Assessing the Use of Footprint Identification Technique to Monitor Bengal Tigers in Nepal

by

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EXECUTIVE SUMMARY
Wildlife survey and monitoring techniques applied in many parts of the world, including Nepal, can be invasive, expensive and unsustainable. However, a new monitoring approach known as Footprint Identification Technique (FIT), developed by WildTrack, has been established to be just the opposite. This project assesses the aspects of using FIT on free-ranging Bengal tigers in Chitwan National Park, Nepal.

Bengal tigers are fascinating animals with their significance deeply rooted in Nepalese culture. Protection of their home and their health impacts other species that cohabitate with them. For this reason, it is important to frequently monitor the growth of their population. However, this should be done without causing physical harm to the animal. Current wildlife monitoring techniques such as radio-collaring requires tigers to be immobilized, and then carry a foreign object on their body. Such devices, including those used for camera trap surveys, are expensive, limited, and usually conducted for a short period of time. On the other hand, conducting FIT is much simpler.

Photographs of tiger footprints are taken, which are then digitized and analyzed in JMP software to identify and sex individual tigers. As costs are low for conducting FIT studies, more time can be allocated for everyday fieldwork. Local villagers experienced at tracking the animals can be employed to locate tiger footprints. WildTrack has established FIT to employ African tribe members for tracking and photographing footprints. The organization has successfully used FIT for many captive and known populations of Amur tigers, cheetahs and white rhinoceroses to name a few. However, this project will for the first time test FIT on wild, unknown Bengal tigers in Chitwan, Nepal. The research objectives were to:

1) determine if tiger footprints can be easily found in Chitwan NP
2) determine the type of substrate that gives the best usable footprints
3) determine if individual tigers can be identified and sexed
4) determine if FIT is better than camera trapping

The method section is divided into collecting footprint images, digitizing the images, and finally, analyzing data for individual identification and sex discrimination. It provides guidelines on the process of collecting footprints according to the FIT protocol. There is detailed description on digitizing images and analyzing the extracted data in JMP software for individual identification and sex discrimination.

The next section discusses the results from the footprint image collection; individual identification and sex discrimination analyses; substrate analysis; and efficiency analysis between FIT and camera trapping. This section presents the number of tiger footprints that were collected in the study site, and the percentage that was acceptable for the analysis. It then states how many individual tigers were identified and sexed by the built-
in FIT model in JMP software. The substrate analysis demonstrates which substrate type is best to obtain usable footprints for future studies. Finally, efficiency analysis compares FIT and camera trapping data in order to identify the advantages of using FIT in Nepal.

The discussion and conclusion section of the report states that conducting wildlife monitoring with FIT is possible in Nepal. It describes how easy it was to find tiger footprints without physically harming the animal, how FIT could identify and sex more tigers with ample data collection, how wet soil and wet sand are the best substrates to find usable footprints, and how FIT can still be utilized alongside camera trap surveys to obtain vital information on the tiger population.

The final section provides management implications on how future studies can be more systematic for better data collection, how FIT can be used to continue collecting data during the gap years between camera trap surveys, how workshops should be held to train local people and park technicians to continue using FIT, how geospatial projects can help assess locations with suitable substrates, and when studies should be conducted without being in conflict with the weather.

Footprint Identification Technique, although not as commonly used as radio-collaring or camera trapping, is a great conservation technique to monitor elusive and vulnerable animals. Nepal's tiger population is slowly growing, and their growth suggests a healthy ecosystem. FIT can be used to closely monitor their growth and assess the state of other species as well. FIT poses minimal harm to the tigers, are cost-effective and sustainable. This study shows that even with its drawbacks, FIT does have the potential to be a valuable wildlife monitoring technique for Nepal.
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1. INTRODUCTION
Nepal has, in the past, suffered a staggering population decline of Bengal tigers (*Panthera tigris tigris*), but is now gradually seeing growth for a positive future. The Bengal tiger has been a flagship species for many conservation efforts in Nepal. They are a symbol of power and grace, and their significance is deeply rooted in the culture and religion of this Hindu-Buddhist nation.¹ Tigers are an indicator for the state of wildlife that share their ecosystem. A healthy population offers smaller, lesser known species a chance to survive. Frequently monitoring these animals without harming them has become a significant aspect of wildlife management. It is important to understand the health of the population and ecosystem, and to prepare for better management scenarios. In an attempt to find better alternatives to current monitoring methods, a new approach called Footprint Identification Technique is tested to monitor Bengal tigers in Nepal.

