Indigenous tribes as participants in monitoring wildlife leading to collaborative management on national forest lands in Taiwan

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Abstract

Since the Taiwan Forestry Bureau (TFB) implemented the Wildlife Conservation Act (WCA) in 1989 to protect wildlife and forbid hunting activities, indigenous tribes have asked for the reinstatement of hunting rights to support their traditional culture. In response to indigenous tribes' request, the TFB revised the WCA for indigenous tribes in 2004 so that they would be able to conduct traditional hunting. However, questions concerning the health of the wildlife population arose because no information on wildlife populations existed. Indigenous tribes argued the wildlife populations had increased because their crops were damaged by wildlife, but the TFB had no information on the population size of any wildlife species to present to the general public on the issue. To decrease conflicts between the TFB and indigenous tribes, I designed a citizen-science survey, the Ungulate Pellet Groups Sign Survey, to encourage the indigenous hunters to participate in wildlife monitoring in the role of citizen scientists in order to track wildlife population change. The objective of this survey was to collect information on focal wildlife (muntjac, serow, and sambar deer), as well as to increase trust between the TFB and the indigenous tribes. In addition, I tested indigenous hunters' ability and performance in conducting scientific wildlife surveys, and encouraged indigenous hunters to participate in wildlife management with the TFB.

To mitigate conflicts caused by implementation of the WCA and encourage indigenous tribes to manage their natural resources, the TFB initiated the Community Forestry Project (CFP) in 2002. This project helped develop the indigenous tribes' abilities in building consensus, inventorying natural resources, and using cultural knowledge to develop nature-based tourism in order to increase tribal incomes. In 2012, ten years after the CFP was implemented, the TFB initiated a tribal-based ecotourism project, the Ecotourism Committee Project (ECP) to encourage indigenous tribes to develop tribe-featured ecotourism in order to manage national forest lands with the TFB. The ECP consisted of a committee composed of diverse members, including tribal representatives, scholars, management experts, and government officials. The TFB officers acted as an interface, integrating step-by-step procedures to help develop the tribes' visions on using national forest land sustainably.

The sign survey yielded not only wildlife population information such as seasonal migration, habitat preferences, and the influence of environmental factors, but also provided government agencies a cost-efficient way of collecting wildlife information to enhance wildlife management where there are terrain constraints. Furthermore, indigenous hunters in my study demonstrated their ability to conduct scientific wildlife surveys and revealed their anxiety about losing their tribal hunting culture. My study suggests employing indigenous hunters as citizen scientists, not only to collect wildlife population information for wildlife management but also to participate in being part of the management system, decreases conflict decrease the TFB and preserves their hunting culture.

Indigenous hunters successfully demonstrated their ability to work as citizen scientists, but the indigenous tribes' transition from working with the CFP to the ECP was not straightforward. Indigenous tribes seemed to perform well in the tribe consensus building for the CFP but failed to be present in the ECP. This study also provides insight into how focal groups can cooperate in the management of wildlife and national lands.

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Chapter 1

Introduction

Thirty years before the start of my study, the Taiwanese government banned wildlife hunting with the Wildlife Conservation Act (WCA). Twenty years after the ban, indigenous tribes began petitioning for their hunting rights, seeking to protect their crops from damage caused by wildlife such as wild boar, muntjac, and sambar deer; they also sought to protect their traditions. The wildlife management authority in Taiwan, the Taiwan Forestry Bureau (TFB), was considering reinstating indigenous hunting rights, but had concerns about wildlife population trends as well as questions about the indigenous management of hunting activities. There was no research or official assessment regarding the wildlife populations, which made decision-making difficult. In response to indigenous tribes' requests, the TFB announced apply-report hunting regulations in specific areas to monitor indigenous tribes' hunting activities, and wildlife species and hunt numbers were reported by indigenous tribes.

After the WCA was announced in 1989, the TFB announced the establishment of more than 50 wildlife-related protected areas and implemented poaching patrols, education of and communication with indigenous tribes, and wildlife monitoring. The wildlife monitoring implemented by the TFB focused on species identification and distribution to ensure that wildlife would survive in the protected areas (e.g., Pei and Su 2007; Pei 2010; Chang 2013). The wildlife protected areas fulfilled their function and the wildlife populations grew over the thirty years of protection.

In addition to the changes implemented by the TFB, the TFB also tried, starting in 2002, to guide local tribes to develop community-based ecotourism projects to improve local economics and reduce the number of hunting requests from indigenous tribes. To this end, the TFB implemented the Community Forestry Project (CFP) to encourage tribes to build-up tribal consensus in community-based tourism, document and translate their traditional knowledge into the tribes' use of natural resources, and to train indigenous tour guides. Additionally, the CFP sought to develop tribe-oriented ecotourism in preparation of managing national forest areas.

Meanwhile, to convince indigenous tribes to hunt sustainably, the TFB had to develop a relatively efficient way to detect wildlife population changes that could be conducted by indigenous tribes as well as achieve a consensus in wildlife management between the tribes and the TFB. As a result, citizen scientists were considered by the agency. Indigenous tribes had already proven effective as scientific helpers (e.g., Danielsen et al. 2007; Denham 2017) and that focal or local groups, such as indigenous hunters, could maintain high participation and retention rates in wildlife monitoring (e.g., Oscarson et al. 2007; Black 2009; Jordan et al. 2012). These approaches also realized economic benefits for the participants (Allendorf et al. 2009).

Due to terrain restrictions, a direct estimate of wildlife populations was not practical and therefore an indirect method was required to provide a crucial role in monitoring wildlife population trends and forming management strategies (e.g., Kushwaha et al. 2004; Forsyth et al. 2007; Steinmetz 2010). Consequently, I implemented a study that examined how indirect methods of wildlife monitoring achieved efficiency in tracking wildlife population change. This was done with help from indigenous hunters serving as citizen scientists. Finally, the study evaluated the potential of indigenous tribes with experience in operating through a CFP to manage forest lands within the framework of tribe-oriented ecotourism.

The goal of this study was to assess wildlife population trends using sign surveys. These surveys yielded information that was/is/would be useful for agency authorities to communicate with indigenous tribes on hunting regulations and wildlife management. In addition, I examined the potential of using indigenous hunters in wildlife monitoring as citizen scientists. I also participated in TFB projects on national forest lands to assess the potential and ability of indigenous tribes to apply tribe-based ecotourism projects that would support work opportunities and support indigenous culture.

In chapter two, I test a sign survey to track ungulate population trends and investigate relations between population trends and environmental factors (e.g., elevation, forest types, and canopy). The ungulates followed in this study – muntjac, sambar, and serow– are large mammals in Taiwan's forested areas as well as species hunted by indigenous tribes.

My goal in testing the sign survey was to build an efficient method for tracking wildlife population change that would be accepted and used by both government agencies and indigenous tribes. To achieve my goal, I applied transect-line sign surveys to analyze if ungulate pellet groups could indicate the ungulates' distributional range and seasonal migratory behavior. I also classified the distribution of a variety of ungulate species with respect to altitude to understand habitat preferences.

In addition to building a tracking method, I also considered human disturbances such as hunting activities, land development and infrastructure impacts on wildlife management efforts in chapter two. I found that ungulates in Taiwan were constrained to mountain areas ranging from 400 to 3,000 meters in altitude because of human activities and the habitat preferences of these ungulates.

In chapter three, I show how indigenous hunters can act as citizen scientists to collect ungulate sign data that can be compared with the TFB professionally gathered data. The goal of the process was to mitigate differences between government agencies and indigenous tribes. The ungulate sign survey process helped the indigenous tribes to understand how the TFB managed wildlife, and the agency was able to gain insights from indigenous tribes. As a result, consensus was built among the different parties.

My goal in testing the credibility between indigenous hunters and trained TFB field workers was to prompt indigenous tribes to participate in wildlife management with the TFB and to apply a method that both parties could accept and operate. To achieve my goal, I invited indigenous hunters to conduct ungulate sign surveys and explained how this sign survey was an indirect method to track ungulate population changes. The participating indigenous hunters showed interest and shared their experience in tracking ungulates. I also interviewed indigenous hunters to understand their hunting culture, concerns for their hunting culture, and their willingness to participate in wildlife management. This was done to encourage both indigenous tribes and government agencies to collaborate in wildlife management.

In chapter four, I discuss my observations from a tribe-based project called the Community Forest Project (CFP) and a three-year tribal ecotourism project, the Ecotourism Committee Project (ECP). The tribe-based CFP project began in 2002 in order to evaluate the potential of indigenous tribes to manage national forest lands. Three indigenous tribes which had CFP experience participated in this three-year project as a trial of the management of national forest for wildlife management, ecotourism, and cultural heritage that included participation from both the tribes and experts.

My goal in participating in the ECP was to obtain insights for the TFB about what would be required for indigenous tribes to manage national forest lands and to offer advice for indigenous tribes in constructing their development strategies. I found tribal consensus was a foundation for tribes to communicate with other agencies as well as a factor in the tribes developing a partnership with the TFB to manage national forest lands.

The importance of these insights for this dissertation was not only to build up an acceptable and useful ungulate monitoring method that could be applied by both the TFB and indigenous tribes, but also to encourage indigenous tribes to participate in wildlife management rather than just be citizen scientists. Furthermore, I assessed the utility of community-based small projects in tribes' development to further construct sustainable management of national forest lands as well as indigenous culture in Taiwan.

The collaboration of stakeholders generated positive consequences not only because the TFB budgets for wildlife and national forest management were limited, but also because the TFB had the obligation to mitigate conflicts between indigenous tribes and the agency itself. This empirically oriented dissertation, which provides a solid method and a potential application of participatory management for the TFB and indigenous tribes, contributes to the understanding of co-management of national forest lands and wildlife while providing insights into the development of consensus among indigenous tribes as well.

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Chapter 2

Monitoring population trends of large mammals in areas with difficult access: An application of a sign survey in Taiwan

Introduction

The national forest occupies nearly 60% of the land surface of Taiwan and provides the main habitat for wildlife. In order to manage and conserve wildlife that live in the forest lands, the Taiwanese government passed the Wildlife Conservation Act (WCA) in 1989. Additionally, commercial hunting was banned in 1973 to conserve wildlife resources. As a result of these two measures, the number and diversity of wild animals in the national forest lands recovered from habitat exploitation caused by economic development (e.g., Pei and Su 2007; Pei 2010; Chang 2013; Chiang 2014). However, top predators in Taiwan such as the Formosan clouded leopard (*Neofelis nebulosa*) and Asiatic black bears (*Ursus thibetanus*) had either become extinct or were already rare in the wild long before the WCA passed (Hwang et al. 2010; Chiang et al. 2015). Because of this, the yellow-throated marten (*Martes flavihula*) and Siberian weasel (*Mustela sibirica*) were the two major carnivores remaining that hunted herbivores such as Reeves's muntjacs (*Muntiacus reevesi*), Formosan serow (*Capricornis swinhoei*), and sambar (*Rusa unicolor*) (Chiang et al. 2012), which suggests that the herbivore populations would likely increase with time.

Wildlife surveys carried out in Taiwan's national forest lands after the WCA was implemented were mostly related to species identification (e.g., Pei 2010; Chiang 2014) because difficult terrain and dense forest cover make direct wildlife population estimation surveys impractical. Research regarding species inventories in Taiwan were primarily based on the use of applied infrared cameras and resulted in camera indices to represent population status (e.g., Chiang et al. 2015), but did not address the critical assumptions such as population status before they were conducted (Rowcliffe et al. 2008). In addition, the complaints from indigenous tribes that wild animals damaged crops had increased in the region indicated that the wildlife populations had grown and expanded in range. Therefore, to deploy a wildlife monitoring method to monitor the fluctuation of the wild animal population was essential.

Given the sense that wildlife populations had recovered, indigenous tribes were requesting restoration of their traditional hunting rights, focusing on muntjac, serow, and sambar. In response to the request of indigenous tribes, the Taiwan Forestry Bureau (TFB), beginning in 2013, cooperated with local counties and began to issue permits to indigenous tribes for cultural and ceremonial hunting. Before 1895, the indigenous tribes in Taiwan were distributed over much of the rugged central mountain range, where the national forest lands are now located. Over the years, traditional hunting customs of these tribes have conflicted with and influenced conservation policy in many aspects (e.g., Tai et al. 2011). In addition, Chiang et al. (2015) note that the main factors affecting herbivores were human activities such as farming or hunting, distance to remote mountains, and altitude, which would suggest an uneven distribution of wild animals in Taiwan.

