To the Graduate Council:

I am submitting herewith a dissertation written by Cara Lin Bridgman entitled "Habitat Use, Distribution and Conservation Status of the Mikado Pheasant (*Syrmaticus mikado*) in Taiwan." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Ecology and Evolutionary Biology.

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Vice Provost and Dean of Graduate Studies

(Original signatures are on file with official student records.)

HABITAT USE, DISTRIBUTION AND CONSERVATION STATUS OF THE MIKADO PHEASANT (*SYRMATICUS MIKADO*) IN TAIWAN

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Cara Lin Bridgman
December 2002

DEDICATION

This dissertation is dedicated to
my grandfather, James Malvern Clopton,
and to my great aunt, Dr. Anna Josephine Bridgman.

It was my grandfather's vision that inspired me to attain this degree
and my aunt's experience that paved the way, tempering dreams with reality.

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ABSTRACT

To evaluate the conservation status of Taiwan's mikado pheasant, *Syrmaticus mikado* (Phasianidae), I test the similarity of preferred habitat to primary and secondary forest, develop models of habitat availability within Taiwan, and examine population trends within two locations inside Yushan National Park. The characteristics of locations with pheasant activity were most similar to secondary forest: high shrub stem counts and low canopy and leaf litter coverage. None of these variables were applicable to geographic information systems analysis. To the known extent of range and area of occupancy, I compared a model based on the habitats described in field guides. This model underestimated extent of range, confirmed that 39% of the pheasant's range is protected inside parks and reserves, and suggest that Taiwan potentially has 6477 km^2 of habitat available to *S. mikado*. Within Yushan National Park, there may be as many as 10,000 *S. mikado*. The small home ranges (<0.86 km^2) and the lack of movement across the 400 m separating the study sites imply limited gene flow between populations and poor ability to colonize suitable habitat. There were 58 pheasants per km^2 in the primary forest site and 48 in the secondary forest site. At the primary forest site, the population appeared stable. At the secondary forest site, the population declined 65% from 3.56 pheasants encountered per day in 1989-1992 to 1.24 in 1996-1999 due to poor productivity because of increased numbers of nest predators (from 1.4 predators per day to 2.2) and the cooler weather conditions during hatching. In 1989-1991, most rainfall was in the last week of June, but rainfall was evenly distributed throughout May and June of 1996-1998. Poaching, a threat to adult pheasants, increased during this time from 0.06 incidents per day to 0.23. As the pheasant lives at elevations naturally disturbed by landslides, tolerance for disturbance would be adaptive. Because of the poaching, the limited nature of the pheasant's distribution, and until the population decline is identified as indicating a general trend or part of a cyclic pattern in the pheasant's population dynamics, I recommend *S. mikado* be considered vulnerable to the risks of extinction.

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PART 1

INTRODUCTION

Species extinctions since the 1600’s have been attributed anthropogenic causes: hunting (23%), habitat loss (36%), and competition with introduced species (39%; World Conservation Monitoring Centre 1992). These effects are predicted to increase as the human population increases. Two of these factors are ascribed to the threatened status of the mikado or long-tailed blue pheasant, *Syrmaticus mikado* (Ogilvie-Grant)(Galliformes: Phasianidae), a pheasant endemic to the high mountains of Taiwan: hunting pressure and habitat destruction (McGowan and Garson 1995, Fuller and Garson 2000). If we are to conserve this and other native species, we need to understand how human activities affect them. One way to gain this understanding is to compare populations in pristine and disturbed habitats.

Species extinctions have long been attributed to hunting pressure. Martin (1984) suggested that human migration into North America via the Bering Straits caused many of the extinctions in the Pleistocene. Hunting pressure continues to threaten species survival and includes hunting for museum collections, market driven hunting for jewelry and medicine, and subsistence hunting for food. New Zealand’s Huia, (*Heteralocha acutirostris*) was hunted to extinction in 1907 for museum specimens (Williams and Given 1981). In Palau, Dugongs (*Dugong dugon*) are endangered because they are routinely poached to produce jewelry from their ribs (Marsh et al. 1995). Subsistence hunting in Amazonia has caused the local depletion of populations of large primates (Alvard et al. 1997).

The most striking example of extinction via hunting pressure is the Passenger Pigeon (*Ectopistes migratorius*). Estimates of total population size at the time of European colonization of North America vary, but there may have been several billion individuals. Hunting pressure was severe and increased with time. In a 4-week period in 1874, about 25,000 pigeons were exported daily from Michigan (Schorger 1955). Due to this indiscriminate hunting, the population plummeted from "countless numbers" (with over one million in a flock) in the early 1870's to extinction in the wild less than thirty years later.

Often habitat destruction and other factors exacerbate hunting pressure. Habitat destruction contributed to the extinction of Passenger Pigeons by eliminating mast-bearing trees and forcing the pigeon to the edges of its breeding range (Schorger 1955). Reduced by hurricanes, Samoan fruit bat (*Pteropus samoensis*) populations were further diminished by over-hunting (Craig et al. 1994). Endemic to Madagascar, Delacour's Grebe (*Tachybaptus rufolavatus*) and the Madagascar Pochard (*Aythya innotata*) may be extinct due to a combination of factors: hunting pressure, habitat loss, and competition with exotics (Wilme 1994).

Habitat loss, alone, affects a species in many ways, from eliminating appropriate feeding or breeding sites to restricting range, which can affect dispersal patterns. In Florida, five vertebrate taxa have gone extinct in the past 50 years as a result of urban expansion and the development of agriculture and range lands: the Ivory-Billed Woodpecker (*Campephilus principalis*), the Dusky Seaside Sparrow (*Ammodramus maritimus nigresces*), the Chadwick Beach

Cotton Mouse (*Peromyscus gossypinus restrictus*), the Pallid Beach Mouse (*P. polionotus decoloratus*), and Goff's Pocket Gopher (*Geomys pinetus goffi*) (Kautz 1993).

A form of habitat destruction, habitat fragmentation has been described as "the single greatest threat to biological diversity" (Noss 1991). Of the 128 species of birds existing in 1911 in the cloud forests of San Antonio, Columbia, 24 were extinct by 1959, and 16 more were locally extinct by 1994 (Kattan et al. 1994). Most of these birds were vulnerable because they were living at the extremes of their altitudinal ranges. Isolated by habitat fragmentation, these populations were prevented from migrating and colonizing new areas. Even after deforestation practices stopped, extinction continued for many of the species with small population sizes living in these cloud forests (Kattan et al. 1994). Thus, habitat loss and fragmentation have long term effects causing extinction of populations generations after the destruction occurred (Kattan et al. 1994, Tilman et al. 1994).

The small and limited populations resulting from restrictions in habitat often exhibit low levels of genetic diversity, further affecting the ability of a species to survive (Ralls et al. 1988, Berger 1990, Roelke 1993). Because of its severely restricted range, the Florida Panther (*Puma concolor coryi*) has lost genetic diversity resulting in defects and abnormalities that greatly reduce the ability of this subspecies to survive. The entire population of Florida Panthers is currently estimated at 30-50 adults, but the allocated 12,000 ha reserve is adequate to contain the home range of only three or four adult panthers (Maehr 1990).

Island endemics are especially vulnerable to species introductions, hunting pressure, and habitat destruction (Johnson and Sattersfield 1990). Of the 11% of the world's birds currently threatened with extinction, 39% are restricted to islands, and most of these are endemics (Johnson and Sattersfield 1990). This high level of endemism makes island species particularly vulnerable to extinction. The decline and extinction of bird species on 36 islands, ranging in size from both the North and South islands of New Zealand (115,000 and 151,000 km^2, respectively) to the minute land masses of the Galapagos island chain, have been attributed to predation by introduced rats, cats and pigs (Atkinson 1985, Veitch 1985). As an additive effect, hunting by humans is a very important cause of extinction (Johnson and Sattersfield 1990).

Hunting pressure and habitat loss account for 63% of the threats to Galliformes (data compiled from King 1981). Of all the bird orders, Galliformes have the third highest number of threatened species, following the Passerines and Parrots (Appendix: Table 1.1), although there are several bird orders with higher percentages of threatened species. Currently, 109 galliform species are threatened with extinction (Table 1.2, Hilton-Taylor 2000), of which 18 are island endemics (from del Hoyo et al. 1994). Within the Galliformes, 75% of the Asian pheasants are threatened (Fuller and Garson 2000). McKinney and Lockwood (1999) labeled pheasants and parrots “global losers” in the face of human activities due to their large size and low fecundity. Demographic information on galliform species is generally lacking (Green and Hirons, 1991).

Galliformes, such as *S. mikado*, are particularly susceptible to hunting pressure because of their colorful plumage and chicken-like bodies. Flying only to escape predators and to reach roost sites, these primarily terrestrial and ground-nesting birds are also threatened by human-introduced predators such as pigs and rats. Most Galliformes are naturally rare and have limited ranges (King 1981). "Any species with highly restricted range is at great risk of extinction from spatially localized forces" (Simberloff 1994).

The stresses limiting the survival of a species can vary from outright over-harvesting, habitat loss, and competition with exotic species to subtle changes in the quality of habitat. Therefore, study of species in their original habitats is important to identify subsequent changes and the causes of changes in demographic patterns (Green and Hirons 1991). Studies of species like *S. mikado*, which exist in both original and marginal habitat are especially useful, permitting the identification of limiting factors and permitting evaluation of the potential for the species to adjust to disturbed habitat.

Syrmaticus mikado is endemic to Taiwan (Figure 1.1), an island bisected by the Tropic of Cancer. This solitary and secretive bird was first described in 1906 (Ogilvie-Grant 1906). Even so, it has been observed on roads, in logging camps, and in a variety of habitats at elevations over 1000 m (Severinghaus 1977). Mainly associated with primary forests (Severinghaus 1977), it is known to live and breed in regenerating clear cuts (Bridgman 1994). It is probably polygynous, with females generally producing one clutch of one to five eggs each year (Severinghaus 1977, Yao et al. 1998, personal observation).

Syrmaticus mikado was initially classified as vulnerable (Groombridge 1993-1994), primarily due to hunting pressure (King 1981). Currently listed as near threatened (Fuller and Garson 2000), *S. mikado* has also been considered safe (McGowan and Garson 1995). In Taiwan, however, it is considered endangered (Yang 1993). Even though the pheasant is found in a variety of habitats (Severinghaus 1977, Severinghaus and Severinghaus 1987), the pressures of economic development are increasing, particularly habitat destruction from road construction and forestry activities. In spite of a sweeping governmental ban on hunting (Yang 1993), poaching still occurs and its effects are unknown.

In this dissertation, I identify the habitat most suitable for *S. mikado*, model its geographic distribution, and examine population trends from 1989 to 1999. Severinghaus (1977) first noticed that *S. mikado* are encountered more frequently in some forest areas than in others. He described the bird as "locally common." In 1990, Alexander et al. mapped the spatial pattern of pheasant activity on a 1.5 km section of the Chunta Logging Road at Kwan Kao (Figure 1.2) inside Yushan National Park, documenting that the pheasants were more frequently observed in certain sections. This pattern of encounters along a logging road in a secondary forest suggests that the pheasant may be selecting for particular habitat characteristics within the secondary forest. From July 1996 through July 1998, I monitored the Chunta Logging Road for pheasant activity. At the same time, I monitored pheasant activity on the nearby Patungkwan Trail, at Dwei Kwan, which passes through primary forest habitat. Pheasant activity in both forests was patchily distributed. These observations of pheasant encounters suggest the following questions, which are addressed in Part 2:

> Are the habitat characteristics of locations with pheasant activity different from those of random locations?
> Do areas of use share a common set of characteristics?

None of the habitat characteristics identified in Part 2 were at a scale large enough for island-wide analysis. In Part 3, therefore, I develop two models to estimate the area of habitat available for use by *S. mikado* based on descriptions in available field guides and on the land-use types found within the study area. Telemetry and sighting data from banded and radio-tagged pheasants were used to estimate the boundaries of the study area and the population density of *S. mikado*. In addition to estimating population size, the objectives of Part 3 were to generate minimum and maximum estimates of habitat available to *S. mikado*, and to compare these estimates to the known extent of range and area of occupancy (P.F. Lee, personal communication).

In 1989, I first began observing and banding *S. mikado* inside the study area (Alexander et al. 1990), adding radio-telemetry in 1991(Bridgman 1994). Returning to the study area in 1996, I noticed a sharp decline in the rate at which I encountered and trapped pheasants. In Part 4, I examine the differences in encounter rates for *S. mikado* between 1989-1992 and 1996-1999 and assess weather patterns, human activity, and the encounter rates for other animals, including predators of *S. mikado,* to address the following questions:

> Did the relative abundance of *Syrmaticus mikado* decline between 1989-1992 and 1996-1999?
> If so, what factors account for the decline?

In Part 5, I follow the guidelines of the Species Survival Commission (IUCN 2001) to evaluate the conservation status of *S. mikado*. This evaluation is based on the pheasant's use of habitat, the availability of habitat within Taiwan, the legal protection given to the pheasant and its habitat, the estimated population size, and the trends and activities observed within the study area.

The fact that the populations studied here are within a national park helps to describe the level of protection Taiwan currently offers. Observation of movements between the adjacent study sites offers insights into the degree of genetic isolation and the ability of *S. mikado* to colonize habitat as it becomes available. Although the trends and conclusions presented in this dissertation are specific to *S. mikado*, some of the patterns may be applicable to other of Taiwan’s endemic species.

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APPENDIX

Table 1.1: Threatened species within each order of the Class Aves. Taxonomy and number of threatened species follows Hilton-Taylor (2000). Species diversity follows Gill (1990). Threat categories included here are: extinct, endangered, vulnerable, conservation dependent, near threatened, and data deficient (Species Survival Commission 1994).

Order	Members	Species (N)	Threatened (N)	Threatened (%)
ANSERIFORMES	Waterfowl	150	39	26
APODIFORMES	Swifts and Hummingbirds	428	66	15
CAPRIMULGIFORMES	Nightjars	105	22	21
CASUARIIFORMES	Emus and Cassowaries	5	5	100
CHARADRIIFORMES	Shorebirds	331	67	20
CICONIIFORMES	Herons, Storks, Ibis	120	36	30
COLIIFORMES	Mousebirds	6	0	0
COLUMBIFORMES	Pigeons and Doves	303	110	36
CORACIIFORMES	Rollers and Kingfishers	200	55	28
CUCULIFORMES	Cuckoos	148	23	16
DINORNITHIFORMES	Kiwis	4	4	100
FALCONIFORMES	Birds of Prey	288	72	25
GALLIFORMES	Fowl-like Birds	281	109	41
GAVIIFORMES	Loons	5	0	0
GRUIFORMES	Cranes and Rails	209	99	47
PASSERIFORMES	Perching Birds	5225	1031	20
PELECANIFORMES	Pelicans and Boobies	62	22	35
PICIFORMES	Woodpeckers, Barbets	383	45	12
PODICIPEDIFORMES	Grebes	21	7	33
PROCELLARIIFORMES	Tube-nosed Seabirds	104	77	74
PSITTACIFORMES	Parrots	340	143	42
PTEROCLIDIFORMES	sand grouse	16	0	0
RHEIFORMES	Rheas	2	2	100
SPHENISCIFORMES	Penguins	18	12	67
STRIGIFORMES	Owls	146	56	38
STRUTHIONIFORMES	Ostriches	1	0	0
TINAMIFORMES	Tinamous	47	11	23
TROGONIFORMES	Trogons	37	10	27

Table 1.2: Threatened species for each family within the order Galliformes. Taxonomy and number of threatened species follow del Hoyo et al. 1994, McGowan et al. 1995, McGowan and Garson 1995, and Fuller and Garson 2000. Species diversity follows del Hoyo et al. 1994. Threat categories included here are: extinct, endangered, vulnerable, conservation dependent, near threatened, and data deficient (Species Survival Commission 1994).

Family	Members	Species (N)	Threatened (N)	Threatened (%)
Megapodiidae	Megapodes	19	8	42
Cracidae	Chachalacas, Guans and Curassows	50	13	26
Meleagrididae	Turkeys	2	0	0
Tetraonidae	Grouse	17	1	6
Odontophoridae	New World Quails	32	11	34
Phasianidae	Pheasants and Partridges	155	75	48
Numididae	Guineafowl	6	1	17

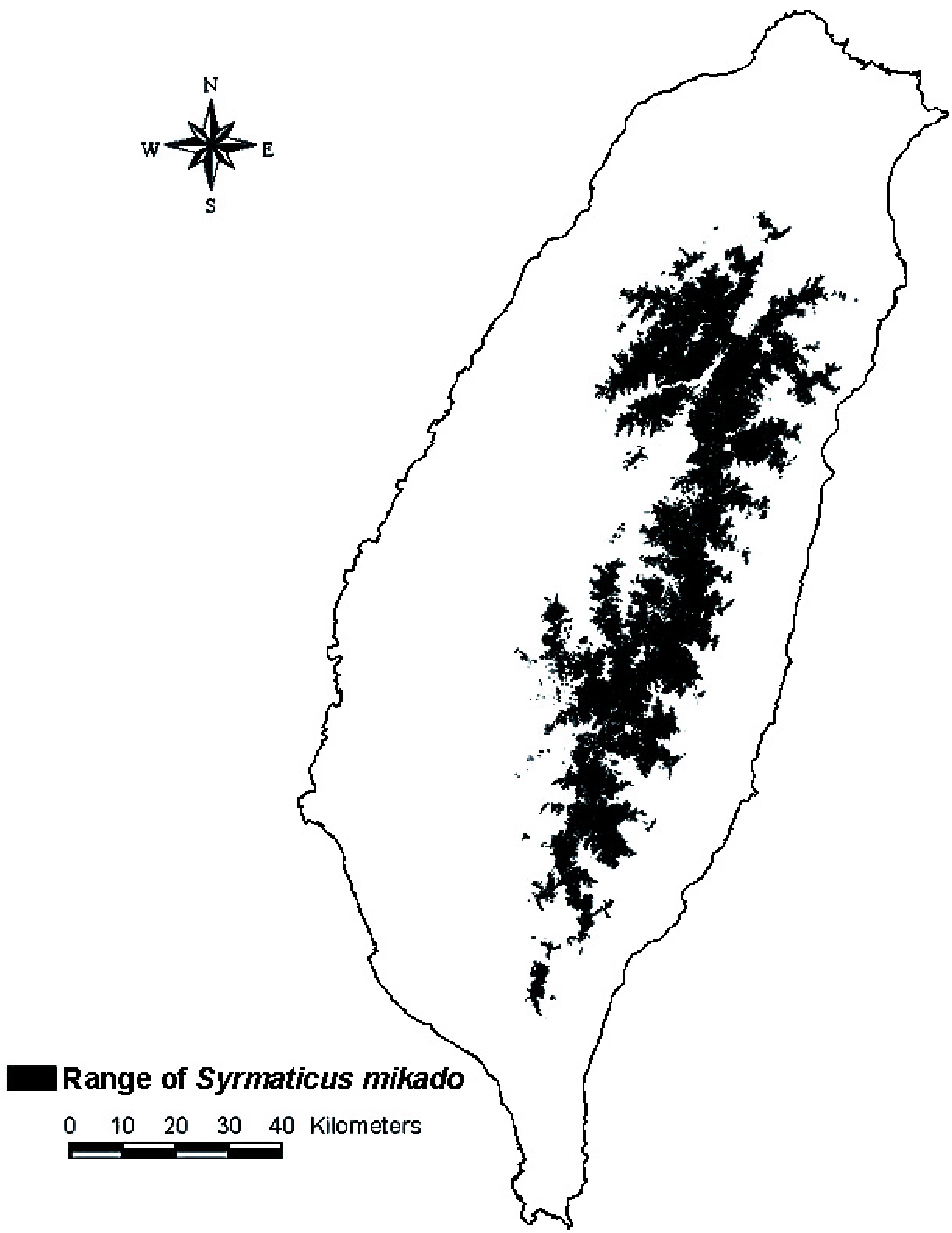

Figure 1.1: Distribution of *Syrmaticus mikado*, endemic to Taiwan. Range is based on Severinghaus 1977.