1.1. Bengal tiger
Within a span of 100 years, the global tiger population has dropped from 100,000 to 3200.² The Bengal tiger (*Panthera tigris tigris*) is one of the six remaining tiger subspecies in the world, and is listed as being endangered.³ The Bengal tiger is a charismatic species that have garnered worldwide attention for several decades. Nonetheless, they have been facing threats from poachers, as well as from habitat destruction, encroachment and loss of prey base. Bengal tigers are native to India, Bangladesh, Nepal, China, Bhutan and Myanmar.⁴ They have the largest total population amongst the subspecies. Fewer than 2500 remain in the wild today, where majority of the population is found in India. In Nepal, Bengal tigers are found in the Terai region of southern Nepal. Populations are congregated in Chitwan National Park, Bardia National Park, Shuklaphanta Wildlife Reserve, Parsa Wildlife Reserve, and Banke National Park. The 2013 national tiger survey in Nepal showed that the current tiger population rose to 198, which is a 63% increase since 121 tigers in 2009.⁵

Bengal tigers, from the family of Felidae, are large cats with distinct black stripes lined over orange fur. They have a white underbelly, and a white tail circled with black rings.⁶ Females weigh about 140 kg, while males can get big as 220kg. Adult males have a nose to tail body length of 2.7-3.1m, whereas females are smaller and are about 2.4-2.7m long.⁶ Bengal tigers are the most common of the tiger subspecies, but are smaller than Amur tigers, which are the largest of the subspecies. Tigers can live up to 12-15 years in the wild⁷, and they

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⁵ DNPWC (2014). Status of tigers and prey in Nepal
⁶ NTGP-USAID (2011). Nepal Tiger Genome Project, Bengal Tiger
depend on sight and hearing more than their sense of smell. They are solitary animals except for when a mother is with her cubs. Females give birth to a litter of 2-3 cubs with a gestation period of 3.5 months. However juvenile mortality is high and some cubs die before they reach 2 years of age.\(^8\)

Bengal tigers have a large home range (16-21 km\(^2\)\(^9\)) and are very territorial, which are marked with urine and feces. The size of their territory also depends on prey density. They prey on ungulates such as Sambar deer and White-tail deer, and large bovines such as the gaur and buffaloes. They prefer dense vegetation but can be sighted close to water sources. Thick grasslands and deciduous forests give them ample coverage to hide and hunt. However habitat fragmentation, loss of prey and forest encroachment, have forced tigers to be in close proximity to humans. There have been incidents where tigers have come near human settlements and have attacked domestic animals and sometimes humans. This only further highlights the importance of conserving natural habitat on top of eliminating poaching, in order to protect the species.

1.2. Monitoring approaches
Several monitoring techniques have been used in Nepal for wildlife conservation efforts, but they are invasive, costly, or unsustainable. Capturing and radio-collaring performed on tigers and a number of other vulnerable species have shown to be detrimental to the animals' health as well.\(^10\),\(^11\) Although monitoring and obtaining information about individual animals is important for conservation purposes, the process involved in capturing and handling can cause serious problems. Compared to animals that have never been captured before, studies have shown that direct physical handling of animals raises their health risks.\(^12\),\(^13\) For the purpose of collaring an animal and collecting its vital statistics, researchers first need to immobilize it. This process of darting the animal and attaching a foreign entity to its body presents great physical risks to its health and wellbeing. A Norwegian-funded radio-collaring project in Nepal in 1998 was blamed for the death of a collared female tiger and the subsequent deaths of its cubs.\(^14\) Similarly, in 2014 in Madhya Pradesh, India, an autopsy of a dead tiger showed that its radio-collar caused an infection

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around its neck.\textsuperscript{15} The same tiger had been treated before for another infection caused by the radio-collar.

