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Individual identification patterns in the Visayan spotted deer and implications on the study of their behavioural ecology

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled "Individual identification patterns in the Visayan spotted deer and implications on the study of their behavioural ecology" independently, all texts in this thesis are original, AI was used for language editing, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague August 15, 2024

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BSc. Natálie Šimáčková

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Abstract

The Visayan spotted deer (*Rusa alfredi*) is considered one of the rarest deer in the world. The extensive hunting and deforestation of its primary habitat have brought the species to the brink of extinction. The remaining populations on the islands of Negros and Panay in the Philippines are estimated to be less than 1000 mature individuals. The threats and lack of current species knowledge are concerning; thus, conservation action is urgently needed to save this species. Within this context, camera traps offer an effective and non-invasive method for monitoring this elusive species. In our thesis, we focused on studying the individual identification patterns of *Rusa alfredi* in the Bayawan Nature Reserve, Negros, Philippines. Over a period of 2 years, we monitored a population of 33 individuals in semi-wild conditions using camera traps, observing four artificial feeding stations. We collected 641 images out of 4,510 videos featuring deer. In the initial analysis, the individual identification software IBEIS identified 45 of 101 images, with a matching score of 44.55 %. By the end of the study, IBEIS achieved an impressive 95.50 % matching success rate in identification. It should be emphasised, however, that this accomplishment was the result of extensive training of the software. When the same analysis was conducted without the training and extensive ID database, IBEIS only identified 50 out of 89 images, scoring 56.18 %. We highlighted the advantages of utilising camera trap videos as opposed to images for individual recognition studies and stressed the significance of a comprehensive identification database with real-life images for the software to operate effectively. The findings of this study will be used for behavioural studies at the individual level. Furthermore, this study serves as an important foundation for understanding the ecology of the species and guiding conservation efforts. Our recommendations can serve as a valuable reference point for others working with spotted cervid species, offering key recommendations for leveraging camera traps and identification software in similar conservation studies.

Key words: artificial intelligence; camera-trapping; IBEIS; Philippines

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List of the abbreviations used in the thesis

CENTROP	Department of Biology and the Centre for Tropical Studies
DENR	The Department of Environment and Natural Resources
DOST-PCAARRD	Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology
EAZA	European Association of Zoos and Aquaria
FERD	Forestry and Environment Research Division
FS	Feeding station
IBEIS	Image Based Ecological Information System
IUCN	The International Union for Conservation of Nature
ROI	Region of interest
VSD	Visayan spotted deer

1. Introduction

Many species have distinct markings that remain constant throughout an individual's lifetime, distinguishing them from others (Ward et al. 2021; Lee et al. 2022; Wiig et al. 2023). These natural markings make species prime candidates for individual-based studies, allowing for non-invasive tracking of population dynamics and individual behaviour patterns (Nipko et al. 2020). This approach provides several advantages, including reduced stress on the population, eliminating the risk of injury, long-term monitoring with minimal interference and avoidance of potential loss of artificial tags (Cheema & Anand 2017; Calmanovici et al. 2018; Lee et al. 2022). Moreover, individual-based studies play a pivotal role by pinpointing factors crucial to population recovery and effective management plan strategies (Lee et al. 2022). The advancement of affordable, high-quality trail cameras and multiple software programs for analysis and image organisation has made this method highly feasible in conservation studies (Nipko et al. 2020).

Tropical cervids play a crucial ecological role (Hanley 1996; Lucas et al. 2013; Ali et al. 2021) but are generally understudied and vulnerable to the effects of land degradation and illegal hunting (Gray 2018). The rapid deforestation of lowland tropical rainforests is a significant concern, leading to the creation of isolated population fragments (Turner & Corlett 1996). The Philippines has suffered serious consequences due to extensive forest clearance and human expansion, endangering a significant portion of its endemic wildlife (Diesmos 2007).

For instance, the Visayan spotted deer (*Rusa alfredi*), formerly found across the 5 islands of West Visayas, is now limited to the islands of Negros and Panay, with a significant population fragmentation (Oliver et al. 1991; Brook 2016). However, monitoring this elusive species in the wild is challenging as their remaining populations are remote and hardly accessible by humans due to steep, dense forests (Cox 1987; Brook 2016; Ali et al. 2021). Thus, camera traps have become crucial in the conservation of Visayan spotted deer (VSD). The VSD's unique spot patterns make this species a prime candidate for individual-based studies. The first image of VSD in the wild was captured by D'Cruze et al. (2013) in North Negros National Park in 2012. Subsequently, there was another confirmed sighting in a forest fragment of the Southwest Negros KBA, where Ward et al. (2024) captured camera trap images of two adult deer in 2022.

These records indicated the species' presence, but further camera trapping efforts could help to identify the species’ population sizes, demographics, or threats to the species. Machine learning tools show promise in achieving this, as population estimates rely on the ability to differentiate individuals. These tools also enable the study of behavioural ecology at the individual level, which is especially important for species that have been under-studied.

Our main objectives include establishing the IBEIS training process, recognising and implementing the best practices, and addressing challenges when working with spotted cervids.

2. Literature review

2.1. Taxonomy of Visayan spotted deer

The Visayan spotted deer (*Rusa alfredi*) is also known as the Philippine spotted deer. The VSD is a member of the Cervidae family, which belongs to the order Articodactyla (even-toad ungulates). Additionally, this species is classified within the superorder Cetartodactyla, as detailed by Ali et al. (2021). The Cervidae family represents the second-most diverse group in the Cetartiodactyla superorder. According to molecular studies, the divergence of the Cervidae family from the Bovidae/Moschidae clade occurred approximately 27-28 million years ago (Grove 2007). The German zoologist Georg August Goldfuss initially described the Cervidae family in 1820. This family comprises 55 species with a global distribution, excluding Australia (Ali et al. 2021). The last representative of this family in Africa is the Atlas deer (*Cervus elaphus barbarous*) (Ismaili et al. 2018).

The genus Rusa, to which the VSD belongs, was reviewed in detail by Ali et al. (2021). Cervids of the genus Rusa are endemic to southern Asia, specifically the Indo-Malaya Archipelago. Currently, this genus consists of four species: Visayan spotted deer (*Rusa alfredi*), Sambar deer (*Rusa unicolor*), Javan deer (*Rusa timorensis*), and Philippine deer (*Rusa marianna*) (Ali et al. 2021). It is important to note that *Rusa alfredi* was officially acknowledged as a distinct species in 1983. Before that time, the VSD was recognised as a subvariant of the Sambar deer (*Rusa unicolor*) (Brook 2016).

All species in the genus Rusa are threatened by habitat loss and poaching within their native home range (Ali et al. 2021). Despite being introduced outside of its native range and listed as vulnerable on the IUCN Red List, the Sambar deer (*Rusa unicolor*) population is declining severely. This trend is particularly noticeable in poorly managed areas, leading to local-level extinctions (Timmins et al. 2015). Moreover, Sambar meat is considered a delicacy in certain regions, such as the Sundaic region, contributing to an increased risk of poaching and driving the numbers of the remaining populations down even further (Ali et al. 2021).

The Javan deer (*Rusa timorensis*), native only to Bali and Java, is also classified as vulnerable on the IUCN Red List and has been introduced to areas beyond its original habitat. Despite the presence of large, introduced populations, such as 60,000 individuals in New Caledonia, the native population is fewer than 10,000 mature individuals and continues to decline. The primary threat to Javan deer in Java was the introduction of the Acacia trees in Baluran National Park, leading to the disappearance of grassland, a significant food source for the deer, and the creation of impenetrable dense bushes. Habitat degradation and poaching remain serious long-term threats for Javan deer (Hedges et al. 2015).

Lastly, the Philippine deer (*Rusa marianna*) is an endemic species to the Philippines, listed as vulnerable on the IUCN Red List. Although the population numbers are unknown, the remaining populations are left fragmented and are primarily threatened by habitat destruction and intensive poaching for meat consumption, hides, and trophies (MacKinnon et al. 2015).

2.2. Visayan spotted deer biology

2.2.1. Geographic range

Visayan spotted deer (*Rusa alfredi*) is a poorly studied endemic species in the West Visayan Islands of the Philippines. Due to extensive deforestation and hunting, the species has vanished from more than 95 % of its original habitat (Oliver et al. 1991). Consequently, it is listed as endangered on the IUCN Red List (Brook 2016). However, the Philippine Red List Committee declared the deer critically endangered (Biodiversity Management Bureau—Department of Environment and Natural Resources 2020).

In the past, the VSD was found roaming on Guimaras, Cebu, Masbate, and likely Ticao islands. However, it has disappeared since the mid-20th century and is now considered functionally extinct at these locations (Brook 2016; Maala 2001). The current and former range is debatable. However, the last remaining populations reside on forest remnants on the island of Negros and Panay, with less than 1000 mature individuals remaining (D'Cruze et al. 2013; Brook 2016; Ali et al. 2021; Ward et al. 2021) and with subpopulations no larger than 250 individuals (Brook 2016; Ali et al. 2021). The remaining Negros populations are severely fragmented, while the Panay population, which occupies a larger continuous forested area, seems to be more viable, according to Talarak Foundation. There have been no reports of deer sightings outside of the areas mentioned above since the 2000s. The overall distribution range from the IUCN Red List assessment is presented in Figure 1. These distinct populations living on different islands have been separated for thousands of years. Even though no molecular studies were performed, taxonomic differences are possible; thus, they are managed separately (Brook 2016).