According to the WCA, hunting is illegal in Taiwan except for approved hunting activities carried out by Taiwan's indigenous tribes for ceremonial purposes. This restriction makes the regular hunting behavior of indigenous traditional hunting illegal. Indigenous tribes have been urging the Taiwanese government to restore their traditional hunting grounds for self-management (e.g., Lu et al. 2006), but it is difficult to understand the impacts of regular hunting on wildlife ecology. Without a doubt, it is challenging to satisfy the needs of Taiwan's indigenous hunting customs and the conservation of wild animals at the same time. Under these circumstances, information on ungulate populations is crucial in order to assess the effects of hunting or other management concerns.

There are no easy methods to track ungulates in the region given that they inhabit rugged and mountainous habitats that are difficult for observers to access. The line transect method (Burnham et al. 1980), which involves sighting animals, is restricted in rugged and dense forest areas as are physical capture and aerial surveys. The camera trap method is considered a reliable, low-cost method, but inappropriate in areas with a high frequency of human activities, such as hunting or poaching, which could lead to the theft of the apparatus. Therefore, a sign-based wildlife survey could potentially overcome those restrictions, yielding an index of population size and trends over time.

Index counts based on signs found along trails may be the most practical means of population monitoring. In other parts of Asia, ungulate sign surveys involving scats and tracks have been adopted as an index of ungulate abundance (e.g., Marques et al. 2001; Kushwaha et al. 2004; Shrestra 2004; Forsyth et al. 2007; Steinmetz et al. 2010; Gopalaswamy et al. 2012). In addition, a positive linear relationship between fecal pellet counts and deer density has been noted (Forsyth et al. 2007) indicating that it is comparable to other population trend survey methods (Loft and Kie 1988).

Wildlife managers must develop a reliable animal occurrence prediction model that includes an understanding of habitat (Sunarto et al. 2012). Many habitat features such as distance to roads or villages, forest or vegetation types and composition, and human disturbance, affect animal distributions and help explain ecological relationships (e.g., Yamada et al. 2003; Forsyth et al. 2009; Ngoprasert et al. 2011; Sunarto et al. 2012). Because of this, I employed fixed-width strip transects in this study to collect sign data (pellets and tracks) of three ungulates (muntjac, sambar, and serow) in Taiwan forest lands. This was done in order to provide a reliable animal occurrence and population prediction model – one which included habitat factors – for management practices. My objectives were to test whether sign surveys as a monitoring system would be able to track population change through time; to assess the population trends of three focal ungulates under the pressure of human encroachments; and to construct a spatial ungulate habitat model to address priorities of habitat management practices.

Methods

Study Areas

This study occurred in the national forest lands (about 2,260 km^2) in Taitung County (220 14' ~230 26'N, 1200 51'~1210 27'E), southeastern Taiwan, managed by the TFB (Figure 2.1). The terrain spans a wide range of elevations (0-3,600m), with varying ease of access (from flat paths to abandoned logging roads to steep hiking trails or animal trails), varieties of vegetation types (from deciduous to coniferous forest to mountain grassland), and a variety of human disturbances (including poaching pressure). In addition, areas that allowed legal hunting by indigenous tribes were included in the study area. To evaluate the effects of human disturbance on ungulates, my study areas were located where hunting activities occurred or within a range of three kilometers. The elevation of the study areas ranged from 326 to 2,218 meters above sea level with moderate slopes ranging from 14%-42%.

Taitung County has a residential population of around 234,000. In addition to the Han people, who are the dominant population, there are seven indigenous tribes with a population of around 80,000. Five of these tribes live around national forest lands. Their members have strong opinions about national forest and wildlife management because they lived in these national forest lands previous to1895 and have retained their hunting culture. Additionally, 40% of TFB employees (a total of 260) in this district office are indigenous people.

Survey Design and Sampling Protocols

Transect establishment

I employed fixed-width strip transects to collect sign data for three ungulate populations (sambar deer, serow, and muntjac), whose sign (pellets and tracks) are easily distinguishable. A survey unit is a three kilometer by three kilometer cell designated within national forest lands. Within each survey unit, I selected one animal trail without human encroachment as a sampling transect. Thirty-seven survey transects were set up throughout the study area, varying in elevation and forest structure.

A survey transect was 200 meters in length and two meters in width. A colored string was placed in the middle of the surveyed transect for clarification. The primary considerations in establishing these sampling transects were adequate coverage of the study area and representation of the habitat types in which target species densities could be expected to differ. I assembled a survey group to conduct these transects surveys. A total of 32 transects covering 288 square kilometers were surveyed on a monthly basis, from July to December 2013, May to December 2014, and March to December 2015 mostly in the dry seasons to ensure that the persistence of pellet groups was consistent (Duangchatrasiri et al. 2019). Another five transects were not surveyed in 2015 due to accessibility restraints (landslides caused by typhoons and heavy rainfalls) and data surveyed from those transects were not applied for analysis.

Measurement of habitat features

Habitat features in each sample unit were surveyed to evaluate their effects in shaping wildlife distribution. I measured habitat variables including forest type (FT), density of canopy (DC), type of ground cover (GC), elevation (EL), slope (SL), access road type (RT), distance to road (DR), and human activities (HA) at the center of each transect in a 25 meter by 20 meter plot format. In order to avoid disturbance to the animals, I set up survey transects two to four weeks before the field survey was conducted.

I classified the forest types which were primary features in my study areas into three categories: broadleaf (FT1), conifer (FT2), and afforestation (FT3). I classified canopy density on a scale of one to four to represent the coverage rate (25%-100%) for the habitat plot; this was done by averaging four observations completed by experienced surveyors. I categorized ground cover into three types: soil with debris, herbaceous, and bush as well as the height of ground cover. I categorized access roads into three types: paved roads (cement or asphalt), operating logging roads, and abandoned logging roads. The distance to road was measured as distance between the center of transects and the nearest roads that vehicles used. I also recorded human activities along the transects.

Sign data

A group of two to three experienced surveyors searched each two hundred meters by two meters survey transect. Surveyors were asked to walk in the middle of each transect and use a stick to document the distance between pellet groups or footprints and the transect. Each surveyor conducted sign surveys ten to fifteen minutes apart and recorded their observations. Surveyors compared their independent results and, if there were differences, they went back to check the transect in order to come to a final agreement of that survey event. Surveyors recorded each sign (pellets or footprints) they found along transects and which animal species produced it. I summed up all pellet groups and tracks for each species within each transect. Surveyors also recorded distances, which I divided into four categories (1:1-25 cm; 2:26-50 cm; 3:51-75 cm; 4:76-100 cm on either side of transects) between the signs and the transects.

In addition, surveyors recorded the degree of freshness of the signs they found in three categories (1: about one week; 2: one to two weeks; 3: longer than three weeks). The decay rate of pellet groups from ungulates varied according to the season and environmental attributes (e.g., Lehmkuhl et al. 1994; Laing et al. 2003; Skarin 2008). Pellet groups of ungulates would either be diminished quickly by beetles or would be retained intact during the winter season. A lack of luster on the pellet surface made it distinguishable. Surveyors who conducted this survey were indigenous hunters or well trained and experienced field workers. Their judgment of the freshness of the sign was not a concern.

I used the Robust Design Occupancy with psi(1), gamma, epsilon setting in a robust design occupancy model implemented in Program MARK version 9.0 (White 2020) to estimate initial occupancy (Psi), local extirpation (Epsilon), local colonization (Gamma), and detection probability for each season (p). I first assumed all parameters were constant for my initial “null” model and developed models describing relationships between animals and habitat attributes to find which habitat attribute had more impact in animal occupancy and detection probability.

Results

Most pellet groups found were within 25 cm of the transect (> 95%), and fresh (freshness < 1 week, 94%) for ungulates and fresh pellet groups that had luster on the pellet surface. Only fresh pellet groups (freshness <1 week) were used for analysis. I also tested and found that pellet group decay was faster in the spring and summer seasons due to dung beetles and rainfall. Fall and winter seasons were dry and cold and there was less degradation of the pellets during those time periods.

The signs of target species included pellet groups, footprints, and claw marks. Records of pellet groups were analyzed for ungulates (muntjac, serow, sambar) because footprints could only be found when the ground was wet soil. Claw marks were used as bear sign, but only a few were recorded during the survey. I recorded bear images/clips using infrared cameras (model: KG680, KeepGuard) in eight sampling sites. Six of the infrared cameras recorded bear images/clips, but only one of them had claw marks. Therefore, I excluded bear sign for later analysis because the detection rate of bear sign was too low to detect the presence of bears. As noted above, the footprints of ungulates were also excluded from analysis.

There was no significant difference of sign in the three ungulate groups between July 2013 and December 2015 ($P>0.05$, Figure 2.2). Further, signs of muntjac decreased when altitude increased ($r = -0.253$, $p <0.001$), and signs of sambar deer increased when altitude increased ($r = 0.42$, $p <0.001$). Signs of serow, on the other hand, showed no change as altitude changed ($P = 0.63$).

Muntjac

The best-supported model for muntjac was initial colonization, extirpation varied among sites with different elevation (EL) and density of canopy (DC) (AICc weight = 0.587; table 2.1). In this model, elevation (EL) and density of canopy (DC) affected local colonization and extirpation negatively. When the survey sites' elevation and density of canopy increased, it resulted in a lower probability of occupancy for muntjac (Figure 2.3, 2.4). The Psi (initial occupancy) was 0.15 (SE=0.10)、Epsilon (local extirpation) was 0.11 (SE=0.02)、Gamma (local colonization) was 0.91 (SE=0.06) (Table 2.2). I calculated output from the best-supported model, the equilibrium occupancy estimate for sites was 0.89 (=0.91/(0.91+0.11)).

Sambar

The best-supported model for sambar was that initial colonization and extirpation varied among sites with different elevations (EL) and forest types (FT) (AICc weight = 0.537; table 2.3). In this model, elevation (EL) and forest type (FT) affected local colonization and extirpation and were positively correlated with sambar occupancy. When the survey sites' elevation increased with broadleaf forest, it also resulted in a higher probability of sambar occupancy (Figure 2.5). The Psi (initial occupancy) was 0.35 (SE=0.14)、Epsilon (local extirpation) was 0.51 (SE=0.14)、Gamma (local colonization) was 0.09 (SE=0.02) (Table 2.4). I calculated output from the best-supported model and the equilibrium occupancy estimate for sites was 0.15 (=0.09/(0.51+0.09)).

Serow

The best-supported model for serow was that initial colonization and extirpation varied among sites with different distances to road (DR) and road types (RT) (AICc weight = 0.863; table 2.5). In this model, distance to road (DR) and road types (RT) affected local colonization and extirpation and were positively correlated with serow occupancy. When the road types were more natural (abandoned logging roads) and distance increased from road (where surveyors parked vehicles) to the survey sites, it resulted in a higher probability of serow occupancy (Figure 2.6). The Psi (initial occupancy) was 0.50 (SE=0.14), Epsilon (local extirpation) was 0.38 (SE=0.05), Gamma (local colonization) was 0.31 (SE=0.04) (Table 2.6). I calculated output from the best-supported model and the equilibrium occupancy estimate for sites was 0.45 (=0.31/(0.31+0.38)).

Discussion

In my study, I found population trends for muntjac, serow, and sambar deer to be stable. There was more fluctuation in the sign survey during the first year of my field survey than in the next two years, partly because indigenous hunters had heard of my project and reduced their hunting activities after the end of the legal hunting season. In 2013, there were fourteen cases of poaching. In 2014, there were six. In 2015, there were just five. The fall in poaching numbers was partly because my field surveyors were indigenous hunters and they informed other hunters about this ungulate monitoring project, which decreased indigenous hunters' activities in my study area and helped me further understand the real status of the ungulate population. I also deepened my understanding by observing indigenous cultural ceremonies and personally discussing with the indigenous hunters how many ungulates they had hunted each year. I found that the real numbers were far more than the numbers reported by the tribes. The statistical difference between ungulate signs and distances to the road was not significant because, given their age, indigenous hunters depended on mobile bikes for their hunting activities.