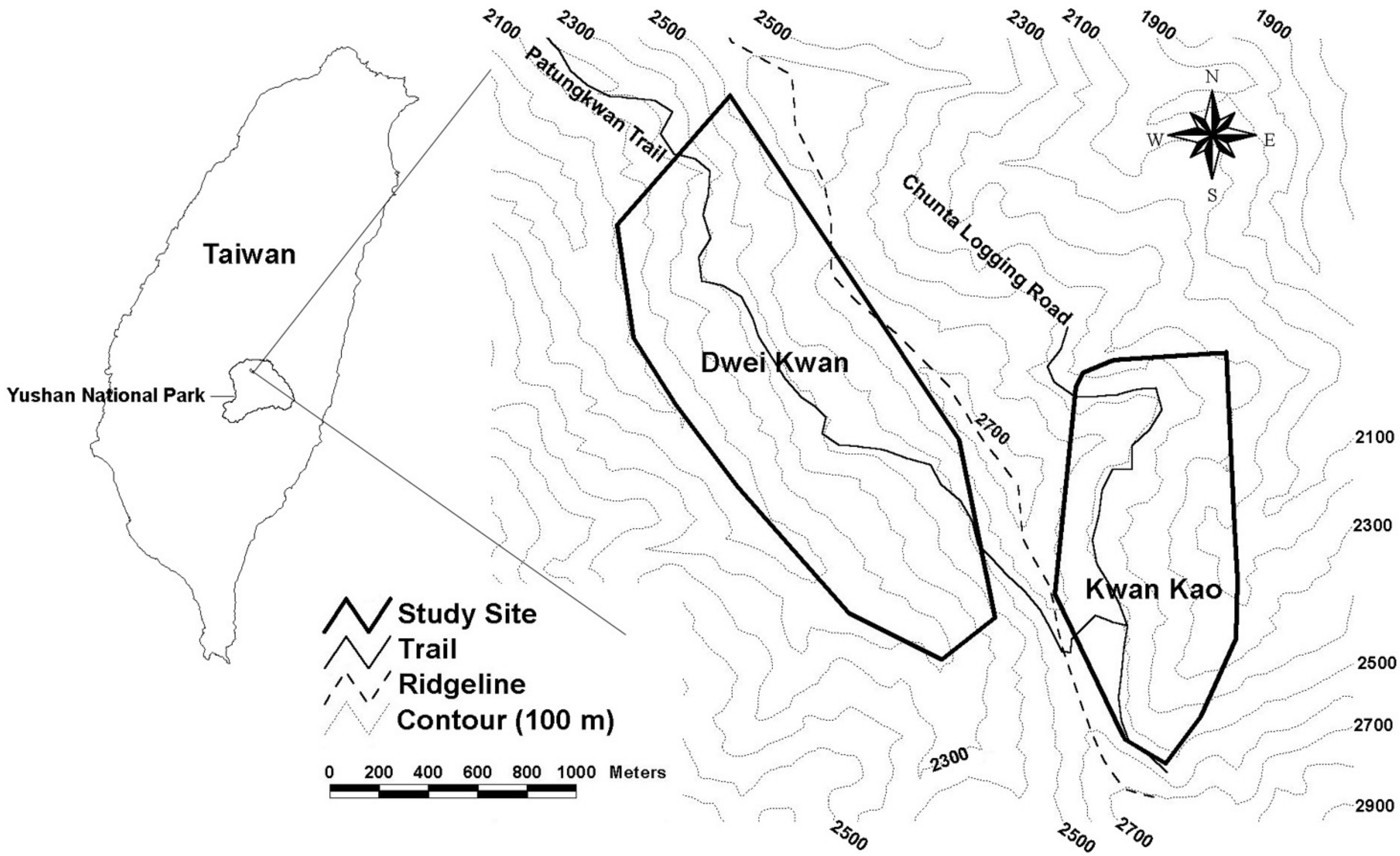

Figure 1.2: Map of the study area inside Yushan National Park, Taiwan, showing main topographic features. The Dwei Kwan study site is primary forest, and the Kwan Kao study site is second growth regenerating from clear-cutting ending in 1985.

PART 2

MICROHABITAT SELECTION BY MIKADO PHEASANTS

ABSTRACT

The endemic mikado pheasant, *Syrmaticus mikado* (Phasianidae) is found in Taiwan's primary and secondary forests over 1600 m in elevation. I test the hypotheses of microhabitat selection by the mikado pheasant. From July 1996 through May 1998, sections of trail inside Yushan National Park were monitored for pheasant activity. Based on observed encounters, 92 trail locations were paired with off trail locations, surveyed for 17 habitat variables and analyzed using logistic normal regression to identify differences associated with pheasant activity. In addition, 12 locations with pheasant activity and 12 without were monitored for monthly maximum and minimum temperatures, with non-significant results. Pheasant activity was not uniformly distributed throughout the study area although the location of activity was consistent between seasons. Spatial autocorrelation was the most useful in classifying pheasant locations. Plots with pheasant activity (pheasant plots) were also identified with high shrub numbers, low canopy dbh, and < 25% leaf litter – characteristics of secondary forest. This model correctly identified pheasant plots 67% of the time. Most pheasants were encountered while feeding, suggesting that this analysis describes preferred feeding habitat. Shrub coverage supplies food as well as protection from predators. As the pheasant lives at an elevation naturally disturbed by landslides, a certain tolerance for disturbance would be adaptive.

INTRODUCTION

The relationship between a species and its habitat is a close one. In order to conserve a species, one must be able to identify specifically the habitat requirements of that species. Quality habitat does more than provide suitable food and shelter. The microclimates within that habitat may make the difference between survival and reproduction (Walsberg 1985). Some species have such specialized habitat requirements that their presence may be determined merely by recording the presence of a particular plant or geologic structure (e.g. Pinyon Jays, *Gymnorhinus cyanocephalus*, and Pinyon pines, *Pinus edulis*, Ligon 1978; Serpentine Morning Glory, *Calystegia collina*, and serpentine soils in California, Wolf and Harrison 2001). Even for generalists, species with distributions across a wide range of habitat types, there exist optimal habitats in which productivity and survival are maximized. Within a particular animal's range of activity, there will be patches of habitat most suitable for particular activities such as nesting, feeding or roosting. Some regions within the range may not be utilized at all.

Although they are primarily associated with forests, pheasants are not considered habitat specialists. Many species, such as red junglefowl (*Gallus gallus*) and the ring-necked pheasant (*Phasianus colchicus*) are well adapted to agricultural habitats (Fuller and Garson 2000). The survival of the Elliot's pheasant (*Syrmaticus ellioti*), however, may depend on preservation of broadleaf forest in China. In contrast, habitat management through grazing or burning has been suggested to help the survival of cheer pheasants (*Catreus wallichi*; Fuller and Garson 2000). Regardless of the general habitat requirements of pheasants, 21 of the 51 recognized species are considered at risk of extinction (Fuller and Garson 2000). The primary threat to 19 of these species is habitat loss or fragmentation. This is despite the fact that 12 show some breadth in their habitat requirements, are known to utilize secondary as well as primary forests, and may seek scrub habitats for breeding or wintering grounds (Fuller and Garson 2000). An additional 14 species are considered near-risk or data deficient (Fuller and Garson 2000). *Syrmaticus mikado* are among those considered near-risk. Study of *S. mikado* may be useful in understanding the effect of habitat loss and fragmentation on the survival of those pheasant species currently at risk of extinction.

Endemic to the sub-tropical island of Taiwan, *S. mikado* exists in a variety of habitats between the elevations of 1600 m and 3500 m (Severinghaus 1977). The mountains within the range of *S. mikado* often exceed 3500 m, have extremely steep slopes, and are separated by steep valleys that dip well below 1600 m. The habitat requirements of this species appear to be quite general, as it is documented as living in primary forests and in secondary forests regenerating from clearcutting (Severinghaus 1977, Severinghaus and Severinghaus 1987, Alexander et al. 1990, Bridgman 1994). Within these forests, however, there is some evidence that Mikado use some locations more frequently than others. Furthermore, these forests are not as uniform in composition as often described (Chou and Wang 1995, Taiwan Forest Bureau 1995). In the secondary forests are patches of the original forest overlooked by loggers. Within the primary forest are patches of secondary forest caused by landslide activity.

Severinghaus (1977) first noticed that *S. mikado* are encountered more frequently in some areas than in others. He described the bird as "locally common." In 1990, Alexander et al. mapped the spatial pattern of pheasant activity on the Chunta Logging Road, documenting that the pheasants were more frequently observed in certain sections. This pattern of encounters along a logging road in a secondary forest led me to suspect that the pheasant might be selecting for particular habitat characteristics within the secondary forest. From July 1996 through July 1998, I was able to continue monitoring the Chunta Logging Road for pheasant activity. At the same time, I monitored pheasant activity on the nearby Patungkwan Trail which passes through primary forest habitat. Pheasant activity in both forests was patchily distributed. These observations of pheasant encounters suggested the following questions:

Are the habitat characteristics of locations with pheasant activity different from those of random locations?

Do areas of use share a common set of characteristics?

STUDY SITE DESCRIPTION

The study area is inside Yushan National Park, located in the center of Taiwan which is bisected by the Tropic of Cancer. Within 10 km of the study area are three of Taiwan's tallest mountains, each exceeding 3500 m in elevation (Appendix: Figure 2.1). *Syrmaticus mikado* have been encountered and studied in this area since 1977. The study area is between 2000 and 3000 m in elevation and 10 km distant from the nearest village. In Taiwan, the habitat types found between 1600 and 3500 m in elevation include bamboo grasslands, primary and secondary mixed forests, and landslides.

Kwan Kao, the secondary forest site (Figure 2.2), was clearcut of its original Taiwan Red Cedar (*Chamaecyparis formosensis*) and Taiwan Hemlock (*Tsuga chinensis*) forest community about 30 years ago. Now overgrown with Japanese Alder (*Alnus japonica*), bamboos, and grasses, and interrupted by frequent landslides, this area is representative of an early successional community (Wang 1968). Some planting of Taiwan Red Cedar seedlings is ongoing. Much of the considerable landslide damage may have originated from construction of the gravel Chunta Logging Road bisecting the study area. The disturbance from typhoons when combined with the steep slopes continues to create and maintain landslides. Concentrated study of the pheasants in this site began in 1989 (Alexander et al. 1990, Bridgman 1994).

Dwei Kwan, the primary forest site (Figure 2.2), is a climax community forest within 1 km of the Kwan Kao site. This steep hillside is indicative of the mixed mesophytic communities of *Chamaecyparis*, *Tsuga*, and *Pinus* that mark the transition zone between the temperate humid forest (1500 - 2500 m in elevation) and the subalpine zone (2500 - 3000 m in elevation). These forests of cedar, hemlock, and pine vary in age due to naturally occurring landslides and fires. The *Chamaecyparis* trees may be 2000 - 3000 years old, are 21 - 31 m tall, and 50 - 110 cm DBH (Wang 1968). The understory varies from dense patches of bamboo and grasses to sparse areas of ferns and leaf litter (Wang 1968). The heavily used Patungkwan Trail bisects this study site. *Syrmaticus mikado* are frequently encountered along the trail, but systematic study of this population did not begin until 1996.

METHODS

Encounter Locations

Two years of encounter data, July 1996 through July 1998, were used to identify the spatial pattern of pheasant activity along the road and trail. During these years, 4.2 km of the Patungkwan Trail (10.1 km to 14.3 km) and 2.9 km of the Chunta Logging Road (65.2 km to 68.1 km)(Figure 2.1) were patrolled (for details see Part 4) during daylight hours for about 10 days each month for sightings of *S. mikado*. In 1991, I mapped the logging road and placed permanent markers every 20 meters (Bridgman 1994). In 1996, I marked the Patungkwan trail in the same way. The location of pheasant encounters (Figures 2.3 and 2.4) was recorded to the nearest marker. This information helped determine the location of plots for the habitat analysis (Figures 2.3 and 2.4) conducted from May 1998 through May 1999.

Plots selected for habitat analysis were at least 40 m apart and identified as pheasant present or pheasant absent based entirely on my records of pheasant encounters (Figures 2.3 and 2.4). To gain an understanding of adjacent forest habitat, these plots were paired with off-trail plots located at 15 - 100 m perpendicular distance from the road or trail. Most off-trail plots were surveyed on short 70 to 400 meter transects paralleling the trail with the plots spaced 50 to 70 meters apart. Some off-trail plots, such as automatic camera locations (see below), were mapped. As no pheasants were encountered away from the road and trail, the designation of off-trail plots was dependent on the designation of the nearest road and trail plots.

Automatic Cameras

I have never observed live *S. mikado* in off-trail areas. I assumed that off-trail plots near road and trail locations where pheasants had been encountered represented suitable habitat for *S. mikado*. The main reason for this assumption is that the bird had to pass through this area if only to reach that section of road or trail. The only test of this assumption was the record made by automatic cameras placed in off-trail sites. Beginning in April 1998, two to four automatic cameras were placed in a total of 23 off-trail locations to record the presence of pheasant activity. Of these locations, 9 were near locations with pheasant encounters and 14 near locations without pheasant encounters. These cameras were maintained at each location for about two months and checked twice a month for battery power and exposed film. Other off-trail locations used by *S. mikado* were those from which I recovered radio-transmitters from radio-tagged pheasants.

Habitat Characterization

Habitat was characterized at three levels: herb, shrub, and tree (Figure 2.5). Herb plots were centered within 1 m of the edge of the road or trail, but shrub and tree levels often included road or trail. In addition, I made general descriptions of each plot based on observations of items within view. These items included general habitat type, disturbance, and the presence of lianas. Forest types were conifer, deciduous, or mixed based on visible trees. Disturbance was mainly described as the presence of road, trail, and landslides. Presence of lianas was determined by the observation of vines hanging from trees. I also measured aspect (nearest five degrees using a compass) and elevation above sea level (nearest 5 m using a barometer).

In all plots, I designated herbs as any vegetation <1 m in height. This designation was adopted despite the fact that herbs such as bamboo, vines, grasses, and ferns could reach heights greater than 1.5 m and attain densities adequate to support a 1-kg pheasant. My main objective was to separate items that may be edible (herbs) from items supplying support or protection (shrubs and trees). Therefore, vegetation <1 m high was designated a herb, regardless of stem thickness or botanical classification. Shrubs were designated as anything between 1 and three meters in height with a dbh < 2 cm. Trees were designated as anything over 1 m in height with a dbh >2 cm.

Shrub plots were five meters in diameter, covering an area of 19.6 m^2 (Figure 2.5). Within these plots, I made visual estimates of the percent shrub cover, as opposed to bare ground or herb coverage, using the cover classes described in Daubenmire (1959). I counted the number of shrub morpho-species and the number of tree stems with a dbh >2 cm.

Centered within the shrub plots was the 1 m^2 herb plot (Figure 2.5). Considering only vegetation cover <1 m in height, I made visual estimates, to a total of 100%, of the percent cover of herbs, bare ground, and leaf litter within the plot, using Daubemire's (1959) cover classes of 1-5%, 6-25%, 26-50%, 51-75%, 76-95%, and 96-100%. Within this plot, I noted the presence of bits of dead wood (bark, branches, logs) greater than 2 cm in diameter and looked for possible food items such as fruits, nuts, or insects (Young et al. 1991). Height of herbs was measured from five places within the plot (the center of the plot and each quadrant within the plot) and averaged (Figure 2.5). To estimate species diversity, I counted number of herb species, based on visible differences in morphology.

It was from the center of the 1-m^2 herb plot that I measured slope and canopy coverage and made descriptions of the canopy. Slope was measured using a clinometer as the change over 5 m from center of the herb plot to 5 m below. Percent canopy coverage was determined from the average value of estimates in the four cardinal directions using a spherical densiometer (Lemmon 1956). I used the point-centered quarter analysis to describe the canopy (Cottam and Curtis 1956). Within each quarter (Figure 2.5), I estimated to the nearest 1 m the distance to the nearest tree with a dbh greater than 10 cm. For this tree, I measured dbh (nearest 5 cm) and estimated the height of the lowest living branch (nearest m). I did not measure tree height because, having occasionally observed pheasants roosting on lower branches, I considered that the lowest living branch was more likely to be important to a pheasant.

The presence of pheasants at a particular location is not likely to be independent of the presence of pheasants at adjacent locations. Therefore, I created a variable to test this spatial autocorrelation by adapting the method described in Augustin et al. (1996) from two dimensions (four or eight neighboring plots) to one dimension (two neighboring plots). This was because pheasant activity was known only for locations on the road or trail and because off-trail plots were labeled as pheasant present or absent based on the nearest on-trail location. I calculated this variable as the mean of the presence (1) or absence (0) of pheasant encounters at the two adjacent plots (40 m distance on the road or trail). This autocorrelation variable was included in analysis along with other habitat variables (Augustin et al. 1996).

Microclimate

Twenty-four maximum-minimum thermometers were placed two to six cm above the ground in the shade near the road or trail. Of the 12 placed in the secondary forest site, six were in locations where pheasants were frequently encountered. Six of the 12 placed in the primary forest site were in pheasant locations. These thermometers were checked monthly from April 1998 through May 1999 to determine the monthly extreme temperatures for each location.

Statistical Analysis

Survey effort for each 20 m segment of road (from 66.2 to 68.1 km) or trail (from 10.1 to 14.3 km) was calculated according to year, season, and time of day. The number of surveys and the distance covered during each survey varied between year, season, and time of day. Therefore, I use the relative effort (percent of total for each particular year, season, and time of day) to test for differences in survey effort among the 20 m segments of road or trail. I used Wilcoxan Signed Rank tests (SAS 1989, proc univariate) to test for significant differences in yearly effort (7/1996-6/1997 and 7/1997-6/1998) and seasonal effort (March through August and September through February). Percent effort for time of day (morning: dawn to 10 am; midday: 10 am to 2 pm; and afternoon: 2 pm to dark) was analyzed using a Kruskal-Wallis Chi-Square (SAS 1989, proc npar1way wilcoxan), a non-parametric analysis of variance test.

The locations of encounters were divided into two seasons: breeding (March through August) and non-breeding (September through February). Seasonal differences in the locations of encounters were tested using Kruskal-Wallis z-test, a non-parametric equivalent to Student's t-test (Daniel 1990).

Since temperature measures are not independent from one time period to the next, monthly minimum temperatures were analyzed using a one-way analysis of variance with month as the repeated measure (SAS 1989, proc mixed). Separate analysis of variance tests were run for each month (SAS 1989, proc glm). I repeated this method to analyze the monthly maximum temperatures.

From the canopy tree survey, I calculated stem density, mean dbh, and mean lowest living branch for each plot. I calculated stem density as: 1/(average distance to the 4 trees)^2. These values were among those (Appendix: Table 2.1) entered as explanatory variables in multivariate logistic regression analysis for site and pheasant activity effects. To reduce the number of categories within the categorical variables, I lumped them (Table 2.1) based on their chi-square distributions (SAS 1989, proc freq). I created dummy binomial variables for each category because categorical variables are inappropriate for multivariate logistic regression (SAS 1989, Johnson 1998, Wang Yating unpublished manuscript).

To eliminate trail effect, the 92 trail plots were paired with the 92 off-trail plots and analyzed as one observation or sample. Each variable (Table 2.1) was tested separately using logistic regression for its ability to predict pheasant presence or absence (SAS 1989, proc logistic; Wang Yating unpublished manuscript). Variables with $p<0.25$ (Table 2.2A) were grouped and analyzed as a single model using multivariate logistic regression. Variables were eliminated from the model, one at a time, until all remaining variables had $p<0.05$ or a Wald Chi-Square >2 (SAS 1989, proc logistic; Wang Yating unpublished manuscript). The resultant variables were then tested on samples with pheasant activity for their ability to distinguish between study site (SAS 1989, proc logistic).

To identify the variables that best distinguish between study sites, using samples with pheasant activity only, variables were first screened separately using logistic regression (SAS 1989, proc logistic; Wang Yating unpublished manuscript). Variables with $p<0.25$ (Table 2.2B) were then analyzed with multivariate logistic regression to develop a model predicting study site (SAS 1989, proc logistic, stepwise, slentry=0.9. slstay=0.1). This method was repeated using all 92 plot pairs (Table 2.2C). The predictive ability of the four models resulting from multivariate logistic regression was tested using a Chi-Square test for goodness of fit (Lehner 1979).

RESULTS

Overall survey effort was greater the first year (7/1996-6/1997) than the second year (7/1997-6/1998). It was also greater during the breeding season (March through August) than in the non-breeding season (September through February). To focus on allocation of effort per 20 m, I used the relative effort per kilometer (percent of the total) rather than the actual effort per kilometer. With this adjustment, relative yearly and seasonal survey effort per 20 m varied significantly (Figures 2.3, 2.4, 2.6 and 2.7). Relative effort per 20 m by time of day, however, did not vary significantly (Figures 2.6 and 2.7). The distribution of effort per 20 m is shown in Figures 2.3, 2.4, 2.6 and 2.7.

From July 1996 through July 1998, I encountered pheasants 210 times within the study area. Encounters were unevenly distributed throughout the study area, but the locations of these encounters did not vary with season ($z=-1.14$; $p=0.26$). These encounters (Figures 2.3 and 2.4) helped identify the location of the 215 plots used to assess habitat characteristics (Figures 2.3 and 2.4). Although the number of visits to a particular 20 m section varied from 13 – 487 on the Chunta Logging Road and 65 – 337 on the Patungkwan Trail, all plots were placed in sections that had been visited over 70 times during the two years. Most plots (n=181) were placed in sections that had been visited over 200 times (Figures 2.3 and 2.4). After eliminating plots with missing data points or plots lacking an on-trail or off-trail compliment, there were 92 observations (pairs of plots) available for logistic analysis. Half of these observations (or 46 pairs of plots) were on locations with pheasant encounters.

Automatic camera evidence of pheasant activity did not result in changes in the designation of off-trail plots as pheasant present or absent. Off trail plots were labeled based on whether or not pheasants had been encountered in the nearest road or trail plot. Therefore, automatic camera evidence of pheasant activity indicates the error associated with labeling these random off-trail locations. Six of the total 23 automatic camera locations captured pictures of *S. mikado*. Of the nine locations designated as pheasant present, pheasants were photographed at three. Three of the 14 locations designated as pheasant absent also photographed pheasants.