Adding to the negative aspects of radio-telemetry devices, they are also very expensive, attached on a small proportion of the population, and usually used for a short period of time. The initial cost of obtaining, and then maintaining or replacing devices during the course of a study can be high. Places that do not have sufficient funding might not be able to sustain the use of such technologies. With a high cost per device, only a few animals are chosen to be collared. Hence, this method is unsustainable, and ignores monitoring of a large fraction of the remaining population.

Unlike radio-telemetry, camera trapping is not invasive, but the equipment required to execute surveys are as expensive. The initial costs are high and could be costly to maintain. Moreover, there is a gap in data collection because camera trap surveys are conducted only once every four years in Nepal. Camera traps are stationary, and data collection is restricted to the area they photograph. However, tigers have a large home range and so camera traps can provide only limited information about the population and movements of the animals. Some tigers even learn the location of cameras, and will change their path to avoid them.\textsuperscript{16}

\section*{1.3. Footprint Identification Technique}

Unlike radio-collaring and camera trapping, Footprint Identification Technique (FIT) was developed to be a non-invasive, cost-effective and sustainable alternative to monitor vulnerable species.\textsuperscript{17} This method incorporates the use of animal footprint images with an FIT feature tool in JMP software (SAS Institute) which is programmed to analyze anatomical similarities and variations between footprints.

Footprint Identification Technique was first developed by WildTrack, a non-profit organization that is dedicated to improving wildlife monitoring techniques. Their experience in radio-telemetry work in Zimbabwe led them to believe that they were causing harm to the animals that they were protecting. While trying to find a solution to this problem, they discovered that footprints are an easily available, and an excellent way of locating elusive species without causing physical risks and disturbance to the animals. Tigers are elusive animals and a person is more likely to find tiger footprints than the actual animal. Data collection for FIT simply entails tracking an animal or its tracks, and taking pictures of the footprints according to FIT photographing protocol.\textsuperscript{17} With these collected, footprint images are digitized and analyzed on JMP data visualization software to identify individual tigers and their sex. Field equipment is a simple set of digital camera, GPS unit, L-shaped ruler and a photo label. As these are not high-tech devices and are easily available, initial costs

\textsuperscript{15} Naveen, P. (2014). Tigress ‘T4’ killed by its own radio-collar in Madhya Pradesh. \textit{Times of India}


\textsuperscript{17} WildTrack
for equipment are very low. Moreover, by tapping into the expertise of local communities to track footprints, they are encouraged to be equally involved in conservation of their environment. These local people are familiar with the terrain and locations of tigers, and can cover a wide range of area in a day.

FIT, led by WildTrack, is currently being used in several countries in Africa, Asia, and the Americas, but has not been formally adopted in Nepal. Studies using FIT have been conducted to monitor Amur tigers in China, white rhinos in Namibia and mountain lions in Texas, USA to name a few.\(^\text{18}\) FIT’s accuracy for correctly identifying individual animals ranges between 90-99\%.\(^\text{19}\) WildTrack has had great success in establishing FIT to identify and monitor numerous species around the world. Therefore I wanted to study and assess if FIT is a viable monitoring approach that can be used to further enhance conservation efforts in Nepal.

1.4. Research objectives
This is a pilot study to assess the use of FIT to monitor tigers in Chitwan. Its purpose is to examine the functionality of this method in the settings and conditions of Chitwan NP. The study serves to demonstrate the chances of finding tiger footprints in Chitwan NP. The type of soil substrate that I find footprints on will determine if they can be used for analysis. The study will highlight whether the conditions of Nepal are suitable for the effective execution of FIT. The research objectives are to:

1. determine if tiger footprints can be easily found in Chitwan
2. determine the substrate that gives the best set of usable footprints
3. determine if individual tigers can be identified and sexed
4. determine if FIT is better than camera trapping

1.5. Study area
Chitwan NP, the oldest national park in Nepal is located in the southern part of Nepal bordering India (Figure 1). At about 150m above sea level, Chitwan is a hot and humid region, and showered constantly by heavy monsoon rainfall in the summer. Summer temperatures can reach a high of 35\(^\circ\)C, and amount of rainfall averages 50cm. Chitwan NP covers an area of 932km\(^2\), and is a mixture of alluvial grassland, deciduous forest and riparian vegetation. It is composed of 70% Sal forest, 20% grassland and 7% riverine forest.\(^\text{20}\) More than 50 different species of grass can be found in the Chitwan NP but the

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\(^\text{18}\) WildTrack
most common is the elephant grass. Elephant grass, of the *Saccharum* species grows up to 8m in height. Imperata grass, a shorter species, is also fairly common.