Due to questions of safety and human activities, it was difficult to conduct field surveys during the indigenous tribes' hunting season, which ran from January to May. For this reason, I found the most practical time period to carry out the surveys was from August to December in order to avoid external factors such as tribal hunting activities. Indigenous tribes applied for hunting permits 26, 31, and 34 times in 2013, 2014, and 2015, respectively. Every permit allowed an indigenous tribe to hunt 2-5 individuals (muntjac, sambar, and/or serow) for cultural use in 2-5 days. All hunters of a tribe participated in hunting activity under a permit. Most indigenous hunters in Taiwan use wire snares to catch ungulates and they do not recycle wire snares. Consequently, these hunting activities led to concern for the surveyor's safety in the low altitude and traffic approachable areas.

I found signs of ungulates indicating ungulate population status in winter, particularly for sambar deer. This finding allows indirect monitoring of ungulate population trends in diverse terrains and climates such as occur in Taiwan that is both practical and inexpensive.

I also found that forest canopy densities indicate ungulate preference. Muntjac was widespread in all altitudes but preferred more open forest areas while sambar deer preferred more dense forest areas. Serow, on the other hand, showed no preference in canopy density because the serow preferred steep bluff areas with little variation in canopy cover. Sambar deer, in contrast, preferred forested areas higher than 1,200 meters in altitude, but displayed migratory behavior when the seasons changed. For future field surveys, surveyors should set up sampling transects in moderate altitude areas between 800 meters and 2,000 meters in order to monitor ungulates for their population changes. In this way, the surveyors are physically safer, and the surveys are more financially affordable.

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Table 2.1. Result of multi-season occupancy models for muntjac during July to December 2013, May to December 2014, and March to December 2015 in Taiwan determined by robust design occupancy modeling.

Model	∆AICc	Wi	K	Dev.
Psi(.)Epsilon(EL+DC)Gamma(EL+DC)P(.)	0.00	0.587	8	315.36
Psi(.)Epsilon(EL)Gamma(EL)P(.)	2.93	0.136	6	322.46
Psi(.)Epsilon(EL+HA)Gamma(EL+HA)P(.)	3.23	0.117	8	318.59
Psi(EL)Epsilon(EL)Gamma(EL)P(.)	3.60	0.097	7	321.05
Psi(.)Epsilon(EL+RT)Gamma(EL+RT)P(.)	5.39	0.040	10	316.52
Psi(.)Epsilon(EL+FT)Gamma(EL+FT)P(.)	7.04	0.017	9	320.30
Psi(.)Epsilon(DC)Gamma(DC)P(.)	10.48	0.003	6	330.02

Table 2.2. The estimate of Psi (initial occupancy), Epsilon (local extirpation), and Gamma (local colonization) of the best-supported model (Psi(.) Epsilon(EL+DC) Gamma(EL+DC) p(.)) for muntjac.

Parameter	Estimate	Standard Error
Psi	0.15	0.10
Epsilon	0.11	0.02
Gamma	0.91	0.06

Table 2.3. Result of multi-season occupancy models for sambar during July to December 2013, May to December 2014, and March to December 2015 in Taiwan determined by robust design occupancy modeling.

Model	∆AICc	Wi	K	Dev.
Psi(.) Epsilon(EL+FT) Gamma(EL+FT) p(.)	0	0.537	9	231.81
Psi(.)Epsilon(EL)Gamma(EL)P(.)	0.30	0.463	5	240.45
Psi(.) Epsilon(RT+FT) Gamma(RT+FT) p(.)	25.50	0.000	11	253.06

Table 2.4. The estimate of Psi (initial occupancy), Epsilon (local extirpation), and Gamma (local colonization) of the best-supported model (Psi(.) Epsilon(EL+FT) Gamma(EL+FT) p(.)) for sambar.

Parameter	Estimate	Standard Error
Psi	0.35	0.14
Epsilon	0.51	0.14
Gamma	0.09	0.02

Table 2.5. Result of multi-season occupancy models for serow during July to December 2013, May to December 2014, and March to December 2015 in Taiwan determined by robust design occupancy modeling.

Model	∆AICc	Wi	K	Dev.
Psi(.) Epsilon(DR+RT) Gamma(DR+RT) p(.)	0.00	0.863	9	439.08
Psi(.) Epsilon(RT) Gamma(RT) p(.)	5.23	0.063	7	448.51
Psi(.) Epsilon(DC+DR+HA) Gamma(DC+DR+HA) p(.)	6.97	0.026	9	446.05
Psi(.) Epsilon(DC+DR) Gamma(DC+DR) p(.)	7.03	0.026	7	450.31
Psi(.) Epsilon(DC+GC+HA) Gamma(DC+GC+HA) p(.)	9.42	0.008	9	448.50

Table 2.6. The estimate of Psi (initial occupancy), Epsilon (local extirpation), and Gamma (local colonization) of the best-supported model (Psi(.) Epsilon(DR+RT) Gamma(DR+RT) p(.)) for serow.

Parameter	Estimate	Standard Error
Psi	0.50	0.14
Epsilon	0.38	0.05
Gamma	0.31	0.04

Figure 2.1. Map of study area in southeast Taiwan (above). Black dots represent locations of sign survey transect lines placed in three kilometer by three kilometer grid cells ranging from 326 to 2,218 meters above sea level in Taitung, Taiwan (below).

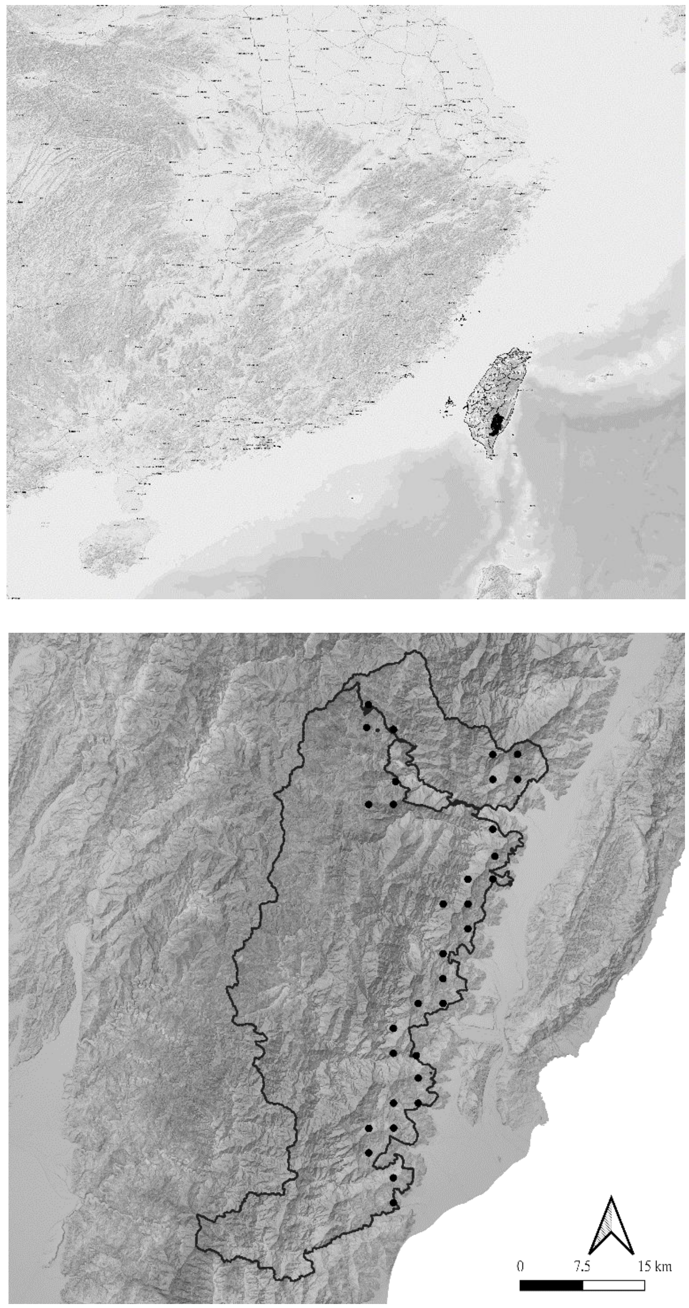


Figure. 2.2. Average number of pellet groups recorded for muntjac, sambar, and serow from 2013 to 2015.

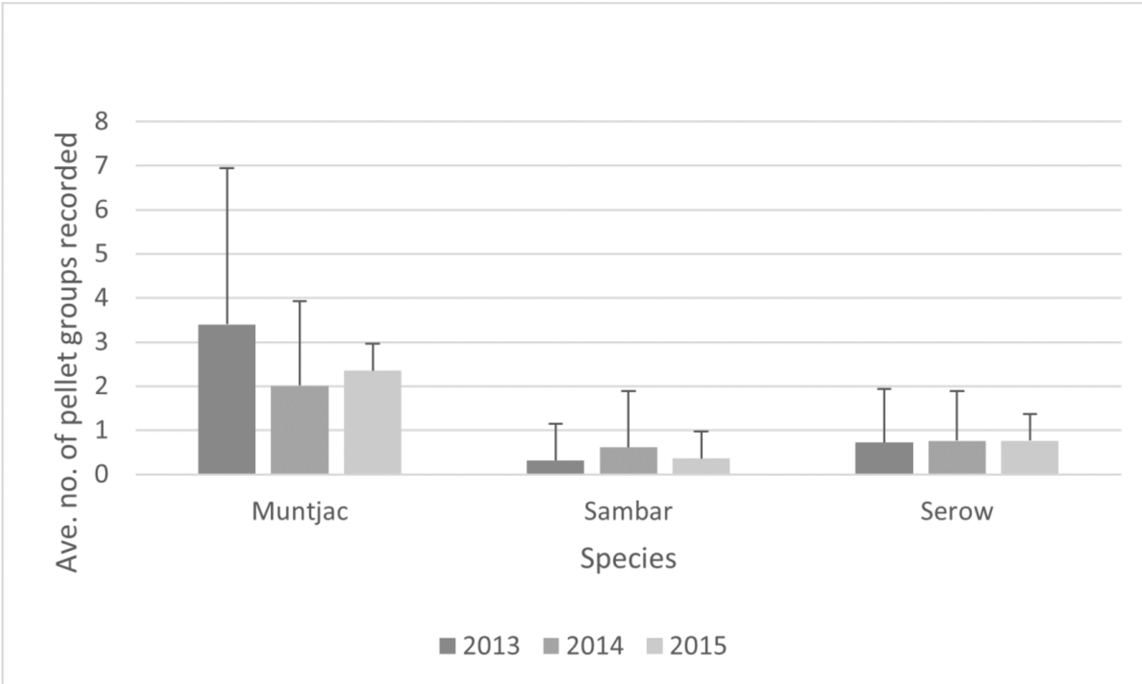


Figure 2.3. Effect of elevation (EL) on probability of occupancy (±95% CI) of muntjac in Taiwan.

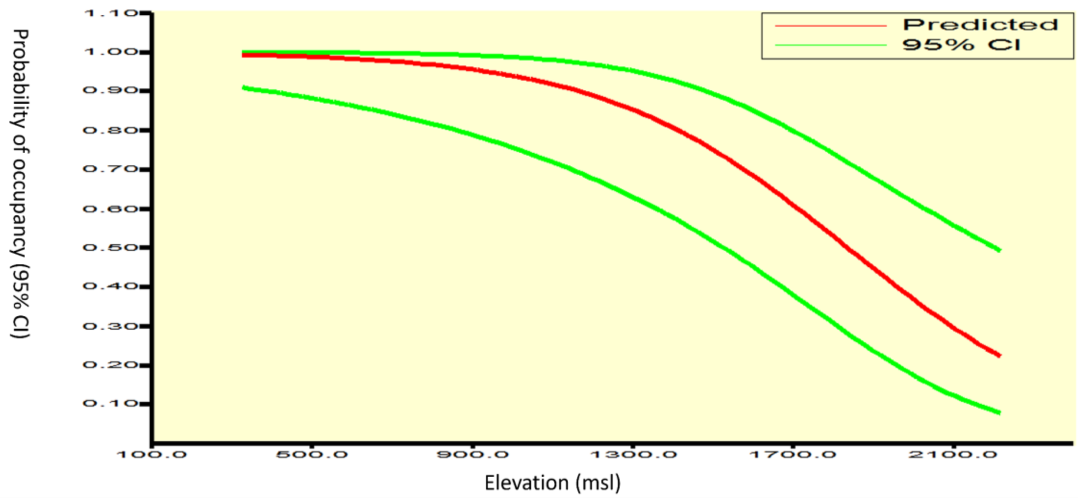


Figure 2.4. Effect of density of canopy (DC) on probability of occupancy (±95% CI) of muntjac in Taiwan.