Neither minimum monthly temperatures nor maximum monthly temperatures varied significantly between plots of pheasant encounter and plots where pheasants were not observed (Table 2.3). Temperatures did vary significantly from month to month. Even so, tests for differences in temperatures between encounter plots and non-encounter plots for each month did not vary significantly (Table 2.4). Therefore, I did not analyze the habitat characteristics of these plots.

Pheasant encounters were positively associated with the presence of other pheasants (autocorr), number of shrubs on off-trail plots (shrub n off), and negatively associated with mean dbh in trail plots (dbh) and trail litter cover (litter) greater than 25% (Table 2.5A). These variables correctly predicted pheasant activity 67% of the time, which is significantly different from expected 100% rate of prediction (Chi-square goodness of fit=7.52, df=1, $p<0.01$)(Table 2.6A). No large-scale variables such as aspect, slope, or canopy cover were significantly associated with the presence of pheasants. The four variables selected to predict pheasant activity (Table 2.5B) managed to correctly predict secondary forest 72% of the time and primary forest 67% of the time, also differing significantly from the expected rate of 100% (Chi-square goodness of fit=4.29, df=1, $p<0.05$)(Table 2.6B).

Using only plots with pheasant activity, the aspect of off trail plots (aspect off) and trail canopy coverage (canopy) were negatively associated with study site or forest type (Table 2.5C). This model correctly predicted secondary forest 88% of the time and primary forest 90% of the time, rates not significantly different from the expected 100% (Chi-square goodness of fit=0.55, df=1, $p>0.10$)(Table 2.6C). These same two variables were negatively associated with study site in a model using all 92 pairs of plots to predict forest type (Table 2.5D). Trail aspect (aspect) and dbh, also part of the model, were negatively associated with forest type. Pheasant activity (autocorr) was positively associated with forest type. This five-variable model using all 92 pairs of plots correctly predicted secondary forest 89% of the time and primary forest 93% of the time, rates not significantly different from the expected 100% (Chi-square goodness of fit=0.72, df=1, p>0.10)(Table 2.6D).

DISCUSSION

The study area within Yushan National Park is very heterogeneous. Stands of primary forests are interrupted by landslides and have patches regenerating from burning. Secondary forest stands have sections of primary forest overlooked by loggers. Within the study area, the distribution of encounters with *Syrmaticus mikado* is also heterogeneous. The most important LakeHouse-Lakevariable identifying locations of encounters was the existence of encounters at adjacent locations – the presence of pheasants was the best indicator of pheasant activity. While importance of this spatial autocorrelation is most likely due to methodology, sampling closely adjacent plots along a line transect, this pattern also occurs with gregarious animals (Augustin et al. 1996). Severinghaus (1977) described the pheasant as “locally common” after observing marked differences in encounter rates from one section of trail to the next. Here, sampled plots were representative of the study sites, including plots with pheasant encounters. Furthermore, the locations of these plots were concentrated in the most intensively surveyed sections of road and trail.

After autocorrelation, high shrub density, low average dbh of canopy species and low litter density were also indicative of pheasant encounter locations. These characteristics are more similar to disturbed or secondary forest than to primary forest. Regardless of the general habitat type, *S. mikado* was selecting for secondary forest characteristics. This selection pattern emerged despite the categorization error revealed by automatic camera placed in off-trail plots, indicating pheasant activity in some plots designated as having no activity. These habitat characteristics are at the smallest scale: within 1 m^2. Dense shrubs are important to pheasants for both protective cover (Hill and Robertson 1988) and food items (personal observation).

The winter range of the pheasant, Cabot’s tragopan (*Tragopan caboti*), has been positively correlated with stem density, the presence of nuts, and bare ground. Large-scale effects such as distance from water and slope were also important (Young et al. 1991). The tragopan seemed to select for food, cover, and ease of movement beneath the shrub layer. Young et al. (1991) suggested that a greater stem density supplied shelter from predators and from the elements. They also noted that within the winter range of individual pheasants, both vegetation and food items were unevenly distributed. Young et al. (1991) studied winter range, as they were concerned about the pheasant’s survival during this season. This pheasant is subject to periods of intense cold, during which the pheasants will try conserving energy by remaining still. This strategy is also discussed for the ring-necked pheasant in Hill and Robertson (1988). I did not focus on the location of pheasant encounters by season. Even though the rate of encounter drops during winter months (Alexander et al. 1990, Bridgman 1994), there is no difference in the location of encounters from one season to the next. Taiwan does occasionally have snow at 2000 m in elevation, but these snows do not limit the access of *S. mikado* to food items (Bridgman 1994).

The location of pheasant encounters along the Chunta Logging Road has remained constant since 1989. Comparisons of mapped locations from Alexander et al. 1990 and records from the current study reveal no significant differences in location (Figure 2.8; Wilcoxan Signed Rank Test, n=14, p=0.38; Daniel 1990). During this time, trees have grown and new landslides have been created. Overall, canopy cover has increased. In 1990, most of the logging road was labeled as having an open canopy (Alexander et al. 1990). In 1999, most locations had moderate canopy coverage. Herb species composition has remained similar (personal observation).

The rate of pheasant activity does vary with site and with season (Bridgman 1994, Bridgman et al. 1998). Activity of *S. mikado* on roads and trails may be correlated with exposure to direct sunlight, a function of season, aspect, and canopy coverage. Throughout most of the year, days begin in clear skies with clouds gradually forming fog by mid-afternoon (Bridgman 1994). The secondary forest site, of eastern exposure, receives morning sunlight with afternoons in shade, often with fog (personal observation). At this site, encounters with pheasants were most common in early mornings and late afternoons, and during the breeding season. The midday exposure of the site to direct sunlight may account for the midday drop in activity. In the primary forest site (Dwei Kwan), encounters are more common during midday and rates are similar throughout the year. The uniform rates of encounter at the Dwei Kwan site may be due to its western exposure. Mornings at this site are in shadow with clouds and fog moving in before direct sunlight reaches the site (personal observation). The activity patterns and locations of some pheasant species (e.g. ring-necked pheasant winter range and nest locations, Hill and Robertson 1988; Cabot's tragopan winter range, Young et al. 1991; Merriam's turkeys winter roost locations, Rumble 1992) have been correlated with tree and shrub cover, which offer protection from predators. The low visibility in afternoon fogs may provide *S. mikado* with the same protection.

Regardless of the fact that clear days do occur and that shrub and canopy cover vary throughout the study area canopy cover was not an important variable for determining the locations of pheasant activities. Neither was microclimate. This lack of significance in microclimate may be due to small number of temperature plots and to the method of recording only the extreme temperatures for each month. As the locations of *S. mikado* encounters are stable throughout the year, the microclimates of pheasant activity locations may be important and may be correlated with some habitat characteristics. Most work on microclimate habitat selection by birds has concentrated on roosting and nesting locations, primarily because of ease of analysis and identification (Walsberg 1985).

Descriptions of shifts in foraging locations are based on time of day or weather (DeWoskin 1980, Cody 1985, Hill and Robertson 1988, Bridgman 1994). Furthermore, it is difficult to separate microclimate selection from predator avoidance. In studies of roost and nest microclimates, the focus is on the effects of temperature and wind (Cody 1985). Within my study area, a distance of 40 meters can describe the difference between a location with pheasants and a place where the birds are never encountered.

Until Bridgman (1994) documented that *S. mikado* can live entirely in secondary forest, the bird was thought to be associated with primary forest habitats (Severinghaus 1977, Severinghaus and Severinghaus 1987). The work here suggests these pheasants use patches of habitat with secondary forest characteristics. The association of *S. mikado* activity with secondary forest may the result of selective pressure by topography. The elevations within which this pheasant occurs are distinguished by landslide activity. The fastest growing habitats within Yushan National Park are landslides (Chou and Wang 1995, Part 3). Although this natural disturbance helps create and maintain secondary forest habitats, human logging and construction activity augments naturally occurring disturbance. The rates at which humans create disturbance and the fact that construction and logging activities are usually accompanied by increased hunting pressure are matters for concern. Hunting is the second largest threat to pheasants (Fuller and Garson 2000). The fact remains, however, that *S. mikado* use both primary and secondary forest in an elevation naturally disturbed by landslides. A certain tolerance for disturbance would be adaptive. As locations of pheasant activity are distinguishable from locations without, further analysis may reveal that microclimate, or some variable not measure here, is more important than overall forest type. Finally, the quality and existence of nesting and roosting sites are arguably more important for the survival of any bird. Examination of these locations will yield a better understanding of the habitat requirements of *S. mikado*.

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APPENDIX

Table 2.1: Independent variables used to categorize *Syrmaticus mikado* habitat within Yushan National Park, Taiwan. All variables were collected from 92 trail and 92 off-trail plots; except for herb height, which was collected from off-trail plots only, and autocorr, which was collected from trail plots only. Plot sizes varied from 1 m^2 to line of sight.

Variable	Description	Plot Size	Units
Litter	% litter on ground	1 m^2	coverage class[1]
Ground	% ground exposed	1 m^2	coverage class[1]
Herb[2]	% herb cover	1 m^2	coverage class[1]
Wood	presence of wood	1 m^2	presence/absence
Herb n[2]	number of herb species	1 m^2	number
Herb ht[2]	average height of plants	1 m^2	Cm
Shrub[3]	% shrub coverage	19.6 m^2	coverage class[1]
Shrub n[3]	number of shrub species	19.6 m^2	number
Canopy	percent cover[4]		percent
Dbh	Diameter Breast Height	quarter[5]	m^2
Density	Stem Density	quarter[5]	m^2
Llb	Lowest Living Branch	quarter[5]	M
Aspect	exposure		degrees
Slope[6]	Slope[6]	5 m distance	degrees[6]
Stems	number of stems > 2 cm dbh	19.6 m^2	number
Lianas	presence of lianas		number
Autocorr[7]	Autocorrelation of Pheasant Activity	40 m	Mean value[7]

[1] coverage classes according to Daubenmire 1959:
1-5, 6-25, 26-50, 51-75, 76-95, 96-100%
[2] herbs defined as <1 m in height
[3] shrubs defined as >1 m in height
[4] canopy percentage from average of 4 measures by spherical densiometer
[5] quarter method according to Cottam and Curtis 1956.
[6] slope measured in degrees
[7] Autocorr = (Presence (1) or absence (0) of pheasants on trail 40 m below the plot + presence or absence on trail 40 m above the plot)/2 (Augustin et al. 1996).

Table 2.2: Results of individual tests of significance for each variables used to evaluate habitat characteristics of locations used by *Symaticus mikado* inside Yushan National Park, Taiwan: A) Pheasant activity as the dependent variable; B) Analysis of samples with pheasant activity using study site as the dependent variable; C) Analysis of all samples using study site as the dependent variable. Location indicates whether variables were measured from on-trail or off-trail plots

	Independent Variable			Likelihood		
	Name	Location	Type	Ratio X^2	P-Value	Odds Ratio
A) Pheasant Activity: All samples						
	Autocor	on	continuous	17.8122	<.0001	11.463
	Shrub n	off	continuous	5.8956	0.0152	1.356
	Litter[1]	on	discrete	2.8022	0.0941	0.495
	Herb n	off	continuous	2.5617	0.1095	1.165
	Wood	on	discrete	2.3994	0.1214	0.050
	Dbh	on	continuous	1.3412	0.2468	0.977
	Shrub[9]	off	discrete	1.2636	0.2610	0.602
	Herb ht	off	continuous	1.2435	0.2648	0.989
	Herb	off	discrete	1.1329	0.2872	0.635
	Stem	off	continuous	0.8886	0.3458	1.034
	Llb	off	continuous	0.8173	0.3660	0.897
	Aspect	off	continuous	0.7760	0.3784	0.998
	Herb	on	discrete	0.7019	0.4022	1.421
	Liana	on	discrete	0.6522	0.4193	0.646
	Aspect	on	continuous	0.6165	0.4323	0.998
	Slope	on	continuous	0.6140	0.4333	0.986
	Shrub[7]	on	discrete	0.5229	0.4696	0.705
	Ground[6]	off	discrete	0.5229	0.4696	0.705
	Litter[2]	off	discrete	0.5229	0.4696	0.705
	Dbh	off	continuous	0.4499	0.5024	1.010
	Ground[4]	on	discrete	0.4384	0.5079	0.746
	Litter[3]	off	discrete	0.4154	0.5192	0.758
	Shrub n	on	continuous	0.3833	0.5359	0.926
	Slope	off	continuous	0.3411	0.5592	0.988
	Density	on	continuous	0.2550	0.6136	4.663
	Ground[5]	off	discrete	0.2146	0.6432	0.807
	Stem	on	continuous	0.2048	0.6508	0.976
	Llb	on	continuous	0.0913	0.7626	1.039
	Shrub[8]	off	discrete	0.0549	0.8147	0.896
	Herb n	on	continuous	0.0513	0.8209	0.980
	Wood	off	discrete	0.0452	0.8316	1.095
	Density	off	continuous	0.0222	0.8816	1.741
	Canopy	off	continuous	0.0089	0.9250	1.001
	Canopy	on	continuous	0.0062	0.9372	0.999
	Lianas	off	discrete	0.0000	.	1.000

Table 2.2: continued.

Independent Variable			Likelihood		
Name	Location	Type	Ratio X^2	P-Value	Odds Ratio
B) Site: Pheasant samples only					
Aspect	off	continuous	26.7916	<.0001	0.976
Llb	on	continuous	21.3299	<.0001	0.286
Dbh	off	continuous	21.0281	<.0001	0.863
Aspect	on	continuous	17.1303	<.0001	0.981
Dbh	on	continuous	14.8195	0.0001	0.820
Canopy	on	continuous	14.0360	0.0002	0.904
Herb	off	discrete	11.9352	0.0006	12.091
Density	off	continuous	9.9220	0.0016	>999.999
Llb	off	continuous	7.3947	0.0065	0.588
Slope	on	continuous	7.2918	0.0069	0.933
Shrub[9]	off	discrete	5.9455	0.0148	6.332
Herb n	off	continuous	5.9259	0.0149	0.718
Ground[4]	on	discrete	5.5349	0.0186	0.217
Lianas	on	discrete	3.6178	0.0527	0.224
Litter[1]	on	discrete	3.5609	0.0592	3.182
Wood	on	discrete	2.9110	0.0880	0.310
Shrub[7]	on	discrete	1.8465	0.1742	2.462
Lianas	off	discrete	1.7447	0.1865	0.333
Shrub n	off	continuous	1.5816	0.2085	0.816
Ground[6]	off	discrete	1.2974	0.2547	2.333
Wood	off	discrete	1.1702	0.2794	1.932
Slope	off	continuous	1.1249	0.2889	0.970
Litter[2]	off	discrete	1.0591	0.3034	0.476
Shrub[8]	off	discrete	1.0510	0.3053	0.500
Herb	on	discrete	0.7909	0.3738	0.589
Density	on	continuous	0.7808	0.3769	0.040
Litter[3]	off	discrete	0.6624	0.4157	1.667
Stem	off	continuous	0.1988	0.6557	1.021
Ground[5]	off	discrete	0.1043	0.7467	1.244
Stem	on	continuous	0.0481	0.8264	1.018
Canopy	off	continuous	0.0389	0.8436	0.996
Herb n	on	continuous	0.0146	0.9038	1.015
Autocor	on	continuous	0.0042	0.9482	0.946
Herb ht	off	continuous	0.0011	0.9735	0.999
Shrub n	on	continuous	0.0006	0.9798	1.004

Table 2.2: continued.

Independent Variable Name	Location	Type	Likelihood Ratio X^2	P-Value	Odds Ratio
C) Site: all samples					
Aspect	on	continuous	43.9394	<.0001	0.977
Aspect	off	continuous	38.3477	<.0001	0.981
Llb	on	continuous	25.9295	<.0001	0.410
Dbh	on	continuous	25.0489	<.0001	0.845
Canopy	on	continuous	19.7935	<.0001	0.937
Slope	on	continuous	19.2098	<.0001	0.902
Dbh	off	continuous	18.9736	<.0001	0.913
Density	on	continuous	13.6632	0.0002	>999.999
Wood	on	discrete	9.8636	0.0017	0.218
Slope	off	continuous	7.3054	0.0069	0.944
Herb	off	discrete	6.1063	0.0135	2.933
Ground[4]	on	discrete	5.3927	0.0202	0.352
Lianas	on	discrete	4.6551	0.0310	0.307
Herb n	off	continuous	4.3925	0.0361	0.811
Autocor	on	continuous	4.0257	0.0448	3.003
Llb	off	continuous	3.8958	0.0484	0.780
Wood	off	discrete	3.4811	0.0621	2.279
Shrub[7]	on	discrete	3.0482	0.0808	2.450
Shrub n	off	continuous	1.8199	0.1773	0.845
Litter[2]	off	discrete	1.5322	0.2158	0.536
Litter[3]	off	discrete	1.2260	0.2682	1.619
Density	on	continuous	0.8511	0.3562	0.032
Shrub[9]	off	discrete	0.8436	0.3584	1.517
Ground[6]	off	discrete	0.5337	0.4650	1.426
Shrub n	on	continuous	0.5246	0.4688	0.912
Stem	on	continuous	0.5099	0.4752	1.039
Herb	on	discrete	0.4930	0.4826	1.348
Stem	off	continuous	0.4459	0.5043	1.024
Shrub[8]	off	discrete	0.4023	0.5259	0.737
Ground[5]	off	discrete	0.3496	0.5544	1.319
Herb n	on	continuous	0.2131	0.6444	1.043
Herb ht	off	continuous	0.1251	0.7236	0.996
Canopy	off	continuous	0.0881	0.7667	1.005
Lianas	off	discrete	0.0476	0.8273	0.886
Litter[1]	on	discrete	0.0054	0.9412	1.032

[1] On-trail leaf litter coverage greater than 25%.
[2] Off-trail leaf litter coverage less than 26%.
[3] Off-trail leaf litter coverage greater than 50%.
[4] On-trail exposed ground greater than 6%.
[5] Off-trail exposed ground less than 6%.
[6] Off-trail exposed ground between six and 25%.
[7] On-trail shrub coverage greater than 26%.
[8] Off-trail shrub coverage less than 26%.
[9] Off-trail shrub coverage greater than 50%.

Table 2.3: Results of a Two-Way ANOVA with repeated measures on the monthly minimum and maximum temperatures of plots with *Syrmaticus mikado* activity (N=13) and plots without (N=11) inside Yushan National Park, Taiwan.

	Effect	Degrees of Freedom Numerator	Degrees of Freedom Denominator	F Value	p
A) Minimum Temperatures					
	pheasant activity	1	22	0.12	0.7355
	month	11	235	678.65	<.0001
	activity*month	11	235	1.54	0.1180
B) Maximum Temperatures					
	pheasant activity	1	22	0.95	0.3403
	month	11	235	12.74	<.0001
	activity*month	11	235	1.97	0.0318

Table 2.4: Results of monthly tests for differences in minimum and maximum temperatures of plots with *Syrmaticus mikado* activity (N=13) and plots without (N=11) inside Yushan National Park, Taiwan.

A) Minimum Temperatures

Month	F Value	p
January	0.20	0.6618
February	0.72	0.4058
March	0	0.9473
April	0.04	0.8531
May	0.29	0.5973
June	0.02	0.9020
July	0.07	0.7875
August	0.10	0.7603
September	0.37	0.5489
October	0.01	0.9234
November	0.33	0.5688
December	0.37	0.5477

B) Maximum Temperatures

Month	F Value	p
January	0.91	0.3495
February	2.04	0.1682
March	3.00	0.0982
April	1.92	0.1806
May	0.22	0.6469
June	0.31	0.5865
July	0.01	0.9441
August	1.37	0.2536
September	0.93	0.3465
October	0.12	0.7306
November	0.48	0.4949
December	0	0.9848

Table 2.5: Habitat characteristics of locations with *Syrmaticus mikado* activity inside Yushan National Park, Taiwan. A) Results of stepwise selection of habitat variables for pheasant activity using all 92 samples (or pairs of on-trail and off-trail plots). B) Application of results for pheasant activity to identifying study site using samples with pheasant activity only. C) Stepwise selection of habitat variables for study site using samples with pheasant activity. D) Stepwise selection of habitat variables for study site using all 92 samples. Variables from off-trail plots indicated with (off).

