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Estimating mammal community biodiversity in Tonda Wildlife Management Area

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Abstract

Papua New Guinea is known for high biological diversity. Yet quantifying biodiversity values remains challenging considering tropical ecosystem complexity and the appropriate diversity index. As wildlife camera trapping assists in biodiversity estimates, the following proposal seeks to utilize camera traps for one year inside of Papua New Guinea's Tonda Wildlife Management Area to estimate mammal community diversity in the hopes of filling trophic knowledge gaps, informing conservation policy, discovering one or more new mammal species, and measuring differences in three commonly-used diversity indices—the Shannon diversity index, Simpson's diversity index, and the relative diversity index—to assess which is the most optimal.

Introduction

Calculating the floral and faunal biodiversity of ecosystems is necessary for conservation biologists and conservation biogeographers in assessing ecosystem conditions while contributing to wildlife management and environmental policies (Arroyo-Arce et al., 2017; Marcus Rowecliff, 2017). Considering the correlation between increasing biodiversity and a closer geographic proximity to the equator, researchers often perform more inclusive biodiversity value estimates related to ecological guilds, vertebrate and/or invertebrate classes, et cetera to better quantitatively assess flora and fauna within complex equatorial ecosystems.

Papua New Guinea (PNG) is an island nation in the South Pacific known for its large tropical forests and wetlands with high species endemism, many of which have yet to be scientifically catalogued (Alamgir et al., 2019). It is characterized by an ecoregion mosaic of lowland rainforests, tropical and subtropical moist broadleaf forests, and tropical savannahs and wetlands (Wikramanayake, Dinerstein & Louck, 2002). Together with neighboring West Papua, and comprising New Guinea, five percent of wilderness areas are still considered virgin tropical terrestrial ecosystems with high biodiversity markers (Mittermeier et al., 1998).

Focusing on mammals and endemism, Lavery (2015) observes that many mammals within the Melanesian subregion of Oceania remain relatively unknown, resulting in limited taxonomic descriptions and mammalian faunal record deficiencies. Regarding PNG, the International Union for Conservation of Nature (2020) notes a taxonomic mammalian class of 299 documented species. Yet as recently as 2014, a number of mammals previously unknown to science were discovered, including *Docopsulus* wallaby, which was discovered with camera traps (Milman, 2014).

Alongside camera traps as a viable alternative for wildlife surveying in tropical environments, there exist diversity indices that have the capacity to quantitatively estimate species diversity. Examples include the Shannon diversity index, the Simpson diversity index, and the relative abundance index (RAI). Each indice comes with its own strengths and weaknesses.

According to Yeom and Kim (2011), the Shannon index is quite effective for estimating species richness (number of different species in a community), yet not as strong when estimating species evenness (number closeness for all species in a community). Moreover, applying the Shannon index results in values that can be difficult to interpret, primarily in inferring the role of species in their community and inferring species biogeographical patterns (Barrantes & Sandoval, 2008).

While Simpson's index is also used quite commonly by ecologists, and while it does take into account species richness and species abundance, it has been shown to place more emphasis on species that are more abundant in a given sample, which runs the risk of ignoring rare and/or elusive species (Simpson diversity index, n.d.).

Finally, RAI has the advantage of quantifying a number of different-sized wildlife species, not to mention being less complex than other diversity index methods of estimation. RAI is also useful if and when alternative options prove difficult and/or too costly. However, RAI can be controversial since it doesn't necessarily account for bias resulting from imperfect methods of detection such as camera trapping (Palmer et al., 2018).

Richards (2017) notes that camera traps for wildlife surveying and estimating biodiversity is a cost effective strategy for biological practitioners interested in long-term monitoring and censusing programs. Moreover, camera trapping methodologies are thought to be effective for elusive and rare species sampling, they provide researchers with robust quantitative data sufficient for statistical analyses, and are considered environmentally friendly (Richards, 2017).