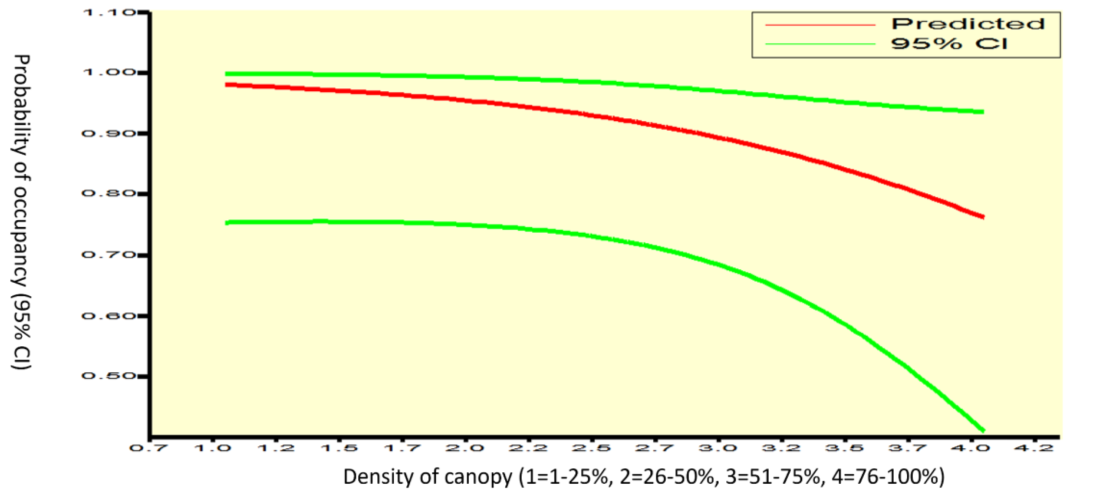


Figure 2.5. Effect of elevation (EL) on probability of occupancy (±95% CI) of sambar in Taiwan.

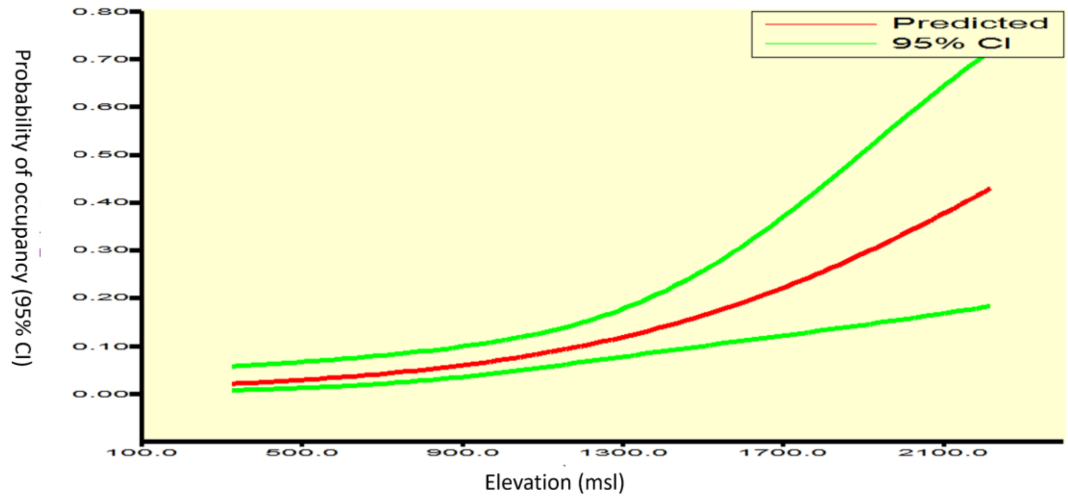
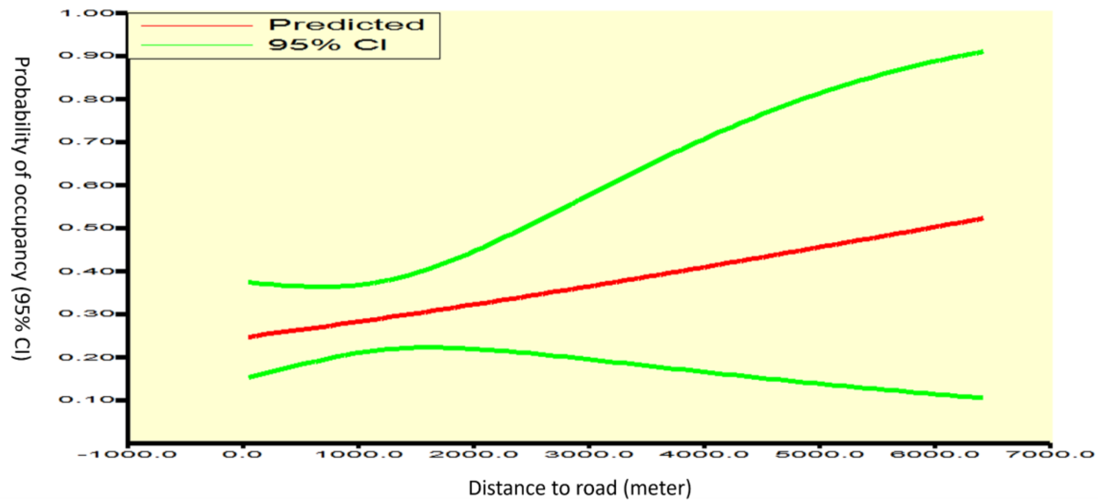


Figure 2.6. Effect of distance to road (DR) on probability of occupancy (±95% CI) of serow in Taiwan.



Chapter 3

Can indigenous hunters be scientific helpers?

A citizen science case study in Taiwan

Introduction

Citizen science projects have been employed on a variety of temporal and spatial scales across a variety of fields and species (e.g., Pattengill-Semmens and Semmens 2003; Lee et al. 2006; Delaney et al. 2008; Crall et al. 2010; Dickinson et al. 2010; Wood et al. 2011). There are many benefits gained from involving citizens in science projects. The most frequently mentioned include reducing funding or logistical limitations (e.g., Pattengill-Semmens and Semmens 2003), advancing survey and technical tools (e.g., Silvertowm 2009), improving sample sizes in spatial and temporal scales (e.g., Lepczyk 2005; Bois et al. 2011), promoting education (e.g., Nerbonne and Nelson 2008; Gallo and Waitt 2011), and involving citizen scientists in both scientific research (e.g., Oscarson et al. 2007) and decision-making (e.g., Danielsen et al. 2005; Ballard et al. 2008).

Citizen science studies have suggested frameworks for monitoring population trends (e.g., Bonney et al. 2009; Devictor et al. 2010; Conrad and Hilchey 2011). With data accumulated across seasons or years, scientists can assess population trends and evaluate their relationships with environmental factors (e.g., habitat and climate). Additionally, by connecting different local citizen scientists, we can better understand the distribution of target species on a larger scale (Allendorf et al. 2009).

However, the qualification or certification of citizen scientists, the problems (and associated solutions) of applying citizen science (e.g., data quality), and the lack of adequate procedures to evaluate citizen science data may lead researchers to question the data collected by citizen scientists. The uncertainty of data quality impedes further application of citizen science and project results have often been questioned by academics. For example, only 50 out of 128 invasive plants surveys carried out by citizen scientists had a data quality check before analysis (Crall et al. 2010). In addition, not all citizen scientists are comfortable making advanced scientific calculations (Gallo and Waitt 2011).

Nonetheless, with the benefits of advanced statistical and technical tools (Bonney et al. 2014) and the participation of local and indigenous communities (Kennett et al. 2014), citizen science has contributed more than data collection. Many citizen science projects have implemented participatory monitoring projects to raise local conservation awareness and promote action, especially in developing regions (e.g., Danielsen et al. 2007). Involving indigenous hunters as local experts can enhance a project’s probability of success and improve data quality (Elbroch et al. 2011) and through the interactive process, traditional knowledge can be bequeathed. Additionally, including indigenous hunters builds trust between tribes and government agencies when communicating scientific research and policy (Danielsen et al. 2010).

Taiwanese indigenous tribes have been urging the Taiwanese government to restore their traditional rights and lands for self-management (e.g., Lu et al. 2006), and hunting in accordance with cultural traditions (e.g., Tai et al. 2011). It is challenging to satisfy the needs of the Taiwanese aborigines’ hunting customs and the conservation of wildlife at the same time. At times, whether correctly or incorrectly, indigenous tribes are expected to demonstrate their ability to conduct scientific surveys, as well as translate their traditional knowledge in managing wildlife to society, in order to prove their ability to participate in governmental policy decision making and in modern wildlife management (Ens et al. 2012).

In order to demonstrate the abilities of indigenous hunters in conducting scientific surveys and providing wildlife management insights, I conducted an ungulate sign survey using indigenous hunters and skilled professionals. I also interviewed indigenous hunters about managing wildlife. My objectives were 1) to compare sign survey results from indigenous hunters and professionals; 2) to test engaging focal groups (indigenous hunters) as a bridge step for participatory management between indigenous tribes and a government agency; and 3) to test if the research design and results were rigorous enough to provide useful management data in order to encourage deeper involvement of local people in environmental and conservation issues.

Methods

Study Areas

This study took place in the national forest lands (about 2,260 km^2) in Taitung County (220 14’ ~230 26’N, 1200 51’~1210 27’E), southeastern Taiwan, which are managed by the Taiwan Forest Bureau (Figure 3.1). The terrain spans a wide range of elevations, from 0 meter to 3,600 meters above sea level, with varying ease of access (from flat paths to abandoned logging roads to steep hiking trails or animal trails), varieties of vegetation types (from deciduous to coniferous forest to mountain grassland), and diverse human disturbances (including poaching pressure). Additionally, a wide range of hunting activities are carried out in the region. To evaluate the effects of human disturbance on ungulates, my study area was confined to spaces within three-kilometers of established sign survey areas. The elevation of the study sites ranged from 326 meters to 2,218 meters above sea level.

Taitung County has a residential population of approximately 234,000. In addition to the Han population, there are seven indigenous tribes with a population of around 80,000. Five of these tribes live around national forest lands and have strong opinions about national forest and wildlife management because their ancestors lived on national forest lands before 1895 and because they have a hunting culture. Finally, 40% of Taiwan Forestry Bureau (TFB) employees in this district (a total of 260 individuals) are indigenous people.

Study Design and Protocols

Interviews of indigenous hunters

To expand the knowledge of traditional indigenous hunting in the region and to assess the relationships between the distribution of animal species, the application of conservation policy, and hunting activity, I interviewed an indigenous tribe of hunters, the Bunun, whose traditional hunting areas, including the location of the field survey, are now managed by the TFB. I focused on interviewing elder hunters or family representatives because young hunters are taught by elder hunters in Bunun tribes. Young hunters inherit their knowledge of hunting, hunting territories, wildlife, and how to interact with other hunters. I used a questionnaire with a semi-opened structure to conduct interviews. I gained help from a Bunun hunter to assist in making interviewees feel comfortable. He also helped with language interpretation because some elder hunters only speak their tribal language. I collected ages, hunting history, information about traditional hunting areas, and the relationship between hunted species and the cultural ceremony of the interviewee. The indigenous hunters I interviewed were mostly seniors (40-50 in ages) with experience inherited from their elders in skills, traditions, and hunting areas.