MULTIVARIATE LOGISTIC REGRESSION MODEL					
Variable	Parameter Estimate	Standard Error	Wald X^2	P	Odds Ratio
A) Pheasant Activity: Stepwise Selection with All Samples					
Intercept	-0.4872	0.7720	0.3982	0.5280	
Autocor	2.4646	0.6856	12.9211	0.0003	11.759
Shrub n (off)	0.3691	0.1542	5.7311	0.0167	1.446
Dbh	-0.0569	0.0246	5.3527	0.0207	0.945
Litter	-1.1058	0.5341	4.2869	0.0384	0.331
B) Site: using results of A) to test Pheasant Samples					
Intercept	6.8398	2.5697	7.0848	0.0078	
Dbh	-0.2466	0.0940	6.884	0.0087	0.781
Shrub n (off)	-0.3777	0.2271	2.7672	0.0962	0.685
Autocor	-1.3592	1.1474	1.4032	0.2362	0.257
Litter	0.6257	0.7859	0.6338	0.4260	1.869
C) Site: Stepwise Selection with Pheasant Samples					
Intercept	35.3416	16.0332	4.8588	0.0275	
Aspect (off)	-0.0613	0.0279	4.8455	0.0277	0.941
Canopy	-0.2793	0.1294	4.6549	0.0310	0.756
D) Site: Stepwise Selection with All Samples					
Intercept	27.1499	7.1661	14.3539	0.0002	
Canopy	-0.1807	0.0487	13.7568	0.0002	0.835
Dbh	-0.3498	0.1110	9.927	0.0016	0.705
Aspect	-0.0267	0.0092	8.3474	0.0039	0.974
Autocor	3.0163	1.3562	4.947	0.0261	20.417
Aspect (off)	-0.0144	0.0065	4.8743	0.0273	0.986

Table 2.6: Predictive ability of models using habitat characteristics to predict *Syrmaticus mikado* activity and study site forest type within Yushan National Park, Taiwan. A) Results of stepwise selection of habitat variables for pheasant activity using all 92 samples (or pairs of on-trail and off-trail plots). B) Application of results for pheasant activity to identifying study site using samples with pheasant activity only. C) Stepwise selection of habitat variables for study site using samples with pheasant activity. D) Stepwise selection of habitat variables for study site using all 92 samples.

	CHI-SQUARE GOODNESS OF FIT				
	Actual (Frequency)	Predicted (Frequency & Percent)	Chi-Square	df	P
A) Pheasant Activity: Stepwise Selection with All Samples					
Present	46	31 (67%)	7.52	1	<0.01
Absent	46	35 (76%)			
B) Site: using results of A) to test Pheasant Samples					
2° forest	25	18 (72%)	4.29	1	<0.05
1° forest	21	14 (67%)			
C) Site: Stepwise Selection with Pheasant Samples					
2° forest	25	22 (88%)	0.55	1	>0.10
1° forest	21	19 (90%)			
D) Site: Stepwise Selection with All Samples					
2° forest	38	34 (89%)	0.72	1	>0.10
1° forest	54	50 (93%)			

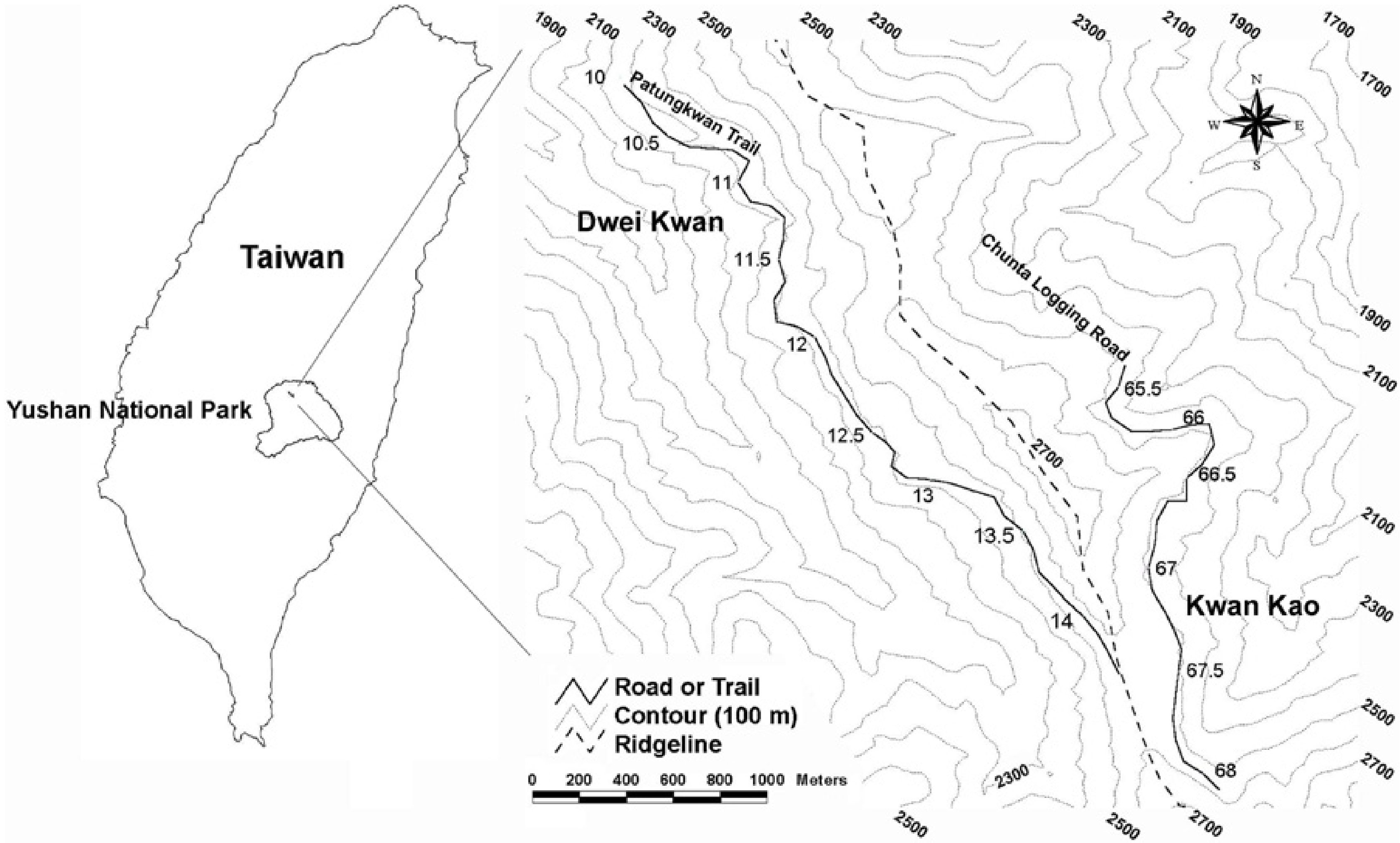


Figure 2.1: Location of sites for study of *Syrmaticus mikado* within Yushan National Park, Taiwan. The primary forest site is at Dwei Kwan and bisected by the Patungkwan Trail. The secondary forest site is at Kwan Kao and bisected by the Chunta Logging Road.

Dwei Kwan: Primary Forest Site **Kwan Kao: Secondary Forest Site**

Figure 2.2: Photographs of sites for study of *Syrmaticus mikado* within Yushan National Park, Taiwan. The Dwei Kwan study site is a patchy tract of primary forest. Coniferous forests are dark patches and deciduous forests are light ones. The Kwan Kao study site is a patchy tract of secondary forest. Note road, landslides, and dark patches of remaining primary forest.

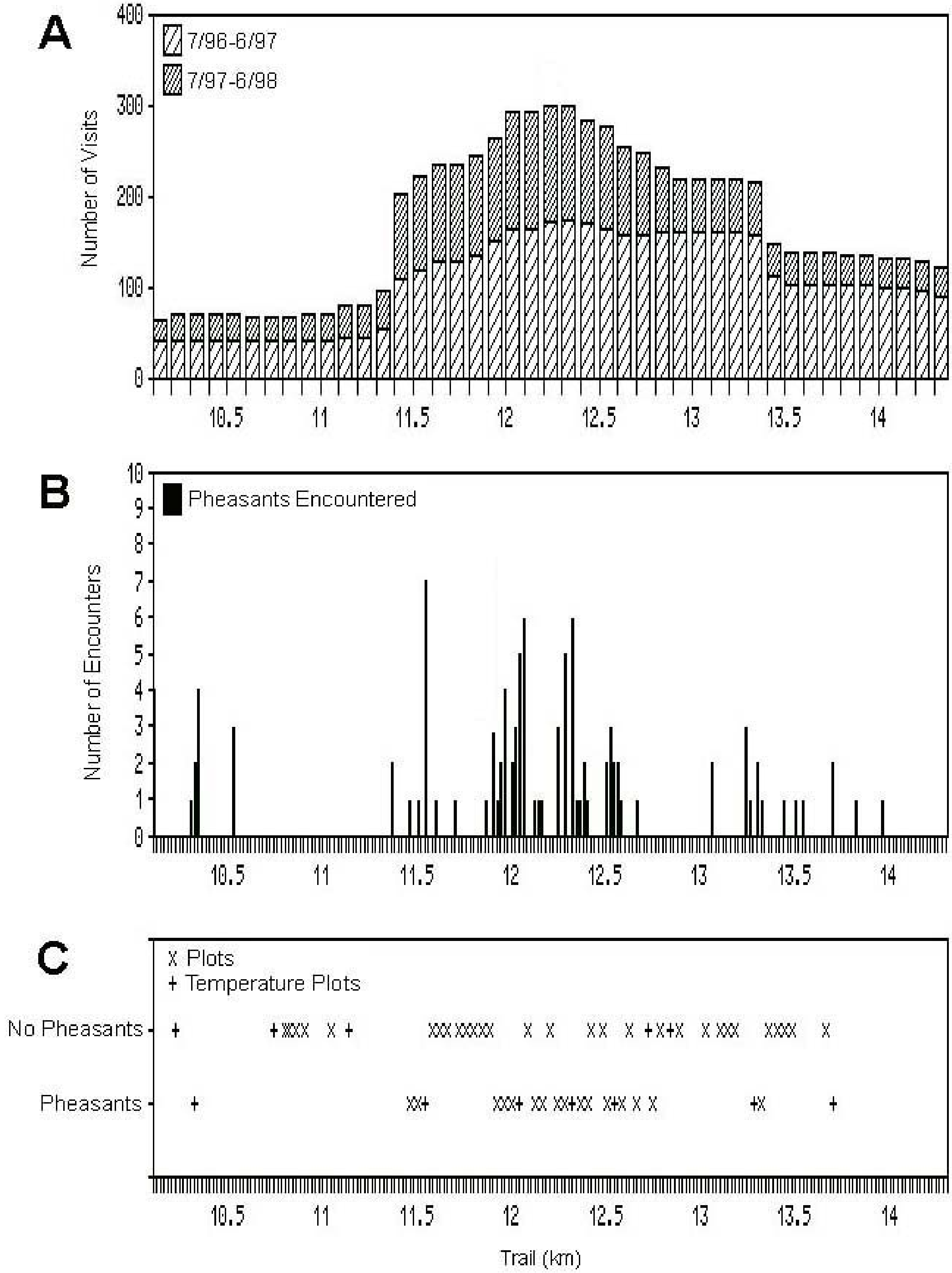


Figure 2.3: Survey effort, *Syrmaticus mikado* encounters, and location of plots used for habitat analysis in the Dwei Kwan study site, Yushan National Park, Taiwan. A) Yearly survey effort: number of visits per 20 m segment of the Patungkwan Trail varied significantly (Wilcoxan Signed Rank Test: s=234.5, p=0.0034). B) Locations of pheasants encountered from July 1996 through June 1998. C) Locations of plots used for habitat analysis, including plots used for microclimate analysis.

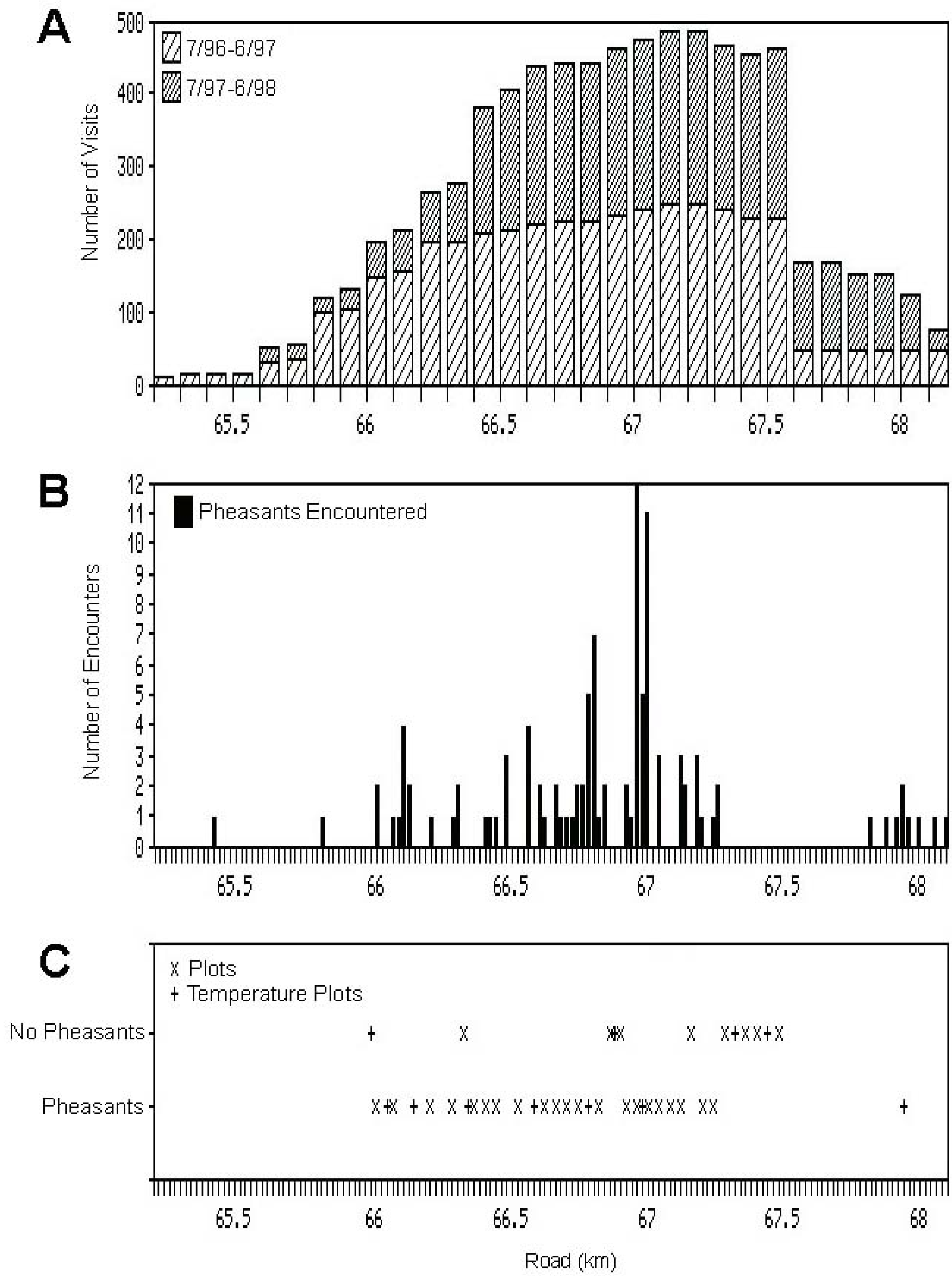


Figure 2.4: Survey effort, *Syrmaticus mikado* encounters, and location of plots used for habitat analysis in the Kwan Kao study site, Yushan National Park, Taiwan. A) Yearly survey effort: number of visits per 20 m segment of the Chunta Logging Road varied significantly (Wilcoxan Signed Rank Test: s=-108, p=0.0236). B) Locations of pheasants encountered from July 1996 through June 1998. C) Locations of plots used for habitat analysis, including plots used for microclimate analysis.

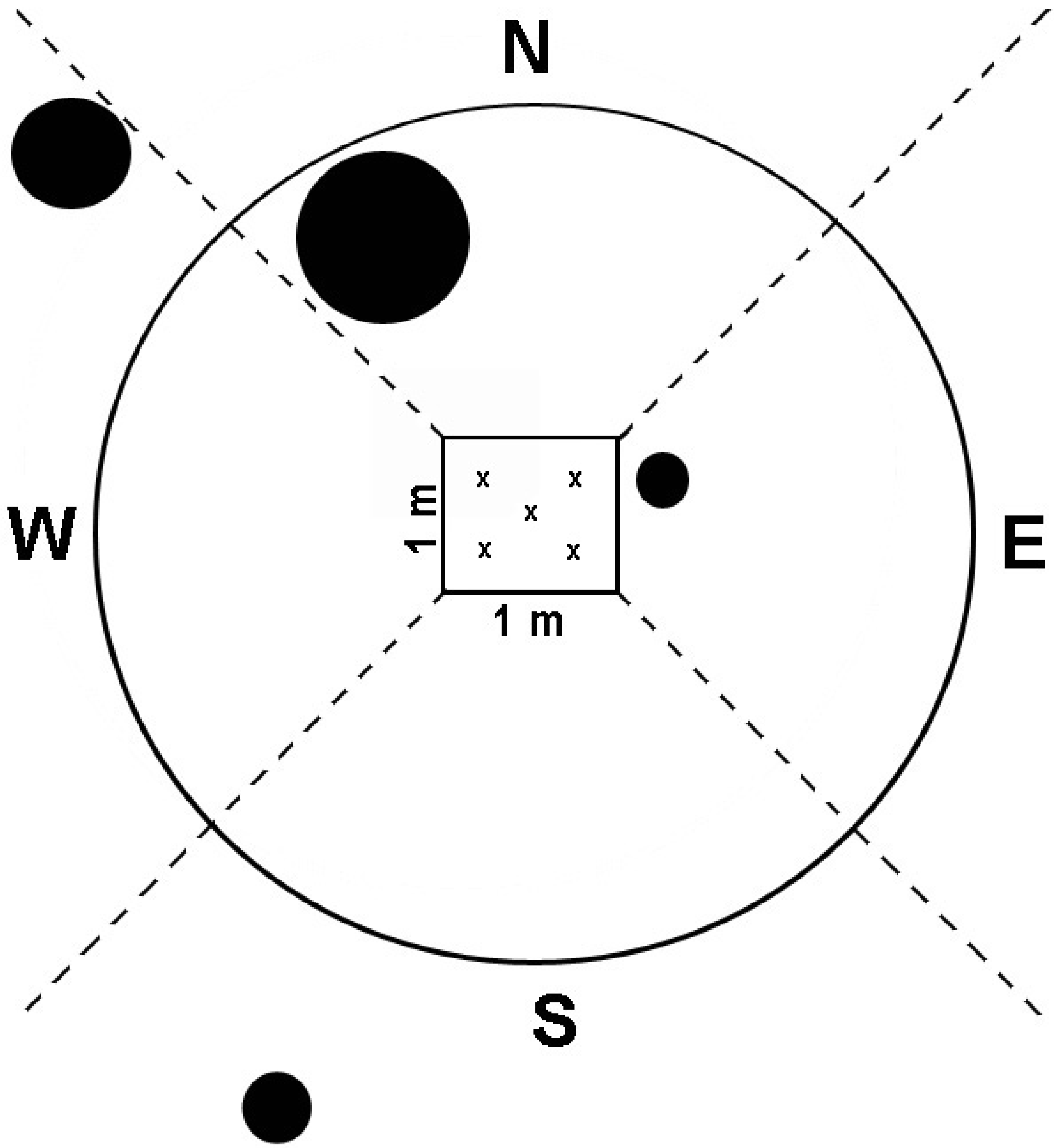
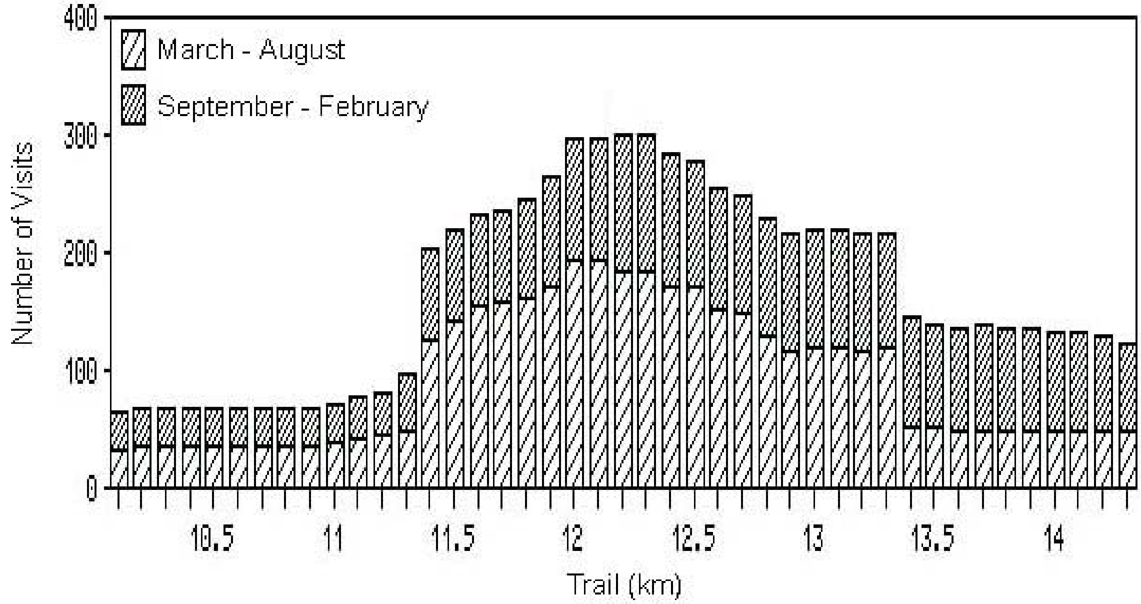


Figure 2.5: Sample plot for measurements of *Syrmaticus mikado* habitat inside the study sites in Yushan National Park, Taiwan. The 1 m^2 plot used to measure herb coverage (square) is centered within the 5 m diameter plot used to measure shrub coverage (large circle). Herb height was measured from five places within the 1 m^2 plot (**x**). Canopy composition was described by measuring the nearest tree from the center with > 2 cm dbh (dark circles) in each quadrant.

