeys, and daily surveys (on the riverbanks) to locate sleeping sites.

Compared sleeping trees to surrounding trees to highlight sleeping tree characteristics in comparison to other available trees located in direct proximity to sleeping trees.

Compared sleeping sites to 'non-sleeping' sites (areas along the riverbank where proboscis monkey groups were never observed to sleep throughout the study).

Results

Most common tree species selected (80%): *Colona serratifolia*, *Pterospermum diversifolium*, *Ficus racemosa* and *Nauclea orientalis*.

Most used species: *C. serratifolia* (possibly do to highest availability along the riverside).

Preferred species: *Ficus racemosa*

Species avoided: *Kleinhovia hospita*

Selected trees' characteristics compared with those of surrounding trees:

- wider trunk circumference
- closer to the riverbank
- taller
- with higher and wider first branches
- with greater abundance of mature leaves and fruits (ripe and unripe)
- with less vines in their crown

Location of selected trees:

- within 50 m of water (82%), especially on wetter days
- Inland during drier periods, warmer temperatures or brighter moon phases

Who sleeps where?

- higher canopy: females and young individuals

References:

Thiry, V., *et al.* 2016. Folia Primatol., 87, 180–196.

Stark, D. J. 2018. Cardiff University.

Danau Girang Field Centre 10th Anniversary Report
UNDERSTANDING WILDLIFE RESPONSES TO HUMAN-DRIVEN LANDSCAPE CHANGES III.

What about the big noses?

Methods

Measures taken from 18 free-ranging males: body mass, nose size and testis volume.

The number of adult males per wild harem group were correlated with the degree of nose enlargement in the core males of the group.

Other audiovisual masculine signals investigated from seven captive males: nose size (facial photographs) and recorded vocalizations.

Results

Big noses:

- Are predictors of masculine characters (like social dominance or high sperm counts)
- Are a badge of status in harem groups.
- Play a role in female attraction and male-male competition.
- Nose size overrides body mass as a cue for other masculine traits and could be selected in parallel by females.

Recordings were turned into spectrograms and based on multiparametric analyses, acoustic features were identified: "shrieks," "honks," "roars," and "brays." "Chorus" events were also noted in which multiple callers produced a mix of vocalizations. The four call-types were distinguishable based on a combination of fundamental frequency variation, call duration, and degree of voicing.

Vocalisations dispersion parameters are indicative of body mass and are, in theory, mediated by vocal tract length.

Male vocalisations may be a truer representation of male quality than visual cues, and the former could more effectively help to ensure offspring survival than the latter, therefore contributing to female mate selection.

References

Koda, H., *et al.* 2018. Sci. Adv., 4, eaaq0250.

Röper, K. M., *et al.* Am. J. Primatol., 76, 192–201.

Health

Endoparasite species richness has been assessed for proboscis monkeys in the LKF, with special focus on lot 6.

Parasite groups found:

- Trichurids (genera Trichuris and Anatrichosoma)
- Strongylida (genera Trichostrongylus and Oesophagostomum/Ternidens)
- Rhabditia (genus Strongyloides)
- Ascaricida (genus Ascaris)
- Oxyurida (genus Enterobium)
- Dicrocoeliid
- Taenia
- Dipylidium-like
- Acanthocephalan

A comparison was made between the LKWS and Labuk Bay Proboscis Monkey Sanctuary (a human-managed area): parasite species richness (including morphotypes) and egg shedding intensity were higher in Labuk Bay than in the Kinabatangan. This suggests a human-managed area may facilitate intestinal parasite transmission between hosts.

References

Salgado-Lynn, M. 2010. Cardiff University.

Klaus, A., *et al.* 2017. Int. J. Parasitol. Parasites Wildl., 6, 320–329.

Klaus, A., *et al.* 2018. PLoS One, 13, e0195584.

Science-based conservation action

Aims

To demonstrate the increased effectiveness of drone datasets when paired with the satellite tracking data of proboscis monkeys to rapidly raise awareness and facilitate policy changes regarding riparian habitat destruction. To compare the extent of forest clearing in the area after the tracking period was complete to investigate the potential impact deforestation could have on the ranging of a one-male group of proboscis monkeys. To show how these visually compelling data can engage the general public and initiate discussions on policy reform and conservation action.

Methods

Forest extent estimates prior to the most recent logging was based on digitised and processed Google Earth Pro (Google Earth 7.1, 2014). The 2014 image was assumed to be representative of the forest cover during 2012.

A drone was fitted with a digital camera that was customised with firmware enhancement. Flights were flown at an altitude of 315 m, with transects 170 m apart, and an inter-image gap of 3 sec to obtain >60% sequential picture overlap.

UD estimated using BRB, and sleeping sites defined as the GPS fixes at 1900 h.

From the drone images, it was calculated that a further 47.54 ha had been cleared in late May 2015, accounting for 18.3% of the forested area.

Result

Importance of riparian reserves for proboscis monkeys: they included 25% of daily ranging points and >88% of sleeping sites.

Area cleared: 30% of the groups' total home range area, including 11% of their sleeping sites.

A press release was prepared by members of DGFC using the drone and satellite tracking datasets to highlight the association of the habitat destruction to a species that is economically important for the tourism industry in Sabah. The press release was published in local and national newspapers, as well as on DGFC's Facebook page.

The following day, the Sabah State Government announced that there would be an immediate cessation of land clearing along sensitive riparian reserves in the Kinabatangan River. A formal investigation was conducted which confirmed a few infractions had taken place.

By providing compelling research and visual aids, using a combination of satellite tracking and drone imagery, rapid responses by authorities and policy makers can be more effective when dealing with time-sensitive issues. Furthermore, the awareness raised using these means can also identify the need to update policies to identify responsible parties, and hold them accountable, should encroachment occur in the future.

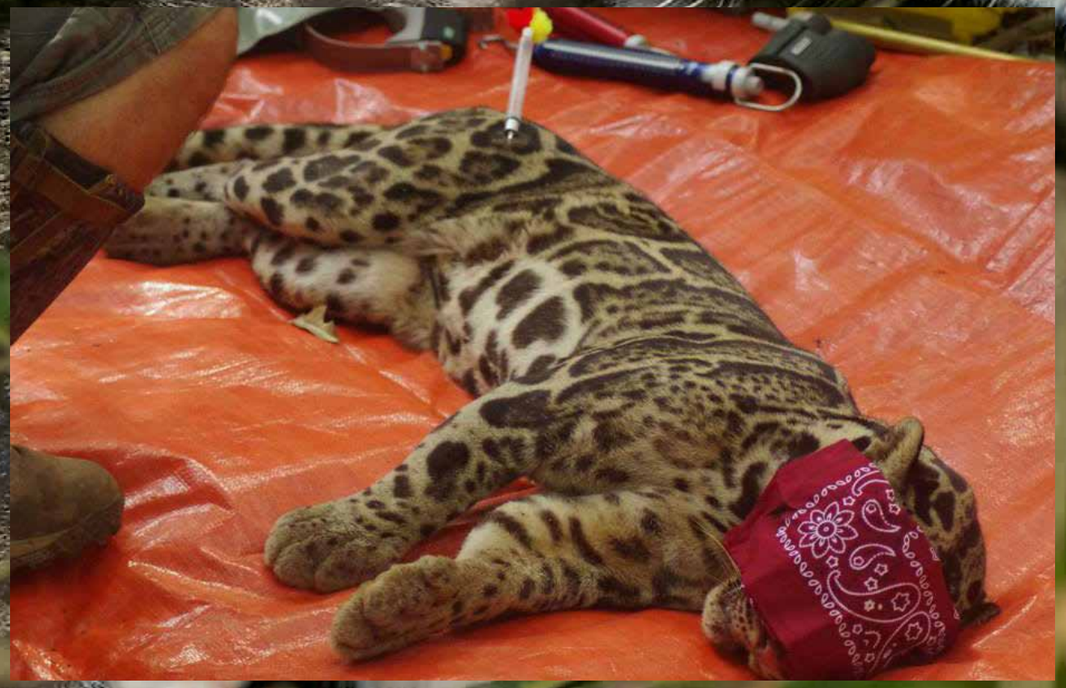
Aerial view of the riparian reserve that was home to a collared proboscis monkey and his group. The white dots represent the animal's movements. The picture was taken after the deforestation took place.

References

Stark, D. J., *et al.* 2018. Remote Sens. Ecol. Conserv., 4, 44–52.

The Kinabatangan Carnivore Programme

The Kinabatangan Carnivore Programme intends to advance understanding, and the conservation, of the diverse carnivore guild of the LKF. It is a long-term programme aiming to provide insights into Bornean carnivore ecology and density and develop species distribution and habitat suitability models within this unique and important region.



Sunda clouded leopard (*Neofelis diardi*)

Movement ecology

Aims

Little is known regarding the movements, dispersal abilities and population connectivity of Sunda clouded leopards. Therefore, an aim of this study was to understand the influence of landscape variables on their movements. In particular, to obtain a detailed mapping of habitat corridors through and around oil palm plantations for these animals.

Methods.

GPS/GSM collars were fitted to three males and one female clouded leopard.

A multi-scale path- level analysis of movement data was applied using known variables associated with clouded leopard habitat (including land cover, canopy cover, carbon density, and road and major river distribution) to develop resistance surfaces and connectivity predictions.

The impact of future possible landscape change scenarios was evaluated. These scenarios reflect changes that are either ongoing or stand a realistic chance of occurring, and that present both potentially positive and negative implications for the Sunda clouded leopard:

1) deforested areas within 50 m of the Kinabatangan River reverted back to forest cover
2) non-productive oil palm converted to forest
3) both 50 m river buffer and non-productive oil palm converted to forest
4) all privately owned unprotected forest converted to oil palm.

How to immobilise a clouded leopard?

Best anaesthesia protocol: Medetomidine and ketamine; Atipamezole as antagonist.

Reference:

Najera, F., *et al.* 2017. J. Vet. Med. Sci., 79, 1892–1898.

Population density

Based on capture-recapture camera trap data, low population densities are estimated for the LKF (1.5 individuals/100 km²). To ensure a viable population over the long-term, it is essential to maintain connectivity through the retention of forest cover. Hunting must also be stopped as there also were indications of high poaching activity in the region.

Area covered: 359.5 km²

Camera trap protocol: split-grid with 66 camera stations on trails

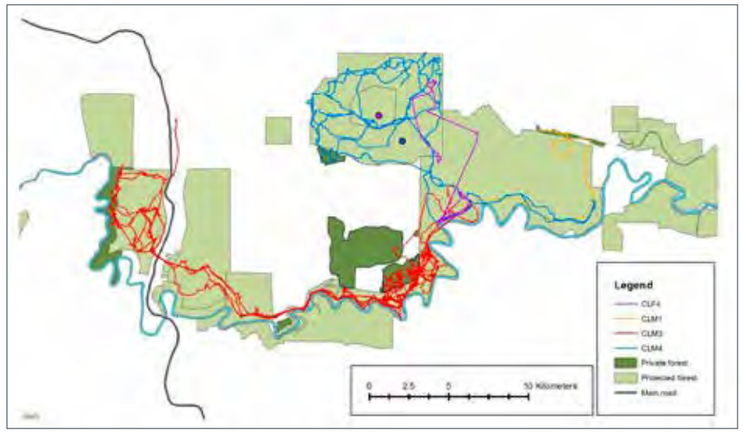
Dataset: 90 sampling occasions, 3060 trap days over six months.

Animals observed: 13 independent captures, 5 different individuals: 2 males, 3 females.

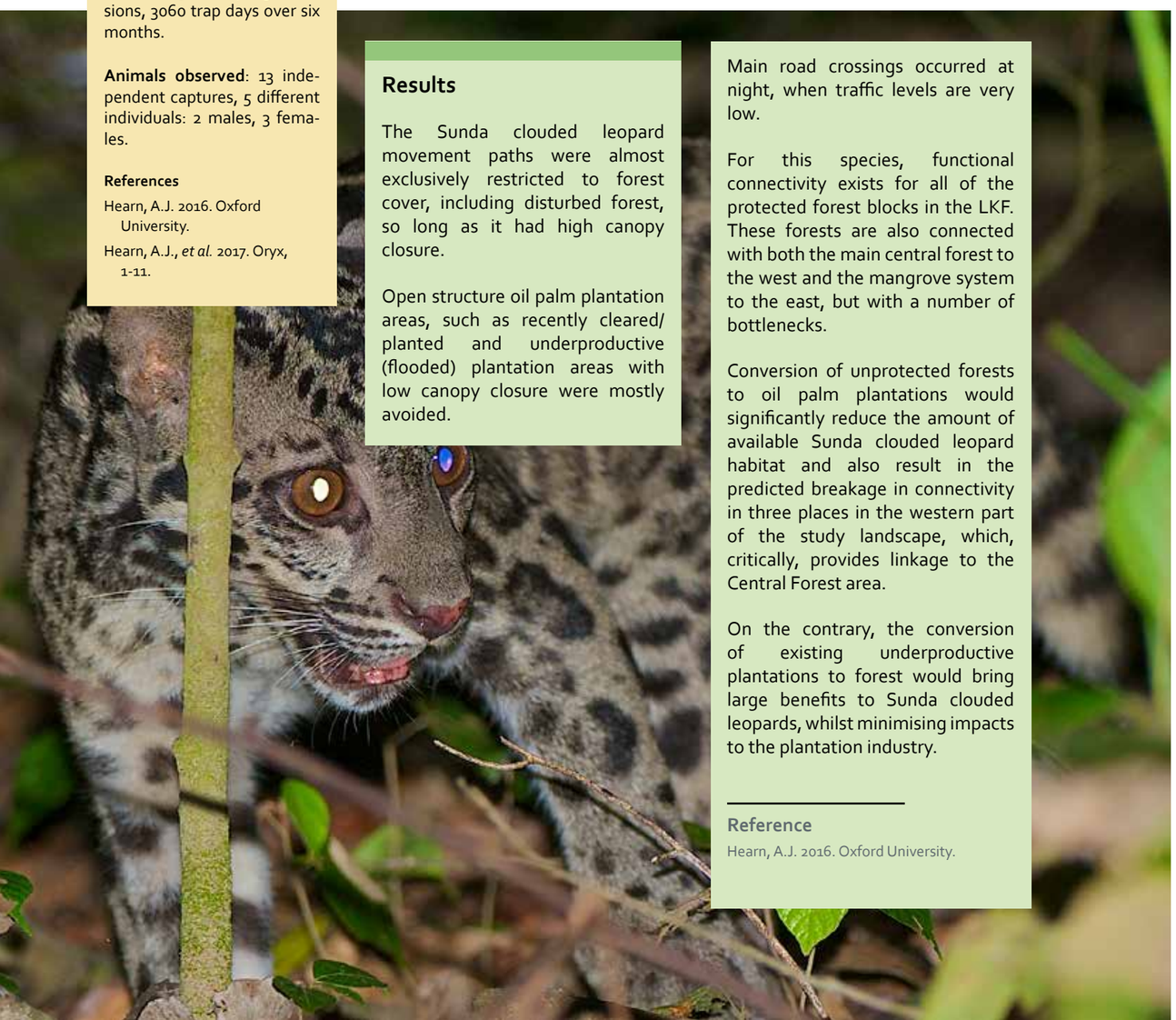
References

Hearn, A.J. 2016. Oxford University.