Sign survey data collection

To compare field data quality of indigenous hunters and experienced professionals, I conducted a field survey using fixed-width strip transects to collect sign data from three ungulates (muntjac, serow, and sambar), as described in chapter 2. Two survey groups conducted sign surveys 10-15 minutes apart and recorded their own observations without interaction between groups. Surveyors recorded each sign (pellet groups or footprints) and to which species it belonged along the transect. A total of four indigenous hunters participated in the project with the team leader being a veteran with more than twenty years’ experience tracking and hunting wildlife. Professionals from the TFB had more than five years’ experience surveying wildlife resources, and knew the study area well.

Poaching activity survey

I cooperated with the TFB to record illegal hunting-related activities between 2013 and 2015 in the sign survey area. This was because the traditional hunting territory of indigenous hunters are now national forests managed by the TFB. The TFB rangers patrol national forest lands and suppress illegal hunting activities. Local indigenous hunters knew that an ungulate sign survey was being conducted, but few of them participated in the survey. Illegal hunting-related activities such as the type of hunting (wire snares, hunting shelters, encounters with hunters, poaching arrests) and locations were recorded.

Data Analyses

Interview of indigenous hunters

I applied SPSS 24 (IBM, 2017) as an analysis tool for quantitative information to analyze the semi-open questionnaires. As for the qualitative questions, I synthesized the interviewee’s opinions and used induction to arrive at a more specific quantitative conclusion in order to give recommendations to the TFB.

Sign survey data collection

Due to the low density of the ungulate population, and in order to avoid human activities affecting the animal distribution and population, I compared data collected after the end of the legal hunting season in the relevant study areas. In that time period, which was between September to December in 2013, 2014, and 2015, I compared ungulate abundance using pellet group count data collected by both indigenous hunters and professionals, using an independent sample T-test with Levene's test for equality of variances in SPSS 24 (IBM, 2017).

Poaching activity survey

Poaching activity can not only reveal the patterns of hunting, but also indicate changes in traditional hunting itself. In order to assess these, I first analyzed forms of poaching activity compared to traditional hunting, including trap materials, ages of illegal hunters, and motivations, if applicable. I then plotted the locations of detected poaching to analyze the distribution of poaching activity to compare it to that in known traditional hunting areas.

Results

Interview of indigenous hunters

I interviewed a total of 47 senior hunters, including 3 between 45 and 49 years old, 22 between 50 and 54 years old, and 22 above 55 years old. Among them, 42 percent were not hunting at the time of the survey due to health and economic issues. According to the best recollections of these senior hunters, family hunting activity began before 1912 (forty-seven percent), between 1913 and 1920 (nine percent), between 1920 and 1945 (twelve percent), and between 1945 and 1950 (twenty-one percent). Eighty-nine percent indicated that there were five ceremonies using wildlife such as muntjac, serow, and sambar in their cultural practices, while eleven percent indicated that their ancestor spirit would decide which animal they could have when they hunted, implying that weather, season, and environment would affect the appearance of wildlife.

As for the number of animals needed for cultural ceremonies, answers ranged from the hunters' ability to carry their prey (eleven percent), not many (2-5 individuals, eight percent), no limits (depend on spiritual will, thirty-four percent), and the decision of an ancestor spirit (forty-seven percent). When it came to questions about tribal self-management in hunting regulations, 87 percent of the hunters thought the tribe could be responsible for self-management, yet only 40 percent were willing to participate in management. Interviewees showed worries about hunting culture being lost, with 74 percent worrying about the younger generation's lack of interest because modern life had changed so much in recent generations.

In addition, the attitudes of young hunters made interviewees uneasy because they did not respect their traditional culture (19 percent) and did not treasure their quarry (11 percent). Interviewees also indicated worry about losing their hunting culture due to too much control by government agencies (seven percent), and the weakening self-management ability of tribes (seven percent).

Sign survey data collection

My test of different pellet groups of species was based on 187, 108, and 196 records from indigenous hunters and professionals for muntjac, serow, and sambar respectively. The records were collected during the same time period (from September to December of 2013, 2014, and 2015) and in the same survey transects. There were no significant differences observed between the two pellet groups for the muntjac ($P = 0.11$; $df = 372$, $t = -1.59$), sambar ($P = 0.49$; $df = 390$, $t = -0.69$), or serow ($P = 0.63$; $df = 214$, $t = -0.48$).

Poaching activity survey

A total of 20 instances of poaching activities were recorded in the study area between 2013 and 2015. The numbers of hunting shelters, iron traps, guns, and wire snares were 11, 7, 6, and 3 respectively. The hunting shelters, iron traps, and wire snares were found and removed, and the six records of guns represented 12 poachers who were arrested by TFB officers patrolling in the forest lands.

The poachers were indigenous people and most of them were younger than 30 years old; only one poacher was above 50 years old. The poachers were reported by local communities not only because they hunted with guns, but also because they hunted outside of their traditional hunting areas. They were arrested by both the TFB and police officers. Eight of the 20 instances of poaching were detected along or near logging roads because poachers were using motor vehicles and reported by local communities. Fourteen of the twenty instances occurred in traditional Bunun hunting areas, while six records were detected outside traditional hunting areas.

Discussion

In this study, indigenous hunters demonstrated their ability in collecting scientific research data, and data quality appears to rely on the skills needed to gather the data that were linked to their culture. In addition, I found that the participants, the indigenous hunters, showed changes in attitude towards the TFB and wildlife management because of their participation. After the first year, participants received respect from tribes and more indigenous hunters expressed their willingness to participate. I suspect that this was because the project provided those hunters a venue to use their traditional hunting skills and demonstrate their knowledge (Dolrenry et al. 2016). This indicated to the TFB that it could enroll local tribes, especially indigenous hunters, in wildlife monitoring and management to mitigate conflicts between indigenous tribes and the TFB.

My study indicates that the greater involvement of local people in monitoring activities leads to less time required to collect data and shorter times required in decision-making following monitoring (Danielsen et al. 2010). Indigenous hunters demonstrated their ability using traditional methods to track and classify animals, as well as to estimate wildlife populations. Additionally, based on the records of poaching reports, I confirmed that local tribes had an interest in protecting their traditional rights. These indicated indigenous tribes had motivation and ability to participate in decision- or policy-making. Therefore, I encouraged indigenous hunters to build connections with the wildlife management agency, the TFB, in order to assist in revising wildlife management policies or regulations. At the beginning of my study, most indigenous hunters replied that they were not interested in participating in the policy- or decision-making process, but they were more willing to be part of it after realizing that the results of wildlife monitoring could influence the agency's management as well as their traditional use in wildlife. Indigenous hunters were also interested in how wildlife management was influenced by the results of the study in which they had participated. We see, therefore, that the wildlife monitoring scheme was able to stimulate indigenous hunters' curiosity and encourage them to participate in wildlife management thereafter.

Finally, this study shows evidence that enrolling indigenous hunters in wildlife monitoring has advantages in reducing poaching activities. Indigenous hunters informed me that, after their enrollment in the wildlife monitoring project, other hunters demonstrated interest in knowing the results of the monitoring and decreased both their hunting and poaching activities during my research period.

The main point of contention between agencies and indigenous tribes was related to the species and number of animals required for traditional indigenous ceremonies. My study showed that there was no consensus among indigenous hunters, and therefore agencies could not set up hunting regulations relating to the species and numbers of wildlife required for indigenous ceremonial use. A communication bridge or committee would be helpful in constructing consensus (Wu et al. 2020) or the TFB process leaders with the capacity to facilitate productive participation from indigenous hunters (Doyle-Capitman et al. 2018). Additionally, given that there are no reserve areas under indigenous control in Taiwan, indigenous tribes are unable to manage wildlife themselves. This indicates that promoting engagement, collaboration, and partnership with indigenous hunters is crucial (Tengö et al. 2021). I suggest that the TFB should involve indigenous hunters in wildlife monitoring plans, open a collaborative knowledge dialogue to communicate with different parties, and encourage indigenous hunters to offer their traditional knowledge in order to help the TFB interpret survey results.

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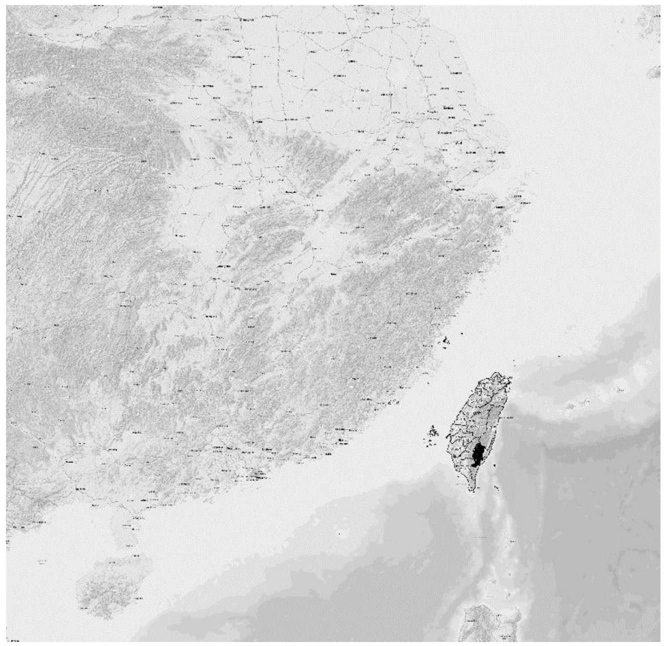
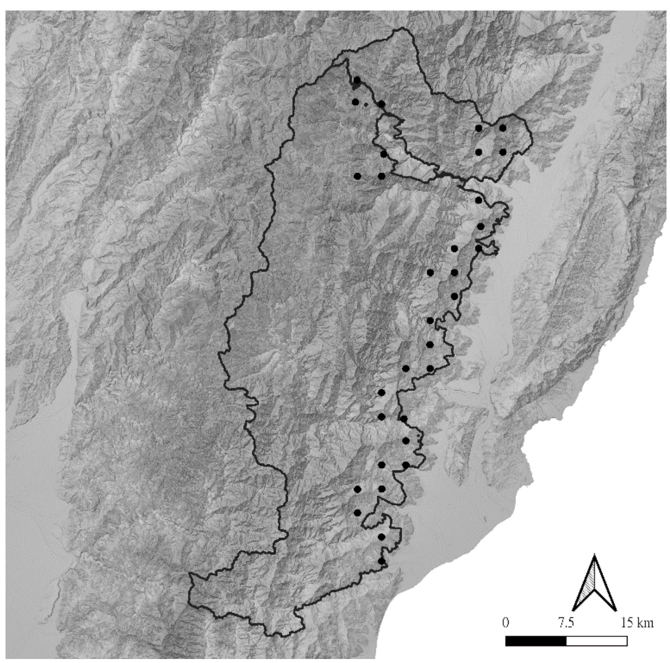
Figure 3.1. Map of study area in southeast Taiwan (above). Black dots represent locations of sign survey transect lines placed in three kilometer by three kilometer grid cells in Taitung, Taiwan (below).





Chapter 4

Turning conflict into cooperation:

Integrating indigenous tribes into the forest management system

Introduction

Indigenous tribes have proven to be helpers in scientific and practical fields in many regions (e.g., Danielsen et al. 2007; Denham 2017), yet land ownership issues often hamper indigenous tribes' ability to participate in local land management, particularly in Taiwan's forests. Forest lands used by indigenous tribes before 1895 occupied nearly 60% of the Taiwanese island and are now managed by the Taiwan Forestry Bureau (TFB). Because of this, Taiwan's indigenous tribes have urged the Taiwanese government to restore their traditional rights and lands for self-management (e.g., Lu et al. 2006) as well as hunting rights (e.g., Tai et al. 2011) on the lands that the government now manages.

The transfer of the ownership of forest lands needs consensus building among indigenous tribes and government agencies, as well as a revision of laws that govern them. To solve real problems on the ground, a consensus-building platform also is necessary to allow stakeholders to discuss the issues in order to arrive at mutually acceptable land management principles (Carrasco et al. 2016). A variety of incentives have been used to encourage the participation and retention of stakeholders in achieving a balance between economic development and ecosystem conservation e.g., developing ecotourism to create or support self-financing for tribes or communities (Krüger 2005; Vannelli et al. 2019), participatory management (Schusler et al. 2000), and community-based co-management (Child 2012; Johnson et al. 2015).