A



B

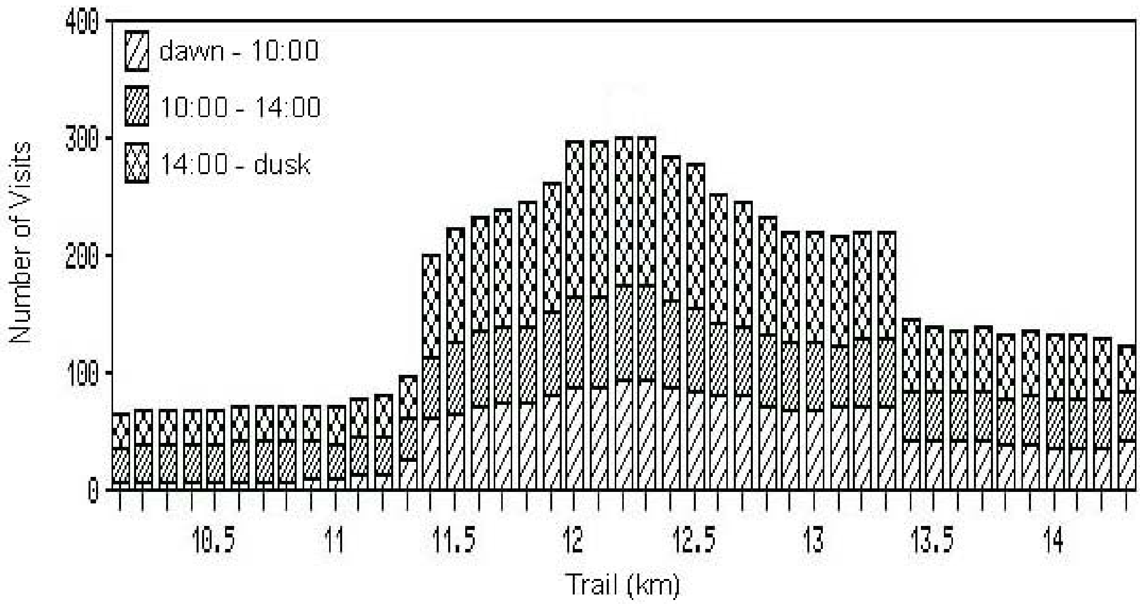
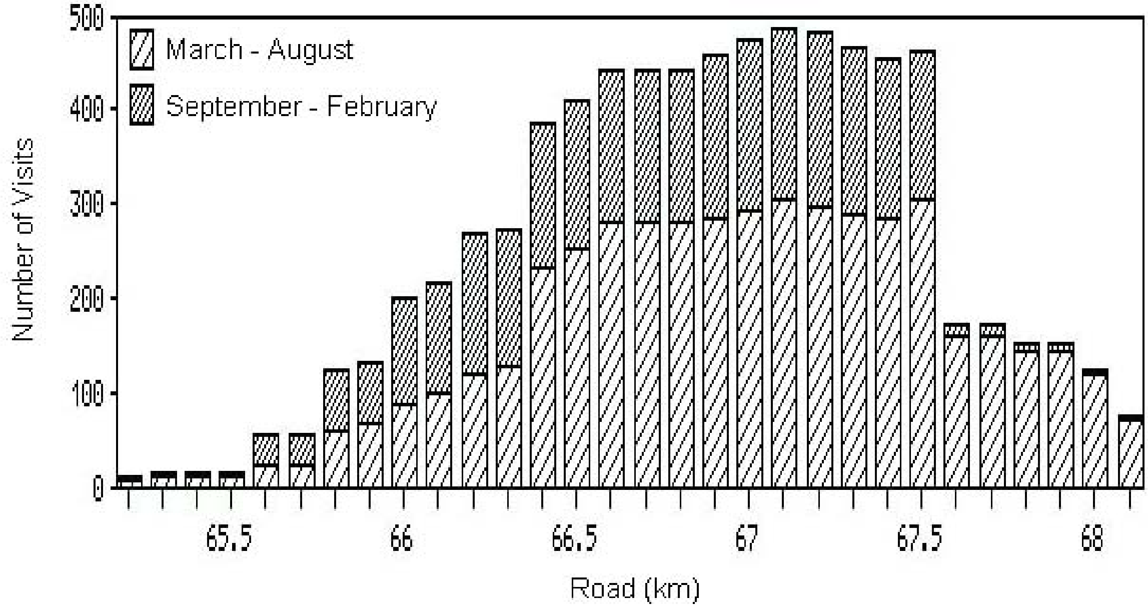


Figure 2.6: Seasonal and hourly survey effort in the Dwei Kwan study site, Yushan National Park, Taiwan. A) Seasonal survey effort between the wet breeding season (March through August) and the dry non-breeding season (September through February) was significantly different (Wilcoxan Signed Rank Test: s=-187.5, p=0.0217). B) Survey effort did not vary significantly between morning, midday, and afternoon periods (Kruskal Wallis Chi-Square: 5.3193, df=2, p=0.07).

A



B

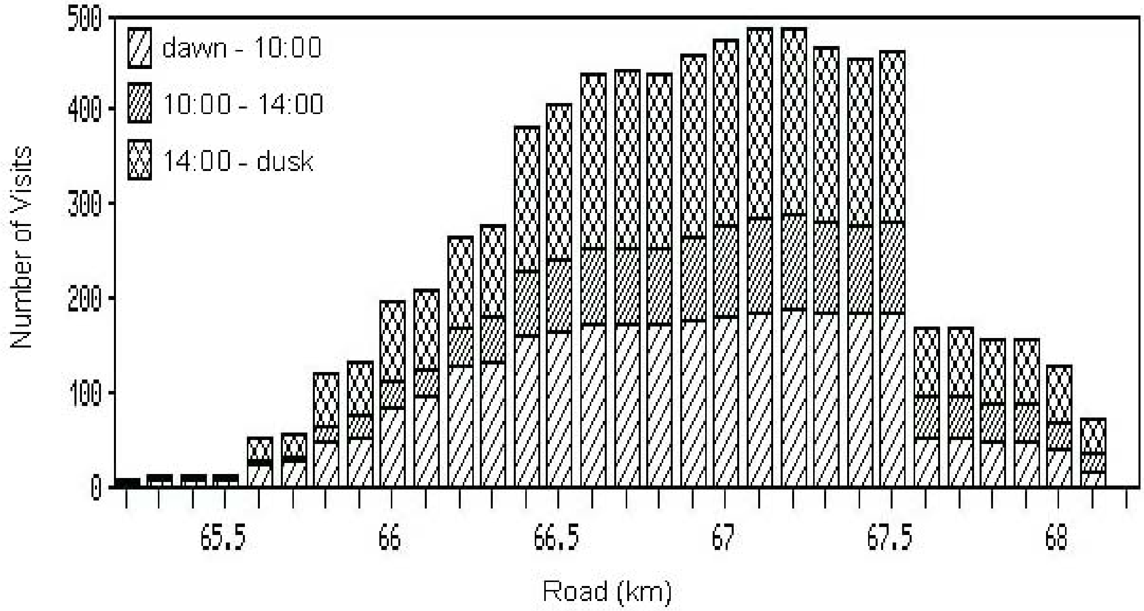


Figure 2.7: Seasonal and hourly survey effort in the Kwan Kao study site, Yushan National Park, Taiwan. A) Seasonal survey effort between the wet breeding season (March through August) and the dry non-breeding season (September through February) was significantly different (Wilcoxan Signed Rank Test: s=-101.5, p=0.0343). B) Survey effort did not vary significantly between morning, midday, and afternoon periods (Kruskal Wallis Chi-Square: 3.4382, df=2, p=0.1792).

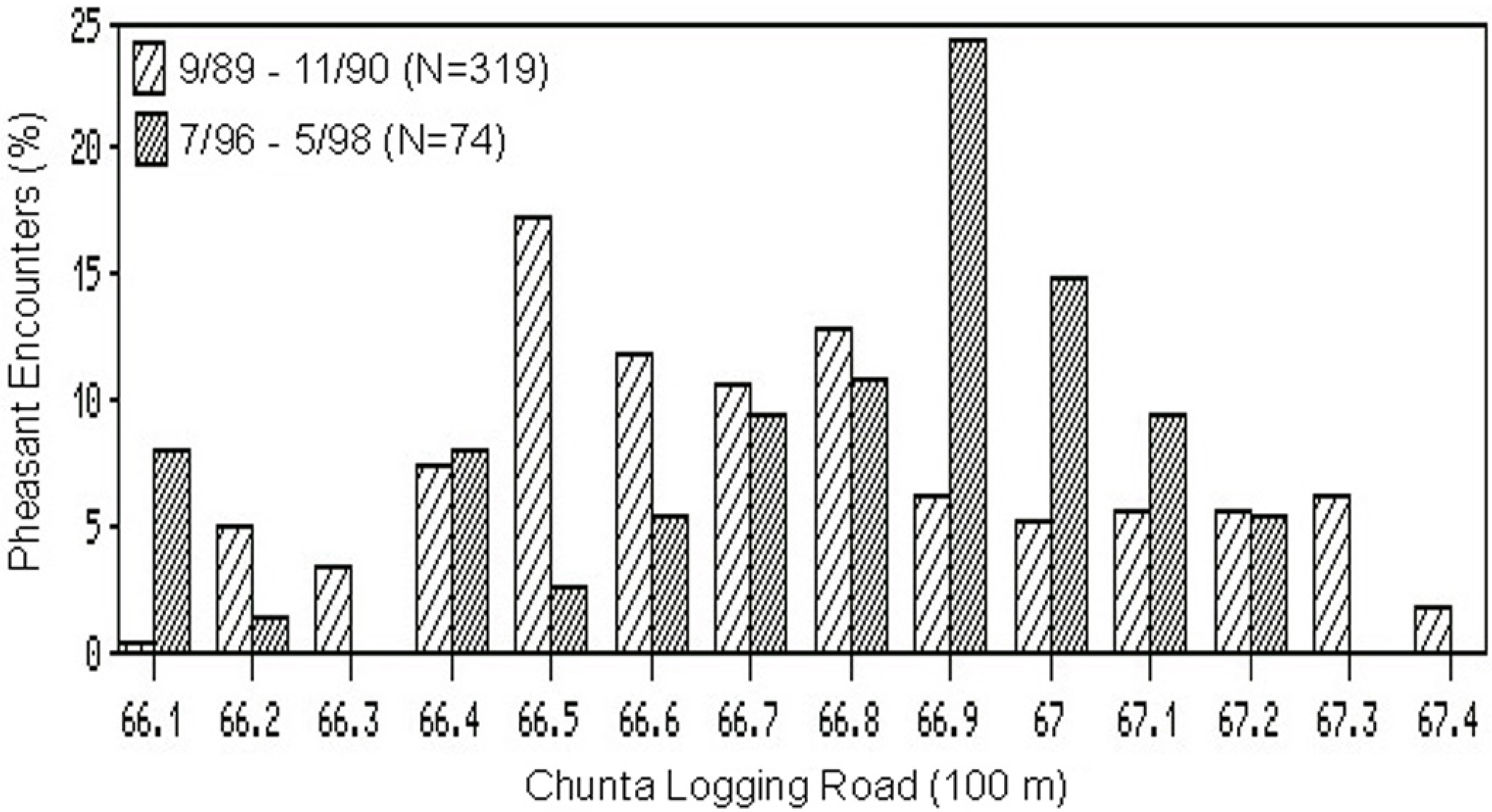


Figure 2.8: A comparison of the location of encounters with *Syrmaticus mikado* between two time periods on a 1.3 km section of the Chunta Logging Road inside Yushan National Park Taiwan. As the number of encounters differed between the time periods (9/89 – 11/90: N=319; 7/96 – 5/98: N=74), encounters are standardized as a percentage of the total. There were no significant differences in encounter rate for each 100m section of logging road (Wilcoxan Signed Rank Test, n=14, t=47, p=0.38; Daniel 1990). Data for 9/89 – 11/90 compiled from Alexander et al. 1990.

PART 3

THE RANGE OF MIKADO PHEASANTS IN THE MOUNTAINS OF TAIWAN

ABSTRACT

Geographic Information Systems (GIS) methodology was used to estimate the habitat available to Mikado Pheasants (*Syrmaticus mikado*), a species endemic to mountainous areas in Taiwan. This information may be useful for locating additional populations of the pheasant and for determining its International Union for Conservation of Nature and Natural Resources (IUCN) status of extinction risk. *Syrmaticus mikado* have been observed along roads and trails passing through primary, secondary, and managed forested and grassland habitats between the elevations of 1600 and 3300 m. Inside Yushan National Park, *S. mikado* were trapped, banded, and radio-tracked in two study sites from 1996 to 1999. Home range size was small (0.01 – 0.86 km^2). Tagged pheasants did not cross the 400 m between adjacent study sites. The models developed here suggest that Taiwan potentially has 6477 km^2 of habitat available for use by *S. mikado*, with 39% protected by three national parks, five nature reserves, and seven nature protected areas. The field guide model, based on habitats and elevations described in five field guides, has only limited use in estimating the extent of range of *S. mikado*. Within Yushan National Park there may be as many as 10,000 *S. Mikado*, based on densities found in the study sites: 48 - 58 *S. mikado* per km^2. This estimate is probably high, as the study sites are known for their pheasant populations. Based on these estimates of population size and habitat availability, *S. mikado* should be considered vulnerable to extinction, particularly as not all habitat described here may be suitable, and actual conditions within most parks and reserves are unknown.

INTRODUCTION

The dilemma of all conservation biologists is that of funding and time are limited. Most studies are species-oriented and yield management conclusions that may or may not be helpful for ecologically associated species (Kareiva 1994, Valone and Brown 1996). In addition, most studies are short-term (Tilman 1989, Gosz 1998), consisting of one-time surveys or of one season to one year's duration. Long-term studies are rare and may be the result of one scientist's "inordinate interest in a particular system" (Wiens 1997), or the focus on species with commercial rather than conservation value (e.g. white-tailed deer, *Odocoilus virginianus*; wild turkey, *Meleagris gallopavo*; ring-necked pheasant, *Phasianus colchicus*). These well-documented species often become models to supply the missing behavioral or demographic data needed for conservation and management decisions on lesser-known species. Even more serious than the limitations of species-specific data is the rate of human-induced change, primarily habitat destruction. Many scientists give the impression of being less than one step in front of the bulldozer as they scramble frantically to make conservation decisions. This is particularly poignant in areas with equally frantic deforestation through harvest or burning (Larsen 2002): Burma (33% remaining of original 138,000 km^2), Indonesia (51% remaining of original 162,000 km^2), and Philippines (less than 5% remaining of original 160,000 km^2). Therefore, it is necessary to explore methods, such as modeling, of determining important habitat without detailed or species-specific data.

Much effort is allocated to developing models that may help predict the status of species or their risk of extinction (e.g., Findlay and Houlahan 1997, Ratner et al. 1997, Vucetich et al. 1997, Akcakaya et al. 2000) or identify geographic locations or hot spots needing protection which will conserve a species or group of species (e.g., Kiester et al. 1996, Brooks et al. 1997). Geographic Information Systems (GIS) play an increasingly important role in the creation and testing of models, and can be particularly helpful with mapping and visualizing the patterns of population distribution (Haslett 1990). Meanwhile, great effort is expended to determine or estimate the distribution and status of species of concern (e.g., papers in Jenkins 1993). Increasingly, GIS is being used to correlate habitat with distribution (e.g., Knick and Dyer 1997, Waller and Mace 1997).

The International Union for Conservation of Nature and Natural Resources (IUCN) has published Red List categories (IUCN 2001). Species are placed into certain threat categories (critically endangered, endangered or vulnerable) based on the status of their population, estimated risks of extinction and/or the extent and status of their distributional range. Distributional range can be described as extent of occurrence: the area within the smallest boundary containing the entire distribution (IUCN 2001). Distributional range can also be determined by area of occupancy: the sum of the areas known to contain populations of the species of concern (IUCN 2001).

Estimating the distributional range and determining whether this range is fragmented or declining is one way to estimate threat of extinction to a species (IUCN 2001). According to the International Union of Conservation of Nature and Natural Resoures (2001), a species may be considered critically endangered if the extent of its occurrence is less than 100 km^2. It may be listed as endangered if the extent of its occurrence is less than 5000 km^2, and it may be considered vulnerable if less than 20,000 km^2. Alternatively, the area of occupancy must be less than 10 km^2 (critically endangered), 500 km^2 (endangered) or 2000 km^2 (vulnerable). In all cases, the amount of habitat within the range, or the population of the species itself, must be demonstrated as at least two of the following: fragmented, declining, or extreme fluctuation.

GIS has been used to determine geographic hotspots of species diversity (Beissinger et al. 1996, Kiester et al. 1996, Reid 1998) and to aid in decision making over reintroductions of wolves (Mladenoff and Sickley 1998). It is also being tested for use in assessing the conservation status of poorly known species (McGowan et al. 1998, this study). There are many studies of the habitat requirements and home range sizes of various species (e.g. Bridgman 1994, Marzluff et al. 1997, Staus 1998). Some of these studies (Knick and Dyer 1997, Waller and Mace 1997) have incorporated GIS in their analysis. Use of GIS to estimate the extent of range could be very helpful in determining the conservation status of these and other species. For many species, studies of habitat, home range, and population demographics have yet to be conducted. The basic habitat associations for these species, however, may already be generally described in field guides. Such material may be useful for estimating the extent of potential habitat and for locating additional populations for further study.

Most Galliformes are naturally rare and have limited ranges (King 1981), a fact which greatly increases their risks of extinction (Simberloff 1994). Habitat loss and hunting pressures account for 63% of the threats to Galliformes (data compiled from King 1981). Of the pheasant species within this order, 96% are threatened by habitat loss, but the habitat requirements of 17% are unknown (McGowan and Garson 1995). The designated conservation status of *Syrmaticus mikado* fluctuates. Currently classified as near-threatened (Fuller and Garson 2000), it has been considered both safe (McGowan and Garson 1995) and threatened with extinction (Groombridge 1993-1994). In Taiwan, this endemic pheasant is still considered endangered (Yang 1993).

The first survey of *S.mikado* began in the 1970s (Severinghaus 1977) and concluded that the bird lives in primary and secondary forests between 1800 and 3200 m in elevation. Studies since have concentrated on Yushan National Park (Severinghaus and Severinhaus 1987), the Kwan Kao area within Yushan National Park (Alexander et al. 1990, Bridgman 1994, Bridgman et al. 1999) and in the Zueyenshi Nature Reserve (Yao et al. 1998). In 1998, Lee et al. published distribution maps for all of Taiwan's terrestrial vertebrates based on sightings published in Chinese within Taiwan since 1978: governmental reports, unpublished theses, bird club reports, environmental impact assessments, and scientific journals. Lee et al. (1998) plotted distributions on a 4-km^2 grid (Appendix: Figure 3.1). From this map, Lee Pei-Fen (personal communication) estimates the extent of range for *S. mikado* to be about 10,000 km^2, and the area of occupancy to be about 900 km^2.

Here, I develop two models to estimate the area of habitat available for use by *S. mikado*: a field guide model, based on descriptions in available field guides (Severinghaus and Blackshaw 1976, de Schauensee 1984, Wang et al. 1991, del Hoyo et al. 1994, Chang 1995, and Lin et al. 1996), and a study site model based on the habitats found within the study area inside Yushan National Park. Telemetry and sighting data from banded and radio-tagged pheasants were used to estimate the boundaries of the study area and the population density of *S. mikado*. The objectives of this study were to generate minimum and maximum estimates of habitat available to *S. mikado* using these two models, and to compare these estimates to the known extent of range and area of occupancy. In addition, I estimate the population size of *S. mikado*. Estimates of available habitat and population size are useful in evaluating the extinction risk of *S. mikado*.

STUDY SITE

Located within Yushan National Park, Taiwan (Figure 3.1), the study area is divided by a ridge into two study sites of different forest types (Figure 3.2). The boundaries of these study sites were defined by the triangulated locations of radio-tagged birds (see telemetry section below). The secondary forest site (Kwan Kao) is composed mainly of mixed plantation forest. It also contains plantations of *Chamaecyparis* sp. and stands of *Tsuga* sp. left over from logging activities. Harvesting of trees stopped in 1985 with the creation of Yushan National Park, but planting and maintenance of planted trees continues. A 2.4 km section of the Chunta Logging Road (2450 m in elevation) bisects this site. The primary forest site (Dwei Kwan) is split by 4.2 km of the Patungkwan Trail as it climbs from 2000 m in elevation to 2600 m. Composed of mixed coniferous and broadleaf forest, this site also has stands of broadleaf forest and *Chamaecyparis* sp. forest. The entire study area, including both sites, is between 2200 and 2800 m in elevation.