Rovero et al. (2014) add that camera trap data enables a better understanding of species composition and richness in addition to documenting species distribution changes and their associations with particular habitats. This is of particular importance for tropical ecology assessments of mammals living in tropical habitats that represent the functional diversity of the greater biome (Rovero et al., 2014).

Looking at PNG and insufficient or lack of published data, honing in on one specific area within PNG might prove invaluable in better understanding community mammal diversity as an important contribution to conservation biology measures, additional field studies, and updated environmental policy.

PNG's Tonda Wildlife Management Area (WMA), located in the Western Province, is the country's largest protected area and a designated tropical Ramsar wetland site, existing as an integral part of the greater Trans-fly complex ecoregion that is comparable with African and South American tropical wetland ecosystems (UNESCO World Heritage Centre, n.d.). Yet unlike such tropical wetlands, there is not a substantial amount of literature concerning species diversity in the Tonda WMA. Likewise, it is difficult to determine which of the three above-mentioned diversity indices would be best in assessing community mammal diversity within the Tonda WMA, let alone the Melanesian subregion. Finally, there exists the possibility of one or more mammal species existing within Tonda WMA that have never before been documented.

Research Questions

This proposed observational study exists to answer two fundamental questions that could be useful for future field surveys in tropical ecosystems and informing conservation policy.

1) First, and based on a comprehensive understanding of Simpson's diversity index, the Shannon diversity index, and the relative diversity index, which of the three diversity indices will work best to quantitatively estimate mammal biodiversity in the Tonda WMA while using camera traps as a wildlife survey technique?
2) Second, given that this proposal seeks to survey mammals in Tonda WMA using state of the art camera traps and modern camera trapping methods, will the research team be able to find new mammal species previously unknown to science in addition to helping better understand community mammal composition in the WMA?

Hypotheses

This grant proposal is threefold. It seeks to quantify community mammal biodiversity at three designated sites within the Tonda WMA using modern remote sensing camera trap equipment, while also assessing the effectiveness of the three diversity indices previously mentioned. Finally, it is not out of the question that new species may be discovered during this proposed wildlife survey, which is critical for informing conservation policy in PNG. Given this, the following predictions have been suggested:

1) Based on a comprehensive understanding of the three aforementioned diversity indices, it is predicted that the relative abundance index will be the most optimal diversity index for assessing community mammal biodiversity in PNG's Tonda WMA.
2) It is also predicted that, in addition to mammal species abundance and richness estimates, it will be likely that this observational study in conjunction with state of the art camera traps will reveal at least one new mammal species previously unknown to science.

Literature review

When assessing the biodiversity of a tropical environment, and when seeking out the possibility of identifying new species that have yet to be scientifically catalogued, camera trapping has been shown to provide researchers with the revelation of new species and a wealth of insight regarding the abundance and richness of distinct biological communities. Further, selecting an appropriate diversity index is concomitant with wildlife surveying methods, including camera trapping. As mentioned in the introduction, three of these indices include the Shannon index, the Simpson index, and the relative abundance index, the latter of which is often used in conjunction with camera trapping.

Taking a look at the tropical region of Papua New Guinea (PNG), there are a number of unpublished, unverified reports that attempt to quantify or at the very least describe some mammal species found in the Tonda Wildlife Management Area (WMA). For example, Palmer (2017) writes in a New Guinea linguistic guidebook that mammal taxa include the bandicoot and wallaby. An antiquated Ramsar report for the Tonda WMA (1993) states that there are upwards of 50 mammal species thought to exist, including the bronze quoll (*Dasyurus spartacus*), the chestnut dunnart (*Sminthopsis archeri*), the false water rat (*Xeromys myoides*), and the spectacled hare-wallaby (*Lagorchestes conspicillatus*). This report, however, is no longer available to access, and the current Ramsar site only states that Tonda WMA is an important tropical wetland for around 250 species of migratory and resident waterbirds (Ramsar, 1993).