To mitigate conflicts and build consensus in managing forest lands, the Taitung district office of the TFB initiated the Community Forestry Project (CFP) in 2002, the Hunting Apply & Report Project (HARP) in 2006, and the Tribal Ecotourism Committee Project (TECP) in 2014. These projects encourage stakeholders to be aware of their community natural resources, to build consensus, and to communicate with government agencies. Although consensus among stakeholders may not be achieved, bringing stakeholders together can facilitate consensus regarding land management (Carrasco et al. 2016).

Indigenous tribes have shown their ability in conducting scientific surveys as well as incorporating their traditional knowledge of managing wildlife into the decision-making process. They have also shown that their ability in modern wildlife management will benefit communities and governments (Ens et al. 2012). In developing regions, when local benefits are addressed as a long-term incentive, the results of conservation actions are more favorable (Krüger, 2005; Biggs et al. 2016). Additionally, local stakeholder involvement in data gathering and analysis can also be applied to ecosystem goods and services (Danielsen et al. 2014). However, community-based initiatives should not replace government and academic experts entirely (Johnson et al. 2015).

Community-based co-management is one method of involving local people. It can create opportunities to develop innovative solutions to reduce negative wildlife impacts, strengthen community, enhance appreciation for resources (Schusler et al. 2000) and open dialogue with local communities (Biggs et al. 2016). However, it is more effective if tribal and community leaders and local authorities are included in the committee composition (Adamson 2010) because the positive response of local people's involvement may shorten the time needed in management decision-making, especially at the local level (Danielsen et al. 2010).

Before initiating indigenous tribes' participation in forestland management, the TFB implemented the CFP to make connections with tribes, empower tribes to communicate with government agencies, and build tribal consensus in managing natural resources. Tribes with CFP experiences were able to apply for the TECP. The proposed goals of the TECP were to reduce conflict among government agencies and tribes, enhance tribal economics, and respond to tribes' claims of sovereignty over their forest land. I participated in a TECP in order to observe the benefits and the costs of the program, gain insights from participants, and consolidate suggestions to improve the success of the TECP process.

Methods

Study Areas

This study took place on the national forest lands (about 2,260 km^2) in Taitung County (220 14' ~230 26'N, 1200 51'~1210 27'E), southeastern Taiwan, and was managed by the TFB (Figure 4.1). Four tribes participated in this study: two Bunun tribes, Hai-Duau and Yan-Paing, in Hai-Duau and Yan-Ping Townships, located near the mountains, and two Amis tribes, Dou-Lan and Dou-Li, in Dong-He and Chang-Kang Townships located near the ocean.

The Bunun tribes live in this area where the terrain spans a wide range of elevations, from 0 meter to 2,100 meters above sea level. Most Bunun people (around 8,000) live in the Hai-Duau and Yan-Ping Townships and have many connections with the national forest lands through their jobs as well as hunting activities,.

The Amis tribes, in contrast, live on the plains and have more interaction with non-indigenous cultures. The Amis have adopted modern agricultural techniques but keep their traditional bamboo boat fishing culture. The Amis population in the study area is around 7,600. Most Amis people live with other non-indigenous people spread throughout Dong-He and Chang-Kang Townships.

Community Forestry Project (CFP)

The TFB initiated the CFP, a bottom-up project, in 2002. Tribal representatives consulted with TFB staff before initiating the tribe's CFP. The idea of the CFP is to first encourage community or tribal associations to describe the nature of their community and cultural resources, and then reach a group consensus in how they wish to manage their natural and cultural resources sustainably. A CFP plan can be applied for a second time in a year if the first time is completed and approved by the TFB reviewing committee. The TFB reviewing committee is composed of TFB senior staff, scholars, and experts in helping communities.

The four indigenous tribes participated in the CFP to varying degrees between 2003 and 2017. I collected their project data to evaluate the project outcomes. I analyzed the structure of these four tribes' CFP as well as evaluated the factors that affected the success of the projects. These community-based projects focused on increasing the communities' abilities to communicate with tribe members and government agencies, inventory community resources, and build community consensus.

Tribal Ecotourism Committee Project

The Taitung district office of the TFB initiated a 2-year partnership project with the Dou-Lan and Dou-Li tribes in 2014, and the Hai-Duau tribe in 2015. (The Yan-Ping tribe failed to participate in this project because the tribe committee did not approve the proposal.) This partnership project organized an ecotourism advisory committee, the Tribal Ecotourism Committee, to discuss how government agencies could help tribes develop their economic industry through the participatory management of forest lands. I participated in the partnership project as an observer from 2014 to 2017.

The advisory committee (13-17 individuals) was composed of representatives from local tribes (3-5 individuals), the township agency (3-5 individuals), experts/scholars (3-5 individuals), and the TFB (3-5 individuals). The committee was created in such a way as to apply internal motivators, such as tribe interests, to encourage local participation (Souto et al. 2014). The chair of the committee was elected from among the non-governmental committee members at the first meeting. The goal and meeting topics were initiated by committee members, with the TFB providing administrative and financial resources. Experts and scholars contributed their experience or insights, and the decisions at the conclusion of the meeting were executed and then reported by the TFB at the next committee meeting. The committee meetings were held every six months, and additional meetings were held if suggested by a committee member.

Interviews of TFB staff

I interviewed five TFB officers who were responsible for the three tribes' ecotourism committee projects throughout the project period. I collected their opinions regarding the operation of the committee, success factors, and management strategy. All interviewee opinions were weighted equally (0-100) for later analysis. I interviewed each participant in person for 20-35 minutes, and each officer was interviewed after each committee meeting to document their opinions concerning tribal associations.

Results

Community Forestry Projects

The Hai-Duau tribal association participated in the CFP 10 times between 2003 and 2017. Five of their 10 projects were related to natural resources, such as wildlife inventories and survey training. Three of the 10 projects were related to developing eco-tours containing cultural elements, such as the importance of wildlife and plants in the tribes' cultures and lives. Two of the 10 projects were related to patrols to prevent illegal hunting or plant-collecting activities.

The tribal association leaders were voted in for a 2-year term, and an association leader could have two consecutive terms. In 14 years, the Hai-Duau tribal association leadership changed five times. The tribal association voted for five different leaders during this period and only two leaders held two turns. I found that the Hai-Duau tribe association applied fewer times for the CFP in natural resources inventory because data from the previous leader's term was not passed on, which indicated that tribal consensus was not thoroughly discussed and built.

The Yan-Pin tribe participated in the CFP 25 times between 2003 and 2017. Twenty-one of their 25 projects focused on patrolling, and wildlife resource inventories. This could be because this tribe had more active hunters than other tribes and they had a deep knowledge of the hunting territory. Four of the 25 projects focused on helping younger hunters become aware of the tribe's hunting boundaries, and how to observe animal signs and set traps.

As with the Hai-Duau tribe, there were numerous changes in tribal leadership, and in 14 years, the tribal leader changed six times, with no leader holding two terms. This tribe applied CFP mostly in forest lands patrol and natural resources inventory because information from previous leaders was not transferred to the new leaders. This indicated that, as with the Hai-Duau tribe, tribal consensus was not established.

The Dou-Lan tribe participated in the CFP 12 times between 2003 and 2017. The Amis people fish rather than hunt in their tradition and the Dou-Lan tribe applied CFP in forest lands patrol-related projects mostly because they wanted to prevent illegal hunting and plant-collecting activities while developing tribal tours and preserving culture. Three of 13 projects were patrol plus culture transition projects in preserving traditional fishing activities. Another three of 13 projects were patrol plus safari tour developing projects. Six of 13 projects were patrol plus wildlife resource inventory projects.

As opposed to the Bunun tribes, there was more consistency in the Dou-Lan leadership, and the tribal leader changed only four times in 14 years. Four tribal leaders were elected during this period, and two of them had two terms. This indicated there was an established tribal consensus, and the tribe was in agreement in wanting their hunting culture and wildlife resources to be part of the eco-tourism based safaris.

The Dou-Li tribe participated in the CFP 11 times between 2003 and 2017. Seven of 11 projects were related to culture and natural resource inventories. These activities were chosen with the goal of helping young tribe members understand how their ancestors used and respected natural resources. Three of 11 projects were patrol-related in teaching tribe members how to recognize and remove wildlife traps. One of 11 projects involved training tribal members to translate elements of their life related to nature into tour commentary, with the goal of developing ecotourism projects.

The Dou-Li tribe had only two leaders in 14 years, indicating the tribe's members thoroughly discussed their visions and the necessary steps to take when applying for the CFP; this in turn indicated that tribal consensus had been established (A summary of these Community Forest Projects is provided in table 4.1).

Tribal Ecotourism Committee

Hai-Duau committee

The Hai-Duau committee held three meetings between 2015 and 2016. The committee had the firm goal of recruiting tribal members to form a mountain-hiking assistance association. The goal of the association was to manage the Chia-Ming-Lake national trail, including trail cleaning and maintenance, porter services, and poaching prevention. The Chia-Ming-Lake national trail is famous for its mountain meteorite lake located at approximately 11,000 feet above sea level and attracts around 15,000-18,000 visiting hikers per year.

Another goal of the committee was to increase local community income through promoting eco- and cultural- related tourism in both national forest lands and community areas. They planned to do this by training tribal members to become guides who could offer tourists an ecotourism experience with natural and cultural elements.

During the first committee meeting it was decided that the township agency would recruit community members to form the hiking-assistance association mentioned above, and that the TFB would provide training resources to help members increase their abilities in trail maintenance, for safety and ecotourism training, and for community building.

During the second committee meeting, doubts arose about joining a hiking-assistance association because an assistance club was already operating and community members were not sure of the benefits of joining this new association. Therefore, committee members decided that the township agency should hold public hearings with community members before the community formed a hiking assistance association.

The third committee meeting discussed collaborating between a potential hiking-assistance association and the TFB. In this meeting, the committee suggested that the TFB should build connections with this potential hiking-assistance association because the existing one had rejected suggestions for collaboration from the committee. They also suggested generating an agreement between the hiking-assistance association and the TFB to manage the Chia-Ming Lake national trail and cabins. In addition, the committee suggested that the association should cooperate with the township agency to build consensus within the community about the distribution of benefits, the duties and rights of members, and the quality of service.

Hai-Duau committee meetings were held in April 2015, November 2015, and August 2016. The committee had only three meetings and could not hold a fourth because the township agency withdrew from the partnership as well as the hiking-assistance association. The township agency thought their mission was accomplished after the hiking-assistance association was established, yet the hiking-assistance association failed to build member consensus in defining service, member duties and rights, and benefit distribution. The TFB still has connections with the township agency and aids the hiking-assistance association in such tasks as recruiting association members in Chia-Ming-Lake national trail maintenance and cabin service.

Dou-Lan committee

The Dou-Lan committee held three meetings between 2014 and 2015. The goals of this committee were straightforward: to maintain the Dou-Lan-Shan hiking trail on the local tribe’s spiritual mountain and to guide tours incorporating natural and cultural elements.

In the first committee meeting, it was suggested that the tribal association help patrol national forest lands with funding provided by the TFB. In addition, the committee suggested that the tribal association document natural and cultural resources while patrolling, incorporate survey data into tour material, and disseminate that knowledge among tribal members.

The second committee meeting suggested that the tribal association continue to request CFP funding to train tribal association members in developing their abilities in surveying resources and guiding tourists. In addition, to help the tribal association craft development strategies, the committee suggested that the TFB invite experts to share their insights and experience in implementing CFP in community and ecotourism development with the tribe association members.

The third committee meeting recommended that the TFB and the tribal association build a stronger partnership. In response to the needs of hikers as well as needs of the tribal association, the TFB offered part-time jobs for tribal association members in trail maintenance and promoting guided tours of the trail. The committee also suggested the tribal association continue to apply for CFP funding to construct the Dou-Lan-Shan hiking trail tour with tribal and cultural features.

The Dou-Lan committee meetings were held in April 2014, November 2014, and July 2015. The committee had only three meetings and could not hold more because the tribal association withdrew from the partnership. The tribal association improved their ability in project planning and implementation with the help of the CFP funding, but decided to apply for other governmental resources and left TFB projects in 2016.