Hearn, A.J., *et al.* 2017. Oryx, 1-11.



Movement patterns of four clouded leopard individuals, each as a different line colour. The movement paths were almost exclusively restricted to closed canopy covers.



Results

The Sunda clouded leopard movement paths were almost exclusively restricted to forest cover, including disturbed forest, so long as it had high canopy closure.

Open structure oil palm plantation areas, such as recently cleared/ planted and underproductive (flooded) plantation areas with low canopy closure were mostly avoided.

Main road crossings occurred at night, when traffic levels are very low.

For this species, functional connectivity exists for all of the protected forest blocks in the LKF. These forests are also connected with both the main central forest to the west and the mangrove system to the east, but with a number of bottlenecks.

Conversion of unprotected forests to oil palm plantations would significantly reduce the amount of available Sunda clouded leopard habitat and also result in the predicted breakage in connectivity in three places in the western part of the study landscape, which, critically, provides linkage to the Central Forest area.

On the contrary, the conversion of existing underproductive plantations to forest would bring large benefits to Sunda clouded leopards, whilst minimising impacts to the plantation industry.

Reference

Hearn, A.J. 2016. Oxford University.

Bornean sun bear (*Helarctos malayanus*)

Movement ecology

Aims

There is very few information on how sun bears are able to survive in the seemingly poor habitat of the LKF. In particular, the aims of this project were to gain baseline data on bear movements and habitat use.

Methods

Camera traps and sign surveys were used to examine trends in bears' habitat use and activity patterns. Camera traps were set along riparian and forests trails and ridgelines. Strip transects were used to search for signs.

Results

Activity peaks were detected around 4.00 am and 8.00 pm. Rest periods seemed to occur between 8.00 am and 4.00 pm.

Sun bears appear to use many (74%) portions of the riparian and forest trails and ridgelines throughout the study site.

Riparian corridors were used to move between larger forests fragments rather that as feeding or resting areas.

Larger forest fragments served as a better buffer from human activities, and were more intensively used by bears.

On certain habitat features, such as forest trails, sun bears were more nocturnal and reduced using these features in proximity to people. Bears that used trails or were near other human travel ways rarely did so during daylight hours.

Reference:

Guharajan, R. 2016. University of Minnesota.

Human-bear conflict

Aim

The absence of sufficient natural food in forest fragments could drive sun bears into oil palm plantations, where they risk coming into conflict with people. The aim of this study was to understand the use of plantations by sun bears, whether their feeding damaged crops, and whether people perceived them as a threat.

Results

Bears were rarely encountered within plantations, more commonly than clouded leopards and Sunda pangolins, but less commonly than elephants and orang-utans.

Bears were not considered to be destructive to the oil palm crop, although they also apparently fed on palm shoots.

Although only a few attacks were reported, bears were generally feared.

References

Guharajan, R., *et al.* 2017. Oryx, 1-9.

Kinabatangan Small Carnivore Project

A project within the Kinabatangan Carnivore Programme, it aims to determine the long-term effects of habitat fragmentation on the significantly understudied Bornean small carnivore guild. The expansion of large-scale agriculture is a very tangible threat to global biodiversity, and by utilizing GPS collars, biological sampling, behavioural data and remote sensing, the KSCP hopes to evaluate how conservation planning can best mitigate carnivore losses.

What is out there?

Aim

To provide an inventory of the small carnivore species in the LKWS.

Methods

25 camera stations (active stations varied in number) deployed from 2010 to 2015 (non-consecutively) within a thin forest corridor.

Cameras were set ~0.5 m above ground level on trees facing each other.

Photos were individually examined for the presence of animals.

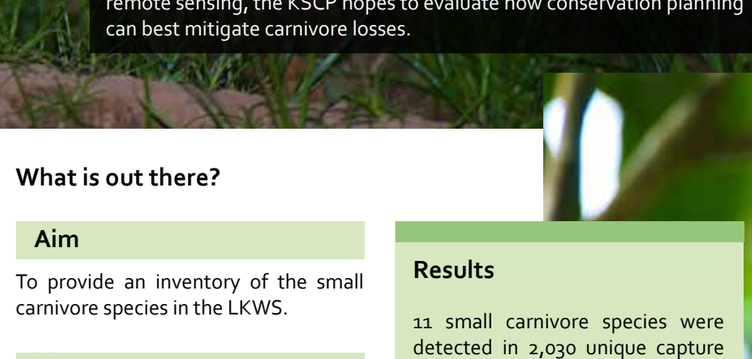
Classification was based on the species present.

Results

11 small carnivore species were detected in 2,030 unique capture events throughout the survey.

First photographic record of an Otter Civet (*Cynogale bennettii*) in the LKWS, representing a new locality for this species.

Opportunistic sightings of five additional species: Small-toothed Palm Civet (*Arctogalidia trivirgata*), Malay Weasel (*Mustela nudipes*), Flat-headed Cat (*Prionailurus planiceps*), Asian Small-clawed Otter (*Aonyx cinereus*), Marbled Cat (*Pardofelis marmorata*).



Location of camera-trap stations along a corridor between lots 5 and 7 in the LKWS (2010—2015).

Case study: Sunda stink-badger (*Mydaus javanensis*)

Based on 756 photo-captures across 470 unique events, it is suggested that this animal is highly nocturnal and, mainly, solitary. Its activity pattern does not significantly vary between seasons or moon phase.

Reference

Vickers, S.J., *et al.* 2017. Raffles Bull. Zool. 2017, 65, 316–324.

Reference:

Evans, M. N., *et al.* 2016. Small Carniv. Conserv., 54, 26–38.

Species	Scientific name	No. of capture events	No. of camera-trap stations detected	No. of trap nights until first detection	2015 IUCN Red List Status
Malay Civet	*Viverra tangalunga*	1,108	24	21	Least Concern
Common Palm Civet	*Paradoxurus hermaphroditus*	179	20	21	Least Concern
Banded Palm Civet	*Hemigalus derbyanus*	62	12	208	Vulnerable
Otter Civet	*Cynogale bennettii*	1	1	208	Endangered
Binturong	*Arctictis binturong*	2	1	19,321	Vulnerable
Banded Linsang	*Prionodon linsang*	1	1	12,211	Least Concern
Malay Badger	*Mydaus javanensis*	470	18	188	Least Concern
Smooth-coated Otter	*Lutrogale perspicillata*	140	12	166	Vulnerable
Yellow-throated Marten	*Martes flavigula*	11	6	565	Least Concern
Mongoose sp.	*Herpestes sp.*	28	11	628	Least Concern
Leopard Cat	*Prionailurus bengalensis*	28	11	48	Least Concern

Small carnivore results from November 2010—May 2015 camera-trapping survey within lots 5 and 7 of the Lower Kinabatangan Wildlife Sanctuary.

Otters

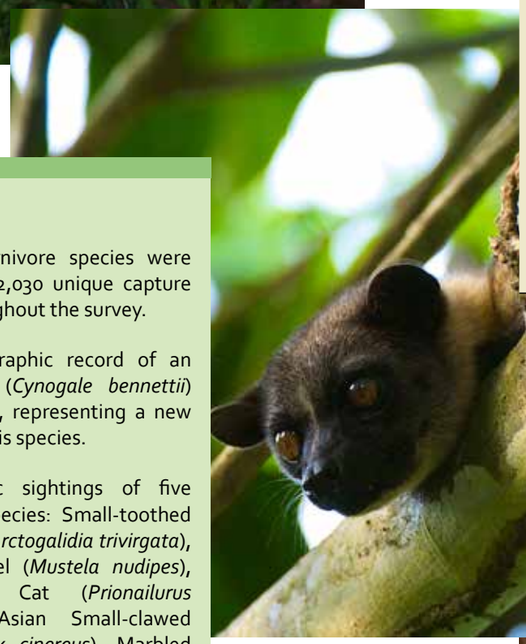
There are four confirmed species of otter in Borneo and two confirmed species in the Lower Kinabatangan Wildlife Sanctuary (LKWS): the Asian Small-Clawed Otter (*Aonyx cinereus*) and the Smooth-Coated Otter (*Lutrogale perspicillata*). Due to lack of information, data about otters is needed urgently in order to establish conservation status and future conservation management plans.

Aims

1) To determine the presence and absence of otter species, and their distribution across the different habitat structure in the LKWS.

2) To evaluate the effect of habitat on otter presence/absence and/or intensity of use.

3) To identify and understand better human-otter conflict.

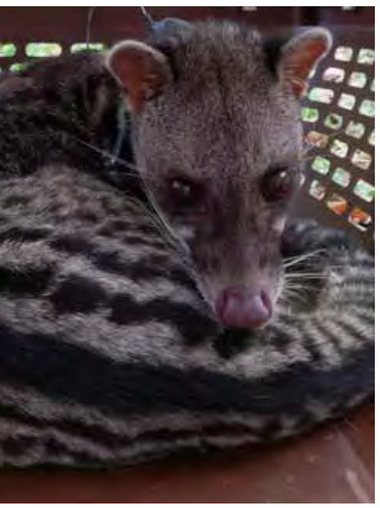


Health

Presence of *Toxoplasma gondii* was found in free ranging domestic cats (*Felis catus*) from villages and oil palm plantations. No Malay civets (*Viverra tangalunga*) were seropositive (titres ≥ 64); however, a few had titres between 16 and 32, and a couple of Viverrid scat samples had potential oocysts.

Reference

Tober, A. 2017. Royal Veterinary College and the London School of Hygiene and Tropical Medicine.



Civets

Aims

To understand the effects of habitat fragmentation and agro-expansion on the spatial ecology, diet, and ecotoxicology of two civet species: the Malay civet (*Viverra tangalunga*) and the common palm civet (*Paradoxurus hermaphroditus*).

General methods

The project is the first in the world to place a GPS collar on a Viverrid species, and the level of spatiotemporal data resolution is providing novel insights into how the guild is responding to the anthropogenic pressures. Non-invasive ecotoxicology analyses and dietary sampling are uncovering otherwise unforeseen data on how these species are being exposed to dangerous chemicals and other pollution sources.

A few preliminary results
(Oct 2013 - Dec 2017)

In total, 43 unique individual civets were captured and sampled during the field season, of which 36 were Malay civets (*Viverra tangalunga*) and seven were common palm civets (*Paradoxurus hermaphroditus*). A female short-tailed mongoose (*Herpestes brachyurus*) was opportunistically sampled in 2017. To January 2018, GPS collars have been deployed on 16 Malay civets and on three common palm civets, and relatively defined home ranges have been estimated for all of them.

Reference

Evans, M. N., *et al.* 2016. Ecol. Res., 31, 475–481.

Nocturnal primates

Only two species of nocturnal primates are found in Borneo: the Bornean slow loris (*Nycticebus menagensis*) and Bornean tarsier (*Tarsius bancanus borneanus*). Only in Borneo we find slow lorises and tarsiers living together in sympatry. Both species' survival is threatened by extensive habitat loss and the illegal wildlife trade, yet studies on these Asian animals, are still lacking despite the importance of understanding the behaviour and ecology of these species for conservation.

Co-habiting the same place.

Aim

To gain information on the potential evolution of niche divergences to reduce resource competition.

Methods

Line transects walked from 6.00 pm to 2.00 am for six months.

Habitat characterisation included DBH, tree height, saplings over 1 m in height.