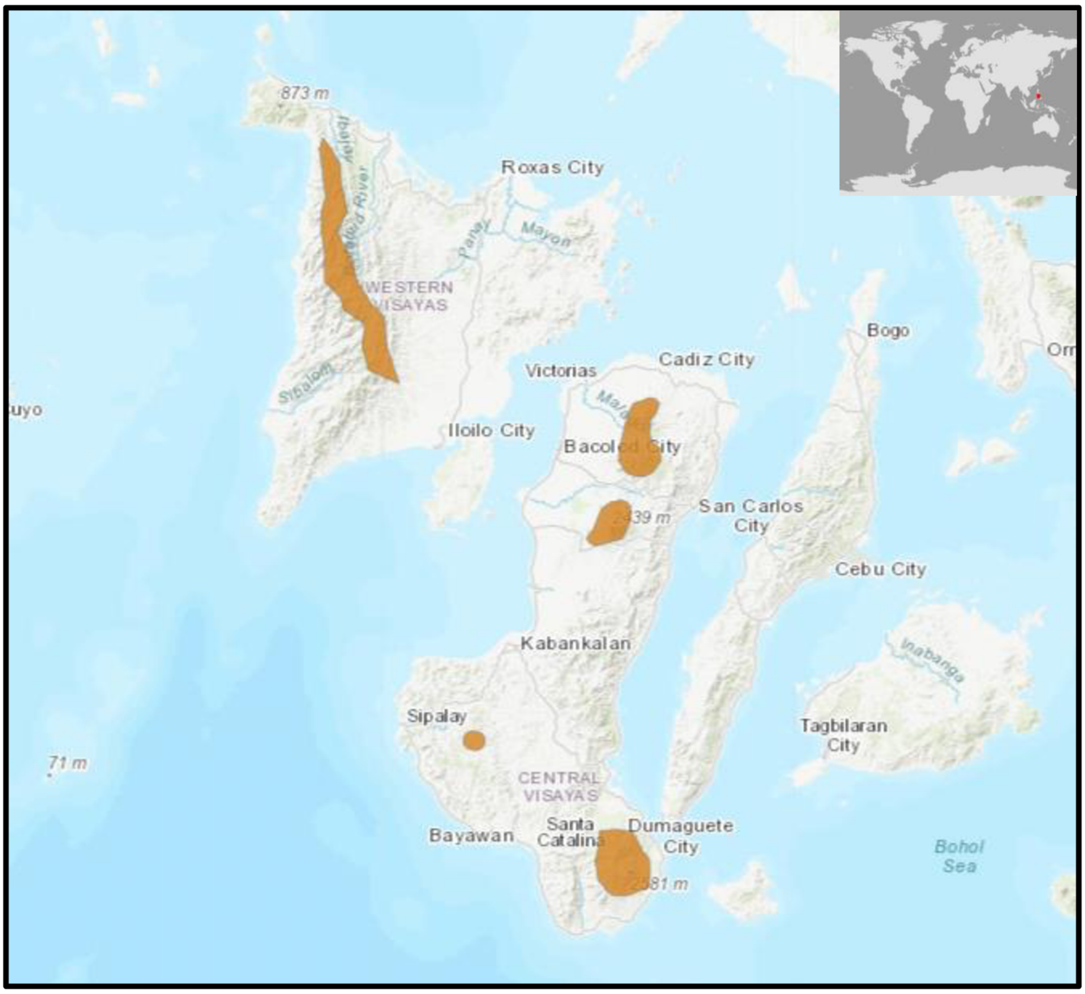

Figure 1. Visayan spotted deer (*Rusa alfredi*) distribution area, IUCN Red List assessment (Brook 2016).

2.2.2. Habitat

Although the habitat preference is unknown and remains poorly studied, the VSD is found in relatively remote, dense dipterocarp forests with steep, rugged slopes up to 2000 metres (Cox 1987; Brook 2016; Ali et al. 2021). Such localities are often inaccessible to humans. While deer can survive and have been anecdotally seen in habitats such as grassland, forest clearings or even naturally disturbed landscapes after wildfires, dense forest cover is required to provide a certain degree of refuge (Brook 2016). According to studies conducted by Talarak Foundation, VSD primarily inhabit the dense dipterocarp forest throughout the day and night, with occasional visits to grassland areas in the evening to minimise threats.

2.2.3. Morphological description

The Visayan spotted deer has dark brown fur with white spots mainly on their flanks and backs (Biodiversity Management Bureau – Department of Environment and Natural Resources 2020; Ward et al. 2021). These spots are most prominent on their hips, gradually fading away towards the shoulders, making them distinct from other species. The underside is cream white with a chin and bottom lip (Ali et al. 2021). There is no sexual dimorphism in colour variations. However, females tend to be smaller than males (Ali et al. 2021). Although *Rusa alfredi* is a small-medium species with mature males reaching up to 1.2 m at shoulder height and 90 kg in weight, they are considered the largest mammal in the Visayan region (Ward et al. 2021). Antlers display a wide range of variation, with some young males maintaining small, single-pointed antlers while others have large up to four-pointed antlers. However, the standard antler setup is a two-point main tine approximately 20-30 cm long with a single brow tine.

2.2.4. Diet

Studies have yet to be done on the dietary requirements of the VSD, even though feeding ecology plays a vital part in conservation efforts. Consequently, the knowledge comes from observation. The VSD have been seen feeding on young leaves, buds, shoots of cogon grass, and particularly certain fern species (Brook 2016; Rode-Margono et al. 2021). Subsequently, wild bananas, ficus, and other fallen fruits are part of the dietary intake as well as ash from grass burning (Rode-Margono et al. 2021). Mineral supplementation is crucial during high energy expenditures such as antler growth and lactation (Ali et al. 2021). According to the Talarak Foundation, VSD are likely to consume their own antlers for mineral supplementation as not many are retrieved by zookeepers in captive populations. Antler consumption, osteophagia, is a common behaviour for many ungulates, providing individuals with minerals such as calcium, phosphorous and other important minerals (Gambín et al. 2017).

2.2.5. General Behaviour and Activity Patterns

The behaviour of the VSD has been poorly studied, and the literature on this topic is scattered, with no behaviour studies done in the wild. However, Ali et al. (2021) provided a basic overview. The VSD is recognised as a nocturnal species, often congregating in groups of no more than three individuals. Males can often be spotted alone, while females are accompanied by their offspring. Furthermore, the VSD possess preorbital glands, a feature commonly observed in ungulates. Besides scent marking, the preorbital gland also facilitates communication between the mother and the calf. Simple opening and closing of the preorbital gland may signal potential hunger, satiety, or even stress in the calf (Ceacero et al. 2014).

2.3. Conservation of Visayan spotted deer

2.3.1. Threats

The Philippines is well known for its unique species and is considered one of the biodiversity hotspots (Galang 2004; Posa et al. 2008; Tanalgo 2017; Ortiz & Torres 2020), along with 17 other countries, collectively holding over two-thirds of the worldwide biodiversity (Galang 2004). An example is the Negros-Panay region, with an endemism rate of 50 %, which is home to the last remaining naturally occurring Visayan spotted deer (Galang 2004). Unfortunately, this conservation priority area faces significant threats due to a lack of government action and considerable corruption (Galang 2004; Posa et al. 2008).

The forest area has rapidly declined over the last 100 years, with only 20 % persisting and less than 3 % representing primary forest (Galang 2004; Ortiz & Torres 2020). Several deforestation drivers have been identified by Western Visayas Conservation Workshop (Rode-Margono et al. 2021): (1) the conversion for human settlements, (2) land conversion for agriculture (slash and burn), (3) land conversion for plantation (monoculture crops). As a result, deer face a decrease in food supply and liveable habitat, further reducing their already fragmented populations (Rode-Margono et al. 2021). Moreover, the Philippines has one of the fastest-growing populations in the world (Galang 2004). Most people live near the forest edges, often leading to human-wildlife conflict (Tanalgo 2017). This may push species to the brink of extinction, but the lives of low-income rural communities are also at stake, with the poverty rate rising to 40 % (Galang 2004).

The threats mentioned above, along with hunting pressure for consumption or sport (trophies), pose a significant risk to VSD and may influence the species population sizes, subsequently leading to decreased genetic diversity (Rode-Margono et al. 2021). Accordingly, a study done by Tanalgo (2017) revealed that poverty and lack of employment opportunities are the main current drivers of wildlife hunting, unlike in the past when it was mainly a cultural practice. In addition, VSD are also captured live, often through leg snares, to be sold as pets (Brook 2016; Hamann 2022), while adults are often shot while feeding on crops (Hamman 2022).

Although detailed information on hunting the VSD is lacking, tropical Asian deer face substantial hunting pressure and consequently have declined in abundance over the past few decades (Corlett 2007). For instance, hunting and habitat loss were identified as primary drivers for the significant population decline of Philippine deer (*Rusa marianna*) in Mindanao Island (Villegas et al. 2022).

The only study focusing on VSD was an interview-based survey conducted by Cox (1987). It stated that deer hunting is more prevalent from January to June during the dry season. Moreover, hunters on Panay Island reported a lower catch rate in 1987 compared to 1982, revealing an unfortunate reality and concerning trend.

Despite the deep connection that the Indigenous people of the Philippines have with the land and their direct reliance on it for their livelihoods, there is a lack of environmental awareness among communities (Galang 2004).

2.3.2. Conservation Measures

Cervids are essential to the ecosystem and serve as reliable indicators for forest management (Hanley 1996; Ali et al. 2021). Their herbivory and seed dispersion can lead to changes in plant communities, altering nutrient cycles and energy flow within the ecosystem (Lucas et al. 2013). For instance, the findings of the study done by Lucas et al. (2013) demonstrated that the presence of white-tailed deer (*Odocoileus virginianus*) had positive effects on the growth of northern red oak (*Quercus rubra*) due to their faecal and urine deposition and their vegetation clearing. Furthermore, deer play an essential part in the food chain, often being an important prey animal for large carnivores. Despite the

Visayan spotted deer having no natural predators in its environment besides humans, the closely related Sambar (*Rusa unicolour*) is an essential prey for tigers and leopards in Asia. Additionally, deer hold a significant economic value for venison meat, traditional medicine and other co-products (Ali et al. 2021).

Unfortunately, VSD conservation had been largely neglected, and the decreasing trend of the Visayan deer population was not recognised until 1985 (Oliver et al. 1991). Nowadays, the VSD is considered one of the most endangered deer species in the world (Brook 2016). VSD is legally protected under the Philippine Wildlife Act 9147. Hunting endemic wildlife in the Philippines is strictly prohibited and illegal except for indigenous people for non-commercial purposes (Brook 2016; Tanalgo 2017; Rode-Margono et al. 2021). However, enforcement of this law is challenging (Brook 2016; Ali et al. 2021), despite increasing awareness (Brook 2016). Even though the deer range covers several protected areas in Negros and Panay, including Balinsasayao Twin Lakes Natural Park, Northern Negros Natural Park, Canlaon Natural Park and the Central Panay Mountain Range (Brook 2016; Ali et al. 2021), D'Cruze et al. (2013) reported frequent illegal hunting activity captured on cameras during their research in North Negros National Park. This suggests that law enforcement is challenging even in protected areas.

To help this endangered species thrive in the future, experts at the Western Visayas Conservation Workshop (Rode-Margono et al. 2021) established a 20-year conservation plan for Visayan spotted deer with the following goals:

1. *"At least two new viable wild populations of Visayan spotted deer exist across its historical range*." To achieve this, high-priority goals include surveys of remaining populations, conducting research to better understand species ecology (diet, habitat requirements, behaviour, carrying capacity/home ranges), and identifying suitable areas for release. Subsequently, captive populations will be used to start the establishment of the two new populations.
2. "*Suitable habitat of the Visayan spotted deer within and outside of PA increased*." The key focus is to identify new potential habitats, legally protect them, and create wildlife corridors to facilitate population movement. Communication with landowners to dedicate land for conservation and promote sustainable agriculture practices will become crucial to the conservation process. Currently, there are three possible suitable locations identified for reintroduction projects:

Balinsasayao Twin Lakes National Park, a protected forest area with the last individual seen in 2006, and Hinobaan, a grassland with potential for reforestation. Lastly, the South Cebu Mountain Range, with approximately 1200 ha of protected land by The Department of Environment and Natural Resources (DENR), was also identified as a potential release site.

3. *"Communities empowered to engage in conservation of the Visayan spotted deer; including reducing hunting and habitat destruction."* Socio-economic research is needed to better understand their needs for implementing awareness programs and promoting conservation. Furthermore, protection of the Visayan spotted deer should be implemented within the Forest management programmes.
4. *"Local and national laws related to wildlife protection, PA, and forestry are strictly implemented to protect the Visayan spotted deer and its habitat."* Implementing and strictly enforcing environmental laws are crucial steps to effectively conserving this important species and its ecosystem.