Figure 1. Map showing the location of Chitwan National Park, Nepal.  

This study was conducted on 212km$^2$ area of the Chitwan NP. The study site is highlighted in yellow (Figure 2). I concentrated mainly along the Rapti River, and areas with frequent and known tiger sightings, such as water holes, river banks and grassy vegetation.

Figure 2. Map highlighting the study site in Chitwan NP (yellow).

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22 CDC (2003).
2. METHODS
The method section was divided into:

1. collecting footprint images,
2. digitizing the images,
3. and finally, analyzing the data to identify individuals and their sexes

2.1. Footprint image collection
Fieldwork for footprint image collection was conducted during May 2013. This was the earliest time proposed to travel to Nepal, conduct fieldwork, and introduce FIT to Nepalese conservation officials. Due to the monsoon season, waiting past this month would be detrimental for image collection. Image collection areas were chosen after discussions with officials at WWF-Nepal and National Trust for Nature Conservation (NTNC). They made suggestions on the regions that should be covered during the short timeframe for fieldwork. They gave advice on where I could observe and photograph maximum number of tiger footprints. Park technicians provided information on known tiger locations, while local villagers gave daily updates of footprint and tiger sightings. We would then track footprints with the help of elephant drivers, game scouts and technicians.

Footprint image collection was done in early mornings, and frequently in the late afternoons. The equipment used were, a compact digital camera, an L-shaped ruler, photo identification labels, and a GPS device. Photographs of footprints were taken with a Canon digital camera. Photo labels were pre-made for the identification of each photographed footprint. Footprints were also photographed with the L-shaped ruler to scale the footprints during JMP analysis. A Garmin GPS device was also used to record the location of each trail that was found.

FIT photographing protocol requires only left-hind footprint images. In a tiger’s stride, their hind feet usually step over the footprints left by the front feet. This is called overstepping. This action usually leaves hind footprints undisturbed, which is why it is better to take photographs of clear hind footprints for analysis. Left footprints are used in order to have consistency. I, however, photographed all observable footprints for possible future reference.

It is necessary to detect a continuous trail of footprints, which generally signifies that footprints came from the same animal. A trail is made by a single animal and consists of a continuous series of footprints. As the identity of each free-ranging tiger was unknown, each new footprint needed to be distinguished by a trail and footprint number. The ideal number of footprints to collect per trail is 6-8 footprints. According to the protocol, the first trail I find that day would be trail 1, and the footprints in that trail would be identified as 1a, 1b, 1c...

23 WildTrack
1b, 1c. Then the second trail would be labeled as trail 2, with footprints assigned as 2a, 2b, 2c, and so on. If I suspect that there are two different animal footprints merged on the same trail, I would ID them as two separate trails to minimize false data collection. Footprints were wiped out after photographing was completed to prevent duplicate image collection.

2.2. Image digitization
After data collection, Adobe Photoshop was used to enhance the brightness and contrast of footprint images. This helped highlight the outline of toes and pad of a footprint which are important for image digitization. This process also improved photos that were taken under harsh lighting or those taken on a light-colored substrate such as sand (Figure 3).

Figure 3: Color and contrast enhancement. Original (left) and enhanced (right) image.