Results

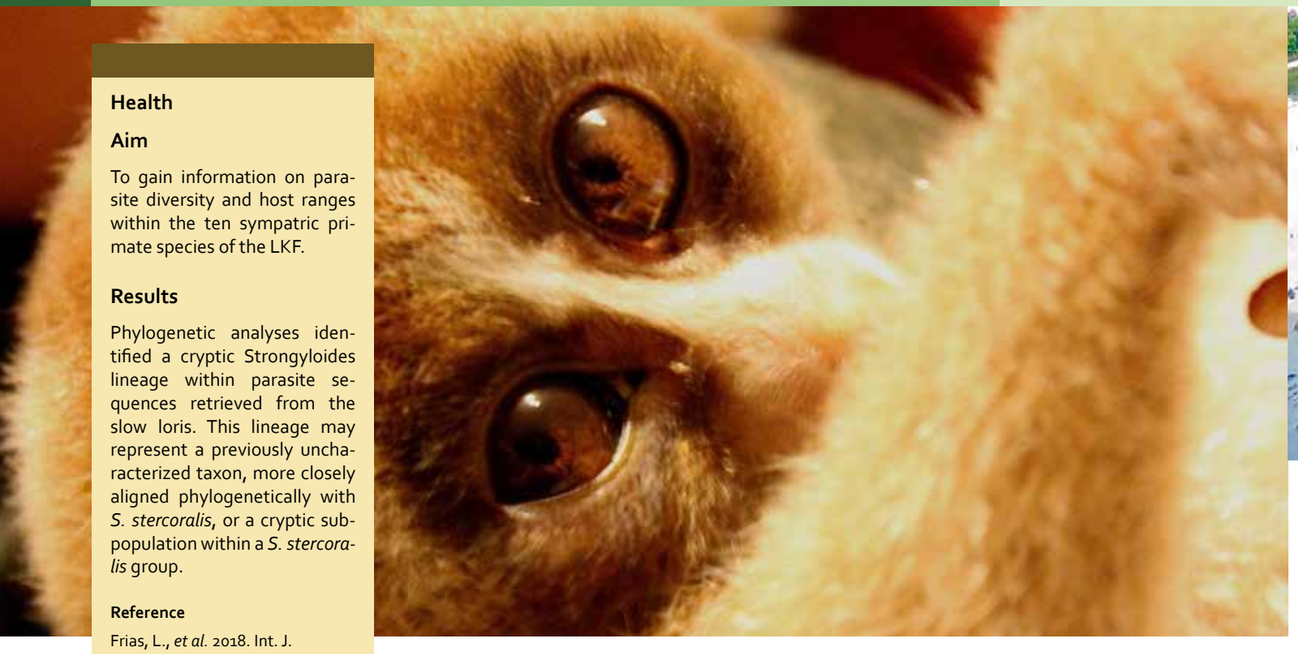
Densities: 5.1 lorises km^{-2} and 3.6 tarsiers km^{-2}.

Habitat use: median height for lorises = 15 m, range = 8.5–30 m; median height for tarsiers = 1.25 m, range = 0.5–3 m

References

Munds, R. A. 2010. Oxford Brookes University.

Munds, R. A., *et al.* 2013. Endanger. Species Res., 22, 269–277.



Health

Aim

To gain information on parasite diversity and host ranges within the ten sympatric primate species of the LKF.

Results

Phylogenetic analyses identified a cryptic Strongyloides lineage within parasite sequences retrieved from the slow loris. This lineage may represent a previously uncharacterized taxon, more closely aligned phylogenetically with *S. stercoralis*, or a cryptic subpopulation within a *S. stercoralis* group.

Reference

Frias, L., *et al.* 2018. Int. J. Parasitol. Parasites Wildl., 7, 141–146.

Locomotion

Aim

To evaluate the deployment of an accelerometer on a Western tarsier (*Cephalopachus bancanus borneanus*) as a mean to obtain valuable information on leaping activity, which is the main locomotive mode of tarsiers.

Result

A set of guidelines to deploy accelerometers on tarsiers (and potentially useful in other primate species).

Reference

Constantini, D., *et al.* 2017. Folia Primatol., 88, 46–56.

Ecology

Aim:

The main aim is to establish the home range, behavioural ecology and habitat use of these animals. In particular:

What is the pattern of habitat use for the Philippine slow loris and Bornean tarsier? Are there any differences between sexes in habitat use?

What are the social structures of these primates?

What is the dietary strategy of the loris and tarsier?

Methods:

Tarsiers and lorises are hand-captured opportunistically. Animals are measured in situ, and a small radio (VHF) collar is fitted on suitable animals followed by immediate release at the same capture site. Using the VHF tracking system, the sleeping sites of the collared animals are found every day, and the trees are marked in order to record re-use and return rates of sleeping trees, as well as to allow characteristics of the sleeping site area to be recorded at a later time. Nocturnal ranging behaviour is collected by following collared individuals for 6-hour shifts (18:00-00:00 and 00:00-06:00), recording the individuals behaviour and location at set intervals. Environmental conditions are also recorded.

Other Reptiles

Water monitor lizard (*Varanus salvator*)

Aims

The main aim is to study the landscape and spatial ecology of this scavenger species, as well as collecting information on parasites' transmission dynamics to assess the bioaccumulation process of different pollutants derived from the different human activities.

In particular:

What is their home range size and how does the landscape define it?

Which factors influence the abundance and dispersion of this animal's populations in the Kinabatangan floodplain landscape?

How the population dynamics of *V. salvator* in this type of landscape influence the presence and transmission of parasites and other pathogens?

How the habitat used by *V. salvator* influences the agrochemicals and heavy metals' bioaccumulation inside this animal's body?

Methods

GPS/VHF devices are deployed on the lizards over several months to gain insights on their home-range size, habitat preferences and movement patterns. Aerial photography and GIS tools will be used to analyse the data provided by the devices. All the lizards that are trapped are measured and sampled. An integral sampling procedure is performed in order to describe the general health of the populations: diet, genetics and microbiological assessment. Toxicological and molecular analyses are performed to assess whether the oil palm plantations' activities around the LKWS influence in the population health of the species.

A few preliminary results

Population assessment – over 3,200 trapping days; over 770 captures; 420 unique individuals. The survival and growth rates have been estimated to be higher in the forest than in the plantations.

Home range assessment - 20 animals have been GPS tagged in both plantation and forested areas. Analysed data suggest that individuals inhabiting forested areas have larger home ranges than those living in plantations. Also, the core area seems to be almost the same size for individuals inhabiting the plantations and those living in the forest, and that individuals inhabiting plantations seem to be restricted into just one plantation almost the same size that their transition area.

Health Assessment – 92 faecal samples analysed; in total, 12 taxonomic groups of nematodes, cestodes, trematodes and protozoans have been identified.

Monitor lizard diet

An assessment of prey diversity within ten core range/transient range sites (five located within local plantations and five within forested lots of the LKWS) indicates:

12 aquatic taxa

4 reptilian/amphibian taxa

18 invertebrate taxa

5 mammalian taxa

Reference

Majewski, K. 2017. Cardiff University.

Reticulated python (*Malayopython reticulatus* (Schneider, 1801))

Aims

The primary aim of this project is to investigate the landscape, dietary and parasite ecology of this species, particularly in relation to their ability to adapt to fragmented habitats and palm oil plantations. A secondary aim is to investigate the levels of human-python conflict within the study area and to explore potential mitigation strategies.

In particular:

How do the density, distribution and habitat differ for pythons inhabiting forests and plantations?

How do home-range and movement patterns of reticulated pythons differ between these two habitats?

Is it possible to use non-invasive molecular techniques to study the diets of pythons, and how this may differ in natural vs. human-altered landscapes?

What conflicts exist between snakes and people in the area, how does this affect the study species and the impact the results of the other research questions, and how can these be mitigated?

Methods

A suitable and standardised survey method is required to locate, mark and recapture pythons in various habitats in order to get an accurate representation of population density, and to monitor changes over time. A novel deployment of GPS tags is also required to track and long-term monitor multiple individuals in this landscape. This will provide information on home range size and activity patterns, which is important for understanding the landscape-level requirements of this species, which will aid in establishing future conservation strategies. DNA is extracted from non-invasive samples to study diet, either using species-specific primers to analyse the predation incidences on important target taxa using PCR, or by using next generation sequencing. Interviews and questionnaires are necessary to assess attitudes towards snakes in general, measure the degree to which pythons are collected for skin or meat, and the impacts of snakes upon people, such as snake bites or livestock predation.

A few preliminary results (Feb 2016 – Dec 2017)

Surveys – 78 individual animals sampled; 75 *M. reticulatus* and 3 *Python breitensteini*; 20% have been recaptured at least once.

Satellite tagging – 4 animals tagged; preliminary intensity distributions have been calculated using dBBMM; tag design is being improved.

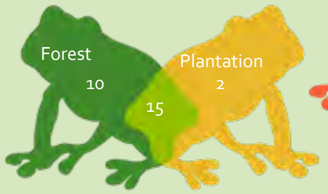
Amphibians

Species
Bufonidae
Ingerophrynus divergens
Dicroglossidae
Fejervarya cancrivora
Fejervarya limnocharis
Limnonectes finchi
Limnonectes ingeri
Limnonectes paramacrodon
Occidozyga sumatrana
Microhylidae
Chaperina fusca
Kalophrynus meizon
Kaloula baleata
Metaphrynella sundana
Microhyla borneensis
Microhyla perpava
Ranidae
Hylarana erythraea
Hylarana glandulosa
Hylarana nicobariensis
Hylarana megalonesa
Rhacophoridae
Kurixalus appendiculatus
Nyctixalus pictus
Polypedates colletti
Polypedates leucomystax
Polypedates macrotis
Polypedates otilophus
Rhacophorus dulitensis
Rhacophorus harrissoni
Rhacophorus pardalis
Rhacophorus rufipe

How do edge effects affect anuran communities?

Results

Species richness was higher at forest sites than at plantation sites.



Frogs found in plantation sites were mostly terrestrial; arboreal frogs were mostly found in forest sites.

Forest habitats supported more endemic species.

Species' richness in forests gradually declined as the distance to the plantation increased and the canopy cover decreased.

Reference

Scriven, S. A., *et al.* 2018. Biol. Conserv., 220, 37–49.

Other mammals

Sunda pangolin (*Manis javanica*)

Aims

Information on the population levels, ecology, or life history of the Sunda pangolin is lacking. The primary aim of this project is to understand how this species is adapting to the fragmented and degraded landscape of the LKWS.

In particular:

To identify habitat suitability and ecological niches for the Sunda pangolin;

To determine the species home range; and

To determine the movements of Sunda pangolin in a fragmented and degraded landscape in Sabah.

Methods

Evidence of pangolins is being determined by sign spotting, spotlighting and camera trapping. Attempts to attach a satellite tagging device to captured pangolins are ongoing to obtain information on activity patterns, habitat use, home ranging, and dispersal distance. Formal interviews within the local communities are providing insights on pangolin ecology, trapping techniques, and hunting activities in Sabah.

A few preliminary results (Jan 2016 – Dec 2017)

Camera trap surveys – 5580 active camera-trap nights; pangolins detected on eight sites.

Sign surveys – 103 burrows recorded

Non-volant small mammals

Aim

To assess the influence of various environmental factors (e.g. patch size, degree of isolation, barriers of various quality and size, habitat structure, edge effects) and species-specific traits (e.g. habitat specialization, activity pattern, degree of terrestriality, reproductive rate) on their population viability.

Methods

Identify structural habitat variations across forests, describe the diversity and abundance of small mammal species for each study site.

Relate the species richness measures to habitat characteristics to assess existing habitat preferences and specialization.

Estimate impacts of habitat fragmentation and disturbance on the diversity and gene flow of small mammal populations.

Bearded pig (*Sus barbatus*)

Aim

To investigate this species' nomadic behavior (or lack thereof), movement patterns at fine and coarse scales, and the effect of oil palm cultivation on resource selection, habitat requirements, and conservation needs.

Methods

Data from line transect surveys was used to model habitat use in forest fragments and oil palm plantations.

Activity patterns, body condition and minimum group size were assessed by camera trap surveys.

Results

Secondary forests are the most important habitat for this species and are used more frequently than adjacent oil palm plantations.

Oil palm plantations are also utilised as habitat.

95% of pigs assessed showed "good" or "very good" body condition.

Groups with piglets showed consistent diurnal activity in contrast with other groups' patterns, possibly as a predator avoidance strategy.

Reference

Love, K., *et al.* 2018. Wildl. Res., 44, 603–612.

From genes to bridges: studies on orang-utan (*Pongo pygmaeus morio*) population genetics

- Data from over 200 wild individuals indicate that despite the fragmentation of their habitat, the orang-utan population exhibited a high level of genetic variability. However, this genetic diversity seemed to be the remnant of an ancient significantly larger population that inhabited the whole region.

- The data indicates strong evidence for a recent and dramatic population decline (more than 95%); namely the exploitation of Sabah's forests which started in 1890, was found to be the only major event that might have significantly influenced orang-utan populations in the last decades or centuries.

- Both male and female orang-utans in the LKWS remain within their natal areas, contrasting with the often-reported male-biased dispersal behaviour of this primate.

- The Kinabatangan River seems to be a natural barrier for orang-utan dispersal. The orang-utans used to move relatively freely between forest patches lying on the same side of the river.

- The genetic data were incorporated into a stochastic population modelling program under different management strategies to predict the evolution of genetic diversity and demography at different times in the future. In contrast to the sole use of translocations or corridors, demographic stability and an inbreeding threshold below 10% were achieved by the mixed approach model where the translocation of one adult female every 20 years was simulated along with the corridor establishment.

- The creation of habitat corridors for sustainable conservation management can be extremely difficult to achieve. Therefore, as a potentially quicker alternative, and in addition to the restoration and size augmentation of the LKWS, it was also recommended to establish orang-utan bridges wherever necessary.

- Eight orang-utan bridges have been set up over four small tributaries of the Kinabatangan River with documented success in all of them.

References

Bruford, M. W., *et al.* 2010. Endanger. Species Res., 12, 249–262.
Goossens, B., *et al.* 2005. Mol. Ecol., 14, 441–456.
Goossens, B., *et al.* 2006. Mol. Ecol., 15, 2577–2588.
Goossens, B., *et al.* 2006. PLoS Biology, 4, 285–291.
Jalil, M. F., *et al.* 2008. Mol. Ecol., 17, 2898–909.

Work on other species

Discovered in the vicinity of DGFC:

Crassignatha danaugirangensis (Araneae: Symphytognathidae) a six-eyed micro-orbweaving spider on the order of 1 mm in total body length.

Reference

Miller, J. A., *et al.* 2014. Biodivers. Data J., 2, e1076.

First observation and description of a male *Opadometa sarawakensis*.