In late 2023, Silliman University initiated a new project in partnership with the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development of the Department of Science and Technology (DOST-PCAARRD) and Forestry and Environment Research Division (FERD) titled "Enhancing the Conservation and Breeding Program of the Philippine Spotted Deer, Using Molecular-based Approaches for Natural Resiliency". The primary objective of this project is to improve conservation efforts for Visayan spotted deer using molecular-based approaches such as barcoding to gain a better understanding of their phylogenetic relationships. Additionally, the project aims to evaluate the level of inbreeding in the captive Department of Biology and the Centre for Tropical Studies (CENTROP) population and assess the overall adaptive immunity of the species (Santiago 2024).

2.3.3. Ex-situ populations

In 1990, the first captive breeding programme was established in collaboration with CENTROP of Silliman University. This initiative was a crucial part of conservation efforts, and the individuals involved in the programme were either caught in the wild or were captive bred from wild parents. Two breeding centres were established: one in Panay (housing three males and four females) for the Panay population and another in Negros (housing five males and five females) to ensure the separation of two likely genetically distinct populations. Additionally, a third group from Negros population (consisting of three males, four females) was introduced in Mulhouse Zoo (Oliver et al. 1991).

In 2019, there were six VSD ex-situ facilities in the Philippines, housing a total of 159 individuals (Rode-Margono et al. 2021), and as of December 2023, there were 30 institutions participating in the European Association of Zoos and Aquaria (EAZA), maintaining 99 individuals as “an insurance population” for the in-situ Visayan spotted deer population in Negros (EAZA 2024). More detailed information about the ex-situ population sizes can be seen in Table 1.

Table 1. Population sizes of known ex-situ holding of Visayan spotted deer of Negros origin (Rode-Margono et al. 2021)

LOCATION	MALES	FEMALES	UNKNOWN	TOTAL	FOUNDERS
TFI-NEGROS FP	7	18	0	25 (29)	>10
TFI-KABANKALAN	19	15	0	34 (23)	>10
CENTROP	50 (38)	55 (49)	0	105 (87)	>10
MARI-IT	10 (12)	7 (7)	3	20 (19)	>10
AVILON ZOO	(1)	(0)	0	(1)	>10
EAZA (27 INSTITUION)	48	42	3	93	10
TOTAL	134	137	6	277 (252)	-
CEBU SAFARI	(Has VSD; but unknown number at time of workshop)				

Data source: Talarak Foundation Inc.; data in brackets were updated by the Western Visayas Conservation Workshop in 2021.

2.3.4. Talarak Foundation Inc.

The Talarak Foundation is a conservation non-governmental organisation (NGO) based on Negros Island, Philippines and is dedicated to protecting and restoring the native wildlife of Negros. Established in 2010 by two passionate conservationists, Fernando Gutierrez and Pavel Hospodarsky, Talarak Foundation has made significant progress in protecting the endemic species of Negros. Their efforts began with the establishment of the first conservation centre in Kabankalan City, Negros Occidental, and have since expanded to include a second conservation site in Bacolod City, formerly known as Negros Forest Park (Talarak Foundation 2020).

Negros Forest Park primarily operates as a captive breeding program while also allowing public access to educate generations about the importance of species conservation and preservation in the Philippines. Public education at the Negros Forest Park includes free guided tours, organised school visits and interaction with ambassador animals. The park also collaborates with universities to provide training and expertise to students. In addition to education, the park breeds the West Visayan Big 5: Visayan spotted deer (*Rusa alfredi),* Visayan warty pig (*Sus cebifrons*), Visayan Tarictic Hornbill (*Penelopides panini*), Negros bleeding-heart dove (*Gallicolumba keayi*), and Rufous-headed Hornbill (*Rhabdotorrhinus waldeni*). They have successfully sent animals to other captive centres worldwide, such as the USA, Europe and Singapore (Talarak Foundation 2020). For instance, 119 Visayan spotted deer have been successfully bred in the Negros Forest Park until recently (Ward et al. 2021).

In addition to captive breeding programmes, the Talarak Foundation conducts field surveys in Negros natural landscapes to evaluate the remaining populations and their environment for effective conservation measures. Camera traps and community surveys are primarily used for this purpose. Additionally, assessments of the remaining forest sites are conducted to identify potential high-quality sites for restoration and future release programs (Talarak Foundation 2020).

Lastly, conservation education is one of the most powerful tools in protecting biodiversity. The Talarak Foundation has its own educational teams, with some from local communities to communicate with and educate local communities in the vicinity of the Bayawan Nature Reserve and young schoolchildren. This helps people understand the importance of protecting species and the environment for the benefit of future generations (Talarak Foundation 2020).

2.4. Camera trap studies in tropical cervids

Remote-sensing camera traps are commonly utilised to monitor wildlife populations in their natural habitat (Trolliet et al. 2014; Caravaggi et al. 2017; Grotta-Neto et al. 2020). With the ongoing threats posed by human activities to the ecosystem, there is an increasing need to monitor the fate of wild populations regularly (Trolliet et al. 2014). Camera traps are considered non-invasive, making them ideal instruments to monitor elusive species that occur at low densities or live in remote locations that are hard for humans to access. Consequently, they enable to maintain the animals' welfare by avoiding physical capture, which is often unfeasible in such circumstances, and preventing further stress to already affected populations while creating permanent records of the study animals (Nichols et al. 2011; Grotta-Neto et al. 2020). Moreover, camera traps are efficient, requiring less time and human resources (Trolliet et al. 2014) compared to other monitoring methods such as GPS and telemetry (Ward et al. 2021). Although quality camera traps have high initial purchase costs, overall expenses are becoming more reasonable in the current market (Nichols et al. 2011), especially for long projects where the initial purchase costs are lower than the costs of daily field visits (Rahman et al. 2016).

Thus, camera traps are crucial for studying deer and other species in tropical rainforests, as deer in these regions can be challenging to observe due to their elusive nature, especially in areas with dense canopy cover. As a result, these species often lack important ecological knowledge necessary for conservation efforts (Grotta-Neto et al. 2020). Camera trapping was found to be the most efficient method in studying critically endangered Bawean deer (*Axis kuhlii*) on Bawean Island when compared to other methods, such as faecal pellet count and transect sampling (Rahman et al. 2016). Furthermore, De Oliveira et al. (2020) used camera traps and faecal DNA samples to discover two new populations of grey brocket deer (*Mazama nemorivaga*) in the Brazilian Atlantic Forest, away from its original habitat. This information can be, therefore, used by authorities for effective management of the species. But camera traps are essential not only for assessing populations but also for understanding trophic interactions. Awasthi et al. (2024) made an intriguing discovery about the diet of deer in a study conducted in

Nepal. Four tropical deer species, including Chital (*Axis axis*), Northern red muntjac (*Muntiacus vaginalis*), Sambar deer (*Rusa unicolor*), and Indian hog deer (*Axis porcinus*) were observed feeding on insects, particularly red cotton bugs on fallen fruit. These deer are the primary seed dispersers of a flowering plant called *Trewia nudiflora.* This observation suggests that deer may consume insects to fulfil their protein requirements.

The first camera image of VSD in the wild was obtained by D'Cruze et al. (2013) during the camera trap survey in North Negros National Park in 2012. The second record of Visayan spotted deer in the wild was captured by Ward et al. (2024) during a field survey in the Southwest Negros KBA in 2022. The team obtained images of two individuals, confirming the species' presence. To our knowledge, there are no further camera trap records of the VSD in the wild besides continuous research in Bayawan Nature Reserve.

2.5. Artificial intelligence/Machine learning tools and wildlife conservation

2.5.1. Individual-Based Recognition

Many species have unique natural marks like stripes or spots, which they use for display or camouflage. As a result, the variation in physical characteristics within a population can be used as a reliable marker for monitoring species (Nipko et al. 2020). While traditional marking methods, such as the application of artificial marks, are still being conducted, several issues are being raised. Most tags are lost during the animal's lifetime, leading to biased data. Additionally, traditional marking techniques require capturing individuals, which can be especially challenging for already endangered populations. This process causes stress for the animals and poses a potential risk of injury and infection (Cheema & Anand 2017; Calmanovici et al. 2018; Lee et al. 2022). Thus, identification of individuals through camera traps or digital photography based on their natural distinct markings is a non-invasive and often cost-effective method for wildlife monitoring and management (Cheema & Anand 2017; Nipko et al. 2020) that may help to obtain important population knowledge such as population structure, behaviour, and overall life history (Bolger et al. 2012; Calmanovici et al. 2018; Nipko et al. 2020; Lee et al. 2022). This is vital for assessing endangered species populations and achieving conservation goals (Calmanovici et al. 2018).

Nipko et al. (2020) emphasised the notable distinction between studies that use remote camera traps and those that manually photograph individuals. While manual photography produces high-quality, detailed images, studies using remote cameras often encounter environmental challenges, such as degraded image quality due to extreme weather conditions. Consequently, the identification software must be robust enough to handle these challenges (Cheema & Anand 2017).

However, with the use of new trail cameras, the quality of images and videos has significantly improved in recent years, and camera trap studies for individual recognition have become a popular technique among researchers (Nipko et al. 2020). This has been effective in monitoring various terrestrial species, including jaguars and ocelots (Nipko et al. 2020), deer (Ward et al. 2021), zebras (Lee et al. 2022) and many more. Whereas manual photography of unique markings is frequently used for research on marine species like turtles (Calmanovici et al. 2018), seals (Koivuniemi et al. 2016), and even fish species such as trout (Haxton 2021).

On the contrary, Clapham et al. (2020) demonstrated that species with distinct markings are not the only candidates for individual recognition research. Their application, BearID, can recognise the face of Brown bears (*Ursus arctos*) within images with an accuracy of 83.9 %. This is especially important since Brown bears lack distinct markings and fluctuate in weight and morphology between seasons.

2.5.2. Pattern recognition software

Recording wild species using images collected by researchers began in the 1950s and has since become a popular technique for wildlife monitoring. However, historically, the process of capturing and processing photographic records required extensive human intervention, with each image needing to be manually identified. This was not only time-consuming but also prone to human error (Cheema & Anand 2017). This was supported by a study done by Ward et al. (2021), who compared the efficiency of HotSpotter and human identification of Visayan spotted deer. Despite similar score results, the identification of 118 images by three human observers took significantly longer (six hours) than HotSpotter, which had a processing time of two hours.

Unlike pixel-based software, feature-based software does not analyse entire images. Instead, it identifies specific features of the targeted animal, such as spots or stripes, and then precisely compares these distinct marks across images. Due to the variations in image quality from camera traps, Nipko et al. (2020) have suggested that feature-based software is better suited for camera trap studies.

Most pattern recognition programs are based on three main components highlighted by Bolger et al. (2012). The user should have a photographic database of a population, the base data. Furthermore, the program extracts the pattern information from each image and then compares every new image to the already existing database. As a result, the user is provided with a matching score, which will require user intervention to verify positive matches.

Several feature-based pattern recognition software is available, including HotSpotter, Wild ID, I3S, and Image Based Ecological Information System (IBEIS). Here, we will discuss HotSpotter and IBEIS, the main focus of this study, in detail. Notably, each software has its own pros and cons. Therefore, preliminary testing is recommended to determine the best fit for the desired study and species (Lee et al. 2022).