METHODS

Encounters

From July 1996 through June 1999, the Chunta Logging Road (65.2 km to 68.1 km) and the Patungkwan Trail (10.1 km to 14.3 km) were patrolled during daylight hours for about two weeks each month for sightings of *S. mikado* (Part 2). Locations of encounters were recorded to the nearest 20 m. The pheasants were encountered only on the road or trail. No pheasants were encountered during forays away from the road or trail. To test for differences in survey effort between study sites, I calculated the number of encounters per km surveyed each day. These indexes were tested with Student's t-test (Daniel 1990).

Automatic Cameras

Beginning in 1998, I placed automatic cameras in 23 locations off the road or trail (Part 2). Of those placed within the study sites, three photographed pheasants (Figure 3.2).

Trapping

Traditional aboriginal foot-snares were placed on or adjacent to road and trail (described in Severinghaus 1977, Bridgman 1994). Between 10 and 30 snares were used daily for about one week each month in each study site from September 1996 through April 1999. Snares were checked hourly during the day (0530 hr to 1900 hr) and were completely destroyed at the end of each visit to the study site. Pheasants were banded with two to four plastic colored leg rings and one numbered aluminum ring. Pheasants over 600 g were radio-tagged.

Radio-Telemetry

Transmitters were Hi-Tech Services Model WL300 backpack transmitters with a mortality switch that turned on if the transmitter remained motionless for 11 hours. Transmitters weighed 20 grams, including harness material, and were about 3% of the body weight of a 600 g pheasant.

Birds were located using AVM LA12-Q portable telemetry receivers and Telonics Model RA-14 antennas.   Radio-tagged *S. mikado* were located via triangulation from markers established at 20 m intervals on the road and trail (Kenward 1987, White and Garrott 1990, Bridgman 1994, Part 2). Radio-locations were made at a minimum of four-hour intervals for a maximum of four locations per day. At least three fixes collected within a 15-minute interval were used to estimate location. All fixes were made within 300 m of the bird.

The coordinates of telemetry locations were determined using the program TELEM (Coleman and Jones 1988). I calculated 100% minimum convex polygon (MCP) ranges for pheasants with $\geq$10 locations using CALHOME (Kie et al. 1996). To determine the boundaries of each study site, primary or secondary forest, I calculated the 100% MCP range using the pooled locations from all radio-tagged pheasants. Using ArcView GIS 3.2 and ArcView GIS Spatial Analyist 2 (Environmental Systems Research Institute, Redlands, CA), I plotted the coordinates of polygons, telemetry locations, and encounter locations overlaid onto the Taiwan Forest Bureau (1995) land use data.

Geographic Information Systems

The Taiwan Forest Bureau (1995) has digitized the elevation and land-use maps of Taiwan. These maps, at a scale of 1:5000, are derived from a 1987 survey of Taiwan's mountainous regions using aerial photographs. Of the 998 land use categories for Taiwan, 75 were applicable to Taiwan's high elevations. Chou and Wang (1995) updated the Taiwan Forest Bureau maps for the area inside Yushan National Park.

Descriptions of suitable habitat for *S. mikado* in five field guides (Severinghaus and Blackshaw 1976, de Schauensee 1984, Wang et al. 1991, Chang 1995, and Lin et al. 1996) and in the *Handbook of the Birds of the World* (del Hoyo et al. 1994) form the basis of the field guide model. These sources generally agree that the bird occurs in forested and grassland habitat (both natural and second growth) between the elevations of 1600 and 3300 m (Appendix: Table 3.1). Of the 75 land-use categories found within these elevations (Taiwan Forest Bureau 1995), 43 (Table 3.2) fit the descriptions in Table 3.1.

The field guide model represents the maximum extent of habitat available to *S. mikado* within Taiwan. I estimated the maximum amount of protected habitat by evaluating the area of each land-use category with the three national parks, five nature reserves, and seven nature protected areas (Table 3.3) with land area between 1600 and 3300 m in elevation. Taiwan has an additional two national parks, 13 nature reserves, and 14 nature protected areas that were not considered for this analysis because they were at elevations below 1600 m. Two reserves, the Wuling Landlocked Salmon Nature Reserve and the Sheipa Nature Protected Areas, were not analyzed separately as they were recently included in Sheipa National Park. The Taguanshan Nature Reserve was not analyzed separately because it is entirely within the Chatianshan Nature Reserve. About half of the Zueyenshi Nature Protected Area is located inside Taroko National Park. Repetition by analyzing both of these reserves negligibly inflates area estimates.

To produce a model with which to compare the field guide estimates and to represent the minimum amount of available habitat within Yushan National Park and Taiwan, I assumed that only those habitats found within the study area (Figure 3.2) were suitable for *S. mikado*. Six land-use types were identified within the boundaries of the study sites (Table 3.2), as determined from radio-telemetry locations. None of the significant variables from study of microhabitat use by *S. mikado* (Part 2) were of a scale large enough for use in this analysis.

Population Estimate

Resighting data of observed and trapped *S. mikado* from July 1996 through June 1999 were combined with sighting data from automatic cameras to estimate the number of pheasants using each study area with Bowden's Estimator in NOREMARK (White 1996). Although banding of *S. mikado* began in 1990 (Alexander et al. 1990), only the four birds recaptured in 1996-1999 were included in the population estimate. Bowden's Estimator assumes the population is open and individuals are encountered at different rates. It calculates population numbers based on the number of encounters with each marked individual, unidentified marked individuals, and unmarked individuals (White 1996). Results include a mean population estimate with confidence intervals based on a user-specified probability value. Both estimate and confidence interval are improved with increased encounters with marked birds. The variables and values used for this estimator are in Tables 3.4 and 3.5. As Bowden's Estimator calculates the number of animals frequenting a study site (Bowden 1993), it is particularly suitable for use in this study because, with the exception of automatic cameras, all pheasants were trapped or encountered on the road or trail. In this case, Bowden's Estimator estimates the number of pheasants frequenting the road and trail within the study area.

Bowden's Estimator (Bowden 1993) does not calculate population density. To estimate the population density for each study site, I calculated the area of each study site by using the telemetry ranges of pheasants captured on the road and trail (see Radio-Telemetry section above). I divided estimated mean number of pheasants and the range, indicated by the 95% confidence interval, by the ratio-telemetry estimate of study site area (McCullough et al. 2000) to obtain a mean and range of population density. As not all land use types within each study site were used equally (Figure 3.2), I calculated proportion of density for each type from the ratio of pheasant activity (encounters, triangulated locations, photographs from automatic cameras) in each land use type (Table 3.6). Within the study area, road and trail were not identified as a separate land use type by the Taiwan Forest Bureau (1995) but were incorporated into adjacent forest. The proportional densities were used to estimate the number of *S. mikado* inside Yushan National Park based on the assumptions used to make the study site model of habitat availability: 1) pheasants only occur between 1600 and 3300 m in elevation (Table 3.1); 2) pheasants are found in all locations with the same land-use categories as the study sites (Figure 3.2) regardless of patch size or degree of isolation; and 3) no pheasants occur in any land-use type not found in the study sites.

RESULTS

Encounters

Survey effort between study sites from July 1996 through June 1999 did not vary significantly (Student's T-test: $t=1.43$, $df=340$, $p=0.1527$)(Figure 3.3). From October 1996 through June 1999, 21 pheasants were trapped and banded in the Kwan Kao study site, of which 16 were radio-tagged (Table 3.4). Of the banded pheasants, 11 were seen again 60 times, including five times by three of the automatic cameras (Tables 3.4 and 3.5). These automatic cameras also photographed five untagged pheasants. Three of the radio-tagged pheasants were first trapped 1991-1992. Resighting rate varied: some pheasants were seen as many as 32 times whereas others were never encountered again (Table 3.4). One male first captured in 1992 was neither recaptured nor seen until May 1999. There were 14 sightings of unidentified, but marked, birds (Table 3.5). Unmarked or unidentified birds were seen 119 times. In the Dwei Kwan study site, 17 pheasants were trapped, banded, and radio-tagged (Table 3.4). Of these, eight were seen again for a total of 18 times (Table 3.4). Only one pheasant was seen as many as four times (Table 3.4). During this 3-year period, unidentified or unmarked birds were encountered 85 times (Table 3.5).

Radio-Telemetry

Thirteen pheasants in each site were followed long enough to estimate individual range (Figure 3.2). Radio-tagged pheasants were followed five to 693 days depending on the condition of the transmitter, recapture rates, and bird survival (Table 3.3). All pheasants, and/or transmitters, were recovered within the study site in which they were captured. Although bounce was considerable, birds were never out of range of the receiver.

Between 1996 and 1999, home range size of individual pheasants with $\geq$10 locations ranged from 0.014 to 0.864 km^2 (Table 3.3). In the secondary forest site, two pheasants (one male and one female) were observed for almost two years. Each of them had a home range of 0.22 km^2. In the primary forest site, two males were followed for about one year each. Their home ranges were 0.36 and 0.86 km^2, respectively.

The size of the primary forest site (Dwei Kwan) based on the 100% MCP area using all locations of all pheasants tagged in this site is 1.72 km^2. The size of the secondary forest site (Kwan Kao) is 0.97 km^2.

Habitat Availability

The land use types found inside Yushan National Park are shown in Figure 3.4. The elevations of Yushan National Park, ranging from 200 – 3952 m are shown in Figure 3.5. Minimum habitat availability for *S. mikado*, according to the study site model, is shown in Figure 6. The maximum amount of habitat available, the field guide model, is shown in Figure 7.

Estimates of available habitat according to both models for Taiwan are in Table 3.3. Because it uses six of the same land use types (Table 3.2), the study site model is a subset of the field guide model, identifies about one-third the land area, and is considered a minimum estimate. Figure 3.1 shows the distribution of available habitat in Taiwan according to the field guide model. Overall, Taiwan contains 6477 km^2 of forests and grasslands between the elevations of 1600 - 3300m. Of this, 39% (2542 km^2) is protected within national parks, nature reserves, and nature protected areas (Table 3.3). Within Yushan National Park, 796 km^2 are available for use by *S. mikado*.

Population Estimate

Forty-seven pheasants are estimated to use the road in the secondary forest site (95% confidence interval: 25 – 90) and 100 to use the trail in the primary forest site (95% confidence interval: 58 – 171)(Table 3.6). The broad range in confidence intervals is due to the low resighting rate of tagged birds, particularly in relation to the number of unmarked sightings. Dividing these numbers by the estimated area of each study site yields an estimated population density of 48 pheasants per km^2 (range: 26 – 93) in the secondary forest site and 58 pheasants per km^2 (range: 33 – 99) in the primary forest site (Table 3.6). Extrapolation of these densities based on the habitat types found within the study site suggests that Yushan National Park has about 10,000 *S. mikado* (range: 5612 – 16,968)(Table 3.6).

DISCUSSION

The habitat requirements of *Syrmaticus mikado* may well be more specific than the variables used here or available for GIS analysis. In Part 2, the habitat variables important to *S. mikado* were of a scale currently too small for use in GIS. The field guides suggest that the pheasant occurs in forested and grassland areas on steep slopes between 1600 and 3300 m in elevation. The model based on these suggestions indicates that inside Yushan National Park, almost all the habitat between 1600 and 3300 m is suitable for *S. mikado*. This field guide estimate can be considered a maximum estimate of habitat availability. A subset of the field guide model, the study site model concentrates only on the habitat types found in the study site and, at best, represents a minimum estimate of habitat availability. Although *S. mikado* probably do not occur in every location identified, and certainly occur in additional locations, these models may be useful in a search for other populations.

Most of the habitat descriptions in the field guides were derived from Severinghaus (1977), the only island-wide survey of *S. mikado*. In this two-year survey, *S. mikado* were encountered by the research team 35 times. All of these encounters, plus descriptions of encounters from interviews, were in or adjacent to forested habitat. Research after 1977 has either confirmed this habitat usage (Severinghaus and Severinghaus 1987) or concentrated study within the forested habitat types already described (Alexander et al. 1990, Bridgman 1994, Yao et al. 1998, Bridgman et al. 1999). Because they were mentioned in the field guides, bamboo scrublands and grasslands were included in the analysis here. Many of these scrublands and grasslands are quite extensive in size and offer little or no cover to the pheasants. Although it is unlikely that individual *S. mikado* utilize these habitats exclusively, they have been repeatedly encountered in these habitats (Chang Yar-ling, personal communication). In addition, *S. mikado* are not limited to the elevations used here. There are sightings at elevations over 3300 m (Chang Yar-ling, personal communication). On the east coast of Taiwan, there have been enough sightings (Wang et al. 1994; Chang Yar-ling, personal communication) and reported sightings from interviews (Chen 1996) at elevations below 1600 m to generate a hypothesis of seasonal altitudinal migration (Chen 1996). This hypothesis, however, is not supported by radio-telemetry data of banded birds in Yushan National Park (Bridgman 1994, Bridgman et al. 1999) or in the Zueyenshi Nature Protected Area (Yao et al. 1998). The validity of these low elevation records are questionable, but if accurate their significance is unknown. If further study supports these records, then the elevation range and area estimates of extent of range will need to be revised.

The field guide model (Figure 3.1) predicts a smaller area compared to the estimated 10,000-km^2 extent of range (Lee Pei-Fen, personal communication). Recognizing this, the field guide model may be useful in predicting a conservative estimate of area as a substitute for the extent of range, particularly for those species lacking information on the location of populations. A review of the habitat requirements for the 24 endangered and threatened pheasants listed in Fuller and Garson (2000) yields descriptions as general as those found in field guides.

At 3356.8 km^2, the study site model overestimates the estimated area of occurrence (900 km^2; Lee Pei-Fen, personal communication)(Figure 3.1). The land-use types used in this model occur throughout the range indicated by the field guide model. If the study site model turns out to be an accurate representation of *S. mikado* habitat, then the degree of fragmentation and the size of the patches (Figure 3.6) may be a problem for the survival of this species. It is most interesting that the study area is within the largest and most contiguous patch, particularly as this location was not selected based on habitat but on frequency of encounters with *S. mikado* (Alexander et al. 1990).

Syrmaticus mikado do not have large home ranges (Table 3.3). Bridgman (1994) concluded that although there was no seasonal altitudinal migration among *S. mikado* at the secondary forest site, the ranges did shrink and expand from season to season. Furthermore, there was no indication that pheasants traveled from one study site to the other (Bridgman 1994, Bridgman et al. 1999). All radio-tagged pheasants stayed within and were recovered from the study site in which they were originally trapped (Bridgman 1994, Bridgman et al. 1999). Pheasants may have ranged more than 1 km from the original trap location, but movements primarily ran parallel to topographical lines (Bridgman 1994, Bridgman et al. 1999). These small home ranges and the lack of movement even between study areas separated by less than 400 m (Figure 3.2) bode ill for the colonization of isolated patches of habitat and for gene exchange between populations.

There are 48 to 58 *S. mikado* per km^2 within the study area. Estimates of densities for other pheasant species (Table 3.5) range from as low as 0.2 per km^2 (*Phasianus colchicus*, Common Pheasant; Edminster 1954) to as high as 140 per km^2 (*Chrysolophys amherstiae*, Lady Amherst's Pheasant; Li 1996). The study site estimate is high compared to other estimates of density for *S. mikado* (Table 3.5), which range from 15 per km^2 (del Hoyo et al. 1994) to 25.6 per km^2 (Poltack 1972) to 32 per km^2 (Li 1996). The density estimate by del Hoyo et al. (1994) is derived from Severinghaus and Severinghaus (1987) who estimated 10,023 *S. mikado* inside Yushan National Park based on the rate of encounter at different elevations. In 1977, Severinghaus suggested a population density of 0.2 per km^2 and thought there might be 5000 to 10,000 *S. mikado* in Taiwan. Assuming that *S. mikado* occurs only in the same habitats and at the same densities as those in the study area, I suggest that there are about 10,000 (range: 5612 – 16,968) *S. mikado* inside Yushan National Park. As *S. mikado* exhibits a patchy distribution, even within similar habitats (Severinghaus 1977, Part 2), it is unlikely that the densities found within the study area are typical. This estimate is probably high as, in 1989, Alexander et al. (1990) selected this study area because, of the three areas surveyed inside Yushan National Park, pheasants were most frequently encountered here. Furthermore, *Syrmaticus mikado* does occur in habitats and elevations other than those used for the study site model.

The question is whether these estimates reflect a stable *S. mikado* population in spite of the variation in the methods used. The Severinghaus (1977) estimate is based on interviews and encounters with pheasants and is for the entire island. The Severinghaus and Severinghaus (1987) estimate is for Yushan National Park, is based on interviews and on encounters with pheasants from surveys of the roads and trails inside the park, and was adjusted for variation in encounter rate at different elevations. My study site estimate is based on the densities and habitat types found within the study site and extrapolated to include the same habitat types within Yushan National Park between the elevations of 1600 and 3300 m. This estimate is similar to that by Severinghaus and Severinghaus (1987).

If human harvest had been limiting *S. mikado,* its population should have increased since the surveys in Severinghaus (1977). Real efforts towards conservation did not begin until 1972 when Taiwan's Ministry of Interior banned the hunting and export of select species, including *S. mikado,* although *S. mikado* has been officially protected from hunting since 1932 (Patel 1989). Before this law was passed, commercial hunting was a major industry, supplying specimens, including *S. mikado*, for tourists, research, and collections (Patel 1989). In 1982, Taiwan strengthened its conservation efforts by passing the Culture Heritage and Conservation Law (Yang 1993). Since 1984, when the first national park was founded (Kenting National Park), Taiwan has created 6 national parks and numerous nature reserves and protected areas, many of which are at elevations suitable for *S. mikado* (Table 3.4). Yushan National Park, founded in 1985, has the largest block of protected habitat. Taiwan is still creating parks, reserves, and protected areas. The newest national park, Makao, was inaugurated May 2002 and may contain populations of *S. mikado*. Currently, any hunting or development within national parks and nature reserves is forbidden (Yang 1993), as is hunting of protected species anywhere in Taiwan. The Taiwan Forest Bureau, which manages the nature protected areas, discourages hunting activities, but there are no particular laws prohibiting hunting within these reserves. Although commercial hunting has subsided, subsistence hunting continues, even within national parks (see Part 4).

Taiwan's mountains are steep, plummeting sharply into deep valleys. This terrain fractures the habitat and increases isolation between populations. Habitat is continuously lost through landslides. Bare ground within Yushan National Park has almost doubled, from 4450 km^2 in 1987 to 8543 km^2 in 1999 (Chou and Wang 1995, Chou et al. 2000). Some of the main causes of erosion have been particularly strong typhoons in 1996 and the earthquake in 1999 (7.9 on the Richter Scale; Chou et al. 2000). In 2001, there were two additional typhoons causing severe damage to the area in and around Yushan National Park (personal observation). In spite of these natural disasters, Chou et al. (2000) noticed that most of the increases in bare ground are near areas of human activity such as roads and rivers.

The terrain has limited human access, probably contributing to the survival of *S. mikado* and other of Taiwan's endemic species. Most human activity continues to be on the plains. For Taiwan's mammals, Lin and Lin (1983) noted a positive association between endemism and elevation. Lin and Lin (1983) also noted an elevation shift from 1940 to 1980 in the distribution range for Taiwan's land mammals, suggesting that as human activities increase on the lower slopes, the mammals have shifted their own activities to higher elevations. These patterns probably hold for other animals in Taiwan. The effects of increased diversity and interspecific interactions on the tops of Taiwan's mountains have yet to be investigated. The expansion in the distribution of *Mustela sibirica* (a lowland mustelid and human commensal; Lin 2000) may have increased predation pressure on *S. mikado*, already a prey item for *Martes flavigula chrysospila* (Yellow-throated Marten) and several avian predators (see Part 4). Taiwan's other endemic pheasant, *Lophora swinhoe* (Swinhoe's Pheasant), may also be shifting its activity to higher elevations (personal observation), and may compete with *S. mikado* for nest sites and food.

Based on the data presented here, *S. mikado* is probably vulnerable to the risks of extinction. The extent of occurrence is about 10,000 km^2 and the area of occupancy is about 900 km^2 (Lee Pei-Fen, personal communication). To qualify as vulnerable, the extent of occurrence must be less than 20,000 km^2 or the area of occupancy less than 2000 km^2, with evidence of either population or habitat decline, fluctuation or fragmentation (IUCN 2001). Although the pheasant population is declining in one area (see Part 4), as yet there is no indication that this decline is island-wide. Even though the pheasant's extent of occurrence is within the IUCN Red List guidelines, 39% of its range is protected within three national parks, five nature reserves, and seven nature protected areas. *Syrmaticus mikado* is known to occur in all three national parks and several of the nature reserves and protected areas. In addition, hunting of *S. mikado* is specifically prohibited (Yang 1993), although it continues to occur (see Part 4). The landscape patterns revealed by the study site model and the increases in bare ground documented by Chou et al. (2000) suggest some fragmentation and decline of habitat. Whether this is followed by succession or continued deterioration, remains to be studied. Wang (1962) states that landslides and typhoons have been important forces in the development of Taiwan's vegetation. Mabry et al. (1998) found that the typhoon disturbance regime was an important force in the turnover of forest communities in Northern Taiwan. As *S. mikado* has evolved in this dynamic landscape, it should be able to tolerate some changes in habitat.