Reference

Miller, J., *et al.* 2018. Biodivers. Data J., 6, e24777.

First known case of a caterpillar (possibly *Negritothripa* sp. in the Nolidae) building its cocoon entirely out of fragments of dried resin on the trunk of *Vatica rassak* (Dipterocarpaceae) and held together with silk. Analysis of resin from the cocoon revealed a complex mixture of 260 deterrent components. The larva appears to have evolved an elaborate and possibly unique behaviour, allowing it to harness the defensive properties of the resin to protect its pupa from predators and/or entomopathogenic fungi.

Reference

Symondson, W. O. C., *et al.* 2014. J. Nat. Hist., 49, 553–560.

Black-and-Red Broadbills (*Cymbirhynchus macrorhyncos*) nests were significantly more often located in areas with a higher proportion of forest habitat type (compared to disturbed habitat type), and preferably on branches and sticks at the river's edge, profiting from the riparian zones along the river.

Reference

van Kolfschoten, L., *et al.* 2016. J. Trop. Biol. Conserv., 13, 157–168.

Thermal imaging techniques have been compared with conventional visual counting surveys to estimate the group size of different primate species. Preliminary results suggest there is a potential in using thermal cameras as an important tool for primate census.

Research at DGFC has also included:

- Hornbills
- Freshwater fish
- Tarantulas
- Millipedes
- Mosquitoes
- Parasites from fish, reptiles and mammals

Ectoparasites have been collected opportunistically through DGFC's projects from a variety of hosts (civets, rats, squirrels, monitor lizards, reticulated pythons and nocturnal primates). The aim is to identify the ectoparasites species and their prevalence in the wildlife hosts. This will lead to the identification of the species and prevalence of rickettsia in the ectoparasites collected from such hosts. A database of rickettsia and ectoparasites in wildlife hosts residing in the LKWS will be created, thus benefiting wildlife and people living and visiting the area.

DGFC has established 20 botanic plots around the vicinities of the field centre and of Sukau village comprising a range of forest types. There is an ongoing investigation of forest resilience to man-made modifications and to the effects of changing composition of animals involved in pollination, dispersal and predation. The richness, diversity and phylogenetic composition of adult and sapling communities are being compared. An open access DNA barcode reference is being created to assist with the identification of adult and sapling trees and to allow the investigation of plant-animal interactions in the future.

IV. Striving towards sustainability in the Lower Kinabatangan floodplain: environmental protection

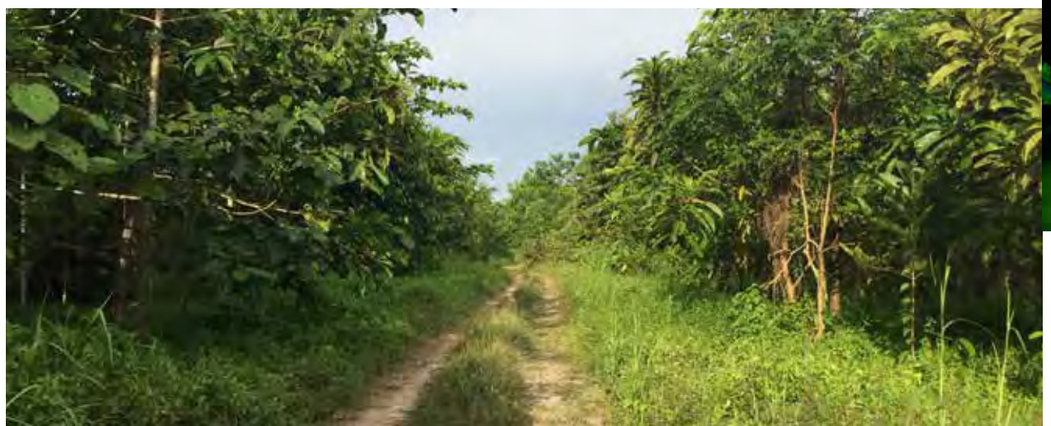
The three pillars of sustainable development are economic development, social development and environmental protection. DGFC has also contributed to the sustainability of the Kinabatangan region through environmental protection actions.

Forest governance

Unlike other protected areas in Sabah, there is no single coordinating government agency and no management plan for the LKWS. Hence, forest governance in the region includes local and international environmental NGO's, international philanthropic foundations, indigenous communities, intergovernmental organisations and international private sector companies.

The consequences of habitat fragmentation have been perceived by many of these actors as the most pressing conservation problem in the LKF. Therefore, motivated by the aim of biodiversity conservation, the main policy objective of environmental organisations working in the region is the restoration of remaining habitat and the reconnection of forest fragments through the development of habitat corridors.

Forest restoration projects have been undertaken by a range of different organisations which are loosely connected through similar objectives and informal networks. These networks have been a significant driver in the implementation of forest conservation policy and institutional change. However, differences between the organisations have manifested themselves as lack of coordination and differences of opinion, especially on the issue of engagement with the private sector. Therefore, better coordination and clearer commonly agreed objectives need to established by all the stakeholders in order to reach their common goal in a sustainable manner. As an example, a key short-term goal is to more effectively enforce environmental protection regulations that already exist.



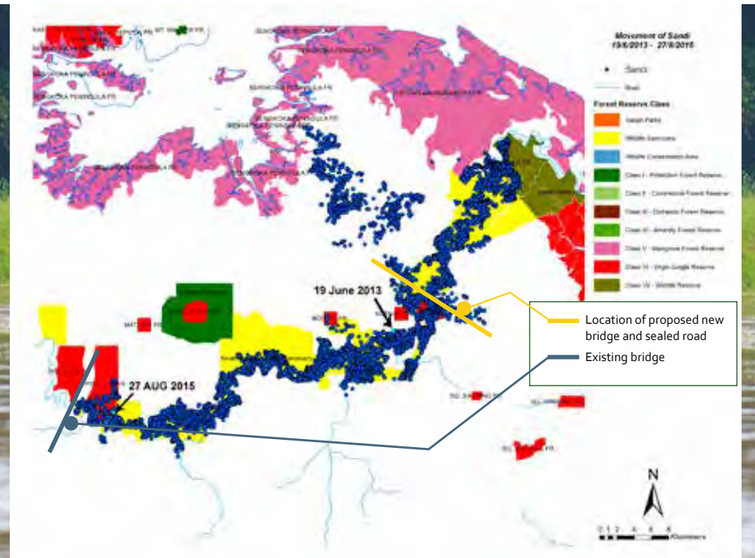
Reference

Bloor, R. 2014. Cardiff University.

Conflictive road development

In line with the State government's initiative to create a better network of roads in the rural area and improve connectivity and transportation for local rural produce, a proposal of constructing a new bridge over the Kinabatangan river was disclosed to the public at the end of 2015. The aim was to upgrade and construct a new paved dual carriageway branching from an existing gravel road of Jalan Sukau to Jalan Moresem via a new bridge over the area of Sukau village.

The satellite data accumulated between 2008 and 2015 from 14 elephants showed the importance of Sukau village for their movement. DGFC disclosed the scientific evidence to the public (press releases), the government and the private sector (*ad hoc* meetings), highlighting the possible human-elephant conflicts to arise if the construction of a road and bridge bisecting the wildlife sanctuary went ahead. DGFC worked in collaboration with other NGOs during 2016 and 2017 to raise awareness on how the road and bridge would have undermined efforts of several organizations, and the Sabah government itself, in maintaining the natural habitat connectivity and healthy wildlife populations in the Kinabatangan. In April 2017 the Chief Minister of Sabah officially determined the abandonment of the project.



The proposed location of the new bridge over the Kinabatangan river (yellow line). The elephant migration route in the Kinabatagan is illustrated here by the movements of one elephant (blue dots) over two years. Note how the movements are constrained by the mangroves in the northeast and the existing bridge (grey line) in the west.

Honorary Wildlife Wardens

10 DGFC members have been trained and appointed by the SWD as Honorary Wildlife Wardens to monitor and report illegal activities.

Reclaiming Ladang Kinabatangan

The kampung (village) of Batu Puteh (through KOPEL/MESCOT) and DGFC started working together in areas such as the identification of riparian zone abuse. Together, they exposed the continued practice of riparian encroachment by the oil palm industry in the Kinabatangan. In 2014, the Ministry of Tourism, Culture and Environment became involved in the problematic and participated in an event where 20 acres of oil palms (1.3 km long and 20-50 metres wide) that had encroached the riparian reserve were removed. More than 400 palm oil trees were excavated and 20,000 native trees were planted. DGFC has been supporting KOPEL in their restoration work and assisting with the research, by monitoring the return of wildlife in the riparian reserve, and by flying a drone every year to monitor and study the forest recovery.

River Keeper Unit

From 2013 to 2015, a River Keeper Unit was set resulting from a collaboration between the SWD, the NGO HUTAN and DGFC. It consisted in a team of two local honorary wildlife wardens who monitored wildlife and its threats along the river and within the LKWS. The unit conducted day and night patrols to monitor and prevent illegal activities such as encroachment into riparian reserves illegal logging and hunting. It also monitored tourism activities along the Kinabatangan river stopping any boat approaching the elephants too closely and also tourists from disembarking on forbidden areas of the riparian corridor.

IV. Contributing to scientific knowledge beyond the Lower Kinabatangan floodplain

Human-driven landscape changes have occurred in the whole of Sabah and in the rest of Borneo. The impact of these changes needs to be addressed in a multidisciplinary way in order to produce the most suitable management plans for the region. At the state level, DGFC has conducted or participated in scientific research projects aiming to better understand the animal responses and the ecology of infectious diseases influenced by such changes. In a multiregional level, DGFC's data has contributed to the better understanding of one of Borneo's most iconic species: the Bornean orang-utan.

Population/Landscape genetics

Bornean elephants possess a single widespread mitochondrial (control region, 630 bp) haplotype. This suggests they probably derive from a very small female population.

The Lower Kinabatangan and North Kinabatangan (Deramakot Forest Reserve) populations possess higher levels of genetic variation compared to the elephant populations from other MERs; these populations are also differentiated and perhaps isolated from the main elephant populations located in the Central Forest and TWR. These results suggest rare dispersal across the current human-dominated landscapes that separate forest fragments, and that populations within forest fragments are already undergoing genetic drift..

Reference

Goossens, B., *et al*. 2016. Biol. Conserv., 196, 80–92.

State-wide animal responses to habitat modification

Bornean elephant

Elephant connectivity: the B-CONNECTED and the Government of Malaysia-UNDP projects to improve elephant management and reduce human-elephant conflict (HEC).

Since 2012 DGFC has been assisting the SWD to understand the movement of elephants in other parts of Sabah besides the Lower Kinabatangan. The areas are mainly in the Telupid Complex, Lahad Datu and Central Sabah and in all the managed elephant ranges (MER).

The B-CONNECTED (Borneo Connectivity Network in Elephant Changing Habitat from Movement Data for Improved Management and Reduced Conflicts with Human Activities) project's main goal is to improve the management of elephant habitat and reduce conflicts by recommending protection and routes based on habitat preferences of satellite tracked Bornean elephants (37 collared individuals from 2008 to early 2018).

The GoM-UNDP (Biodiversity Conservation in Multiple Use Landscapes in Sabah) project's main was to ensure and maintain revenue for the socio-economic development in Sabah by bringing the management of critical protected areas and connecting landscapes under a common management umbrella. The Sabah Forestry Department raised concerns of HEC in the project area especially in relation to a 33,000 ha area of forest that was to be converted to oil palm in the near future. DGFC members were part of a Technical Working Group comprised of local and international experts with vast experience in various fields was formed to address and provide credible current information on biodiversity within the GoM-UNDP project area.

Results

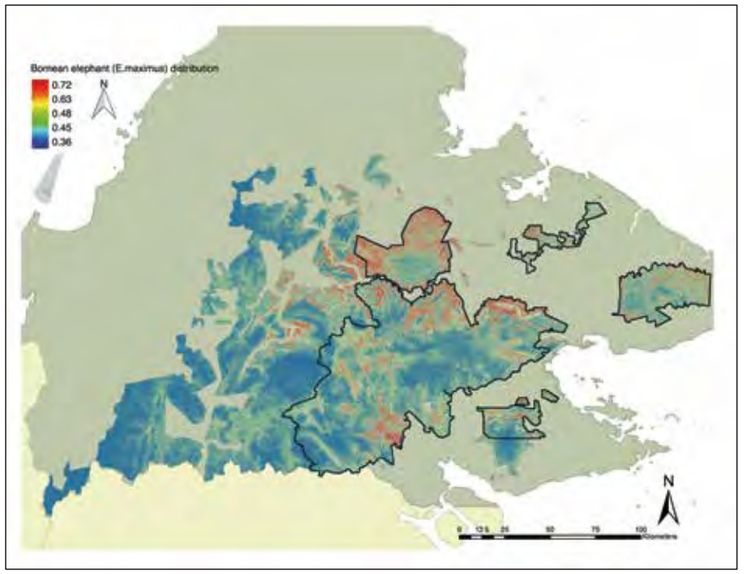
The information provided on the ranging patterns, habitat use, behaviour and ecology of the elephants within the project area led to the inclusion of elephant's needs in the planning. In particular, a broad north-south corridor (to include low-lying forest) to maintain connectivity between the INIKEA area with the Mt Magdalena Forest Reserve was identified and immediately gazetted to a First Class Forest Reserve by the Sabah Forestry Department.

Habitat suitability analyses

GPS data from 29 elephant individuals and from airborne LiDAR forest mapping was used to model the distribution of elephants throughout Sabah in the most wide-scale analysis of forest use by Bornean elephants to date.

Flat lowland areas, with optimal forest stature of ~13 m, were found to be of highest suitability for elephants. These habitats are at high risk of conversion, often viewed as suitable for oil palm cultivation.