From this collection, I chose images that had clear, visible outlines of the footprints, and rejected others that were not clear enough. This reduced the number of left-hind footprints that could be used for digitization. Due to the necessity of data, I had to flip some right-hind footprint images with the assumption that the right and left mirror each other (Figure 4). The final chosen images were then imported into the Image Feature Extraction tool in JMP to be digitized. First, images were resized. Then two landmark points were placed on bottom of Toe 2 and 5 (App. D and E). A line connecting these two points are formed, and the image is rotated to where the line becomes horizontal (App. F). With the help of crosshairs, landmark points are placed along the boundary curve of a footprint to compute 15 derived
points, which then are used to obtain 128 measurable variables (Figure 5). Measurable variables constitute every possible distance, angle and area formed between landmark and derived points. After digitizing the images, the variables are exported to a JMP data table where each row represents measurements from one footprint. This makes up the data that will be used for data analysis (App. B).

Figure 4: Photograph of the original footprint image (left) has been flipped (right). The flipped image can now be used for image digitization.

Figure 5: A Chitwan tiger footprint image with landmark points in red/black circles and derived points in yellow (Left image). Similar digitization of a footprint collected at the Carolina Tiger Rescue Center showing landmark points (black), derived points (white), and all possible distances and areas that can be formed between those points (Right image).²⁵

²⁵ WildTrack
2.3. Data analysis
The built-in FIT feature in JMP software applies discriminant analysis to identify individuals and their sex. A footprint database of captive and known Bengal tigers is required for analysis, which was provided by WildTrack. This database has been created over several years from collections at Carolina Tiger Rescue in Pittsboro, USA; Big Cat Rescue in Florida, USA; Ranthampur, India; and Sundarbans, Bangladesh.

2.3.1. Individual identification
For this step, I ran the Pairwise Data Analysis model which applies discriminant analysis on measurable variables (App. G). The program chooses 16 variables according to a stepwise variable selection process that provided the best discriminating power. This is a preset number established by WildTrack studies to find the optimal number of variables that provide best discriminating power.\textsuperscript{26} This analysis for individual ID compares two tiger trails at a time until the model runs through all the possible combinations in the database. The process then creates a cluster dendrogram that shows which trails are from one tiger, and which are from a different individual.

2.3.2. Sex discrimination
Likewise, for sex discrimination, I used the same tiger database to run another discriminant analysis model (App. H). This method identifies linear combination of variables that group or

separate footprints into the male or female category. I used JMP stepwise variable selection to select 25 variables to give the highest degree of discrimination. Again, this number was determined by WildTrack studies conducted in the past. This process then generated a canonical plot which grouped male and female footprints into two separate groups.

3. RESULTS

3.1. Footprint data collection
A total of 152 individual tiger footprint images were collected in my study area (App. A). Multiple photographs of the same footprint were taken to ensure that I captured at least one clean photo. However, only 29 tiger footprint images were used for analysis. These chosen images showed clear contours of the toes and pads as required for the analysis. Out of those that were used, 14% were left-hind footprints and 5% were flipped, right-hind footprints (Figure 6).

Figure 6: Graph illustrating the total number of footprints collected (blue) and total number of footprints used (green and red). The percentage of left- and right-hind footprints used out of total collected footprints are given above the respective bars.

The 29 usable footprints made up 11 different trails. To make it easier for analysis, I reassigned trail names. Figure 7 demonstrates that most of these trails do not have the 6-8 footprints required for analysis except 2 No. Machan a and Badrahni Ghat a.

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3.2. Individual identification

Pair-wise analysis with the 11 Chitwan trails and the WildTrack tiger database created a cluster dendrogram that grouped trails formed by the same tiger. The model predicted identification of eight individual tigers. Figure 8 illustrates the cluster dendrogram that was formed where trails from the same tigers are highlighted by the same color. For example, it suggests that two trails highlighted in orange are from one tiger, and that three trails highlighted in teal come from another separate tiger. However, only 2 No. Machan a and Badrahni Ghat a, comprise the ideal 6-8 footprints. I can hence be certain that the model predicted at least two different tigers.