Further research led to the discovery of a study by Richards (2017), whose researchers used camera trapping to quantify the biodiversity in what has been referred to as the Upstream Project Area—earmarked for the Papua New Guinea Liquefied Natural Gas Project by ExxonMobil—in the hopes of developing a biodiversity strategy that would endure oil and gas exploration and exploitation. The observational experiment utilized 21 camera traps over a five to nine day period as event rates for statistical analysis to produce a RAI to map out mammal and bird diversity (Richards, 2017). After data was counted based on image events, 21 elusive and rare mammal species were successfully quantified. Such findings clearly underscore the importance of RAI as supplemental to camera trapping to quantitatively estimate species biodiversity.

Richards et al. (2018) performed a similar study as two separate transects near the same area designated for oil and gas exploration; both were termed biodiversity assessment areas. The goal was to to quantitatively assess the biodiversity of mammals, frogs, and avifauna. The difference, however, was that camera trapping was used as a secondary method outside of the two transect areas. (Primary surveying techniques were mist-netting and quadrat counting, with results producing very high taxa biodiversity.) Camera trapping specifically revealed mammal species never documented nor known within the scientific community before (Richards et al., 2018). The study not only revealed the importance of weighing different methodological options while assessing biodiversity, but the emphasis itself was also on the discovery of new species, which highlights the effectiveness of camera trapping as a wildlife surveying technique.

Wearn and Glover-Kapfer (2019) write an argumentative essay article in favor of camera traps, citing a number of recorded qualitative and quantitative data analysis studies on camera tramp effectiveness against 22 alternative methods, finding that the majority of studies recommend camera traps in general, and that camera traps were 39 percent more effective when assessing quantitative data. This was especially true when estimating a larger number of species and for detecting species, making them (digital in particular) the preferable method for biodiversity surveys.

Turning to diversity indices, Hedwig et al. (2018) make a compelling case for RAI to use in conjunction with camera traps for biodiversity assessments. The Hedwig et al. (2018) study specifically used camera traps in an effort to find out whether or not ecological gradients influenced the occurrence of forest mammal communities in Gabon's Batéké Plateau National Park of West Africa. Researchers predicted that there would be a decrease in species richness, abundance, and occupancy as distance increased from the Gabonese rainforest (Hedwig et al., 2018). After 6000 images in slightly less than 6000 days, 31 mammal species were discovered, including a lone male lion (*Panthera leo*) which was thought to have been locally extirpated in Gabon. What is most interesting, however, is that the use of RAI helped refute their hypothesis, showing that species composition of the mammal community did not change along an ecological gradient, with the exception of a slight decrease in some species abundance (Hedwig et al., 2018).

Lastly, Palmer et al. (2018) argue that RAIs provide an exceptional alternative to more common estimation methods, particularly when abundance is costly and performed in challenging environments. Yet they are not afraid to acknowledge the possibility of bias due to lack of image clarity. By comparing RAI data obtained for surveying ten herbivorous mammals in Africa with aerial survey data, they found that the RAI method was equally as strong as more traditional mathematical estimates, and that they were particularly reliable for nonmigratory species dwelling in open environments with high daily movement rates. This suggests that RAI holds significant promises for monitoring the relative abundances of herbivorous mammals.

Materials and Methods

The first part of this observational study will involve camera traps installed at three separate site locations within natural contiguous wetlands of the Tonda WMA, ensuring some level of abiotic continuity, though certain environmental gradients such as an ecotone are assumed. This will be performed in partnership as a cooperative agreement with Papua New Guinea's Conservation and Environment Protection Authority (CEPA), the governmental body charged with ensuring that resources are being managed with the goal of sustaining environmental quality and promoting human well-being (Papua New Guinea Conservation & Environment Protection Authority, n.d.). All findings will be used to promote conservation policy in PNG that upholds the charge issued and carried out by CEPA.

The camera traps will record images during two temporal intervals: the rainy season (November to March) and the dry season, (July to October) (Roggeri, 2013). Setup will occur between April and June.