HotSpotter is among the most popular pattern recognition software available and has been used across various species with distinct patterns. It enables fast and accurate identification of individuals against an existing database. Users must select the region of interest (ROI) of each image that provides the software with an area of focus, a distinguishable feature (Crall et al. 2013; Raphanaud 2022). The software runs a query against the existing image database to provide the user with six potential matching pairs based on pattern similarity. However, HotSpotter still requires extensive user input. The user must decide based on scoring to confirm a positive, negative or no match (Crall et al. 2103, Raphanaud 2022; Wiig et al. 2023). Thus, the final decision of match or no match always relies on the user (Crall et al. 2013; Wiig et al. 2023).

In this study, we have chosen to use the IBEIS software for several reasons. First, Ward et al. (2021) achieved satisfactory results with HotSpotter. However, HotSpotter is no longer being updated. Instead, sources recommend using an improved version of HotSpotter, which is IBEIS. Second, IBEIS is available to the public and free of charge. Third, after some training, IBEIS is user-friendly.

2.5.3. Image Based Ecological Information Software (IBEIS)

The Image-Based Ecological Information Software (IBEIS) is a computer vision algorithm that manages and stores population data. IBEIS has been used for various species, including Shore skink (*Oligosoma smithi*) (Raphanaud 2022), Eastern box turtle (*Terrapene Carolina Carolina*) (Zoppa 2024), and Grevy's zebra (*Equus grevyi*) (Berger-Wolf et al. 2016). To our knowledge, IBEIS software has not been used in Cervids, despite several species having spotted coat patterns, making them prime candidates for individual-based studies, including Persian fallow deer (*Dama dama mesopotamica*), Indian hog deer (*Axis porcinus*), Chital (*Axis axis*), and Sika deer (*Cervus nippon*) (Ward et al. 2021).

IBEIS is considered an improved version of HotSpotter based on a neuron network. Moreover, IBEIS undergoes continuous updates, while HotSpotter software has not received any in the last six years. Similarly to HotSpotter, the user must select the region of interest (ROI) and then run the images against the already existing database. This is based on nearest neighbours by kd-tree. The user is then provided with matches based on scoring. The user must confirm each match, whether positive or negative. Initially, the software may propose many matches as unknown, but these will be further reduced later in the analysis as the software is trained (Raphanaud 2022). Positive matches will then appear in the Tree of Names, a user-friendly overview.

Accordingly, IBEIS can only handle medium-sized populations. Larger data sets require a new computer algorithm, as demonstrated by Berger-Wolf et al. (2016), who processed over 40,000 images of Grevy's zebra.

One drawback of this software is its compatibility with the Linux operating system. Therefore, Windows and IOS users must operate within the virtual window or install Linux on their computers.

3. Aims of the Thesis

This study aimed to analyse camera trap data from Bayawan Nature Reserve using specialised artificial intelligence software IBEIS to identify unique patterns of the Visayan spotted deer (*Rusa alfredi*). We aimed to define the training process, identify good practices and address challenges when using IBEIS to study spotted cervids. Furthermore, we aimed to provide Talarak Foundation with the individual identification dataset for existing and newly detected individuals, demonstrating the practical application of the research.

Lastly, the intention to lay the groundwork for subsequent studies on the individual-level behavioural ecology of this poorly studied species highlights the broader significance of this research.

4. Methods

4.1. The study site: The Bayawan Nature Reserve

The Bayawan Nature Reserve, also known as the Danapa Nature Reserve, is a 300-ha forest-fenced site on Negros Island in the West Visayas (Figure 2). This reserve was donated by the government of Bayawan City to the Talarak Foundation Inc. for conservation and educational purposes while retaining its ownership. Since then, various species, including the Visayan spotted deer (*Rusa alfredi*), Visayan warty pig (*Sus cebifrons*), Visayan Tarictic Hornbill (*Penelopides panini*), and Negros bleeding-heart dove (*Gallicolumba keayi*) have been released into the reserve, some fitted with tracking devices for monitoring. In addition to these, the reserve is also home to other species, such as the Visayan leopard cat (*Prionailurus bengalensis rabori*), Philippine Pita (*Pitta erythrogaster*), Malayan civet (*Viverra tangalunga*), and Philippine long-tailed macaque (*Macaca fascicularis philippensis*) (Talarak Foundation 2020). However, the conservation efforts primarily focus on the big five. The study site is mainly rugged terrain with steep slopes and is mostly covered by tropical forests with a mix of open and closed forests and grassland patches. The Philippines has a tropical climate with high temperatures, humidity, and heavy rainfall. The country has two main seasons: the rainy season from June to November and the dry season from December to May (PAGASA 2024). Although no climate data is available for the Bayawan Nature Reserve, the average temperature in Bayawan ranges from 24.4 °C to 31.6 °C, with minimal variation between the hot and cold seasons. The average wet season in Bayawan lasts 6.3 months, starting at the end of May and continuing until December. July is the wettest month of the year, with an average rainfall of 15.24 cm. In contrast, the driest month of the year is March, with an average monthly rainfall of 3.81 cm. The length of the day remains relatively constant throughout the year, staying within 40 minutes of 12 hours (Weatherspark 2024).

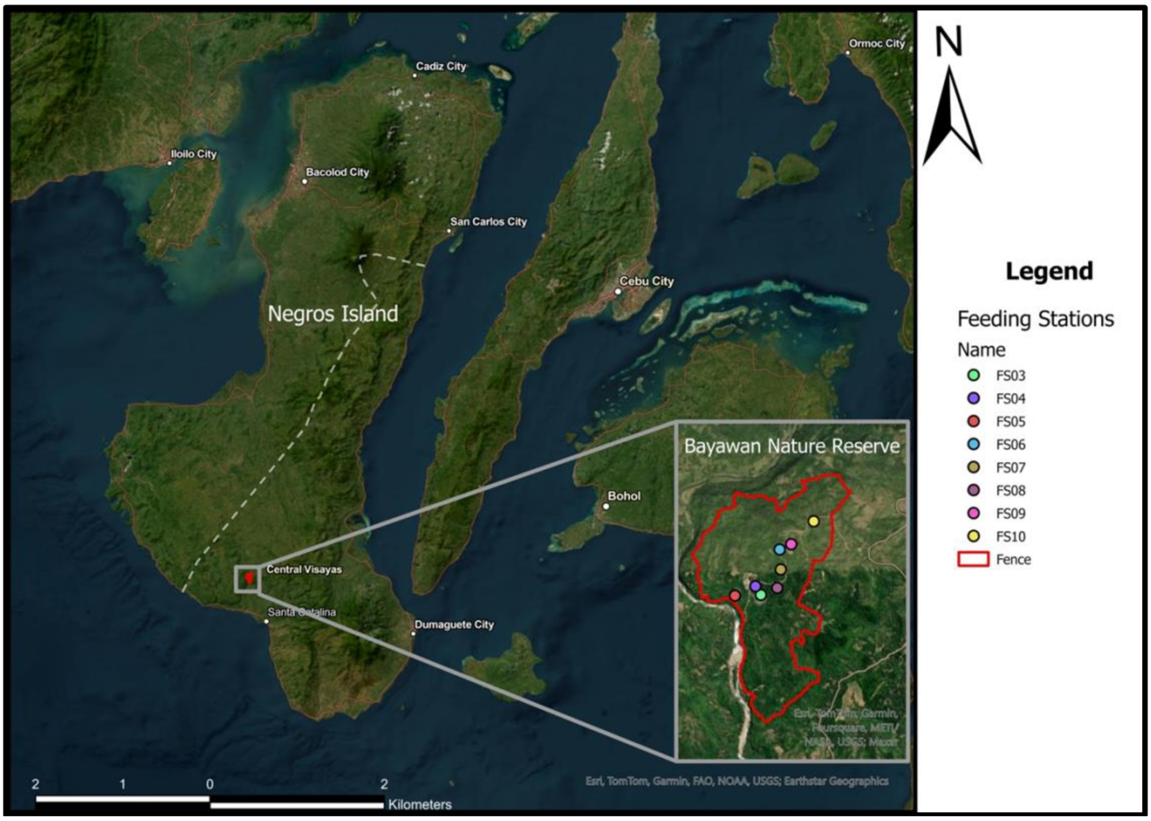

Figure 2. Location of the Bayawan Nature Reserve on Negros Island, Philippines.

4.2. Data collection

4.2.1. Animal identification and release

Between June 2020 and July 2021, a total of 21 male and 12 female individuals were successfully transferred from the Talarak ex-situ centres Negros Forest Park and Talarak Kabankalan to the Bayawan Nature Reserve. The Visayan spotted deer were photographed from both the right and left sides prior to release while in captivity. This created an ID database to capture unique individual spot patterns and assess overall body condition. These were used as control images in this study. Additionally, each deer was marked with an ear tag, while three males and one female were fitted with radio transmitter collars.

It is confirmed that three males and two females perished, while one unidentified female successfully escaped from the reserve. The complete list of released individuals can be seen in Table 2.

Table 2. List of deer released to the Bayawan Nature Reserve.

ID	NAME	SEX	TRANSFER	NOTES
TFI 064	Danny	Male	Jun 16 2020	-
-	Lucho	Male	Jun 16 2020	-
TFI 096	Ethan	Male	Jun 16 2020	GPS collar
TFI 009	Pepe	Male	Jun 16 2020	Died in the typhoon, Dec 2021 (GPS collar)
TFI 057	Leander	Male	Jun 16 2020	Died from unknown injury, early 2021
TFI 061	Nestor	Male	Jun 16 2020	-
TFI 060	Jesse	Male	Jun 16 2020	-
TFI 107	Yaw	Male	Jul 06 2020	-
TFI 132	Manoling	Male	Jul 06 2020	-
TFI 089	Sebastian	Male	Jul 06 2020	-
TFI 134	Cap Kal	Male	Jul 06 2020	-
TFI 135	Wan	Male	Jul 06 2020	Died in a ravine, May 2024
TFI 087	Monching	Male	Jul 06 2020	-
TFI 105	Bay	Male	Jul 06 2020	-
TFI 145	Bambi	Male	Aug 08 2020	-
TFI 147	-	Male	Aug 08 2020	-
TFI 162	-	Male	Dec 01 2020	-
TFI 139	Bert	Male	Dec15 2020	GPS collar
TFI 161	Unknown Male 2	Male	July 15 2021	Found during this study
TFI 171	-	Male	July 15 2021	-
TFI 133	-	Male	-	Found during this study
	Jane Doe	Female	Aug 08 2020	No tag
TFI 058	-	Female	Aug 06 2020	-
TFI 137	Deerty Face	Female	Aug 06 2020	-
TFI 099	Rogue	Female	Aug 06 2020	-
TFI 136	Baby Face	Female	Aug 06 2020	Died from antler puncture, Dec 2023
TFI 113	-	Female	Aug 08 2020	-
TFI 148	-	Female	Aug 08 2020	-
TFI 098	Doera	Female	Dec 01 2020	-
TFI140	Berta	Female	Dec 15 2020	-
-	Daria	Female	Aug 08 2020	No tag
-	Deanne	Female	-	-
-	Bella	Female	-	GPS collar

4.2.2. Data collection – camera traps

This study used remote camera traps alongside artificial feeding stations in the Bayawan Nature Reserve. Visayan spotted deer are very timid, so remote cameras were preferred over photographing free-ranging individuals. Each feeding station had a single camera trap, which the Talarak Foundation regularly serviced every two months. Ten feeding stations were built in total, eight of which were set up with camera traps. To control for camera variables, we chose to work with camera traps from four feeding stations (FS04, FS05, FS09, FS10) (Figure 3).