Less than a quarter of fully-protected intact forests in Sabah were of suitable stature for elephants, whereas disturbed commercial forest reserves were found to be highly suitable. Therefore, a focus on the sole protection of remnant primary forest is detrimental to the future of the Bornean elephant.



Areas of higher suitability for elephants are largely located on the peripheries of currently forested areas, especially of the Managed Elephant Ranges (MERs, black lines). A large percentage of the highly suitable areas border the Kinabatangan and Segama floodplains. Considering the high agricultural conversion rates in these two regions, it is possible that the most highly suitable elephant habitat in Sabah has already been lost.

Origins

Two competing hypotheses have been proposed on the origin of Bornean elephants: one suggests that elephants are non-native to Borneo and were historically introduced and the other that they are indigenous to the island.

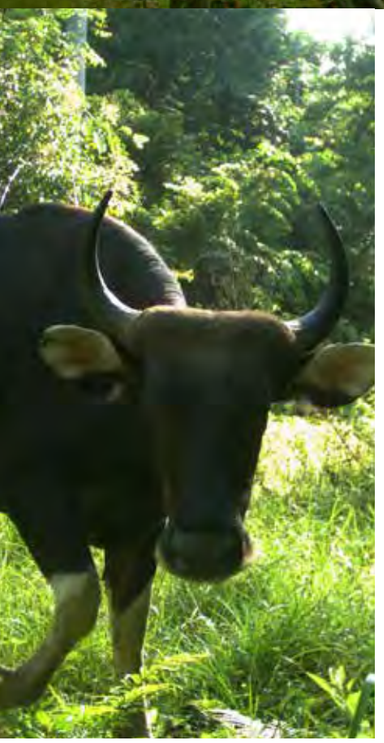
Bayesian statistics based on mitochondrial and microsatellite data strongly indicate that a recent anthropogenic introduction of the elephant to Borneo is less in agreement with genetic data than a natural origin. Since a bottleneck was identified most probably between 11 kya and 18 kya - at the end of the Last Glacial Maximum where land bridges connected Sundaland - a likely interpretation is that the elephant colonized Borneo from another part of Sundaland at this time.

Reference

Sharma, R., *et al.* 2018. Sci. Rep., 8, 880.

Reference

Evans, L. J., *et al*. 2018. Biol. Conserv., 221, 365–373.



Bornean banteng (*Bos javanicus lowi*)

Aims

To describe the natural history of banteng.

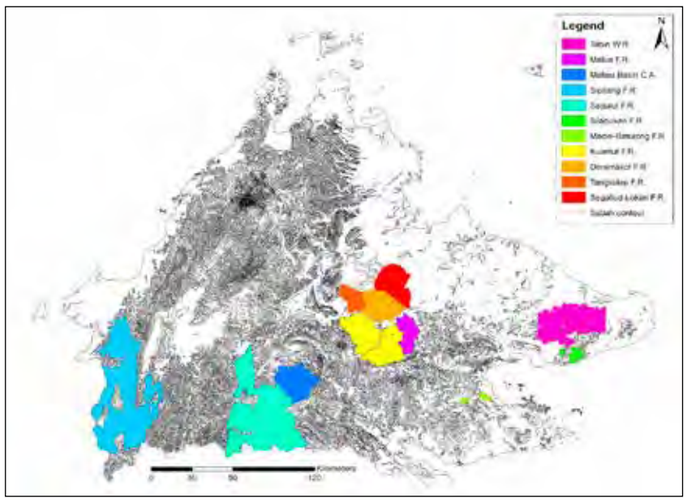
To identify suitable and effective non-invasive survey methods that are appropriate for long-term monitoring and estimating population parameters.

To characterise activity patterns and identify the effect of habitat disturbance upon activity budgets and site use.

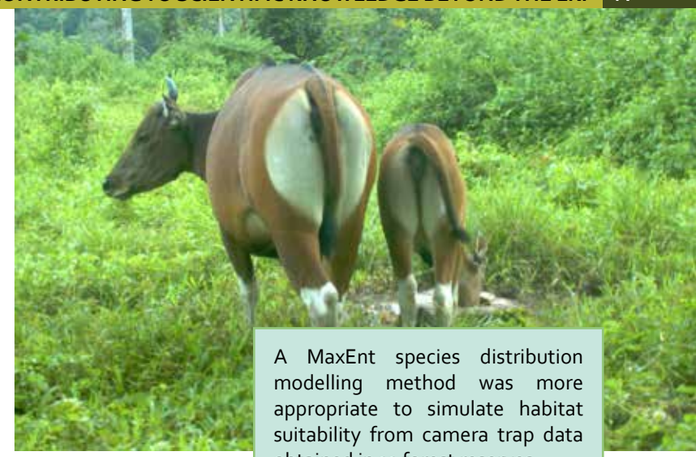
To investigate the population genetic structure of banteng.

To locate the remaining subpopulations of banteng across Sabah and assess their conservation status and longevity in their current locations.

To identify key environmental predictors influencing the habitat suitability for the banteng and highlight suitable habitat that may need restoration and protection.



Location of the camera trap surveys to trace the existing banteng populations.



Results

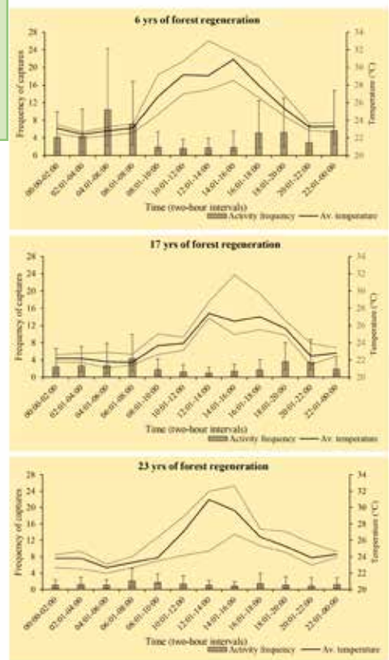
A detailed natural history of this species is now available. Gaps in knowledge essential for conservation were identified.

Camera traps were suitable for surveys and individuals could be distinguished despite the lack of unique pelages.

Three secondary forests in Sabah, Malaysian Borneo were studied, varying in the time since last logging (6, 17 and 23 years respectively).

A MaxEnt species distribution modelling method was more appropriate to simulate habitat suitability from camera trap data obtained in 11 forest reserves.

The rainfall during the dry season was the most influential factor that regulated the habitat suitability and distribution of this species. In addition, a combination of relatively flat terrain, degraded forest condition with some extent of canopy cover retained is also favourable to the banteng.



In a 24-hr cycle, activity noticeably decreased after sunrise and when ambient temperatures were high and remained infrequent until sunset.

28.5% of the land in Sabah is suitable as banteng habitat; this land is confined to protected areas.

Banteng utilise open areas for long periods. However, in the forest that had the shortest regeneration time and offered the least vegetative cover, utilisation of exposed areas was greatly reduced during high temperature hours, especially while traveling and foraging. Nevertheless, these activities dominated the activity budget.

The predicted highly suitable habitats were largely situated in patches of the southern, central, and eastern protected areas of Sabah. The forest in the central Sabah is the largest and has the greatest extent of the highly suitable habitat.

In regenerated forests activity was more consistent throughout the day; traveling and using the closed canopy were the most dominant behaviours.

Continuous canopy cover appears to be essential for reducing stress. Therefore, man-made internal foraging sites may be beneficial for conservation.

References

Gardner, P. C., *et al.* 2014. Cambridge Univ. Press; pp. 216–230.

Gardner, P.C., *et al.* 2018. PLoS One, 13, e0195444.

Gardner, P.C. 2015. Cardiff University.

Lim, H. Y. 2017. Universiti Malaysia Sabah.

Population genetics

The Bornean banteng is distinct from other banteng subspecies and should be recognised as such.

The banteng colonised Borneo circa 340 kya.

20 haplotypes were identified from 33 individuals residents of 11 areas in Sabah. Three haplotypes originate from suspected banteng-Bali cattle hybrids from the Felda Kalabakan oil palm plantations whilst the remaining 17 are thought to be from true wild banteng.

Evidence suggests two management units that can be managed separately.

Reference

Gardner, P.C. 2015. Cardiff University.

Gardner, P.C., *et al*. Unpublished data.

Demography

222 herds and 1 solitary male were identified in six forest reserves.

Herd size: 2 – 21 individuals. It is influenced by the forest regeneration age, type of site, presence of salt licks, sex, habitat vegetation and distance to the nearest forest border.

Bachelor herds were observed as frequently as mixed-sex herds, and there was a significantly higher capture frequency of female herds in the dry season, supporting the theory of sexual segregation.

Frequency of calf births was highest in March and September.

Reference

Journeaux, K. L.; *et al*. 2018. Endanger. Species Res., 35, 141–157.

Health

A body condition scoring was created for the Bornean banteng using camera trap photographs.

Banteng within forests that had a recent history of reduced-impact logging had higher body condition scores than banteng within conventionally logged forest. Conversely, when past logging was conducted using a conventional technique and the period of forest regeneration was relatively long the banteng had higher body condition scores.

Reference

Prosser, N. S., *et al*. 2016. BMC Zool., 1, 8.

Where to create protected areas next?

The mapping of carbon stocks in the whole of Sabah was obtained through a combination of LiDAR data, satellite imaging and other geospatial data. The results suggest that more than 40% of the highest carbon stock forests are outside of areas designated for maximum protection and that previously logged forests still have high carbon densities.

Sabah could double its total aboveground carbon storage if previously logged forests are allowed to recover in the future.

Reference

Asner, G. P., *et al*. 2018. Biol. Conserv., 217, 289–310.

Turtles

DGFC collaborates with the Marine Research Foundation (MRF) on a green turtle (*Chelonia mydas*) population genetics project. The analysis of samples collected by MRF will provide deeper insights on potential beaches of origin which then could be incorporated in the conservation efforts in the area.

Estuarine crocodile

DGFC is leading an estuarine crocodile survey in 10 major rivers in Sabah: Bengkoka, Kalumpang, Kinabatangan, Klias, Labuk, Padas, Paitan, Segama, Serudong and Silabukan to provide baseline information on the number of crocodiles in the state. This is coupled with a landscape genetics and a habitat viability analysis which will be useful for the management of this species.

Felids

A two-year intensive camera trapping programme in TWR re-confirmed the presence of the five wild felid species, including the flat-headed cat *Prionailurus planiceps*, and the bay cat *Catopuma badia*. Some captures were obtained from areas not previously surveyed by this method.

Reference

Gardner, P. C., *et al*. 2014. CAT News, 61, 37–41.

Proboscis monkey

Aims

The aim of this study has been to examine the phylogeographic patterns, genetic diversity and differentiation within and between Sabah's five major centres of continuous population distribution and of the small isolated populations of proboscis monkeys.

In particular:

To determine the population structure and demographic history of the proboscis monkey in Sabah.

To identify the level of genetic differentiation between sub-populations and the threats to genetic diversity.

To determine if and how are landscape (riverine and mountain barriers) and environmental factors are influencing gene flow and population structure in the proboscis monkey populations in Sabah

To simulate changes in genetic diversity and differentiation within and among fragmented populations of proboscis monkeys in Sabah using different management scenarios and examine the genetic implications of management options for fragmented populations of proboscis monkeys.

To subsequently, identify appropriate intervention measures to maintain gene flow and diversity between the proboscis monkey sub-populations in Sabah.

Some preliminary results

Blood and/or tissue samples were collected from 102 proboscis monkeys. The animals were free-dwelling individuals residing in 11 known areas in Sabah, except for seven individuals which were of suspected geographical origin.

Phylogenetic analyses on the mtDNA control region strongly indicate that current proboscis monkey populations pertain to three major genetic lineages and that one of these linages could have expanded to originate the other two.

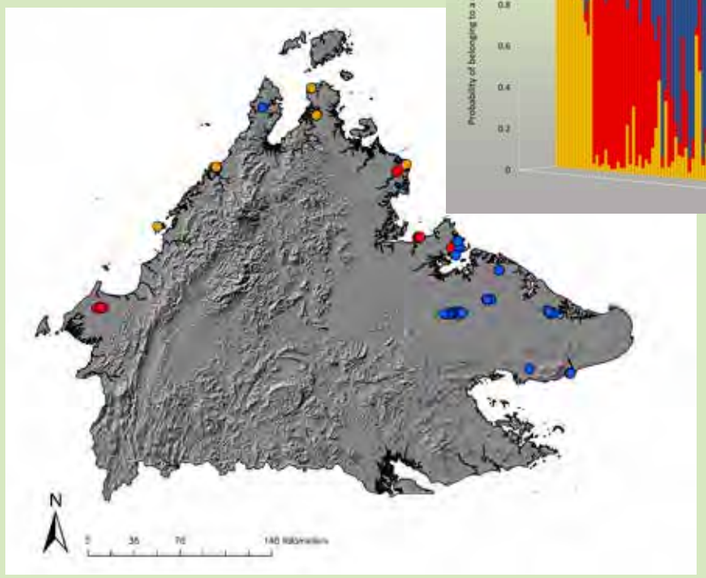
Bayesian analyses for population structure and F-statistics based on 12 nuclear DNA markers show three current genetically distinct groups that correlate with geographical areas: the north of the Crocker Range (North group); the populations of Klias, Sugut and Labuk Bay as another group (Middle group); and the populations from Sandakan to the east as a third cluster (East group).

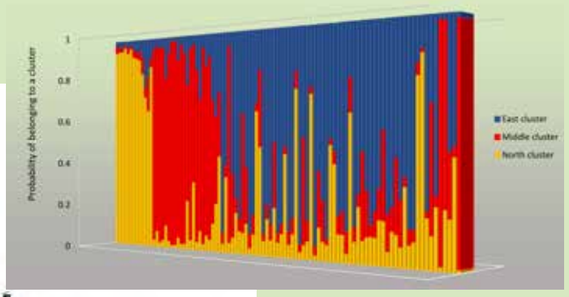
Each genetically distinct group appears to have a relatively high level of inbreeding although there also seems to have been historical connectivity allowing gene flow between said groups.