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APPENDIX

Table 3.1: Elevation and Habitat Requirements of Taiwan's *Syrmaticus mikado* as described in available field guides.

Author and Date	Elevation	Habitat
Severinghaus and Blackshaw 1976	1800-3200 m	Forests and second growth with dense undergrowth
de Schauensee 1984	1800-3050 m	Thick forest
Wang et al. 1991	mid- to high	Understory of Coniferous, Mixed, and Bamboo forests, thickets
del Hoyo et al. 1994	1600-3300 m	Forests with dense undergrowth and secondary growth habitats
Chang 1995	1800-3200 m	Natural coniferous forests, thickets, and bamboo
Lin et al. 1996	mid- to high	Mixed coniferous and broadleaf natural forests, coniferous forests, and *Yushania* bamboo thickets.

Table 3.2: Habitat types available for use by *Syrmaticus mikado.* Listed are the land-use types used in the field guide model and those used in the study site model (in **bold**), a subset of the field guide model. Land-use categories are from the Taiwan Forest Bureau (1995).

Forest Type	Land-Use Type
Coniferous Forest	*Abies*, ***Tsuga, Chamaecyparis,*** *Pinus, Picea,* Mixed coniferous, and Bamboo coniferous.
Mixed Forest	**Hardwood coniferous** and Bamboo hardwood coniferous.
Broadleaf Forest	Mixed hardwood, Bamboo hardwood and **Other hardwood.**
Plantation Forest	***Chamaecyparis,*** *Pinus, Cunninghamia, Taiwania, Cryptomeria, Calocedrus,* Other conifers, Mixed coniferous, **Mixed hardwood-coniferous,** *Acasia, Liquidambar formosana, Cinnamomum camphora, Fraxinus formosana, Zelkova serrata, Aleurites, O*ther broadleaf plantations, Mixed hardwood, Mixed conifer-bamboo, Mixed hardwood-bamboo, Mixed hardwood-conifer-bamboo, other plantation.
Bamboo Forest and Thicket	*Phyllostachys makinoi, P. pubescens, Dendrocalamus latiflorus, Bambusa stenostachya*, *P. makinoi* plantation, *P. pubescens* plantation, *D. latiflorus* plantation, *B. oldhamii* plantation, Other bamboo plantation, *Yushania*, and Thicket.

Table 3.3: Comparisons of field guide and study site models of habitat availability (km^2) in Taiwan between 1600 and 3300 m for *Syrmaticus mikado*.

	Total Reserve Area	Study Site Model	Field Guide Model
National Parks	2127.0	983.3	2057.8
Yushan	819.9	320.1	796.2
Taroko	697.2	358.6	667.9
Sheipa	609.8	304.6	593.8
Nature Reserves	136.8	55.9	135.2
Tawushan	97.9	36.7	96.4
Chuyunshan	20.7	8	20.6
Chatienshan	13.9	7.6	13.8
Yuenyanghu	3.7	3.5	3.6
Taiwan Pleione	0.6	0	0.6
Nature Protected Areas	365.5	214.2	349.7
Shuanggueihu	237.7	160.2	235.1
Yuli	104.2	45.9	101.2
Zueyenshi	6.2	3.7	5
Lulinshan	3.5	1.3	3.5
Beitawushan	4.3	2.6	2.1
Kuanwu	0.6	0.5	0.6
Kuanshan	0.1	0.1	0.1
Total Protected	2620.2	1253.4	2542.6
Total Island-wide	6679.3	3356.8	6477.4

Table 3.4: *Syrmaticus mikado* trapped within Yushan National Park, Taiwan, between July 1996 and June 1999.

	ID	Sex	Sightings and Recaptures[1] (N)	100% MCP[2] (km^2)	Locations[3] (N)	Duration[4] (days)
Dwei Kwan (primary forest)						
	272	♂	4	0.864	94	350
	487	♂	3	0.357	123	364
	187	♀	2	0.296	45	149
	1029	♂	0	0.280	28	118
	331	♂	0	0.255	17	58
	369	♂	1	0.218	45	143
	911	♂	2	0.153	19	16
	208	♀	2	0.047	11	5
	890	♂	0	0.039	11	102
	171	♀	0	0.027	13	56
	931	♂	1	0.027	12	25
	228	♀	3	0.026	17	23
	531	♀	0	0.014	13	37
	851	♀	0	.	6	6
	384	♀	0	.	3	37
	1111	♀	0	.	8	10
	51	♂	0	.	.	.
Kwan Kao (secondary forest)						
	707	♀	4	0.472	75	268
	869	♀	2	0.330	152	407
	288	♀	2	0.320	75	262
	833	♂	0	0.308	100	313
	1189	♀	8	0.221	48	671
	406	♂	32	0.217	187	693
	727	♂	0	0.159	19	89
	1209	♂	0	0.147	44	154
	749	♂	1	0.116	34	122
	1169	♀	2	0.115	40	91
	770	♀	0	0.065	22	55
	1050	♂	0	0.060	10	22
	81	♀	2	0.023	11	60
	811	♀	0	.	7	34
	1091	♀	0	.	7	4
	987	♀	0	.	3	26
	60	♂	4	.	.	.
	63	♂	2	.	.	.
	23	♂	1	.	.	.
	32	♂	0	.	.	.
	68	♂	0	.	.	.

[1]The number of sightings and recaptures per bird were used in Bowdon's Estimator (Table 3.5).
[2]Mimimum convex polygon ranges were calculated only for pheasants with 10 or more locations.
[3]Sightings and radio locations were used to calculate range.
[4]Number of days each pheasant carried a radio transmitter

Table 3.5: Estimates of population size and density of *Syrmaticus mikado* within the study sites inside Yushan National Park, Taiwan. Bowden's Estimator uses mark-resighting data to estimate population number. This divided by study site area estimates generates population density (pheasants per km^2).

Values for Bowden's Estimator	Study Site Kwan Kao	Study Site Dwei Kwan
Marked pheasants (N)	21	17
Marked but unidentified (N)	14	0
Unmarked sightings (N)	119	96
Total sightings and recaptures (N)	60	18
alpha level (%)	0.05	0.05
Population Estimate: mean (95% confidence interval)	47(25-90)	100(58-171)
Study Site Area (km^2)	0.97	1.72
Population Density: mean (range)	48.5(25.8-92.8)	58.1(33.7-99.4)

Table 3.6: Population density of *Syrmaticus mikado* for each study site and population estimate for Yushan National Park, Taiwan. The population density (pheasants per km^2) listed for each habitat type is based on the proportion of pheasant locations and is used to estimate the population (N) within Yushan National Park.

	STUDY SITES				YUSHAN NATIONAL PARK		
	Locations		Population Density		Area	Population Estimate	
HABITAT	(N)	(%)	Mean	(Range)	(km^2)	Mean	(Range)
KWAN KAO							
Tsuga Forest	9	0.9	0.4	(0.2-0.8)	86	36	(19-70)
Chamaecyparis Plantation	81	7.8	15.8	(2.0-7.3)	16	61	(32-117)
Mixed Plantation	944	91.3	44.3	(23.6-84.7)	25	1097	(583-2099)
TOTAL	1034	100	48.5	(25.8-92.8)			
DWEI KWAN							
Chamaecyparis Forest	5	0.9	0.5	(0.3-0.9)	46	24	(14-40)
Mixed Forest	558	98.6	57.3	(33.2-98.0)	149	8557	(4963-14641)
Broadleaf Forest	3	0.5	0.3	(0.2-0.5)	3	1	(0-1)
Mixed Plantation	0	0	0				
TOTAL	566	100	58.1	(33.7-99.4)			
YUSHAN NATIONAL PARK							
TOTAL					325	9776	(5612-16968)

Table 3.7: Comparative densities of pheasants worldwide. Data compiled from Johnsgard (1999).

Species	Common Name	Density (km^2)	Source
Ithaginis cruentus	Blood Pheasant	10-15	Lelliot and Yonzon 1981
		6.7-66.0	Li 1996
		11.3-22.6	Jia et al. 1997
		17	Sun and Fang 1997
Tragopan melanocephalus	Western Tragopan	0.8-1.6	Mirza 1980
		1.3	Islam 1983
Tragopan satyr	Satyr Tragopan	16.7	Lelliot and Yonzon 1981
Tragopan temmincki	Temminck's Tragopan	1.1-9.6	Li 1996
		13	Li 1991
Tragopan blythi	Blyth's Tragopan	4.3	Zeliang 1981
Tragopan caboti	Cabot's Tragopan	7.1-21.4	Li 1996
Pucrasia macrolopha	Koklass	3.6	Mirza 1980
		46	Severinghaus et al. 1979
		3-20.8	in Severinghaus et al. 1979
		10-50	Gaston et al. 1981
		2-46.6	Li 1996
		22	Han et al. 1990
Lophophorus impeyanus	Himalayan Monal	2	Mirza 1980
		8-16	Gaston et al. 1981
		5-14	Gaston et al. 1981
		10-40	Sathyakumar et al. 1993
Lophophorus ihuysi	Chinese Monal	4.5	Li 1996
		1.32-1.58	Lu and Liu 1986
		4-6	Rimlinger et al. 1997
Gallus gallus	Red Junglefowl	25-50	Bump and Bohl 1961
		100	Collias and Collias 1967
		1.1-1.6	Li 1996
Crossoptilon crossoptilon	White Eared Pheasant	1.5-4	Li 1996
Crossoptilon auritum	Blue Eared Pheasant	12.4-57.5	Li 1996
Crossoptilon mantchuricum	Brown Eared Pheasant	0.9-7.7	Li 1996
Lophura leucomelana	Kalij Pheasant	31.7	Fleming 1976
Lophura nycthemera	Silver Pheasant	12-44	Gao and Zhang 1990, Li 1996
Lophura swinhoei	Swinhoe's Pheasant	13-18	Li 1996

Table 3.7: continued.

Species	Common Name	Density (km^2)	Source
Lophura erythropthalma	Crestless Fireback	0.6-6	Davison and Sriven 1987
Lophura ignita	Crested Fireback	2.67-10.67	Davison and Sriven 1987
Syrmaticus reevesi	Reeve's Pheasant	7.6-15	Wu et al. 1993, Li 1996
Syrmaticus humiae	Bar Tailed Pheasant	10-33	Li 1996
Syrmaticus elliote	Elliot's Pheasant	3.6-6.9	Li 1996
Syrmaticus mikado	Mikado Pheasant	25.6	Poltack 1972
		15	del Hoyo et al. 1994
		18-32	Li 1996
		48-58	current study
Phasianus colchicus	Common Pheasant	2.3-13.8	Westerskov 1963
		3.9-38.6	Schwartz and Schwartz 1951
		12.3	Stokes 1954
		9.6	Einarsen 1945
		0.2-2.5	Edminster 1954
Phasianus colchicus	Common Pheasant	7.4-19.8	Baxter and Wolfe 1973
		30.8	Kozicky and Hendrickson 1951
		60	Dementiev and Gladkov 1967
		0.6-64	Li 1966
Chrysolophus pictus	Golden Pheasant	3.6-69	Li 1996
		7.5-45	Wu 1994
		23.8-31.6	Liang 1997
Chrysolophys amherstiae	Lady Amherst's Pheasant	3-140	Li 1996
		6.2-5.9	Han et al. 1990
Polyplecton bicalcaratum	Grey Peacock Pheasant	1.5-2	Li 1996
		1.5	Gao 1991
		3.7	Gao 1997
Polyplecton malacense	Malayan Peacock Pheasant	6.49-10.2	Davison 1983
Polyplecton emphanum	Palawan Peacock Pheasant	27-68	Caleda 1993
		15-25	Caleda 1993
Argusianus argus	Great Argus	0.6-9	Davison and Scriven 1987
Pavo cristatus	Indian Peafowl	100	Johnsingh and Murali 1980
Pavo muticus	Green Peafowl	2.3-3	Stewart-Cox and Quinnell 1990

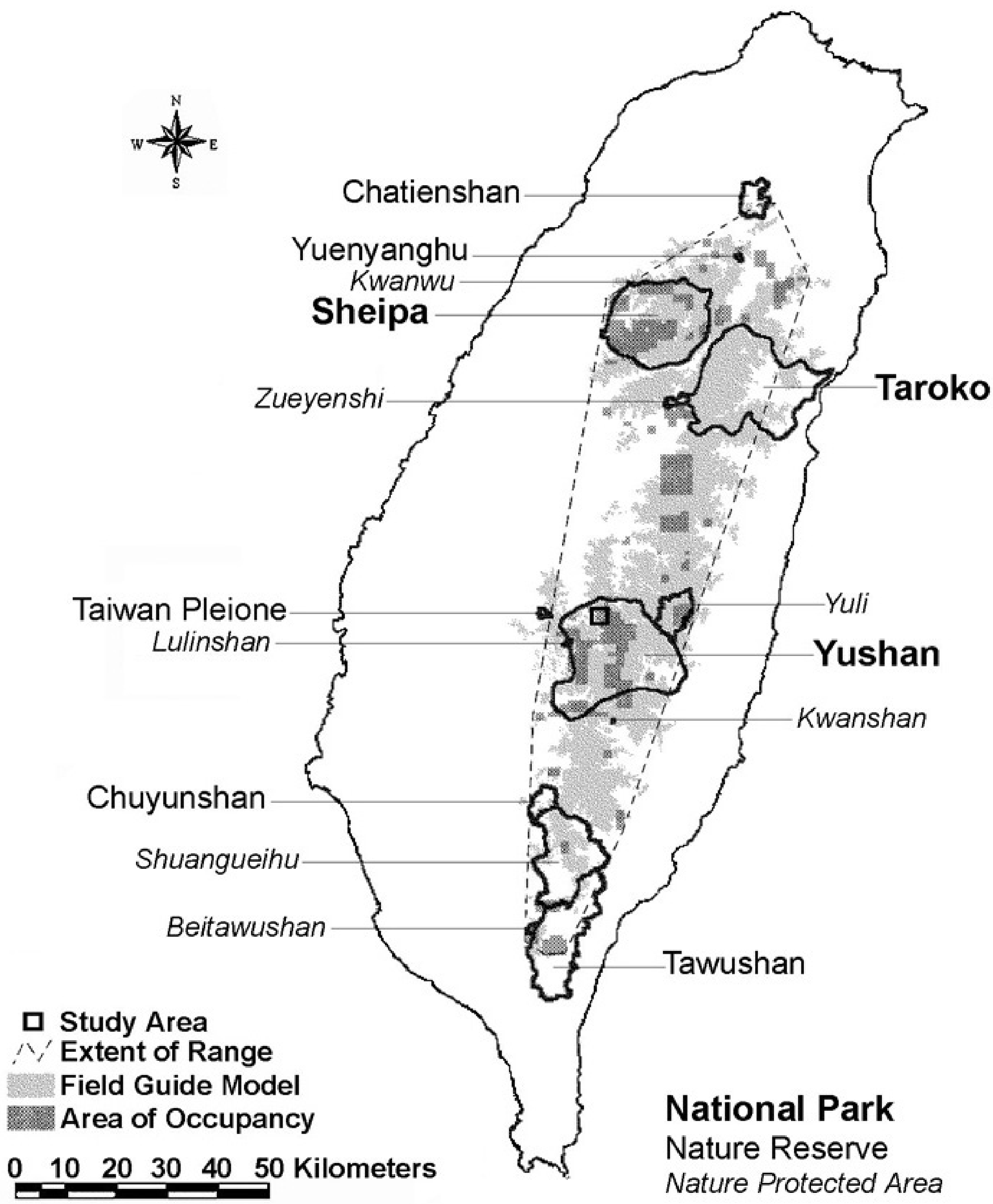

Figure 3.1: Map of Taiwan showing A) the distribution of habitat available for *Syrmaticus mikado* according to the field guide model; B) extent of range (estimated from Lee et al. 1998); C) area of occupancy (redrawn from Lee et al. 1998); D) location of the three national parks, five nature reserves, and seven nature protected areas with suitable elevations (1600 - 3300 m) and habitat; and D) location of the study area within Yushan National Park (◘).

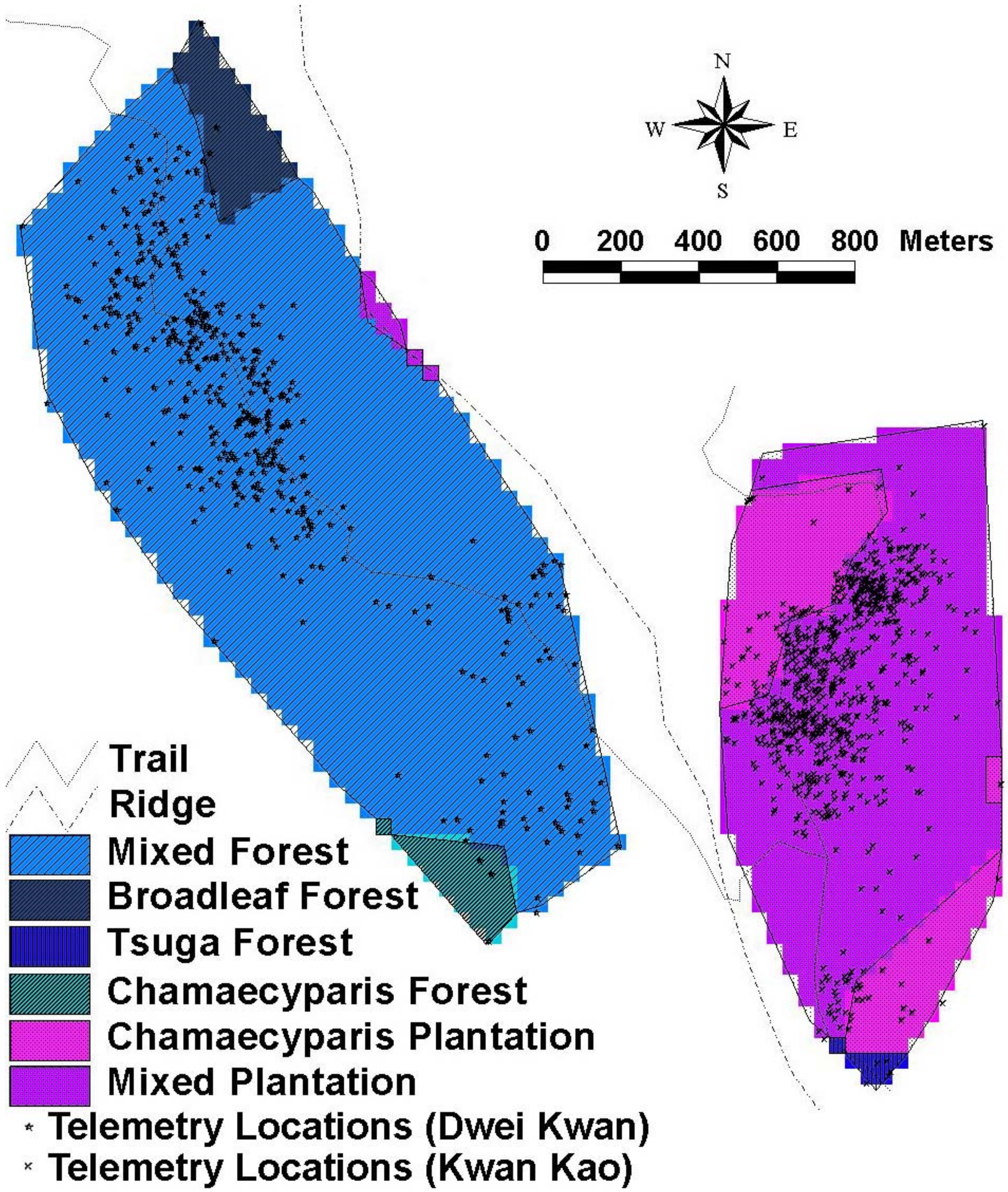

Figure 3.2: Map of the habitat types within the two study sites inside Yushan National Park, Taiwan: Kwan Kao (secondary forest) and Dwei Kwan (primary forest). The boundaries of each site were determined from the 100% minimum convex polygon of all telemetry locations from all radio-tagged *Syrmaticus mikado* trapped between July 1996 and June 1999: Kwan Kao telemetry locations (✕), Dwei Kwan telemetry locations (★). Primary forest indicated by stripes and blue shades, secondary forest by stippling and pink shades.