Dou-Li committee

The Dou-Li committee held four meetings between 2014 and 2016. The goals of this committee were to preserve shoreline beaches, national forests, and the tribe’s fishing culture. It also wanted to develop a more modern project that was oriented around surfing tourism.

In the first committee meeting, it was suggested that the tribal association help patrol national forest lands and funding for this was provided by the TFB. In addition, the committee suggested that the TFB and the tribal association map out patrol areas and target species to be protected. The tribal association requested use of the national forests for cultural purposes, and the committee suggested the TFB build a partnership with the tribal association.

In the second committee meeting, it was suggested that the TFB increase planting traditional plants because it was important to the tribe in areas in the national forest lands patrolled by the tribe. This would help the tribe develop a culture-related trail for ecotourism in national forest lands. In addition, the TFB confirmed that the tribal association could apply to use national forest lands for cultural use when needed. Furthermore, the committee suggested including shoreline and beach areas into their patrols because they were important for both traditional and cultural reasons, and they were also an attraction for surfers and tourists. The tribal association wanted to preserve their culture in this beach and at the same time adopt tourism to increase tribal revenue.

In the third committee meeting, the group discussed strategies to improve national forest land patrols, a natural resources survey, and beach management. A tribal style beach tower, funded by the TFB, was built to serve as an example of tribal culture and to address protection of the environment.

The fourth committee meeting discussed the possibility of a tribe or community reserve for the tribal association because the tribal association had demonstrated achievements in environmental protection, tour education, and the tribal members' consensus to conserve the national forest and the beach environments. In addition, the tribal association had developed a mechanism to monitor cultural heritage and natural resources as well as to build a partnership with the TFB.

The Dou-Li committee meetings were held in April 2014, November 2014, September 2015, and March 2016. During the meetings there was thorough discussion between the tribal association and the TFB. Through consensus and partnership, plans to manage the national forest lands and shoreline beaches were successfully built between these two stakeholders.

Results of Interviews

I synthesized the information from the interviewees, and found there were eight factors that affected the success of the tribal ecotourism committee: tribe goal affirmation; diversity of committee members; tracking of the committee's conclusions;

supportive resources (funding, training, and bureaucracy); tribal consensus; policy/agent support; benefit distribution; and ability of communication with agency. I asked interviewees to rate (0-100) performance of tribal association in these eight factors and this revealed that tribal consensus (86.8±4.6), benefit distribution (75.3±5.0), and ability to communicate with agency (71.6±6.1) were the three influential factors for a successful tribal association. The first step of the three ecotourism committees was to build the tribal associations' consensus in developing an association and managing national forest lands (Table 4.2).

Hai-Duau committee

The tribal association was not yet established when the committee was initiated in 2015. The TFB invited the township agency, tribal leaders, and experts to organize the ecotourism committee and to encourage tribal association participation after the tribal association was established. The purpose was to engage the tribe in national forest lands management, as well as to mitigate tension between the TFB and the tribes.

In this committee, interviewees agreed that tribal consensus (86.6±4.9), supportive resources (73.8±16.2), and benefit distribution (70.6±10.1) were the most influential success factors (Table 4.3). The TFB supported the committee's suggestion that the township agency should help establish a tribal association in order to take over the operation of Chia-Ming-Lake national trail, including trash cleaning, trail maintenance, and cabin service. This operation would not only increase tribal income but also mitigate poaching activity in that area. All required supportive resources, such as training, funding and administrative assistance, were provided by the TFB. In spite of the assistance provided by the TFB, the tribal association failed to demonstrate their consensus and determination to persevere in the committee. Interviewees concluded that the committee had done their best to help the tribal association build consensus and benefit distribution principles before the tribal association could operate service of Chia-Ming-Lake national trail, and affirmed that the TFB support resources had been delivered. However, the tribal association failed to provide an operating team to take over management of Chia-Ming-Lake national trail as well as to present their agreement in benefit distribution.

Dou-Lan committee

The tribal association was established before the committee was initiated. The TFB initiated this ecotourism committee in response to the tribal association. The purpose was to engage the tribe in Dou-Lan-Shan national trail management, as well as provide jobs and income for tribal members.

In this committee, interviewees agreed that tribal consensus (86.4±4.3), benefit distribution (74.4±5.7), and ability to communicate with agency (70.0±2.8) were the most influential factors for achieving success (Table 4.4). The tribal association was in firm agreement that they wanted to manage the Dou-Lan-Shan national trail in order to preserve one of their spiritual symbols and to develop culture-based tourism. The committee supported this request and suggested the tribal association enhance the tribe's skills in natural and cultural interpretation, as well as generate a benefit distribution agreement. All required support resources such as training, funding, and administrative assistance were provided by the TFB. Nonetheless, the tribal association eventually decided to leave the project because the tribal association acquired funding from other sources. Interviewees concluded that the committee did their job to guide the tribal association in building up tribal consensus.

Dou-Li committee

The tribal association was established before the committee was initiated. The TFB initiated this ecotourism committee in response to the tribal association's request. The purpose was to engage the tribe in national forest management, as well as preserve the tribe's fishing culture.

In this committee, interviewees agreed that tribal consensus (87.4±4.1), benefit distribution (79.0±1.6), and ability to communicate with agency (74.8±4.8) were the most influential factors in achieving success (Table 4.5). The tribal association had a partnership with the TFB before the committee was initiated, and had consolidated consensus in preserving a beach that was important spiritually and culturally, and in developing culture-based tourism. In addition, the tribal association requested permission to utilize a national forest land that includes a beach area for cultural (fishing ceremony) and fuel use. The committee suggested the TFB respond to the tribal association and adopt the tribal association into their management system. The ability of the tribal association to deal with project planning and execution was affirmed by the TFB as well as the committee. Furthermore, consensus of the tribal association was consistent and demonstrated throughout the period the committee was in operation. Interviewees impressed the tribal association with their consensus and benefit distribution agreement.

Discussion

Community participation has significant positive influences on ecotourism development for the sustainability of protected areas (eg., Rahman et al. 2022), yet community members need to build up their capacities and abilities to participate in ecotourism as well as resource affirmation before community-based tourism is developed (Rodrigues and Prideaux 2018). The Community Forestry Project (CFP), a small fund project, provided the tribal associations an opportunity to build consensus, be aware of community cultural and natural resources, and empower the tribes. This project was initiated in 2003 and helped the tribe and community associations thrive. From this research, I found tribes who had experience with the CFP enhanced their ability to build and maintain tribal consensus, implement projects, and communicate with government agencies. While the CFP provided a fundamental basis for communities, the TECP provided a two-way mechanism in sharing knowledge, tribe development advice, cooperation and collaboration (Austin et al. 2019).

In this research project, three tribal associations participated in the CFP beginning in 2003, but only the Dou-Li tribal association successfully transferred their experience to work with the Dou-Li ecotourism committee. One crucial factor was that the leader of the Dou-Li tribal association stayed with the tribe even though the leader did not have a title in the association. The leader spent more than a decade with the tribal association and fostered a new generation to participate in tribal affairs; this allowed the tribal association to develop sustainable management. In the Dou-Lan tribal association, on the other hand, the association leader shifted several times, indicating that core values of the tribal association were still under construction, and the process of building tribal consensus had to be re-done each time the association leader changed. Finally, the Hai-Duau tribal association was newly formed for the TECP, but members mostly had experience in association operation. The Hai-Duau Township organized this new tribal association because the previous association leader refused to participate in the TECP for political reasons.

In this research, staff whose duties were to work on the CFP for the TFB had more than ten-year's experience in consulting and working with the tribal associations. From the interview process, I found interviewees pessimistic about the results of the Hai-Duau and Dou-Lan ecotourism committees. Interviewees expressed concern that the Hai-Duau and Dou-Lan tribal associations had not consolidated tribal consensus before participating in managing national trails. For instance, the Hai-Duau tribe association had only considered revenues from the Chia-Ming-Lake national trail cabin service, and not how much effort would be needed in areas such as service training, maintenance costs, salary, and benefit distribution. Ultimately, it became clear that the Hai-Duau tribal association failed at the beginning stage.

In order to develop a variety of abilities such as project planning and implementation, tribal member training, and the ability to communicate, the tribal association needed to build consensus before participating in the CFP or the TECP. However, only the Dou-Li tribal association had built consensus and knew that their goal was developing a self-sufficient tribe. To achieve this goal, the tribal leader and members had thorough discussions, in the form of inter- and intra- party communication, on topics such as member duties and rights, and new member recruitment. From the development process, tribal members could further communicate with each other and achieve consensus and the tribal goal.

I found that tribal consensus played a crucial role in uniting tribes because tribal leaders do not stay with the tribe forever, but consensus does, and the tribal association was a communication platform for tribes and other agencies. In addition, tribal consensus evolved alongside the background and interests of members, government policies, and environmental conditions. Interviewees strongly suggested that the tribal association should build tribal consensus before applying for TFB projects, especially when the projects related to funding or revenue distribution (Rodrigues and Prideaux 2018).

I generated a framework from my study to help tribal development (Figure 4.2). The first half of the framework is to assist the tribal association to prosper. To do so, tribal leaders first must affirm the goals or visions of a tribal association with tribal members. Second, tribal leaders should build a consensus among tribal members. Third, tribal leaders should discuss establish the process for distribution of benefits with the tribal members before any economic revenues are generated an construct a pathway for tribal members to communicate with government agencies in order to pursue tribal goals as well as collaborate with the agencies. Experts played a role in this in order to assist the tribe in building the necessary skills of the tribal leaders.

The second half of the framework is to indicate a communication platform where the various stakeholders can exchange information. This communication platform contains representatives from tribes, government agencies, and experts with diverse knowledge and experiences that can contribute to tribe development. The decisions and suggestions made through the platform should be sent back to the stakeholders, and the stakeholders implement the decisions and consider the suggestions in order to offer feedback to the communication platform for further discussions. This platform offers a virtuous circle to empower tribes' development.

Recommendations

This case study of the ECP and TECP process working with indigenous tribes in Taiwan suggests that in order to build successful projects involving national forest managers and indigenous tribes the following items need to occur:

1. Communities or tribes need internal discussions to achieve a consensus regarding development, efforts, and benefit distributions.
2. Government agencies need to assure funding, administrative and technical aids, and patience.
3. A communication platform with diverse background experts could alleviate conflicts and accelerate consensus building among stakeholders.

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Table 4.1. Topic, frequency, and alternation of leaders of three indigenous tribes participating in CFP from 2003-2017.

Name of Tribe	Topic of CFP	Frequency	Alternation of Tribal Leaders
Hai-Duau	Nature resources inventory	5	5
	Ecotour-Hunting Culture	3	
	Patrol	2	
Yan-Pin	Patrol-Wildlife Resource	21	6
	Patrol-Hunting Culture	4	
Dou-Lan	Patrol-Hunting Culture	3	4
	Patrol-Wildlife Tours	3	
	Patrol-Wildlife Resource	6	
Dou-Li	Culture-Natural Resource	7	2
	Patrol-Hunting Culture	3	
	Ecotour	1	

Table 4.2. Factors and scores recognized by the TFB participants that relate to tribal ecotourism committee success.

Factor relates to tribal success	Scores (0-100)	Priority for success
Tribal consensus	86.8±4.6	1
Benefit distribution	75.3±5.0	2
Ability to communicate with agency	71.6±6.1	3
Diversity of committee members	-	
Tracking of the committee's conclusions	-	
Supportive resources (funding, training, and bureaucracy)	-	
Policy/agent support	-	
Tribe goal affirmation	-	

Table 4.3. Factors and scores recognized by the TFB participants that relate to Hai-Duau ecotourism committee success.

Factor relates to tribal success	Scores (0-100)	Priority for success
Tribal consensus	86.6± 4.9	1
Benefit distribution	70.6±10.1	2
Ability to communicate with agency	-	
Diversity of committee members	-	
Tracking of the committee's conclusions	-	
Supportive resources (funding, training, and bureaucracy)	73.8±16.2	3
Policy/agent support	-	
Tribe goal affirmation	-	

Table 4.4. Factors and scores recognized by the TFB participants that relate to Dou-Lan ecotourism committee success.