An interesting detail is that the Riu Khola trail, although consisting of only one footprint, is categorized as a separate tiger. This footprint was found 40km west from all the other trails (App. I). Knowing that the habitat range of a tiger in Chitwan is 16-21km², it is reasonable for the model to classify it as a separate individual.
3.3. Sex discrimination
For sex discriminant analysis, I used data from footprints instead of trails. This is to increase our confidence in determining the sex of a tiger. If 90% of footprints are female and 10% are male, then I can confidently state that that tiger is a female. The discriminant analysis created a canonical plot (Figure 9). The pink ellipse defines female footprints and the blue defines male footprints. The black symbols represent Chitwan footprints, which almost all are clustered on the female section. Two footprints out of the 29 were predicted to be male (App. J). These two are from Bhimpur Ghat a and Padna Ghole b, but as these trails have less than 6 footprints, I cannot be certain that if the tiger is male or female. However, all the footprints from 2 No. Machan a and Badrahni Ghat a are female, which implies that these trails are from two individual female tigers (App. K).

Figure 9: Canonical plot distinguishing male and female footprints.

3.4. Substrate analysis
Footprints were observed in various types of substrate. Tiger footprints were observed in wet and dry water holes, along sandy and muddy banks of streams and rivers, inner grasslands and lightly forested areas. Every location rendered footprints in varied conditions. There were six distinct types of substrate that was observed: wet soil, wet sand, dry, hard soil, dry, loose soil, dry sand, and wet, muddy soil (Figure 10).
Figure 10: Tiger footprints in wet soil, wet sand, dry, hard soil, dry, loose soil, dry sand, and; wet, muddy soil, respectively.

I compared the number of footprints that were used from each type of substrate. Figure 11 shows which substrate supports collection of usable footprint images. 24% of footprints photographed on wet soil and 24% photographed on wet sand were used for the analyses. This makes these two the best substrates that sustain usable footprints. Whereas none of the footprints collected from dry sand and wet, muddy soil were used, which make these the worst substrate to find viable footprints.

Figure 11: This chart shows the percentage of footprints that were used for analysis.
3.5. Efficiency analysis: Camera trap vs. FIT

My final objective was to determine if FIT is a better monitoring method than camera trapping for Nepal. Table 1 presents the differences between FIT and camera trapping. Information for camera trap survey was obtained from the 2013 national tiger status report. In a time period of 2.5 months, camera trap surveys identified 78 tigers in an area of 1448km$^2$. FIT identified only three, counting the tiger from Riu Khola trail. However, the initial cost for FIT is significantly more than for camera trapping. The initial cost for camera trapping was calculated from the estimated number of trail cameras used for the 2013 survey.

Figure 12 and 13 compares the efficiency of the two methods. The first chart shows that camera traps can identify 5 tigers per 100km$^2$, while FIT can identify only 1. If the Riu Khola tiger is included, FIT can identify 1.4 tigers per 100km$^2$. Figure 13 on the other hand shows that the initial cost per tiger is $363 for camera trapping, and $272 for FIT. Again, if the Riu Khola tiger is included, initial cost decreases to $182 per tiger, which is half the cost of camera trapping.

Table 1: Comparison of camera trap data versus FIT data

<table>
<thead>
<tr>
<th></th>
<th>Camera Trapping</th>
<th>FIT</th>
<th>FIT (including Riu Khola tiger)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of tigers found</td>
<td>78</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total area covered</td>
<td>1448km$^2$</td>
<td>212km$^2$</td>
<td>212km$^2$</td>
</tr>
<tr>
<td>Total field time</td>
<td>2.5months</td>
<td>1 month</td>
<td>1 month</td>
</tr>
<tr>
<td>Total Initial Costs</td>
<td>$28,300 (estimated)</td>
<td>$545</td>
<td>$545</td>
</tr>
</tbody>
</table>

Figure 12: Comparison between camera trapping and FIT showing the total number of tiger identified per 100km$^2$ with each method.  

Figure 13: Comparison between camera trapping and FIT showing the total initial cost per tiger with each method.

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28 DNPWC (2014). Status of tigers and prey in Nepal
4. DISCUSSION

From the footprint data analysis performed, FIT can be considered to be a valuable method to monitor tiger populations in Nepal. A lot of footprints were collected in a short period of time with the help of few, inexpensive resources. Even though only 19% of the collected footprints were accepted, tigers were identified and sexed. The number of usable footprint images decreased for various reasons. Firstly, there were some images of right footprints; secondly, some images were later discovered to be front footprints; and thirdly, some footprint images were projected poorly on a computer screen even after image optimization. Some of the right-hind images were also flipped to be used as left-hind. This was a major assumption made for the continuation of the analysis. In order to have increase the number for suitable footprints for accurate analysis, systematic data collection, including trails containing the optimal number of footprints, should be conducted.