In general, the populations of proboscis monkeys in Sabah are very fit and evolutionarily able to cope with natural environmental pressures. This is due to the historically high levels of genetic diversity and also to the current moderate to high levels of genetic diversity.

Reference

Salgado-Lynn, M., *et al.* 2017. Unpublished data.





Genetically distinct proboscis monkey populations correlating with geographical locations. Each of the 102 animals tested (individual columns in the chart; dots in the map) belonged to one of three possible genetic groups (depicted in yellow, red or blue).

Danau Girang Field Centre 10th Anniversary Report
CONTRIBUTING TO SCIENTIFIC KNOWLEDGE BEYOND THE LKF V.

Searching for novel viruses.

As part of the PREDICT Consortium, DGFC contributed to a multi-country research on Coronaviruses (CoV). This study shows that patterns of CoV diversity correlate with those of bat diversity, thus consolidating these animals as the major evolutionary reservoirs and ecological drivers of CoV diversity.

Reference

Anthony, S. J., *et al.* 2017. Virus Evol., 3, vex012.

Disease ecology

Habitat loss and fragmentation promote the concentration of different species in limited areas. This situation favours the transmission of pathogens and increases the risk of new diseases emerging. In Sabah, the shifts in land-use and deforestation have increased dramatically during the last decades. More people can now enter, or be very close to, previously inaccessible forested areas. The combination of all of these factors can lead to the (re-)emergence of zoonotic and/or anthroponotic diseases. DGFC has been participating in projects that contribute to the better understanding of disease ecology in Sabah.

The Wildlife Health, Genetic and Forensic Laboratory (WHGFL) and the Wildlife Health Unit (WHU).

A joint initiative between the SWD, EHA and DGFC, the WHGFL is a Bio-Security Level 2 (BSL-2) laboratory, certified to the USA's National Institutes of Health (NIH) and the Centres for Disease Control (CDC) standards. Zoonotic disease diagnosis and population genetics are the main areas developed in the WHGFL with DGFC leading the latter. DGFC has generated genetic information for banteng, proboscis monkey and estuarine crocodile among other species. An ongoing goal is to assist the government in analysing the confiscated illegal bushmeat and other items of wildlife origin, hence the three organisations are working towards obtaining the certification to perform forensic analyses. EHA, SWD and DGFC have also established a WHU, a branch of the Wildlife Rescue Unit. This team conducts active wildlife disease surveillance across Sabah sampling rodents, bats, small mammals and primates.

From monkeys to people: *Plasmodium knowlesi.*

MONKEYBAR was a multi-disciplinary, integrated research programme to investigate the disease ecology of Pk, a malaria parasite which is now considered the fifth malaria parasite infecting humans. DGFC led the Malaysian Primatology Component of this project aiming to gain better understanding of the role played by long-tailed macaques in the infection risks.

The key objectives were:

- To determine the species and location of diurnal primates in the study area.
- To determine the number of long-tailed macaque troops, number of individuals per troop, and location of each troop within the study site.
- To determine troops/individuals infected with Pk (and other primate malarias) using non-invasive samples.
- To determine the home range and movement patterns of the (infected) macaque troops.
- To define factors which influence the proximity and interaction between human and macaques.

Some results

Predictive models were consistent with the hypothesis that macaque ranging behaviour is disturbed by deforestation but begins to equilibrate after seeking and occupying a new habitat, potentially impacting human disease risks.

Molecular diagnosis of the disease and *Plasmodium* spp. prevalence in long-tailed macaque troops was attempted via non-invasive sampling. The results suggest a troop level Plasmodium prevalence of 87% (CI 67- 98%) in the Kudat district.

Reference

Stark, D. J., *et al.* Submitted.

Spotted Fever Group Rickettsia: A detailed case report.

Members of DGFC contributed to describe in detail the severe case of spotted fever rickettsioses in a wildlife researcher. There is a need for increased awareness of rickettsioses as a cause of acute febrile illness in Sabah.

The main recommendations presented in the report were:

Clinicians in Sabah should closely monitor patients with acute febrile illness given the historical and current prevalence of rickettsioses and the rapid and unpredictable fatal course of spotted typhus.

Typhus and typhus-like diseases must be included in the early differential diagnosis of nonspecific fevers in Sabah.

Reference

Salgado Lynn, M., *et al.* 2018. Trop. Med. Infect. Dis., 3, 29-36.

Expanding the knowledge on orang-utans

DGFC members have contributed survey and genetic data from wild orang-utans dwelling in the LKF. The data have been incorporated into several studies which have enhanced the understanding of the population history and dynamics of the genus Pongo throughout its geographical range.

Phylogenetics

There is strong evidence of female philopatry and long-distance male dispersal. The (pre-historical) genetic partitioning of the genus has been shaped by combination of historical, geographical, and socio-behavioural factors. In Borneo, Pleistocene refugia and river barriers (especially for females) seem to have been the drivers of such partitioning while in Sumatra, volcanic activities explain the permanent separation of mtDNA lineages between the populations north and south of Lake Toba. In fact, the Tapanuli orang-utan (*Pongo tapanuliensis*) has been recently described as a new species. This species dwells in Batang Toru, at the southernmost range limit of extant Sumatran orang-utans south of Lake Toba; fewer than 800 individuals of *P. tapanuliensis* survive in the wild.

References

Arora, N., *et al.* 2010. Proc. Natl. Acad. Sci. U.S.A., 107, 21376–81.

Nietlisbach, P., *et al.* 2012. Mol. Ecol., 21, 3173–86.

Nater, A., *et al.* 2011. Mol. Biol. Evol., 28, 2275–88.

Nater, A., *et al.* 2017. Curr. Biol., 27, 3487–3498.e10.

Population dynamics

Drastic historic demographic changes seem to have also occurred before the recent anthropogenic activities in the region. In Borneo, a severe bottleneck happened ~135 kya, followed by a population expansion from a glacial refugium and sub-structuring starting ~82 kya. In Sumatra, the multiple eruptions of the Toba volcano were the probable drivers of population splits. However, in both islands there are signals for strong population collapses probably associated with hunting and/or farming activities by early humans.

On a recent temporal scale, novel methods for integrating field and interview survey data revealed that Bornean orang-utan populations have declined at a rate of 25% over the last 10 years. More specifically, between 1999 and 2015, half of the orang-utan population was affected by logging, deforestation, or industrialized plantations: more than 100,000 individuals were lost. Decline rates were highest when habitat was removed and absolute losses were largest in selectively logged and primary forests.

References

Sharma, R., *et al.* 2012. PLoS One, 7, e49429.

Nater, A., *et al.* 2015. Mol. Ecol., 24, 310–327.

Santika, T., *et al.* 2017. Sci. Rep., 7, 4839.

Voigt, M., *et al.* 2018. Curr. Biol., 28, 761–769.

Sustainable management?

In Borneo, only 22% of the orang-utan distribution range lies in protected areas of which 29% befalls in natural forest concessions. Largely undeveloped oil palm and tree plantation concessions shelter 19 and 6%, respectively. The remaining 24% of the orang-utan distribution range occurs outside of protected areas and outside of concessions. Therefore, 49% of the distribution will be lost if all forest outside of protected areas and logging concessions is lost. In Sabah, the government's proposal to implement sustainable forest management in all its forest reserves during the current decade has been strongly supported by models linking land-cover and global climate. In particular, Sabah orang-utan persistence would likely be maximized under deforestation and CO_2 mitigation strategies. Failure to do so could result in a 40 to 80% regional decline in orang-utan abundance by 2100.

References

Gregory, S. D., *et al.* 2012. PLoS One, 7, e43846.

Gregory, S. D., *et al.* 2014. Divers. Distrib., 20, 1044–1057

Wich, S. A., *et al.* 2012. PLoS One, 7, e49142.

Additional fact

Bornean orang-utans also move on the ground. This activity is part of their natural behavioural repertoire to a much greater extent than previously thought, and is only modified by habitat disturbance.

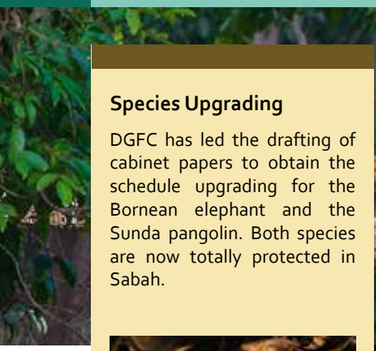
Reference

Ancrenaz, M., *et al.* 2014. Sci. Rep., 4, 4024.

VI. Conservation in action

Research on its own is insufficient to achieve the conservation of any given species; there is a need for effective dialogue between researchers and policy makers and of effective dissemination of scientific results to the general public. Historically, science-based information has not been sufficiently incorporated into (inter)national biodiversity policies and therefore has contributed relatively little to the management and conservation of wildlife populations.

DGFC has shared its scientific results with stake holders and government agencies, attempting to influence the decision-making process in Sabah and to apply the knowledge gained into conservation activities. DGFC's members have also engaged in the coordination and design of species-specific state action plans, schedule upgrading of key species, and in public outreach.



Species Upgrading

DGFC has led the drafting of cabinet papers to obtain the schedule upgrading for the Bornean elephant and the Sunda pangolin. Both species are now totally protected in Sabah.

Species specific State Action Plans

In 2010 DGFC collaborated with the Sabah State Government, the SWD, WWF-Malaysia, and the NGOs HUTAN and BORA in the organisation of a workshop to present and discuss the three state action plans for the Bornean elephant, the Bornean orang-utan and the Sumatran rhinoceros. DGFC's members were key in providing scientific results and drafting the five-year action plans for elephants and orang-utans, which were approved in 2011. Currently, the state action plan for the Bornean elephant is under review and re-drafting by DGFC's members.

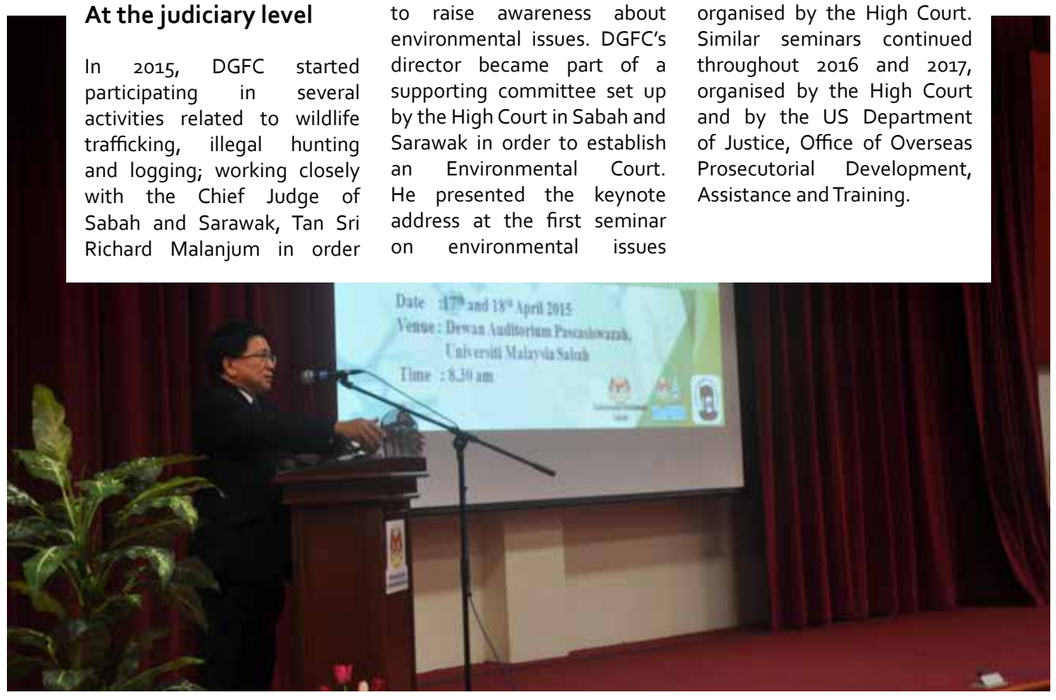
In 2017, DGFC and the SWD organised three international closed-door meetings and workshops with the final goal of obtaining action plans for the proboscis monkey, the Sunda clouded leopard and the Bornean banteng. Population and Habitat Viability Analyses (PHVA) were performed for the proboscis monkey and the Bornean banteng by panels of experts and government officers. The results of the PHVA were presented to the stakeholders during the international workshops. The workshops consisted in quality presentations, discussions in ad-hoc working groups, and a general discussion to incorporate relevant information into the action plans. The ten-year action plans have been drafted by DGFC's director, reviewed by the experts, and are to be presented for final discussion and approval in September 2018. A video on the 2017 workshops can be viewed in DGFC's website (www.dgfc.life).

International Environmental Organisation	Number of DGFC members
IUCN SSC Crocodile Specialist Group	2
IUCN SSC Wild Cattle Specialist Group	2
IUCN SSC Primate Specialist Group, Great Ape Section	1
IUCN SSC Otter Specialist Group	2
IUCN SSC Asian Elephant Specialist Group	2
IUCN SSC Pangolin Specialist Group	1
IUCN SSC Small Carnivore Specialist Group	1

Increasing conservation awareness

At the judiciary level

In 2015, DGFC started participating in several activities related to wildlife trafficking, illegal hunting and logging; working closely with the Chief Judge of Sabah and Sarawak, Tan Sri Richard Malanjum in order to raise awareness about environmental issues. DGFC's director became part of a supporting committee set up by the High Court in Sabah and Sarawak in order to establish an Environmental Court. He presented the keynote address at the first seminar on environmental issues organised by the High Court. Similar seminars continued throughout 2016 and 2017, organised by the High Court and by the US Department of Justice, Office of Overseas Prosecutorial Development, Assistance and Training.