The selected feeding stations utilised two types of cameras (Bushnell - Prime Combo; Browning - Recon Force Edge, HD, 4K, PXD). Each camera was set up in video mode, with a 30-second video length and flash mode, with no glow infrared. The camera trap data of FS04 and FS05 covered the period from November 2020 to August 2023, while the data of FS09 and FS10 was from April 2021 until August 2023. It is important to note that all data from August 2021 to August 2022 is missing.

To optimise the monitoring effort to see the desired species, cameras were safely secured to a tree or a pole at a height of 1-1.2 m (hip-waist height), with an angle between 10-30 degrees and aimed at a point 1.5-2 m away on the ground. Any loose vegetation, such as vines, grasses, and shrubs in front of the camera, was cleared so as not to set off the camera motion sensor.

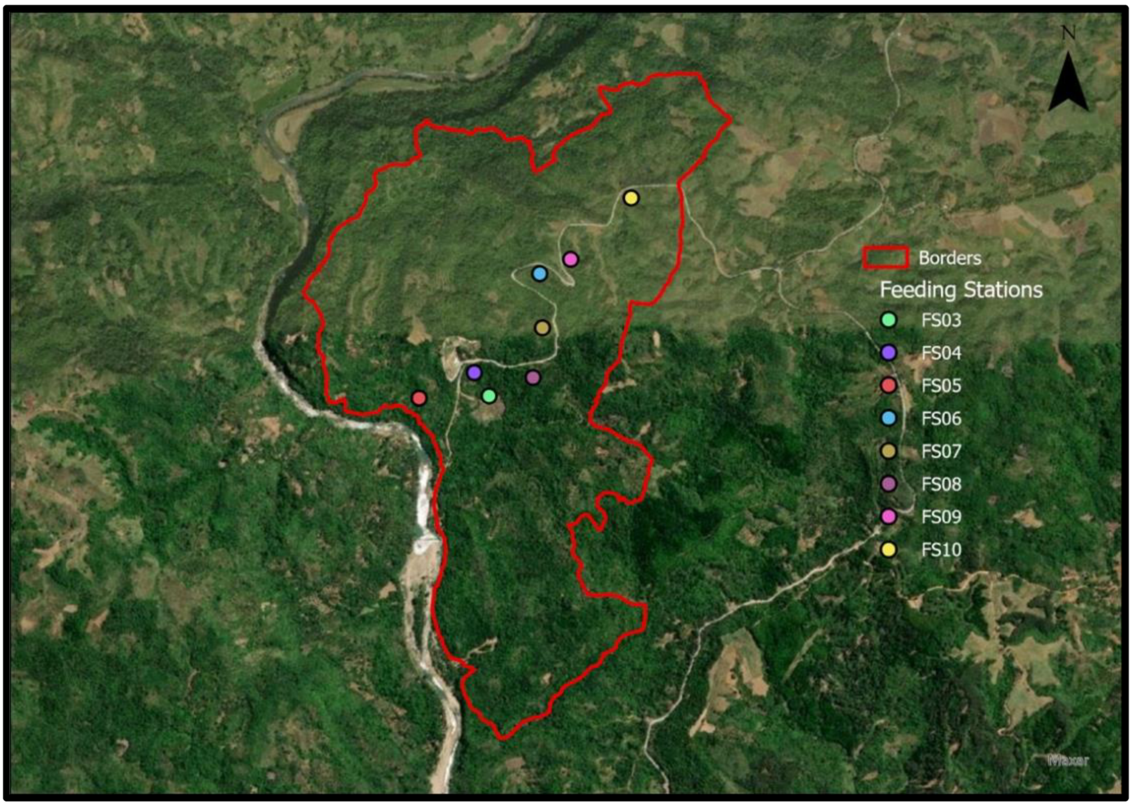

Figure 3. Map of the Bayawan Nature Reserve indicating locations of all feeding stations. During our study, we worked with FS04, FS05, FS09, FS10.

4.2.3. Data analysis IBEIS

We evaluated IBEIS for its spot pattern recognition capabilities. While a comprehensive manual for IBEIS is currently unavailable, our approach predominantly relied on the HotSpotter manual (Crall et al. 2013) and other relevant studies (Berger-Wolf et al. 2016; Ward et al. 2021; Raphanaud 2022; Wiig et al. 2023; Zappa 2024)

Initially, a new database with the ID deer portfolio was established. Areas to mark regions of interest in an image were selected. Our research specifically focused on the area between the shoulder and the rump to ensure clear visibility of the individual's spot pattern. Each deer had both sides documented. Along with annotations, the name, sex, and species of each individual were documented as recommended by the IBEIS manual. These images served as a baseline for our study.

The 4,510 videos captured by camera traps showing deer were reviewed. For every deer with a visible spot pattern, we took a screenshot. Two screenshots were taken if both sides were visible: one of each side. If multiple consecutive videos featured the same deer, one screenshot was taken. Each screenshot was named according to the video for easier recognition later during the analysis. All selected images were imported into a virtual window machine, AnyDesk, to further upload them to IBEIS. We uploaded the images in batches of 30-40 images to prevent the software from crashing. Each image was annotated by selecting the region of interest in the same way as creating the ID portfolio. We used the batch identification method "ID Encounters", running all query annotations against all species database annotations as this method proved to provide us with the best results. The results were based on the similarity of the patterns, with ellipses indicating the matching regions. Each match needed to be visually inspected to confirm whether it was true or false. The overview of the process can be seen in Figure 4.

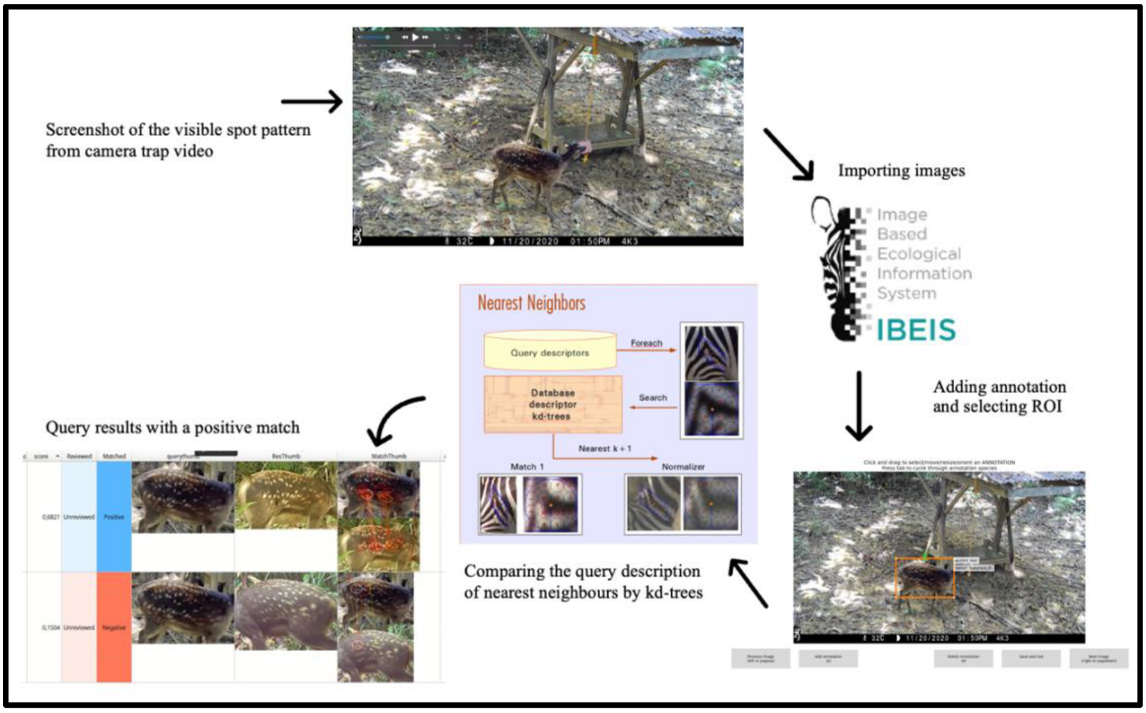

Figure 4. A flow diagram describing the analysis of this study. Every camera trap video featuring deer was analysed; a screenshot of the visible spot pattern of each individual was taken; images were imported into IBEIS; annotation and region of interest were defined; a query for matches in the database was made; IBEIS provided with results based on similarity with the ellipses showing the matching regions; the user marked each result either positive or negative based on visual inspection.

5. Results

Data were obtained from deployed camera traps at four artificial feeding stations at Bayawan Nature Reserve from November 2020 until August 2022. Visayan spotted deer were detected in 4,510 videos, of which 641 images were selected for individual-based analysis in IBEIS. Each feeding station was done individually to build the ID deer database and effectively train the IBEIS software. Notably, individuals with no previous ID database, such as fawns or young individuals born in reserve, were excluded from the analysis.

5.1. Feeding stations

5.1.1. Feeding station 9

We began our analysis at feeding station 9. Out of 942 videos, 101 images were selected. IBEIS recognised 45 images out of 101, resulting in a matching success of 44.55 %. All identified deer, except one female, were males. IBEIS effectively grouped the same individuals but failed to recognise 56 images. After human observation, an additional 25 images of five individuals were identified. To improve future analysis, we revisited videos with identified deer and added 33 additional images to increase the ID database and increase matching success in future analysis.

5.1.2. Feeding station 4

Feeding station 4 was the most extensive data set, capturing 1,480 deer videos, with 303 high-quality images selected for analysis. Out of these, 55 images were not identified by the IBEIS software, and 23 images were not analysed even when separate analysis was performed. The matching success rate, including the 23 error images, was 74.26 %. Additionally, a human observer successfully identified 42 out of the 55 images that the software could not. Five females and three males remained unidentified. This likely occurred due to an error, as repeated analysis gave us the same result. Thus, we manually IDed 23 error images, each taking approximately 10 minutes.

5.1.3. Feeding station 5

Feeding station 5 contained only 240 files featuring deer, with half the dataset as images. 33 images were selected with a 90.91 % matching success rate, and the software or the human observer could not identify three individuals.

5.1.4. Feeding station 10

Feeding Station 10 captured 1,848 videos featuring deer, from which 89 images were chosen. During the last analysis, IBEIS successfully identified 75 individuals with an overall success rate of 84.27%. However, ten unidentified images belonged to the same individual, Young Male born in the reserve. This individual could not be identified due to no image records. As a result, the matching success rate for the last analysis was 95.5 %, with only four images going unidentified.

5.2. IBEIS efficiency

IBEIS has improved its efficiency with each analysis, proving how important the training of the software is. We then decided to run a further analysis using data from feeding station 10, which had a previous matching success of 95.50 %. However, this time, this analysis was conducted separately, using only the initial ID database (one image of each side for every individual) to compare performance without the extensive ID database. IBEIS identified 50 out of 89 uploaded images with an overall matching success of 56.18 %. As in the previous analysis, ten images of Young Male born in the reserve were excluded from the analysis. The overall matching success rate throughout this study can be seen in Figure 5.