Obtaining the optimal number of footprints per trail is vital. Individual and sex ID cannot be certain without the 6-8 footprints necessary. The cluster dendrogram for individual ID predicted eight different tigers. However, this number is overestimated as most of the trails contain less than 6 footprints. There are only two trails that have the required number of footprints for analysis. These two trails, 2 No. Machan a and Badrahni Ghat a, are classified as two separate tigers. As these trails have the ideal number of footprints, I can be certain that I have at least two individual tigers. Similarly, I can be certain that these two individuals are female tigers. The sex discrimination model predicted that all the footprints from 2 No. Machan a and Badrahni Ghat a are from female tigers. I cannot be confident on the sex assignments for the rest of the tigers, as footprints per trail were less than what is required (App. L).

The project was aimed at assessing the bio-geographical suitability to collect footprints in Nepal. Substrate analysis presented that wet sand and wet soil are the two best types of substrates to collect usable tiger footprints. This suggests that if image collection was focused more on these substrates, a better dataset could have been established. The results show that suitable substrates can definitely be found in specific regions. Nonetheless, areas with the less suitable substrates can also be further researched. This can determine if FIT, when used with the optimal number of footprints per trail, can be effective for images from less suitable substrates.

This study was also designed to understand if FIT is beneficial in the context of existing Nepalese management framework. Camera trapping shows a higher efficiency in terms of identifying tigers, but can cost double the amount to conduct the surveys. If the number of tigers identified by FIT was much greater, the efficiency of camera trapping could have decreased. Further research with systematic data collection is therefore necessary to consider the benefits of FIT.
5. CONCLUSION & RECOMMENDATIONS

Observation, experience and photographic evidence have established the practical applicability of using FIT to monitor tigers in Chitwan NP. Camera trap is an excellent method for monitoring and censusing but it is costly, limited and done once in a couple of years. Although FIT identified fewer tigers than camera trap surveys, it is less expensive and can be conducted on a daily routine. FIT could be used during the gap years to compensate for data that is uncollected between camera trap surveys. To make future FIT surveys more systematic, the same survey grid made for camera trapping can be used to assign areas for FIT tracking. Areas that already have camera traps set up can be used as starting points for FIT monitoring. The use of FIT can be expanded to include core park areas (areas of the Chitwan NP outside of the study site); community forests that are in the buffer zones; and habitat corridors that connect Chitwan NP and Parsa WR on the east, and Valmiki Wildlife Sanctuary, India on the southwest border.

If FIT is to be implemented in Nepal, the first agenda would be to create an extensive database of known Nepalese tigers in order to strengthen the analysis. Secondly, workshops to train local surveyors should be conducted to continue and sustain the use of FIT in Nepal.

To improve this technique in the conditions of Nepal, we need to identify appropriate substrate locations. This study has already highlighted that image collection should be focused on wet soil and wet sand, but future geospatial analysis studies can be carried out to assess where these suitable substrates are located in Chitwan NP. This can cut down search time and help obtain large amount of data. The best and the worst time period to collect footprints should also be identified in order to overcome weather challenges. From this study, I have found out that peak summer months are not suitable for footprint data collection. Summer heat would dry up water holes and the soil. There would be a lot of footprints in the dried up water holes, but they were deeply sunken in the once muddy substrate, and were cracked and chipped (App. M). On the other hand, when it drizzled, it would wash away or distort footprints on loose substrate. Recommendations from park technician and department officials included spring and fall season. During this time, the temperature and precipitation are not at an extreme level. They also suggested that a good time to collect footprint images could be after a forest fire because in their past experience, they have seen footprints imprinted clearly on ash.