At the general public level

Through social media (Facebook, Twitter, YouTube and Instagram) and the local press (165 press releases), DGFC continuously raises issues such as illegal logging and poaching within the LKWS and other protected areas in Sabah. In 2016, DGFC in collaboration with Sabah Wildlife Department and Scubazoo, and funding from the US Embassy in Malaysia, produced three short video clips on illegal pet trade, wildlife parts and poaching. DGFC's members and research have also been featured in local and international television.

An education and outreach program has also been core in raising conservation awareness. Either as organiser or participant, DGFC has been present in 43 events (2013 – 2018), 31 of which were at schools located throughout the state reaching approximately 2000 children. In addition, since 2014 DGFC has been a member of the Sabah Environmental Education Network (SEEN) as a step towards further developing conservation-related activities in the state.

Awareness video clips on illegal activities are available on DGFC's website (www.dgfc.life):

Stop Illegal Hunting: Illegal hunting is destroying wildlife worldwide

Stop the Illegal Pet Trade: The illegal pet trade is causing wildlife populations to decline worldwide

Stop Buying Illegal Wildlife Products: Buying illegal wildlife products only encourages people to keep hunting and killing wildlife

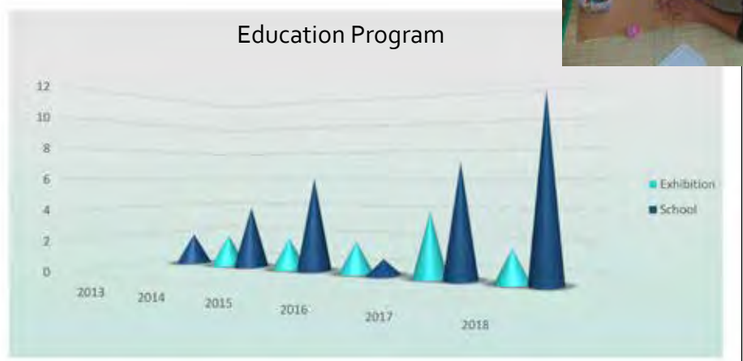
Wildife Crime: You can be part of the solution by reporting illegal activites

We're Social!

Facebook 27,318 likes; 27,340 followers; 59% Malaysian

Twitter 213 followers

Instagram 810 followers



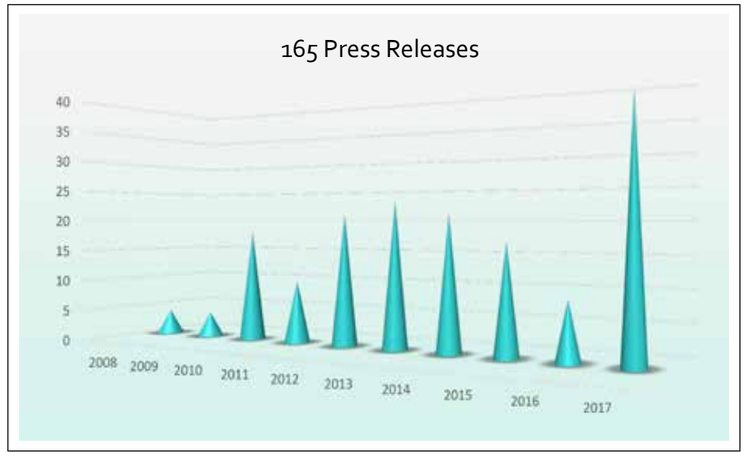
The Sunda Clouded Leopard and Other Carnivores Outreach Programme

Led by DGFC in collaboration with the SWD, this program targeted schools mostly within oil palm plantations at the LKWS and other regions such as Tambunan and Keningau. Participating schools were selected based on the advice of the district education offices and on the distribution and habitat of clouded leopards and other carnivores which are more exposed to human activities.

Objectives:

- To increase awareness and understanding of the importance of carnivores and nature conservation among communities living near carnivore habitats.
- To reduce poaching, forest encroachment, and human-wildlife conflicts in the long term, targeting at-risk families, through their children's education at school.
- To inspire children to study science and ecosystems, and to become future leaders in wildlife conservation, especially in Sabah.
- To develop a Mentorship Programme after the end of the Outreach Programme.

From 2013 to 2015, 12 primary schools were visited with a total of 279 primary students as participants.



DGFC in TV

TV Show	Original broadcasting	Year
Into the Wild with Jack Hanna	USA	2010
Outback Wrangler with Matt Wright	NatGeo Australia	2010
Freaks & Creeps with Lucy Cooke	NatGeo USA	2010
How Nature Works	BBC UK	2011
Simfoni Alam	RTM Malaysia	2013
Konservasi Gajah Borneo	RTM Malaysia	2013
Majalah 3	TV3 Malaysia	2013
Les mondes inondés: Kinabatangan L'éden sauvage de Bornéo	One Planet/ARTE France	2014
Naomi's Nightmares of Nature	CBBC/BBC UK	2015
The Amazon of the East	Animal Planet Asia	2017

Awareness books

DGFC published "Itin: A Bornean elephant" and "Upin: A Bornean banteng". Narrated from the perspective of a young elephant and a young banteng, respectively, these books cover facts of both species such as their origin, habitats, daily routine, social organisation and behaviour. It also touches on threats faced by them.

References

Kler, J. K., *et al.* 2014. Natural History Publications

Kler, J. K., *et al.* 2016. Natural History Publications

The Borneo Jungle Diaries

Launched in 2017, ten short video clips portray DGFC's young scientists and their efforts to protect Borneo's wildlife.

All episodes can be watched in DGFC's website (www.dgfc.life) and in Scubazoo TV (SZTV; www.scubazoo.tv/borneo-jungle-diaries).

VII. Impact on higher education and scientific research

Higher education students based in DGFC

Australia	2
Belgium	5
Canada	3
Chile	1
France	6
Germany	3
Malaysia	12
Mexico	3
Peru	1
Spain	1
UK	18
USA	3

Field courses

China	2
Germany	3
Netherlands	3
Singapore	5
Switzerland	1
United Kingdom	41
United States	19

Presence in scientific gatherings

Belgium	1
France	2
India	1
Indonesia	2
Japan	1
Malaysia	46
Mexico	3
Singapore	3
South Africa	1
Thailand	2
The Philippines	1
USA	2
Vietnam	1

Canada 37
USA 492
Mexico 20
Jamaica 1
Venezuela 1
Colombia 2
Peru 1
Brazil 4
Uruguay
Argentina 2
Chile 1
Norway 2
Finland 2
Sweden 3
United Kingdom 953
Denmark 4
Poland 7
Ireland 10
Netherlands 47
Belgium 30
Germany 71
Luxemburg 1
Austria 2
Switzerland 22
Slovenia 1
Romania 1
France 71
Serbia 1
Bulgaria
Spain 11
Italy 12
Portugal 8
Turkey 3
Egypt 1
Nigeria 2
Republic of Congo 1
Kenya 1
Rwanda 1
Zambia
South Africa 2
Seychelles 1
Maldives 1
Sri Lanka 1
Pakistan 1
China 42
Republic of Korea 4
Japan 63
Bangladesh 1
India 13
Myanmar 1
Thailand 2
Cambodia 1
Philippines 3
Malaysia 118
Singapore 10
Indonesia 8
Australia 36
Fiji 1
New Zealand 13

DGFC's scientific publications shared on Twitter*

Visitors (Volunteers, students, field course participants, others)

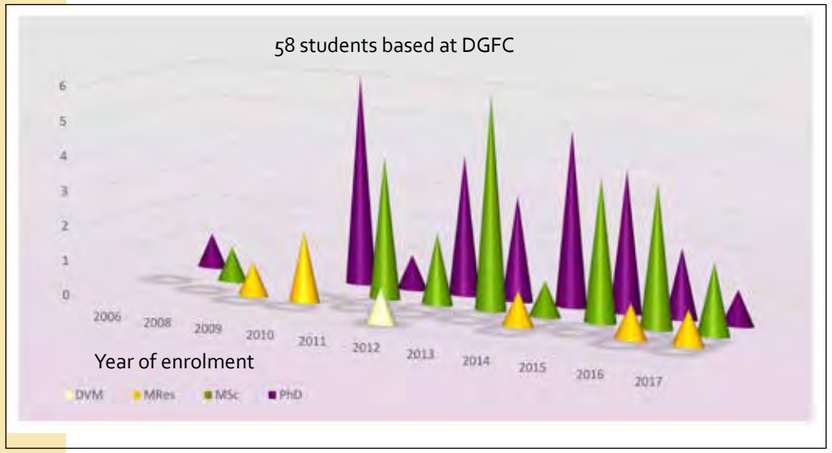
*Data from Altmetric (altmetric.com), compiled by Wildlife Impact (wildlifeimpact.org) (July 2008 to March 2018).

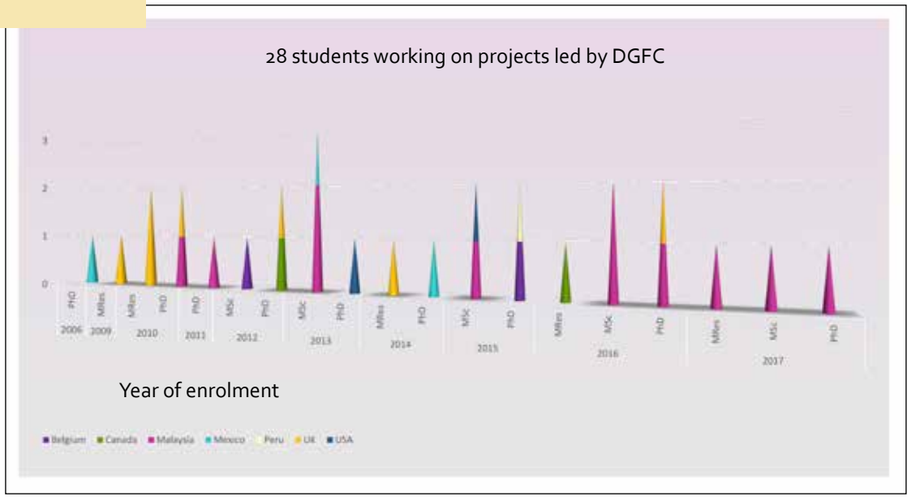
Students' Institutions

Cardiff University
Imperial College London
Kyoto University
Leiden University
Oxford Brookes University
Oxford University
Universidad Complutense de Madrid
Université Joseph Fourier
Université Libre de Bruxelles
Université Paris XII
Universiteit Antwerpen
Universiteit van Amsterdam
Universiti Malaysia Sabah
University of Minnesota
University of Antwerp
University of California - Berkeley
University of Glasgow
University of Hannover
University of Kent
University of Liège
University of Liverpool
University of Portsmouth
University of Veterinary Medicine Hannover
University of Western Ontario
University of York
Victoria University of Wellington

Higher education students

Most of our PhD, MRes and MSc students have been registered at Cardiff University. However, we welcome students from other institutions and any nationality.





Field courses

DGFC has organised two permanent field courses per year. In addition, we also welcome other institutions worldwide hosting a total of 82 field courses (2008-2018). The students participating in the field courses contribute to and benefit from the long-term monitoring efforts that are carried out in the LKWS.

Participating institutions (2008 -2018)

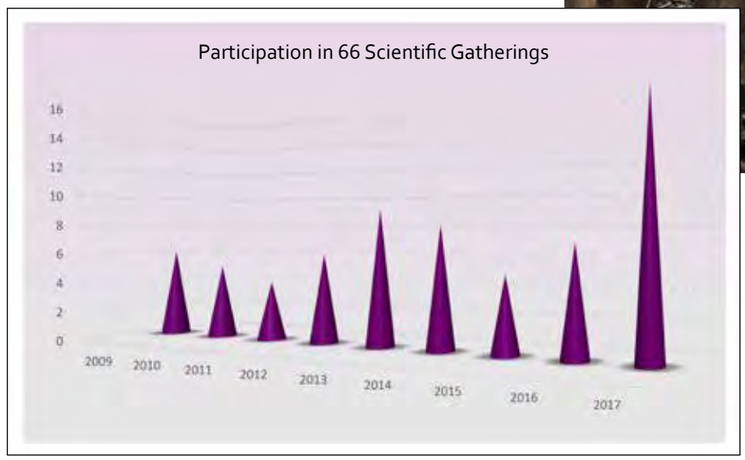
Aberystwyth University
Albert-Ludwig's University of Freiburg
Anglia Ruskin University
Anthropological Institute and Museum, University of Zürich
Bungay School
Cardiff University
Cornwall College
Cornwall College Newquay
DGFC's Primate Behaviour and Ecology
Earlham College
Ilkley Grammer School
Leiden University
Linton Village College
Miami University and Earth Expeditions
Oregon State University
Oxford Brookes University
Portland State University
Scientific Exploration Society Expedition
United World College of South East Asia
University of Glamorgan
University of Hannover
University of Hong Kong
University of Kent
University of La Verne
University of Minnesota
University of South Wales
University of Veterinary Medicine
Wallingford School
Wimbledon High School

Cardiff University's Professional Training Year students

An opportunity for students wishing to gain experience in tropical forest research and in field centre infrastructure development. They learn about the local biodiversity and way of life and witness the progression of active conservation work throughout the year.