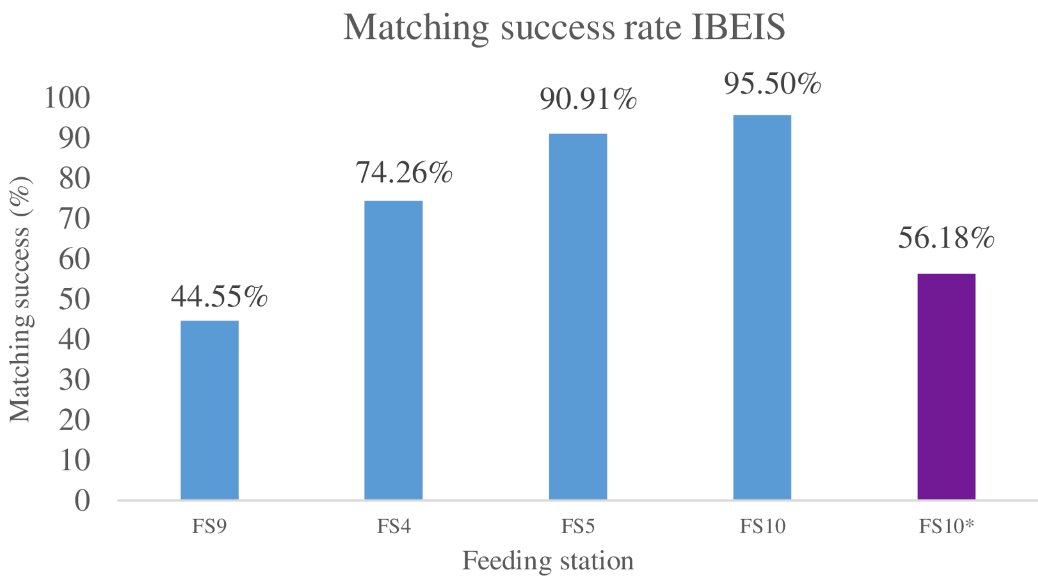

Figure 5. The overall matching success rate of IBEIS during this study. With each analysis performed, IBEIS increased its performance due to the expansion of the ID database. The last analysis (FS10*) was performed separately, in a new virtual window with only the initial ID database (2 images/deer) highlighting a reduction in matching rate.

5.3. Newly discovered individuals

In the course of our study, we identified six fawns/offspring (staying with the mother) at the designated feeding stations. We documented each newly discovered fawn for the Talarak Foundation by creating a fawn ID portfolio. The portfolio included pictures of each side of the fawn, the mother's name, the date, and the feeding station (Figure 6).

Figure 6. An example of an ID fawn portfolio that was provided to the Talarak Foundation. Images will be used in further analysis to track the new deer at the individual level.

Additionally, we identified three new males, all lacking ear tags, indicating their birth within the reserve. Their images were compared against the fawn database for potential matches, but none were found. Their images were added to the database and assigned temporary names such as Unknown Male 1, Unknown Male 3, and Young Male.

Moreover, we observed a male deer with ear tag TFI 133 recurrently visiting feeding stations 4, 5 and 10. However, no official records of a deer with tag TFI 133 being released into the reserve were found, indicating this deer was not properly recorded upon release. Consequently, we established a database of 40 images and added deer to the identification portfolio. We also addressed the absence of image records for a deer with the ear tag TFI 161 by creating an image database comprising 44 images and assigning the temporary name Unknown Male 2.

Despite our significant identification efforts, we were unable to identify five males (six images) and six females (22 images).

5.4. IBEIS best practices for Visayan spotted deer

5.4.1. Data organisation

We recommend capturing the entire screen when taking a screenshot from the video rather than just cropping the image of the deer itself. This is particularly important for camera trap studies, where important information like the date and time of the videos is displayed at the bottom. Despite some studies benefiting from cropped images (Zoppa 2024) to exclude background noise, we found that it was not beneficial in our study. Including the entire screen helps with better orientation within the data.

Furthermore, when selecting images for the analysis, it is essential that the spot pattern is recognisable to the human eye. Consequently, we advise against using extremely low-quality, blurry images. Even though IBEIS can recognise lower-quality images after proper training, the general rule should be that the human eye still recognises the spot pattern.

Lastly, we suggest dividing the data into two sections. During our study, each deer had two sets of photos labelled "L" and "R". This prevented pseudo replication and IBEIS from crushing, as a large amount of data running simultaneously often caused the IBEIS software to operate inefficiently, resulting in slow response. It is unknown whether this was due to operating in a virtual window or if it was an issue with IBEIS itself.

5.4.2. Camera trap videos vs images

Based on our experience, we recommend utilising camera trap videos over images for individual recognition. Although processing a large volume of videos is time-consuming, it was beneficial for our study in several ways. Firstly, it allowed us for a closer examination of individual spot patterns. Therefore, we were able to capture the spot pattern from the right angle to achieve good visibility and avoid vegetation obstruction. We found the 30-second videos to be the most effective length. Due to faulty cameras, we had to work with some videos that were only 5 seconds long. Even though these were more effective than images, longer videos provided an additional benefit: a valuable insight into the behavioural ecology of the species. Notably, a significant portion of the feeding station 5 data set consisted of images with many unsuitable for analysis, mainly due to restricted view caused by vegetation (Figure 7).

Figure 7. An example of images unsuitable for pattern recognition at feeding station 5 due to obstructed views. Cameras were set up in a picture mode and positioned further away from the feeding station, limiting individual identification.

Consequently, feeding station 5 had the least images selected for analysis. When cameras are set up for images only, there is a high chance the image is not taken at the right moment, resulting in a partial view of the animal. For instance, Negroes et al. (2012) experienced 10 % of camera trap photos of the jaguar consisting of tail only, making individual identification difficult and limited. Therefore, using videos over images provides more precise data and an overall larger data set suitable for individual recognition.

5.4.3. Building up ID database

IBEIS efficiency relies on a substantial ID database to train the software effectively. Therefore, it is essential to build the ID database to increase the matching success and reduce the need for human input in future analysis. Especially at the beginning of the study, we recommend reviewing videos that IBEIS successfully matched and taking further screenshots of deer at different positions and angles to add more real-life images to the database. This will not only enhance the overall matching success but will also increase the range of photos suitable for further analysis. Additionally, it is advised to include images taken in different weather conditions and at night to broaden the variety of real-life images in the database.

5.4.4. Identification of IBEIS unknown individuals

In the beginning, the IBEIS matching rate was low. Therefore, many individuals remained unidentified and classified as IBEISUNKNOWN by the software. To address unsuccessful matches, we suggest revisiting the videos around the targeted footage to gain more perspectives on the spot pattern. In our study, it often resulted in successful identification. Additionally, we propose paying closer attention to ear tags to clarify the individual's origin and confirm reserve-born individuals. While we acknowledge this step may not be relevant to wild studies, it was a crucial aspect of the identification of unknown individuals in the Bayawan Nature Reserve. Finally, sex played a crucial role in identification. Males were identified by the presence of antlers or the pedicle if antlers were shed or by the presence of external testicles. Notably, image evaluation of unidentified deer was the most time-consuming aspect of the process.

6. Discussion

6.1. IBEIS identification methods

In our study, we experimented with two different IBEIS identification methods to determine the best fit for our data. Initially, we used the Query vs Exemplars method, which involves comparing all images against the exemplars while allowing the user to select images to be used as ID exemplars. However, this method yielded poor results, likely due to insufficient base data for the IBEIS software to operate effectively. Nonetheless, it could be more suitable for further research once a robust ID database has been established. Therefore, for our research, we used Intra Occurrence analysis for all our tests, which involves running all query annotations against all species database annotations. Despite initially low matching scores, IBEIS performed overly better than in the previous analysis. The main advantage of this method was its effective grouping of not-identified but similar-looking individuals, making the subsequent identification less challenging. In our view, this saved time for the user, as even though IBEIS could not identify the individual, it grouped photos of the same individual together. Additionally, IBEIS provides the option of a single annotation method when the user can select individual images for analysis, and the software runs the analysis against ID exemplars. As this method is more suitable for smaller datasets, we only used it in our preliminary training with the software.

6.2. IBEIS results and performance

Many studies have considered IBEIS user-friendly (Raphanaud 2022; Zoppa 2024). However, our experience revealed a learning curve, particularly due to the absence of a comprehensive manual and limited studies. As of now there are no reported studies done on cervids using IBEIS. Nonetheless, with proper training, we found IBEIS relatively easy to operate. However, developing a detailed manual would greatly enhance its usability.

Initially, our help was needed to train the software effectively. In the beginning, IBEIS proposed many unknown matches with very low scoring, requiring significant human input to clarify each match, either True or False (Figure 8), like the results of

Raphanaud (2022), who also reported difficulty at the beginning. However, considering our limited baseline data, we did not anticipate IBEIS performing exceptionally well in the initial analysis. Furthermore, we noticed that males with the most prominent spot patterns were the most recognised by IBEIS. Among the 45 images correctly matched by IBEIS at FS09, 29 images belonged to three males (Jesse, Yaw and Danny). Although this is not a surprise, as these males' spot patterns are also easily recognisable by human observers, it provides certain limitations to the initial results.

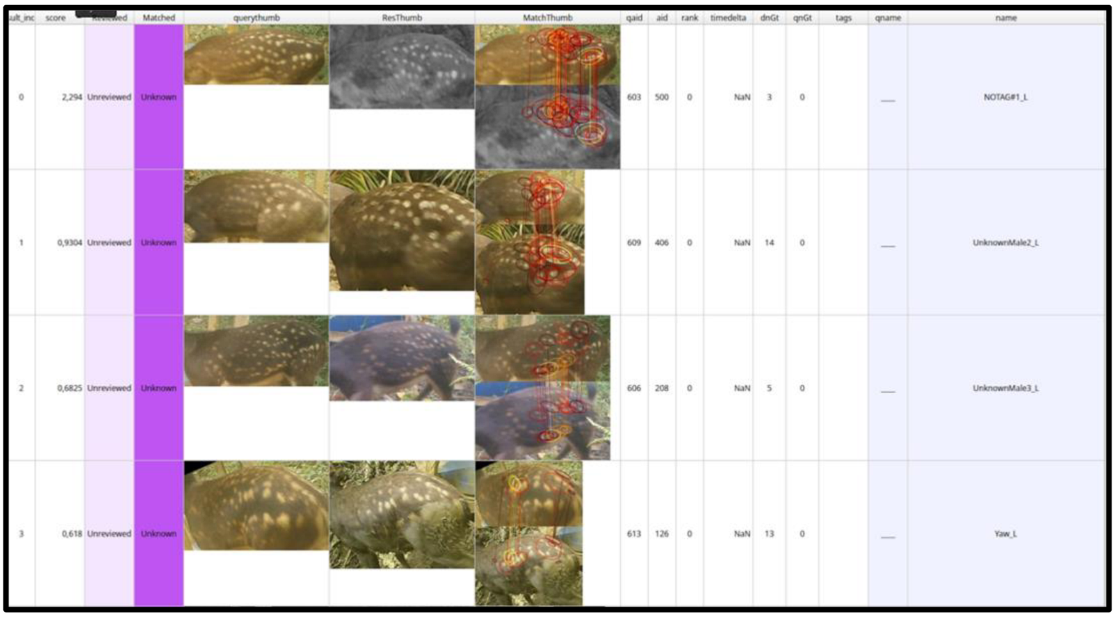

Figure 8. An example of initial IBEIS analysis proposing all matches as unknown. Human help was needed to confirm each match visually and to train the software effectively.