Factor relates to tribal success	Scores (0-100)	Priority for success
Tribal consensus	86.4± 4.3	1
Benefit distribution	74.4± 5.7	2
Ability to communicate with agency	70.0± 2.8	3
Diversity of committee members	-	
Tracking of the committee's conclusions	-	
Supportive resources (funding, training, and bureaucracy)	-	
Policy/agent support	-	
Tribe goal affirmation	-	

Table 4.5. Factors and scores recognized by the TFB participants that relate to Dou-Li ecotourism committee success.

Factor relates to tribal success	Scores (0-100)	Priority for success
Tribal consensus	87.4± 4.1	1
Benefit distribution	79.0± 1.6	2
Ability to communicate with agency	74.8± 4.8	3
Diversity of committee members	-	
Tracking of the committee's conclusions	-	
Supportive resources (funding, training, and bureaucracy)	-	
Policy/agent support	-	
Tribe goal affirmation	-	

Figure 4.1. Map of study area in Taitung County, southeast region of Taiwan.

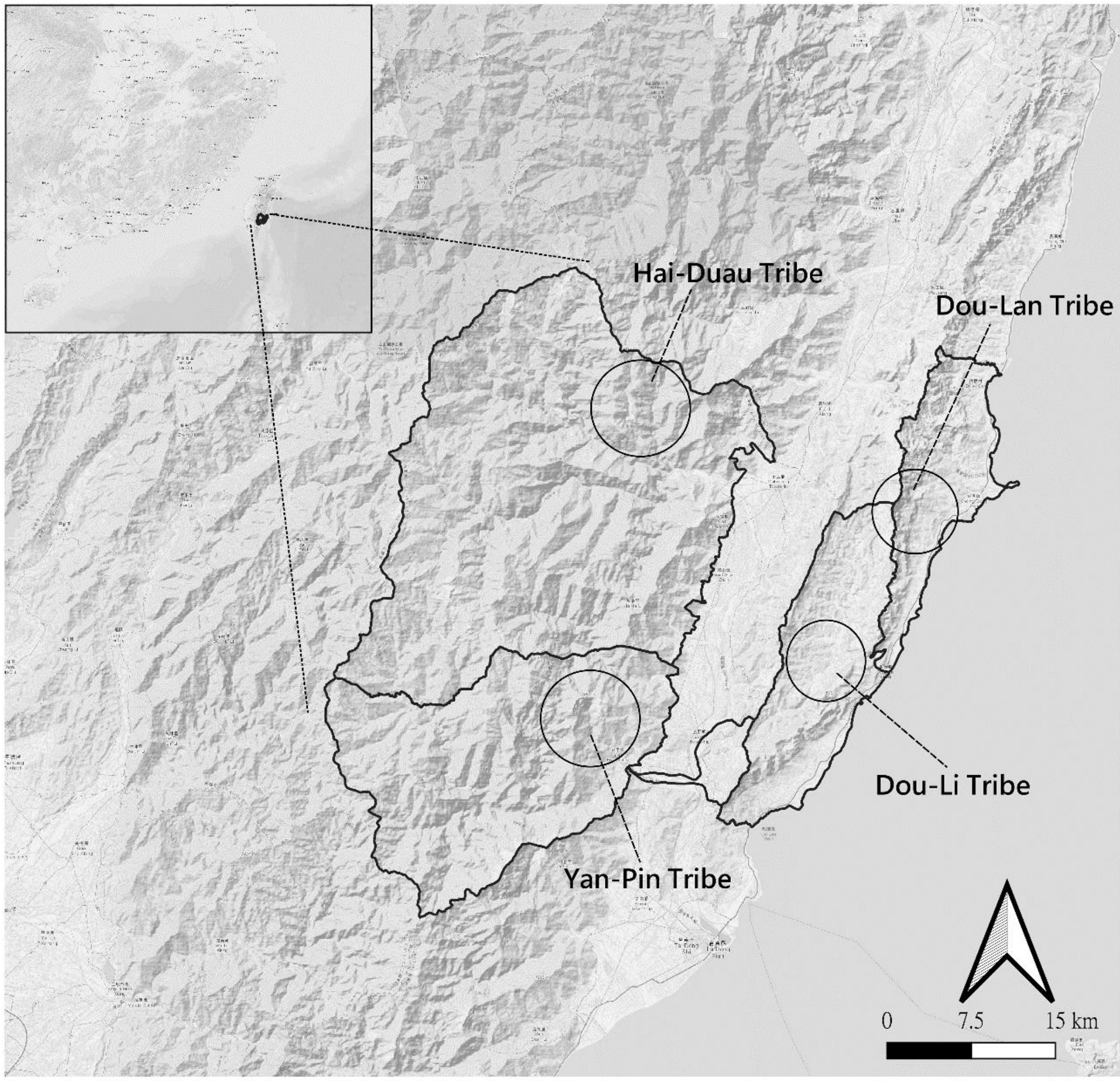
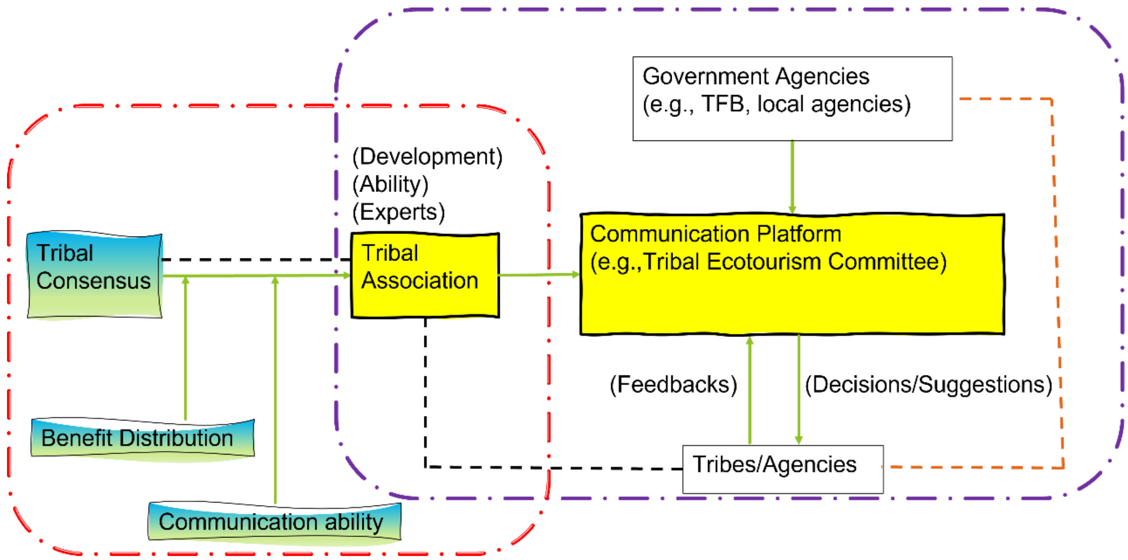


Figure 4.2. A framework of inter-communication of tribal association (red-dashed line) and intra-communication of stakeholders (purple-dashed line).



Chapter 5

Conclusion

My research focused mainly on developing and applying an efficient method for tracking wildlife population changes in order to meet wildlife management challenges. It also responded to the requests of indigenous tribes to hunt wildlife without restrictions. In addition, I confirmed the validity of indigenous hunters as citizen scientists who could collect wildlife sign data in preparation for collaborating with government agencies in wildlife management. My research also synthesized requirements that indigenous tribes need to meet in order to build an economically and ecologically sustainable co-management relationship with government agencies (Gullison and Hardner 2018). To facilitate connections to both indigenous tribes and government agencies, an appropriate citizen science monitoring project, such as my ungulate sign survey project, could provide a stepping stone to involving indigenous tribes in co-management with government agencies. Further research should focus on eliminating prejudices between indigenous tribes and government agencies.

Incorporating indigenous tribes benefits wildlife monitoring

The indigenous hunters in my study had intrinsic advantages in wildlife monitoring because of their familiarity with their traditionally occupied national forest areas. In addition, their hunting traditions made them more sensitive in observing wildlife. My research indicated that indigenous hunters had the ability to comply with scientific research protocols and a willingness to participate in wildlife management. This offered an opportunity to alleviate tension between a government agency and indigenous tribes in Taiwan. Incorporating indigenous hunters into the design of the ungulate monitoring plan was an interface that allowed the creation of trust between the two parties. This in turn allowed the inclusion of indigenous tribes' participation in wildlife management policy design, practice, and feedback.

The next step should be to enhance indigenous hunters' participation in this ungulate monitoring scheme and to translate findings based on the collected data to the indigenous hunters. To further optimize the monitoring scheme, the TFB should synthesize feedback and questions from indigenous hunters throughout this process. Lack of trust makes this time-consuming. I participated in this process as a TFB employee for more than twelve years during my dissertation research, and have formally interacted more than a hundred times with tribes. I spent much time explaining my research to indigenous hunters, encouraging them to participate in my research, and asking them to help me interview other indigenous hunters. The process and results of my research should benefit both indigenous tribes and government agencies in wildlife management; it should also benefit tribal development.

Sign survey method indicating wildlife population trends

Compared to a direct monitoring method, an indirect monitoring method such as sign surveys makes wildlife monitoring approachable and acceptable to Taiwanese government agencies like the TFB. This is because the wildlife habitat is in national forest areas containing hills and mountains. My research found fall and winter seasons are appropriate for conducting sign surveys to measure wildlife population information because pellet groups of ungulates are more persistent; such studies allow monitors to avoid disturbances such as indigenous hunting seasons and extreme weather when conducting the surveys.

I also set infrared camera traps in eight of my 32 sign survey sample plots to test the credibility of sign surveys. I did not use infrared cameras as a tool to collect ungulate data because of theft by poachers and the malfunctioning of the equipment in the high humidity forest environment. Ungulates such as muntjac, serow, and sambar deer are not distinguishable from images, but trap rates such as the number of photos per 100 trap nights can be used as an index to represent overall population status (Burton et al. 2015). The camera trap results also corresponded with my sign survey results that showed that ungulates had migratory behavior between seasons. Another reason I chose sign surveys over infrared cameras as a data collection tool was that I wanted to develop a wildlife monitoring method that could be operated by indigenous hunters. Finally, I wanted the method used to remain closer to indigenous traditional practices, such as wildlife tracking and observation, to increase the participation of indigenous hunters and to gain their feedback; this would in turn improve the sign survey methods. According to my research, indigenous hunters changed their attitudes and perspectives when sharing their traditional knowledge in tracking wildlife in partnership with government agencies. They also showed their interest in participating in wildlife monitoring and management.

Consensus building makes co-management possible

Research emphasizes the importance of co-management in wildlife management, especially when working with local communities or indigenous tribes (e.g., Danielsen et al. 2005; Cox et al. 2010; Fernandez-Gimenez et al. 2010; Conrad and Hilchey 2011). My research notes the process the TFB used in working with indigenous tribes, from building trust to encouraging co-management. Internal and external trust, tribe consensus, and patience from both the government agency and tribes were key points to success in wildlife co-management. Arriving at tribal consensus was the most important milestone and variable for both tribes and the government agency, but was a time-consuming process related to tribal leadership and internal discussion. Indigenous tribes need incentives to inspire their internal discussions and to help them form tribal consensus. With more than 10 years of data from the TFB's community forestry projects, I conclude that wildlife-related ecotourism managed by the tribe is an acceptable solution for both tribes and the government agency. This consensus consolidates my finding that indigenous hunters have the potential to participate in wildlife management as more than citizen scientists.

According to my research, to achieve a more flexible, localized, and approachable wildlife management, the TFB needs to recruit local indigenous hunters to participate in wildlife monitoring as citizen scientists (Weckel et al. 2010), maintain participants' retention, and involve them in the decision-making process (Danielsen et al. 2005; Ballard et al. 2008). The TFB also needs to integrate indigenous knowledge into monitoring and management strategies (Lauter 2020). This citizen scientist application in management is a process of trust building to induce indigenous hunters to participate in the wildlife monitoring design as participatory management. Extending wildlife monitoring to participatory management is a transition to co-management in response to indigenous tribes' concern about their hunting cultural heritage; it also benefits tribal economics and wildlife management. It is important to understand key feedback between indigenous tribes and natural factors that influence wildlife, land use and indigenous values. Such a wildlife management policy could provide valuable information in constructing sustainable conservation and management strategies in national forest lands.

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