An unforeseen difficulty that I experienced was using a motorized vehicle for fieldwork. Although a jeep can cover longer distances than on an elephant, it was difficult to travel in for fieldwork. I was forced to stay on the predefined paths that were made for tourist sightseeing. This eliminated possible footprint sightings in nearby grassland areas of the park. Moreover, the path was restructured with loose gravel instead of soil. Gravel paths are not suitable for tigers to leave their footprint impressions. Riding in the jeep over a gravel path also made a lot of noise which scared away the animals. On the contrary, using
elephants to travel through the grasslands of Chitwan NP was a better mode of transportation. With elephants, I was able to cover more area, could travel through densely vegetated areas, were less noisy, and were already being used for other monitoring purposes. This further encourages employment of elephant drivers in conservation efforts held in the park.

Conservation strategies for working with vulnerable tiger population in Nepal must be sensitive to the health consequences of directly handling these animals. FIT offers a non-invasive mode to lessen the physical stress on animals. This method involves local people and park technicians to be more involved in conservation efforts. FIT can work well with other non-invasive techniques like camera traps to help expand the utility of an already established monitoring approach. This demonstrates the potential of FIT as a valuable wildlife monitoring technique to foster the growth of tiger population in Nepal.

7. ACKNOWLEDGEMENTS
This project is the result of complete support and assistance from various people and institutions. I would firstly like to thank my advisor, Dr. Stuart Pimm, for his continual support, and for introducing me to WildTrack. This project would not have been possible without the guidance and assistance from Zoe Jewell and Sky Alibhai at WildTrack. I would also like to thank the Rufford Foundation and the KLN Endowment Fund and for funding my project, and making this a possibility. Furthermore, I would like to thank Dr. Maheshwor Dhakal and Kamal J. Kunwar from the Department of National Parks and Wildlife Conservation, who aided the process of authorizing my work in Chitwan. I am also grateful to Sabita Malla, Dr. Narendra Pradhan, and Rajendra Suwal from World Wildlife Fund-Nepal, and Naresh Subedi from National Trust for Nature Conservancy for helping me prepare for the initial phase of fieldwork and providing field equipment. I am thankful for the immense support from Chiranjibi Pokharel from NTNC for his guidance and answering my endless questions. Image collection process of this project would not have been complete without the technical assistance of Bishnu Lama and Deep Prasad Chaudhary at NTNC, and Ishwori Mahato at Chitwan Park office, individuals immensely capable and knowledgeable in tracking tigers. Lastly, I want to thank my family and friends for their support and encouragement throughout the project.
8. REFERENCES


CDC (2003).


DNPWC (2014). Status of tigers and prey in Nepal


NTGP-USAID (2011). Nepal Tiger Genome Project, Bengal Tiger


WildTrack


9. APPENDICES

Appendix A
Data table for tiger footprint images (most entries have multiple images for the same footprint)

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Appendix B

A part of JMP data table showing Chitwan tiger footprints that was used for FIT analysis

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Appendix C
FIT built-in feature in JMP software

FIT APPLICATION

Main Menu
Select Species  Bengal Tiger

FIT Option
- Image Feature Extraction
- Pairwise Data Analysis
- Validated Discriminant Analysis
- Mapping
- Help

Launch Application

For More Information
www.wildtrack.org
info@wildtrack.org

Appendix D
An initial process during digitization in the Image Feature Extraction tool

Bengal Tiger  (Panthera tigris tigris)
Feature extraction template for left hind footprint image
Appendix E
Footprint during digitization showing the two rotation points in red/black circles.

Appendix F
Footprint after rotation and with crosshair for further digitization.

Appendix G
Pairwise analysis model for individual identification in JMP software

Robust Cross-Validated Pair-wise Analysis
Appendix H
Sex discriminant analysis model in JMP software

Appendix I
Map showing locations of the 29 used footprints
Appendix J
Canonical plot from sex discrimination analysis highlighting two footprints predicted to be male in red circles

Appendix K
Canonical plot showing footprints from 2 No. Machan a (green) and Badrahni Ghat a (red) to be from female tigers
Appendix L
Chart summarizing sex prediction made by the sex discrimination model, and what I concluded footprints from each trail to be.

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Appendix M
Footprint dried up and cracking from summer heat (Left). Footprint disturbed by raindrops (Right).