Total (2008 – 2018) = 40

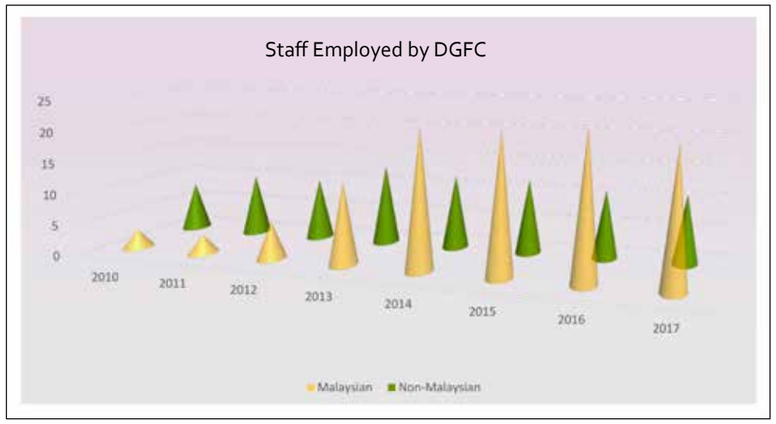
Presence in scientific gatherings



In conferences, symposiums, congresses, workshops

Capacity building in Malaysia

DGFC has contributed to the training of students and staff to higher education standards and/or continuing education (from cooking classes to becoming certified instructors in specific areas).



Malaysian students

Name	Degree	Institution	Status	Focus
Mohd. Fairus B. Jalil	PhD	Cardiff University	Completed	Primates
Nurzhafarina Othman	MSc	Universiti Malaysia Sabah	Completed	Bornean elephant
Nurzhafarina Othman	PhD	Cardiff University	Completed	Bornean elephant
Senthilvel Nathan	PhD	Cardiff University	In Progress	Proboscis monkey
Roshan Guharajan	MSc	University of Minnesota	Completed	Bornean sun bear
Gilmoore Bolongon	MSc	Universiti Malaysia Sabah	Termination	Sunda clouded leopard
Lim Hong Ye	MSc	Universiti Malaysia Sabah	Completed	Bornean banteng
Amaziasizamoria Jumail	MSc	Universiti Malaysia Sabah	In progress	Primates
Leona Wai	MSc	Universiti Malaysia Sabah	In progress	Otters
Elisa Panjang	PhD		In progress	Sunda pangolin

Cyrlen Jalius	MSc	Universiti Malaysia Sabah	In progress	Ectoparasite vectors & Rickettsiae
Sai Kerisha Kntayya	PhD	Cardiff University	In progress	Estuarine crocodile
Timothy Chang	MRes	Cardiff University	In progress	Bornean elephant
Sylvia Alsisto	BSc	Universiti Malaysia Sabah	Completed	N/A
Hussien Muin	BSc	Universiti Malaysia Sabah	Completed	N/A

Funding

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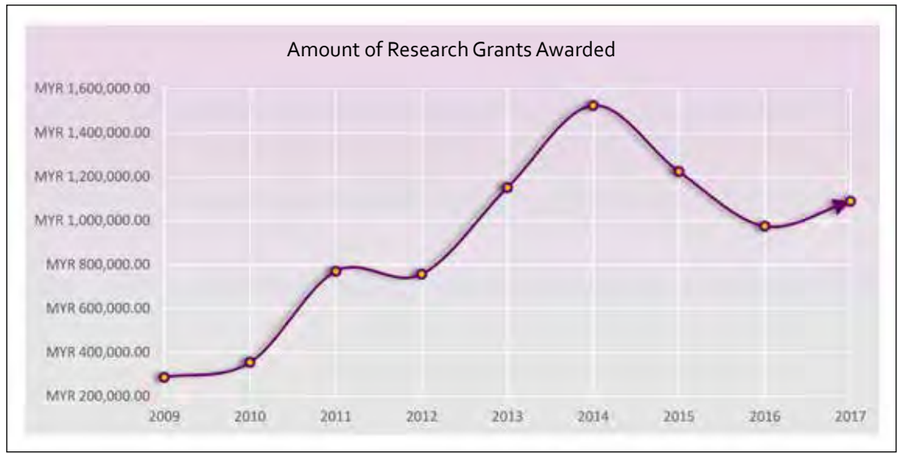
Total received (2009 – 2017) = MYR 8,128,166.88



International News Outlets featuring research done by members of DGFC*

ABC
BBC
Breitbart
Business Insider
Business Standard
Buzzfeed
CBC
CNN
Daily Mail
Der Spiegel
Discover Magazine
El Mundo
El Pais
Environmental News Network
EurekAlert!
Fox News
HuffPost
IFLScience
International Business Times
Japan Times
Mongabay
NBC
New Scientist
Newsweek
National Public Radio
Popular Science
Scientific American
Seeking Alpha News
Taipei Times
Technology.org
The Economist
The Equation
The Guardian
The New York Times
The Star
The Washington Post
Times of India
Voice of America
Wikipedia
Yahoo! News

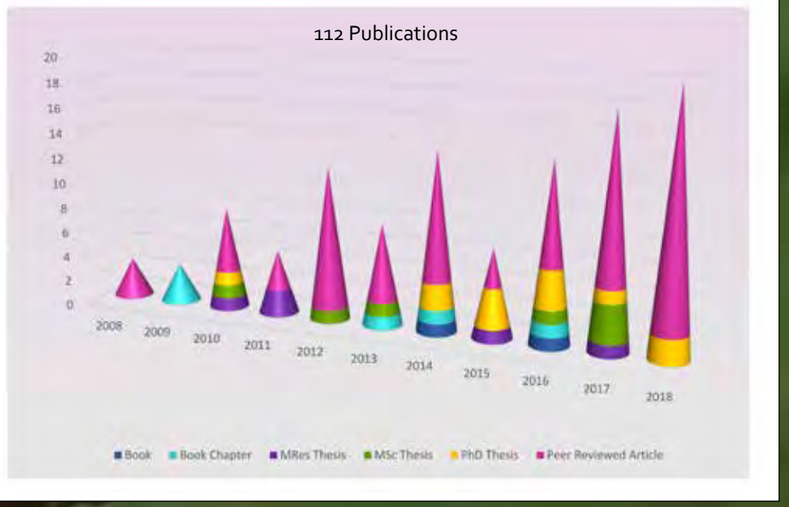
Publications

At DGFC we're continuously publishing our research results.

112 publications from 2008 to 2018, 80 of which are peer reviewed articles.

"The Twitter reach for the peer reviewed articles (upper bound) is 5.9 million (n=39 papers with Altmetrics), and the average attention score in Altmetric (n=42) is in the 79th percentile for all papers tracked by Altmetrics and in the 81st percentile compared to all papers within the same 12 week period. Five of the papers analysed for this study were among the highest performing in their journal of publication, or among all of Altmetric-tracked publications."*

*Data from Altmetric (altmetric.com), compiled by Wildlife Impact (wildlifeimpact.org) (July 2008 to March 2018).



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*Data from Google Scholar and Web of Science

**Data from Altmetric (altmetric.com), compiled by Wildlife Impact (wildlifeimpact.org). It refers to the Upperbound Twitter Reach (maximum number of users who have seen a link to the publication in their timelines).

NA – Data not available

NAp – Not applicable

VIII. The path ahead

DGFC's long-term conservation targets are to: increase functional connectivity throughout the Lower Kinabatangan landscape; to secure the extent and condition of protected forests in the area; and to improve the conservation status of key species in Sabah. We believe this can be achieved through a joint effort of research, engagement with the relevant stakeholders and a strong capacity building scheme. We are aware of our limitations and we have learned from the lessons of the past ten years. We want to make a difference and have a long-lasting effect on the Kinabatangan, and anywhere in the world that faces a similar problematic to the one in this fragile region, by sharing our knowledge and experience.

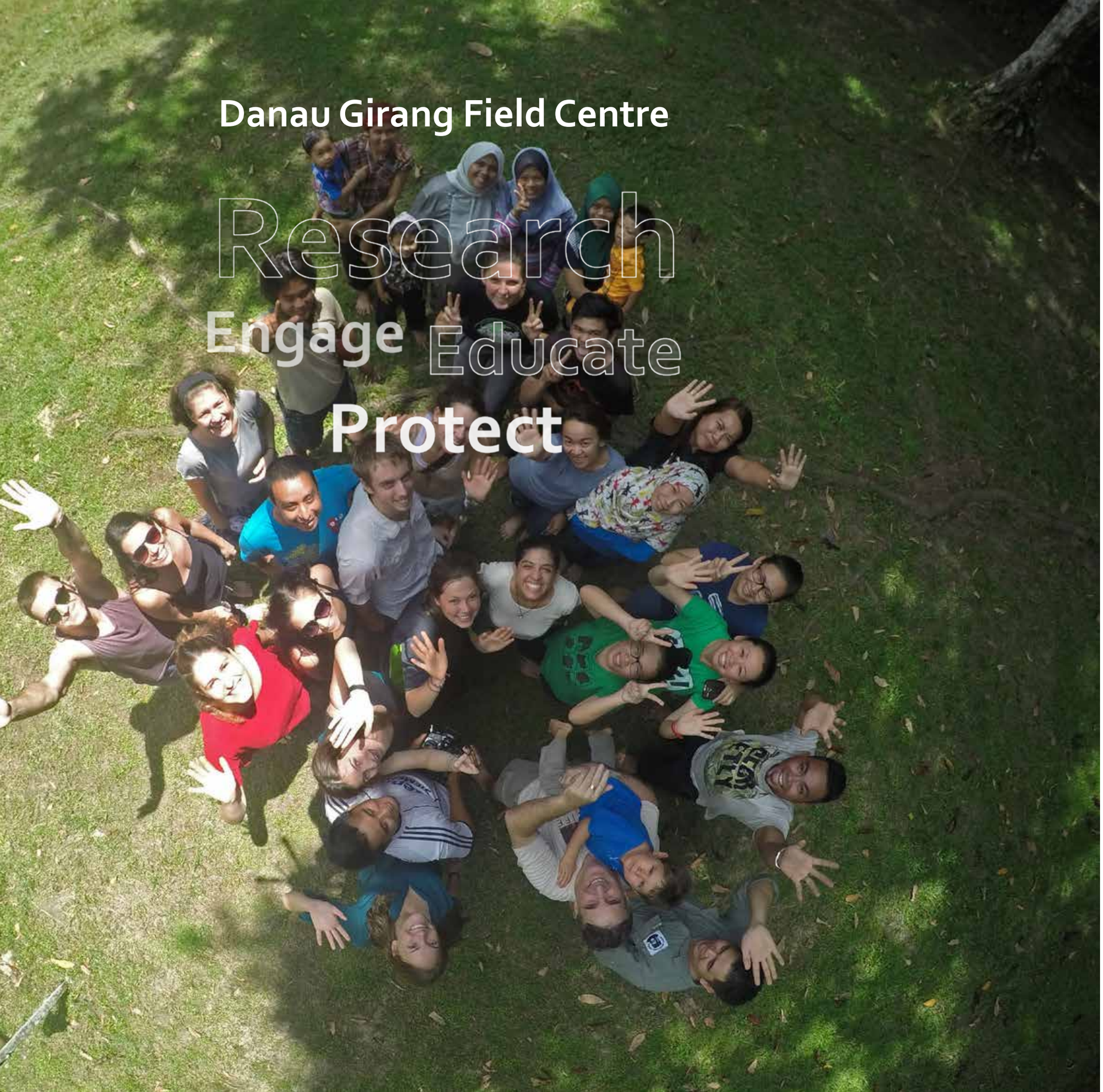
In terms of research, we have advanced in the right direction by increasing the knowledge on biodiversity and ecosystem processes in the LKF. We have amassed vast amounts of data on spatial ecology of flagship model species residing within the LKWS, and some additional species are still being studied. We have also started to gain insights into the ecosystem's health through our projects on parasites and ecotoxicology. The collaboration with the Sabah Wildlife and Forestry Departments has been instrumental as well in reaching our goals. The results of our research have been directly translated into active conservation initiatives, such as the drafting of species-specific State Action Plans, the creation of protected forest corridors along wildlife migration routes (like in Ladang Kinabatangan and in central Sabah), the mitigation of human wildlife conflicts through informed infrastructure developments (like the Sukau bridge), and the potential design of more sustainable palm oil plantations (see Horton *et al.*, 2018). However, approximately 15,000 ha of forested land within the LKF are still classed as unprotected, providing a large biodiversity conservation opportunity.

In the coming years, it is our intention to work more actively on restoration ecology and to execute an innovative and complex multi-species approach to design a productive protection plan for the whole of the Kinabatangan lowlands. By combining the spatial ecology data with the LiDAR mapping data shared by collaborators, forest management strategies and forest corridor options will be tested using landscape mosaic models to determine the effectiveness of conservation strategies on the sustainability of focal species. In particular, we will evaluate currently unprotected forests and their importance in species ranging to scientifically support the expansion of protected areas within the LKF.

These protected areas cannot be complete without taking into consideration the disease risks and their consequences, not only in wildlife but also in humans, livestock and other domestic animals inhabiting this landscape. The main focus of our work will be those pathogens that, although neglected, may have a strong impact in the local economy and in the dynamics of the wild populations. Pollutants' bioaccumulation (heavy metals and agrochemicals) in indicator species will also be investigated. We will work towards building inter- and trans-disciplinary networks that provide information on disease ecology and look for strategies to mitigate these impacts at a local scale.

Capacity building has been a strong aspect of the DGFC mission since the beginning and this will be no different in the following ten years. In reality, this is the true path ahead. We will continue being a platform for scientists and conservationists from all over the world. However, we are very aware of the need for more Sabahans to work in conservation as, without their direct involvement, no planning can be fully implemented. This means we need to work harder on community engagement to better listen to their needs and problems, to understand how to pass the research messages across better, and to work together for the health and wellbeing of both humans and environment.

Finally, all our work would not be possible without the support of the Malaysian Government. We will continue supporting their quest towards sustainability whilst keeping a critical thinking perspective and providing solid, scientific facts. With the enactment of proposed planning conservation measures, this landscape-level approach will not only benefit focal, endangered species, but the entire lowland ecosystem. Sabah can become a model to follow on how to manage complex, fragmented, agriculture-dominated ecosystems, and DGFC will help by sharing its experience worldwide.



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