Camera traps will be placed near the ground and some will be modified to take pictures of arboreal mammal species, such as bats. Placement in trees will require climbing, and two members of CEPA will be commissioned to assist in placing the traps.

Grids will be set up at the three designated sample sites, each measuring 75 km2. The first will use the northern boundary as a baseline reference (Bruce et al., 2018), with cameras set over an average distance of 8.5 km apart from one another. The second will use the southern boundary as a baseline reference, with cameras set over an average distance of 8.5 km apart. The third will be designated near the middle of the WMA, with GPS coordinates used to mark a baseline reference. Cameras here will be set in a grid over an average distance of 8.5 km apart.

There are a total of 45 camera traps, 15 at each site. Camera traps will be Bushnell trail cameras. To manage image metadata, the team will utilize the free *Exiv2* software (Huggel, 2012), then draw on local expertise to identify any mammals that have never before been observed. Data extraction will take place using Aardwolf software, which is compatible with Windows, Mac, and Linux operating systems (Aardwolf, n.d.; Young, Rode-Margono, and Amin, 2018).

Camera traps operate via an infrared detector, which responds when something hotter or colder than what is in the background moves within a detection zone (Apps & McNutt, 2018). At night, camera traps will illuminate a moving subject with infrared lights (Apps & McNutt, 2018). This is preferable to flash, which is considered invasive.

The second part of the study will occur after data processing. Researchers will estimate species richness and species abundance using three indices, with RAI being the most commonly used for wildlife camera trapping surveys (Jenks et al., 2011).

The Shannon index assumes random sampling of individuals in a large, independent population, and that all species in the sample are represented (Shannon & Weaver, 1998). Simpson's diversity index is defined as a diversity measure that takes the number of species present and relative abundance of each species present into account (Barcelona Field Studies Centre, n.d.). As evenness and richness increases, so diversity is shown to increase, with n equalling the total number of organisms for a particular species (Barcelona Field Studies Centre, n.d.).

Simpson and Shannon indices are similarly calculated as follows:

1) **Shannon index** - p is proportion (n/N) of individuals of one particular species found (n) divided by total number of individuals found (N), Σ is the sum of the calculations, and s is the number of species.

$$\text{Shannon Index (H)} = -\sum_{i=1}^{s} p_i \ln p_i$$

Above equation courtesy of the University of Florida.

2) **Simpson's index** - p is proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is still the sum of the calculations, and s is the number of species (University of Florida, 2020).

$$\text{Simpson Index (D)} = \frac{1}{\sum_{i=1}^{s} p_i^2}$$

Above equation courtesy of the University of Florida.

While the two formulas are similar, the difference between these two indices is that the Shannon diversity index will assume all mammal species are represented in the sample and are sampled randomly (University of Florida, 2020). Simpson's index, meanwhile, is a dominance index since it gives more weight to common and/or dominant species, meaning that few rare species defined by few representatives will not affect diversity (University of Florida, 2020).

These two indices will be calculated using a free statistical software package called *vegan* under R programming language (R Project, n.d.; Bruce et al., 2018; Vegan: community ecology package, 2019). They will then be measured against the relative abundance index, which is observed in the context of camera trapping as the ability to indicate a relative species abundance by assuming that photo detection rates are similar to that of animal abundance (Jenks et al., 2011). This will be calculated by the total number of individual species divided by the total number of species for each population (Yokoo, 2018).

Time – Table

Month/Year	Milestone
April/2021	Field expedition/Coordinate with CEPA/Camera traps purchased. Grids plotted/Camera traps set for site one
May/2021	Coordinate with CEPA/Camera traps set for site two
June/2021	Coordinate with CEPA/Camera traps set for site three
July/2021	Images captured during dry season
August/2021	Images captured during dry season
September/2021	Images captured during dry season
October/2021	Images captured during dry season
November/2021	Images captured during rainy season
December/2021	Images captured during rainy season
January/2022	Images captured during rainy season
February/2022	Images captured during rainy season
March/2022	Images captured during rainy season
April/2022	Final field expedition/Cameras and images collected/Return trip
May/2022	Final field expedition/Cameras and images collected