Throughout our analyses, IBEIS demonstrated consistent improvement in performance, resulting in an impressive overall matching success rate of 95.5 % upon establishing a substantial ID database. Even when dealing with individuals not fully perpendicular to the camera or those with less prominent spots, IBEIS effectively identified them. This contrasts with the findings of Ward et al. (2021), who noted challenges with HotSpotter in recognising individuals with faint spots, such as Beast, relying on human observers for identification. Our study, however, successfully identified Beast in 33 images, suggesting that the software may require additional training. Ward et al. (2021) only analysed 118 images, which may not have been sufficient for the software to operate as effectively.

The necessity for software training became more apparent in our recent experiment, where we introduced an additional virtual window and uploaded the initial

ID portfolio for reference. Despite achieving a 95.5 % success rate with images from feeding station 10, the software only recognised 56.18 % this time.

Furthermore, IBEIS is designed not to identify the background. When selecting the ROI, we focused solely on the area between the shoulder and the rump. In some cases, some background was included in the ROI when the animal was at an angle or bending, but IBEIS effectively focused on the spot pattern only. Raphanaud (2022) similarly highlighted IBEIS' ability to exclude the background. On a different note, we observed that when vegetation was between the shoulder and the ramp, IBEIS targeted the vegetation, resulting in false matches (Figure 9). It is, therefore, essential to regularly clear the vegetation in front of the camera to prevent this.

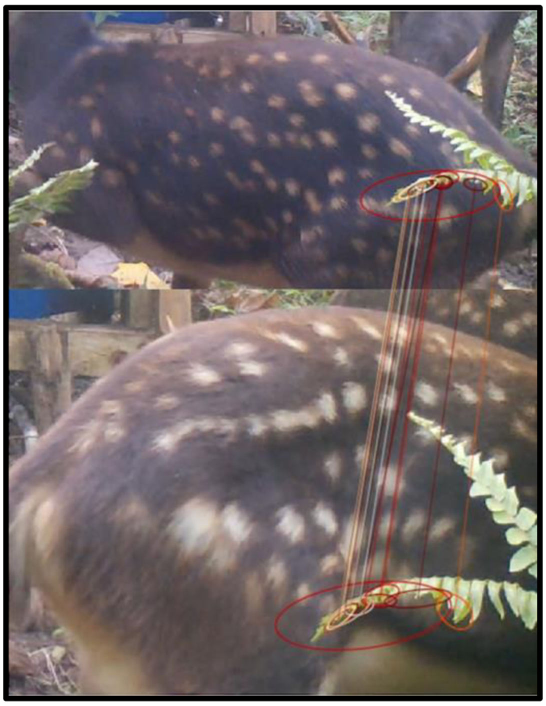

Figure 9. IBEIS targets vegetation instead of a given individual's spot pattern, resulting in false matches.

As previously stated, we did not find the match scoring highly helpful during our study. Zoppa (2024) and Raphanaud (2022) reported the scoring as beneficial during their studies, considering matching scores over 1 to be a positive match. However, despite the scoring being more reliable towards the middle of the analysis when the software had more reference images to work with, we occasionally received low scores for positive matches (Figure 10). Therefore, we could not simply rely on matching scores alone. Instead, we visually inspected each matching image.

Figure 10. An example of a low-scoring positive match that IBEIS detected as an unknown match. Human help was required to confirm a positive match.

Overall, we found IBEIS to be beneficial. Despite encountering initial difficulties with the virtual window and the software, IBEIS saved much time during image processing later in the analysis while establishing a permanent database for the deer population in the Bayawan Nature Reserve. While working in the virtual window was challenging and we recommend installing Linux, the virtual window enables other students working on the project to access the data.

6.3. Limitations of this study

The study encountered certain limitations. A significant drawback was observed in the poor-quality ID portfolio. Specifically, the photos in the initial ID portfolio were captured solely to record body condition and often were taken from a great distance, with many deer having fluffy fur in the images. This blended the spot patterns, posing a challenge for both the human observer and the algorithm to differentiate. Figure 11 illustrates the reference images of Leander, taken from a considerable distance, which subsequently made it difficult for the software to identify the spot pattern. Consequently, only a human observer initially recognised this individual due to its GPS collar. In the context of this study, having more controlled pictures of each deer, particularly different angles of spot patterns and more detailed photographs, would prove highly advantageous for individual recognition. This is consistent with the findings of Nipko et al. (2020), who stated that a larger reference database consisting of images of different qualities can greatly improve the overall matching success in pattern identification. We can confirm that when we started building our database and starting to include reference images of different qualities, such as night images or images at different angles, we observed significant improvement in matching success.

Figure 11. ID photo of Leander. The photos were taken from a great distance, creating a blurry image of a spot pattern when zoomed in, making subsequent identifications difficult.

Additionally, we observed a predominance of male visits to the feeding stations, resulting in skewed data. Females were rarely seen, and when they did appear, they approached the feeding station very carefully, often revealing only their heads to the observers and not staying for long. For instance, IBEIS detected only one female at FS09, while at FS04, four females were recognised. In the overall study, eight females out of 12 released were successfully recognised, although many were captured only once while the rest remained unidentified due to poor baseline data, making it difficult for both software and human observers to match the spot pattern.

Lastly, we encountered some challenges in accurately identifying patterns at nighttime, resulting in a lower matching success rate. The Visayan spotted deer is considered a nocturnal species (Ali et al. 2021), so a large portion of the camera data captured is during nighttime. Surprisingly, IBEIS performed well in identifying deer in night images, especially after we added more photos of deer at night to our identification database. However, this success was limited to deer in close proximity to the camera and to those with very distinct spot patterns (Figure 12). When the deer were further away, many of the images were of poor quality and often blurred. Similarly, Ward et al. (2021) also noted a decline in HotSpotter's ability to match deer in night images when the deer were located more than 2 meters away from the camera. This is probably due to the use of infrared light, which is known to produce lower-quality images but is considered less intrusive and disruptive than white flash (Henrich et al. 2020). Despite occasional instances of deer displaying attention to and investigating the camera traps, it appears that infrared light did not significantly disturb the deer. To capture high-quality images of spot patterns and thus have more precise data, it would be beneficial to conduct assessments on the efficacy of white-flash camera traps, particularly during nighttime and their potential impact on deer. Similarly, we observed a decline in image quality and, therefore, matching success when weather conditions were not optimal, such as heavy rain or fog. Despite being unable to control this in tropical areas, having a robust ID database with true reference images across different weather conditions may help increase the matching success (Nipko et al. 2020).

Figure 12. Examples of night images of an unidentified female (left) and male, Jessie (right), at FS04 showing the differences in spot pattern visibility at night. Individuals with faint spot patterns were difficult for the software and human observers to identify at night.

6.4. Recommendations for future research

Our study was conducted in semi-wild conditions, with the use of camera traps near feeding stations. Despite this initially not being intended for individual recognition, Ward et al. (2021) achieved significant results during a pilot study studying the spot pattern of released males in the Bayawan Nature Reserve. However, for future studies, it would be beneficial to consider using two cameras at each feeding station to ensure the optimal visibility of spot patterns on both sides of the animals, as Nipko et al. (2020) suggested. Another suggestion from Ward et al. (2021) is to use a single camera but position it to provide a full perpendicular view of the animal's flank. While achieving substantial results in Bayawan Nature Reserve may be possible with one well-positioned camera, studies in the wild would benefit from paired cameras facing each other across trails (Negroes et al. 2012; Rovero et al. 2013; Nipko et al. 2020). For instance, Negroes et al. (2012) compared the effectiveness and data precision using one and two cameras per station while studying jaguar densities in Amazon. While one camera could identify six individuals, two cameras combined could identify ten individuals. More precise data are especially important for rare and cryptic species occurring at low densities, as in our case, Visayan spotted deer, to ensure proper population assessment for effective conservation management (Negroes et al. 2013). Notably, both approaches would not only provide a higher detection probability but also increase the species ID portfolio and subsequently reduce the need for human interference in future analysis.

Furthermore, our analysis revealed that many of the videos we examined only showed partial views of the animals, such as just the head or part of the side. This presented a limitation in the number of videos suitable for our analysis. Despite our research being in relatively controlled conditions with animals typically stationary at feeding stations, we anticipate that most animals would be in motion in the wild, where cameras are positioned on trails, resulting in partial views or blurry images. To address this challenge, Nipko et al. (2020) proposed the need for the development of new reference databases focused on different parts of animals. Nowadays, identification software can work with species with no distinct patterns and recognise individuals based on facial recognition (Clapham et al. 2020) or natural markings, including scars or cuts (Grotta-Neto et al. 2020). While this solution would offer research with more precise data, it would also require additional time for processing.

Despite IBEIS working efficiently towards the end of our study, a significant issue arose as the software exhibited instability, frequently crashing when handling a growing volume of uploaded photos. For instance, during our second analysis at feeding station 4, IBEIS excluded 23 images. Consequently, manual identification of each image became necessary, a process that proved to be time-consuming. Similarly, in the study conducted by Zoppa (2024), challenges with the software were also encountered, as several functions did not operate as expected during the project. While we are not certain whether this is due to working in a virtual window or whether it is the software itself, we recommend installing Linux on the computer rather than working in a virtual window. This would decrease the time it takes for the images to be uploaded into a virtual window as well as overall processing time.

7. Conclusions

Our results found that the Visayan spotted deer's unique lateral spot patterns are good matching points for individual identification. Once effectively trained, IBEIS demonstrated exceptional performance, even when dealing with images taken from different angles, showcasing its robust matching algorithm.

Our pilot study indicated the potential for practical application in the assessment of the remaining viable populations of Visayan spotted deer on the islands of Negros and Panay, where knowledge of population sizes is limited. In light of these findings, individual identification using machine learning emerges as a crucial tool in the conservation efforts for this poorly known species.

References

Ali NANG, Abdullah ML, Nor SAM, Pau TM, Kulaimi NAM, Naim DM. 2021. A review of the genus Rusa in the indo-malayan archipelago and conservation efforts. Saudi Journal of Biological Sciences **28**:10-26.

Awasthi B, Chen J, McConkey KR. 2024. Fruiting trees provide fruit and insect resources for four tropical deer species. Ecosphere (e4889) DOI: 10.1002/ecs2.4889.

Berger-Wolf T, Crall J, Holberg J, Parham J, Stewart C, Mackey BL, Kahumbu P, Rubenstein D. 2016. The great grevy's rally: The need, methods, findings, implications and next steps. Grevy's Zebra Trust, Nairobi Kenya.

Biodiversity Management Bureau-Department of Environment and Natural Resources. 2020. Philippine RED List of threatened wild fauna. Biodiversity Conservation Society of the Philippines.

Bolger DT, Morrison TA, Vance B, Lee D, Farid H. 2012. A computer-assisted system for photographic mark-recapture analysis. Methods in Ecology and Evolution **3**:813-822.

Brook SM. 2016. *Rusa alfredi*. The IUCN Red List of Threatened Species. Available from https://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T4273A22168782.en (accessed January 2024).