June/2022	Data extraction and sharing new information with CEPA
July/2022	Diversity index comparison/Final report written

Significance/Recommendations

Given the above mentioned challenges, and given the general lack of available biodata on mammalian fauna in the Melanesian subregion of Oceania, it is justifiable to perform an updated community mammal survey with a focus on PNG's largest protected area for the purposes of informing conservation biology measures, updating potentially outdated wildlife conservation policies, and understanding how mammal taxa obtained from different sites within the Tonda WMA fit into trophic levels and the greater food web when analyzing them in intraspecific and interspecific capacities along with other mammal and non-mammalian species. To reiterate, this includes the possibility of discovering new mammal species never before known to science.

Likewise, and for the purposes of cost efficiency for such an important endeavor given these assumed constraints, it is important to determine and ultimately utilize the most effective method of quantitatively estimating community mammal biodiversity within Tonda WMA. This is important since an initial mammal survey should be followed up by additional surveys to verify or challenge the validity of initial findings and see how communities and populations change within a temporal context. Given this, it is believed that the relative abundance index will pair well with camera trap surveillance.

Recall that cost often limits the scope of any scientific undertaking, which is also important to consider when deciding on which of a number of survey options and statistical analysis mechanisms would work best in an explicit, real-world scenario. While this cannot possibly be 100 percent predictable given environmental stochasticity and additional factors such as time, space, and season, existing knowledge of tropical ecosystems, mammal diversity, and mammal behavior can help in determining the best course of action.

This survey will ultimately estimate species richness and abundance to better understand mammal communities within Tonda WMA to augment knowledge gaps related to mammalian biological species concepts, taxonomy and systematics, and informing wildlife conservation policy and conservation biology measures within PNG.

Distribution

Upon completion of the final report, findings will be presented for peer review to *Conservation Biology* (ISSN 0888-8892). Following publication, the findings related to the biodiversity assessment will be submitted to the appropriate government branch of Papua New Guinea. This will be done initially through a media release, followed by a truncated version of the final report in order to leave out details that are not relevant for government officials. Given that it is important to form a cooperative agreement with Tonda WMA management, this will bolster the potential for future conferences, field research, and additional recommendations. Finally, it is likely that a presentation would be made at the Society for Conservation Biology biennial conference (see https://conbio.org/).

Author C.V.

Michael Schwartz is a wildlife researcher whose interest is species biodiversity, conservation biology, zoology, and tropical and neotropical ecology. With freelance experience in Africa since 2005, he has assisted in lion telemetry collaring, researched conservation issues related to lion, elephant, rhino, leopard, hyena, and mountain gorilla populations, studied elephant migration corridors between northern Uganda and South Sudan, and designed qualitative surveys to assess local attitudes toward predator species in Queen Elizabeth National Park. As an environmental journalist, his work has been featured in National Geographic, Swara magazine, and Mongabay. For more information, please visit his website at http://www.michaelwschwartz.com.

Budget

Year	Budget Item	Cost
2021	Roundtrip flight from NYC/JFK to Port Moresby/POM	U.S. $2,150.00 including excess baggage fee for camera equipment
2021	45 Bushnell trail cameras infrared/$213.00	U.S. $9585.00
2021/2022	Food/Camping Gear/Immunizations/ Medication for four months in the field (3 months during first trip and 1 month for return trip)	U.S. $3000.00
2021/2022	Emergency funds	U.S. $1000.00
2021/2022	Inmarsat IsatPhone 2 Satellite Phone	U.S. $694.44
2021/2022	Salary for one PNG CEPA field technician	U.S. $500.00
2021/2022	Salary for second PNG CEPA field technician	U.S. $500.00
2022	Roundtrip flight from NYC/JFK to Port Moresby/POM	U.S. $2,150.00 including excess baggage fee for camera equipment
	Total	U.S. $19579.44

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