Calmanovici B, Waayers D, Reisser J, Clifton J, Proietti M. 2018. I3S Pattern as a mark-recapture tool to identify captured and free-swimming sea turtles: an assessment. Marine Ecology Progress Series **589**:263-268.

Caravaggi A, Banks PB, Burton AC, Finlay CM, Haswell PM, Hayward MW, Rowcliffe MJ, Wood MD. 2017. A review of camera trapping for conservation behaviour research. Remote Sensing in Ecology and Conservation **3**:109-122.

Ceacero F, Landete-Castillejos T, Bartošová J, García AJ, Bartoš L, Komárková M, Gallego L. 2014. Habituating to handling: factors affecting preorbital gland opening in red deer calves. Journal of Animal Science **92**:4130-4136.

Cheema GS, Anand S. 2017. Automatic detection and recognition of individuals in patterned species. Pages 27-38 in Altun Y, Das K, editors. Machine Learning and

Knowledge Discovery in Databases: European Conference. Springer International Publishing, Skopje, Macedonia.

Clapham M, Miller E, Nguyen M, Darimont CT. 2020. Automated facial recognition for wildlife that lack unique markings: A deep learning approach for brown bears. Ecology and evolution **10**:12883-12892.

Crall JP, Stewart CV, Berger-Wolf TY, Rubenstein DI, Sundaresan SR. 2013. HotSpotter-patterned species instance recognition. Proceedings of IEEE Workshop on Applications of Computer Vision:230–237.

Crall JP, Parham J, Stewart CV. 2013. HotSpotter user guide. Department of Computer Science, Renssealer Polytechnic Institute.

Corlett RT. 2007. The impact of hunting on the mammalian fauna of tropical Asian forests. Biotropica **39**:292-303.

Cox R. 1987. The Philippine spotted deer and the Visayan warty pig. Oryx **21:**37-42.

D'Cruze N, Sawyer J, De Vere R, Benares J, Farrance D, Megson S, Can OE. 2013. First images of the Visayan spotted deer and Visayan warty pig. Oryx **47:**16-17.

de Oliveira ML, de Faria Peres PH, Gatti A, Morales-Donoso JA, Mangini PR, Duarte JMB. 2020. Faecal DNA and camera traps detect an evolutionarily significant unit of the Amazonian brocket deer in the Brazilian Atlantic Forest. European journal of wildlife research **66**:28.

Diesmos AC. 2007. Conservation of Herpetofaunal Communities in Fragmented Lowland Rainforests in the Phillippines. National Museum of the Philippines, Philippines.

EAZA. 2024. Visayan spotted deer. Available from https://www.eaza.net/conservation/programmes/eep-pages/visayan-spotted-deer-eep/. (accessed June 2024).

Fahrig L. 2003. Effects of habitat fragmentation on biodiversity. Annual review of ecology, evolution, and systematics **34:**487-515

Galang R. 2004. A critical review of wildlife conservation in the Philippines. Philippine Spotted Deer Conservation Foundation, Melbourne, Australia.

Gambín P, Ceacero F, Garcia AJ Landete-Castillejos T, Gallego L. 2017. Patterns of antler consumption reveal osteophagia as a natural mineral resource in key periods for red deer (*Cervus elaphus*). European Journal of Wildlife Research **63**:1-7.

Gray TNE. 2018. Monitoring tropical forest ungulates using camera-trap data. Journal of Zoology **305**:173-179.

Grotta-Neto F, Peres PH, Piovezan U, Passos FC, Duarte JM. 2020. Camera trap feasibility for ecological studies of elusive forest deer. Wildlife Society Bulletin **44**:640-647.

Grove CP. 2007. Family Cervidae. Pages 249-256 in Prothero DR, Foss SE, editors. The evolution of Artiodactyls. The Johns Hopkins University Press, Baltimore.

Hamann A. 2002. The North Negros Forest Reserve: a biodiversity hotspot at risk. Silliman Journal **43:**142-151.

Hanley TA. 1996. Potential role of deer (Cervidae) as ecological indicators of forest management. Forest Ecology and Management **88**:199-204.

Haxton T. 2021. Use of unique brook trout spot patterns over a short duration for a mark-recapture study. Environmental Biology of Fishes **104**:1391-1399.

Hedges S, Duckworth JW, Timmins R, Semiadi G, Dryden G. 2015. *Rusa timorensis*. The IUCN Red List of Threatened Species. Available from https://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T41789A22156866.en. (accessed November 2023).

Henrich M, Niederlechner S, Kröschel M, Thoma S, Dormann CF, Hartig F, Heurich M. 2020. The influence of camera trap flash type on the behavioural reactions and trapping rates of red deer and roe deer. Remote Sensing in Ecology and Conservation **6**:399-410.

Ismaili B, Diouri M, Ouijja A. 2018. Getting the dietary knowledge to restore a missing species: seasonal diet of Atlas deer *Cervus elaphus barbarus* in Tazekka National Park, Morocco. Wildlife Biology **2018**:1-8.

Koivuniemi M, Auttila M, Niemi M, Levänen R, Kunnasranta M. 2016. Photo-ID as a tool for studying and monitoring the endangered Saimaa ringed seal. Endanger Species Research **30**:29-36.

Lee DE, Lohay GG, Cavener DR, Bond ML. 2022. Using spot pattern recognition to examine population biology, evolutionary ecology, sociality, and movements of giraffes. A 70-year retrospective. Mammalian Biology **102**:1055-1071.

Lucas RW, Salguero-Gómez R, Cobb DB, Waring BG, Anderson F, McShea WJ, Casper BB. 2013. White-tailed deer (*Odocoileus virginianus*) positively affect the growth of mature northern red oak (*Quercus rubra*) trees. Ecosphere **7**:1-15.

Maala CP. 2001. Endangered Philippine wildlife species with special reference to the Philippine eagle (*Pithecophaga jefferyi*) and tamaraw (*Bubalus mindorensis*). Journal of International Development and Cooperation **8:**1-17.

MacKinnon JR, Ong P, Gonzales J. 2015. *Rusa marianna*. The IUCN Red List of Threatened Species. Available from https://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T4274A22168586.en. (accessed November 2023).

Negroes N, Sollmann R, Fonseca C, Jacomo AT, Revilla E, Silveira L. 2012. One or two cameras per station? Monitoring jaguars and other mammals in the Amazon. Ecological research **27:**639-648.

Nichols JD, O'Connell AF, Karanth KU. 2011. Camera traps in animal ecology. Springer, Japan.

Nipko RB, Holcombe BE, Kely MJ. 2020. Identifying individual jaguars and ocelots via pattern-recognition software: comparing HotSpotter and Wild-ID. Wildlife Society Bulletin **44**:424-433.

Oliver WL, Cox CR, Dolar LL. 1991. The Philippine spotted deer conservation project. Oryx **25**:199-205.

Ortiz AMD, Torres JN. 2020. Assessing the impacts of agriculture and its trade on Philippine biodiversity. Land **9**:403.

PAGASA. 2024. Climate of the Philippines. Available from https://www.pagasa.dost.gov.ph/information/climate-philippines (accessed January 2024).

Posa MRC, Diesmos AC, Sodhi NS, Brooks TM. 2008. Hope for threatened biodiversity: lessons from the Philippines. BioScience **58:**231-240.

Rahman DA, Gonzalez G, Aulagnier S. 2016. Benefit of camera trapping for surveying the critically endangered Bawean deer *Axis kuhlii* (Temminck, 1836). Tropical Zoology **29**:155-172.

Rahman DA, Gonzalez G, Haryono M, Muhtarom A, Firdaus AY, Aulagnier S. 2017. Factors affecting seasonal habitat use, and predicted range of two tropical deer in Indonesian rainforest. Acta Oecologica **82**:41-51.

Raphanaud P. 2022. Investigating the use of AI-based image identification to monitor wild cryptic lizards: The shore skink, *Oligosoma smithi*, as a case study. [MSc. Thesis]. Czech University of Life Sciences Prague, Prague.

Rode-Margono J et al. 2021. Western Visayas Conservation Workshop: Final Report. IUCN SSC Conservation Planning Specialist Group, Apple Valley, MN.

Rovero F, Zimmermann F, Berzi D, Meek P. 2013. " Which camera trap type and how many do I need?" A review of camera features and study designs for a range of wildlife research applications. Hystrix **24**:148-156.

Santiago CHD. 2024. DOST-PCAARRD and Silliman University kicks off project on conservation of the endangered Philippine spotted deer. S&T Media Services, Philippines. Available from https://www.pcaarrd.dost.gov.ph/index.php/quick-information-dispatch-qid-articles/dost-pcaarrd-and-silliman-university-kicks-off-project-on-conservation-of-the-endangered-philippine-spotted-deer#:~:text=To%20conserve%20the%20Philippine%20spotted,%2C%20launched%20the%20project%2C%20%E2%80%9CEnhancing (accessed July 2024).

Talarak Foundation. 2020. Bayawan Nature Reserve. Available from https://www.talarak.org/bayawan-nature-reserve (accessed January 2024).

Tanalgo KC. 2017. Wildlife hunting by indigenous people in a Philippine protected area: a perspective from Mt. Apo National Park, Mindanao Island. Journal of Threatened Taxa **9**:10307-10313.

Timmins R, Kawanishi K, Giman B, Lynam A, Chan B, Steinmetz R, Sagar Baral H, Samba Kumar N. 2015. *Rusa unicolor*. The IUCN Red List of Threatened Species.

Available from https://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T41790A22156247.en. (accessed November 2023).

Trolliet F, Vermeulen C, Huynen MC, Hambuckers A. 2014. Use of camera traps for wildlife studies: a review. Biotechnologie, Agronomie, Société et Environment **18**:446-454.

Turner IM, Corlett RT. 1996. The conservation value of small, isolated fragments of lowland tropical rain forest. Trends in ecology & evolution **11:**330-333.

Villegas JP, Ibañez JC, Cabrido CKT. 2022. Abundance and distribution of the Philippine Brown deer (*Rusa marianna desmarest*, 1822) in the obu manuvu ancestral domain, Mindanao island, Philippines. Acta Biologica Universitatis Daugavpiliensis **22:**67-89.

Ward M, Ward-Montano Y, Magbanua J. 2021. Individual identification through lateral spot patterns in the Visayan Spotted deer, *Rusa alfredi*. DSG Newsletter **32**:3-13.

Ward M, Tan E, Magbanua J. 2024. Confirmation of a population of the Visayan Spotted Deer *Rusa alfredi* in a forest fragment of the Southwest Negros KBA, Negros, Philippines. DSG Newsletter **35**:12-18.

Weatherspark. 2024. Climate and Average Weather Year Round in Bayawan Philippines. Available from https://weatherspark.com/y/137982/Average-Weather-in-Bayawan-Philippines-Year-Round (accessed January 2024).

Wiig Ø, da Silva Teixeira K, Sena L, Santos de Oliveira HC, Mendes-Oliveira AC. 2023. Identifying individual jaguars from camera-trap images using the HotSpotter program. Mammalia **87**:602-605.

Zoppa S. 2024. Using Community Science to Monitor Eastern Box Turtles and Engage Public in Conservation [MSc. Thesis]. Eastern Illinois University, Illinois.