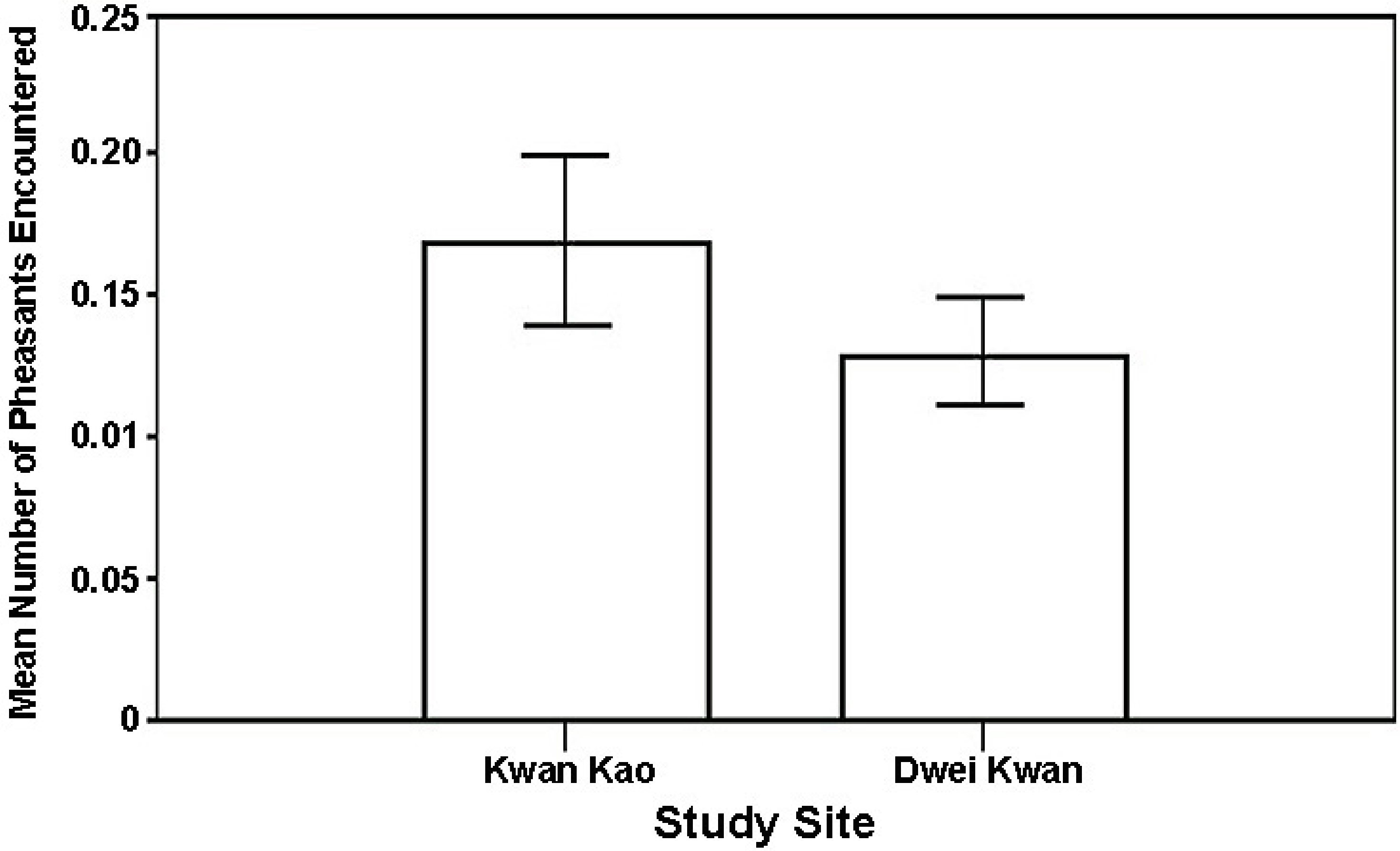

Figure 3.3: Number of *Syrmaticus mikado* encountered within each study site per kilometer surveyed each day (mean ± standard error). Encounter rates between sites did not differ (Student's T-test: t=1.43, df=340, p=0.1527).

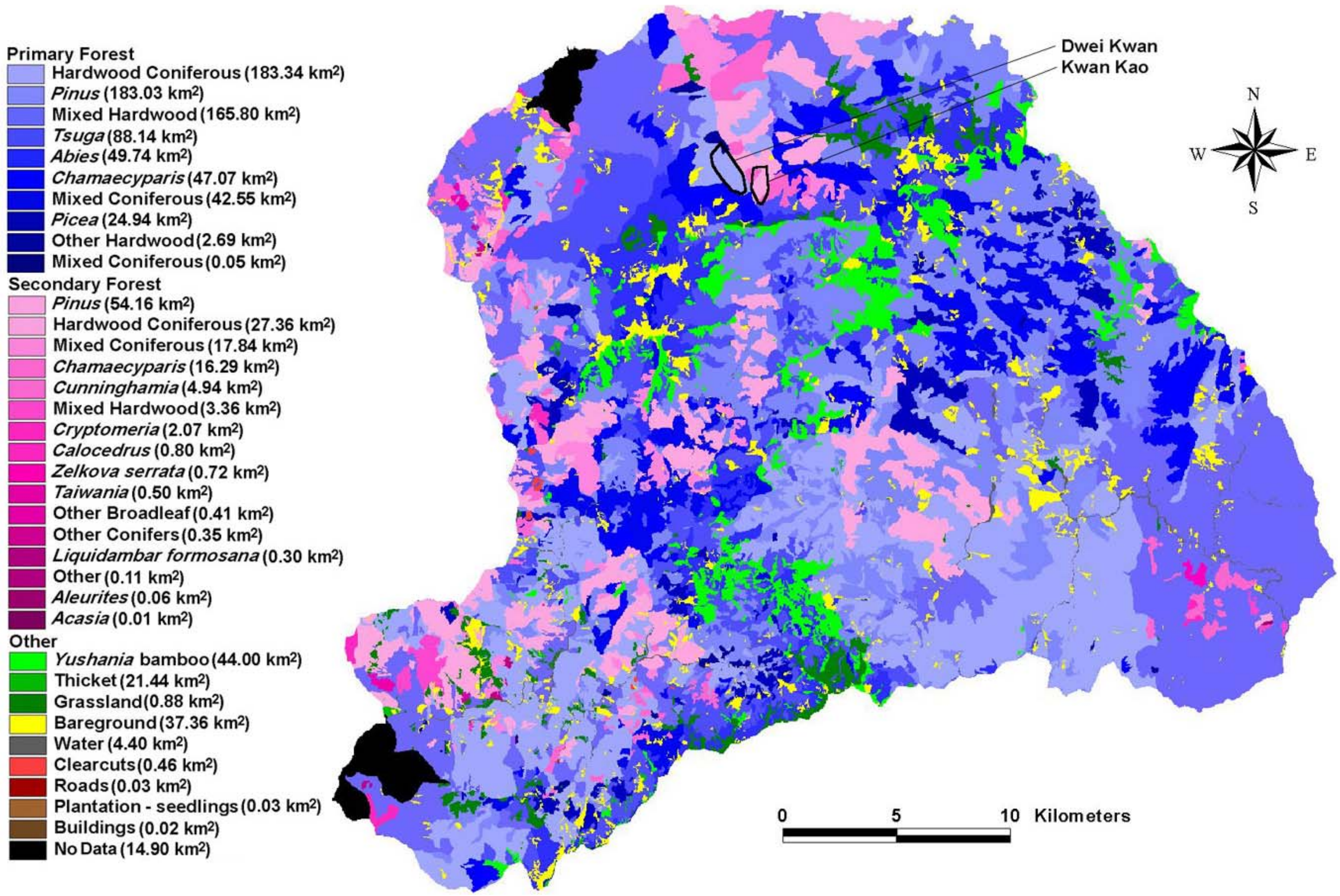

Figure 3.4: Forest and land-use categories found inside Yushan National Park, Taiwan. Black color indicates land not managed by the Taiwan Forest Bureau.

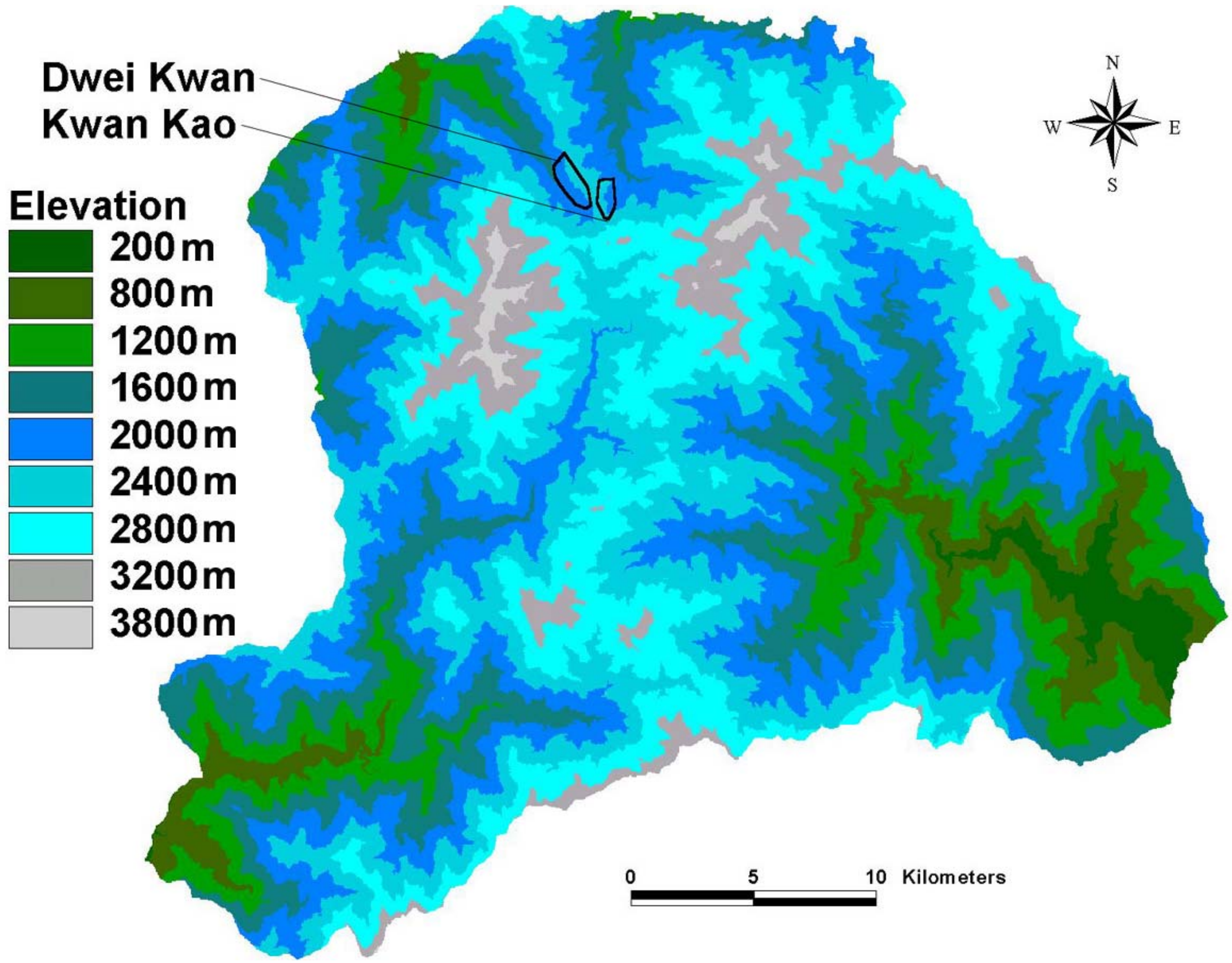

Figure 3.5: Elevations of Yushan National Park, Taiwan. *Syrmaticus mikado* are found between 1600 – 3300 m.

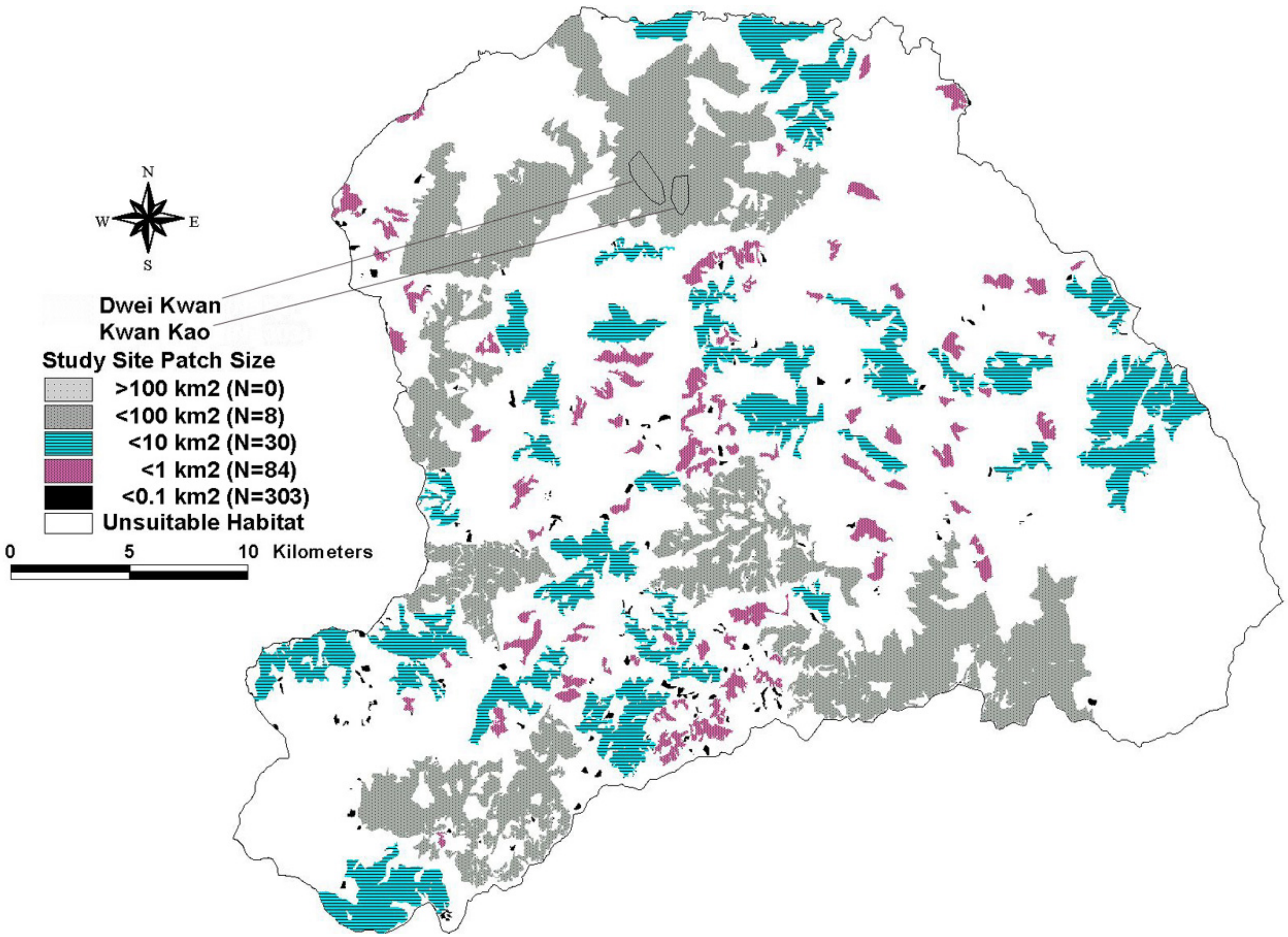

Figure 3.6: Patch size, shape, and dispersion within Yushan National Park for the study site model of habitat available for *Syrmaticus mikado*. Patches range from smaller than the average telemetry range of individual pheasants (about 0.1 km^2) to the size of the study sites (1.0 km^2), to the largest patch (46.5 km^2 or 5.7% of the total area of Yushan National Park), which hosts the study area.

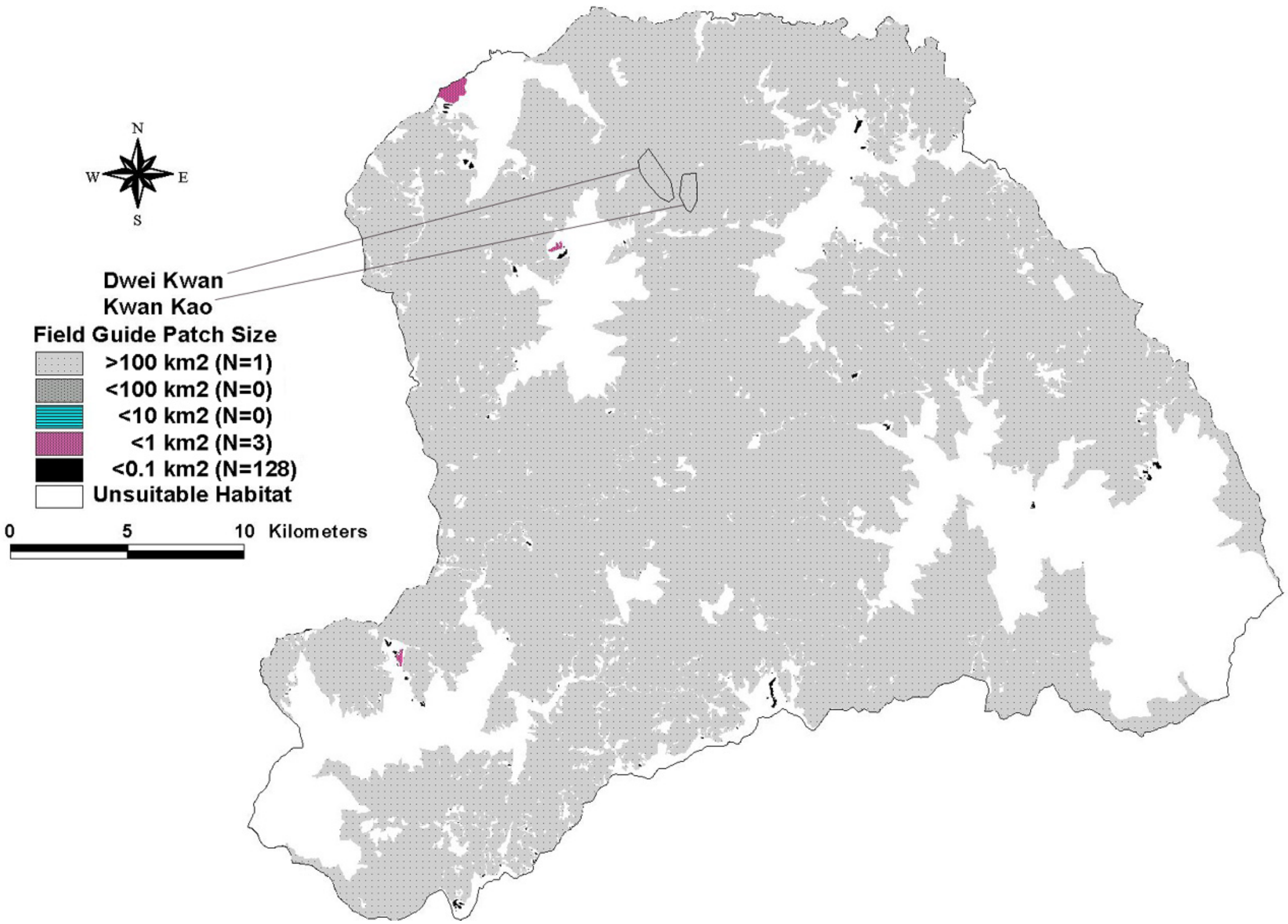

Figure 3.7: Patch size, shape, and dispersion within Yushan National Park for the field guide model of habitat available for *Syrmaticus mikado*. Patches range from smaller than the average telemetry range of individual pheasants (about 0.1 km^2) to the size of the study sites (1.0 km^2), to the largest patch (759.4 km^2 or 92% of the total area of Yushan National Park).

PART 4

ACCOUNTING FOR THE DECLINE IN MIKADO PHEASANTS

ABSTRACT

The Mikado Pheasant (*Syrmaticus mikado*) populations at the adjacent Kwan Kao and Dwei Kwan study sites in Yushan National Park, Taiwan, were surveyed for 1-2 weeks monthly from July 1989 through July 1992, and from July 1996 through June 1999. Records were kept of encounters with pheasants, survey effort, evidence of poaching, and potential predators. From 1989 to 1999, pheasant observations in Kwan Kao declined from 3.5 per day to 1.25 (65%), a significant decline (linear regression: $p<0.0001$). The encounter rate at Dwei Kwan ranged from 0.40 to 1.33 per day, but did not differ between years (linear regression: $p=0.89$). For both study sites, survey effort per hour of day and month of year did not vary significantly among years (Kruskal Wallis Chi-Square: $p>0.3$, all tests). The incidence of poaching, some of which specifically targeted pheasants, increased from 0.08 encounters per day for 1989-1992 to 0.23 for 1996-1999. In addition, the relative abundance of possible nest predators of *S. mikado*, increased from 1.4 encounters per day to 2.2. Weather patterns also varied between study periods with May and June of 1989-1991 being slightly warmer and calmer (one-way ANOVA: $p=0.04$ and $p=0.05$, respectively). Although the amount of rainfall did not vary significantly between study periods (one-way ANOVA: $p=0.98$), the pattern did, with most of the rain from 1989-1991 occurring in the last week of June. Despite comparable reproductive activity, females with broods declined from 1.11 encounters per day to 0.07 at Kwan Kao (linear regression: $p<0.0001$), but remained stable at Dwei Kwan (range: 0 – 0.29; linear regression: $p=0.56$). The decline in the Kwan Kao population is most likely due to poor productivity over the last three years. Whether this decline indicates a general trend or is part of a cyclic pattern in the population dynamics of *S. mikado* remains to be determined.

INTRODUCTION

Extinctions have long been attributed to hunting pressure. Martin (1984) suggested that human migration into North America via the Bering Straits caused many of the extinctions in the Pleistocene. Hunting pressure continues to threaten species survival. Hunting pressure and habitat loss account for 63% of the threats to galliformes (data compiled from King 1981). Of the pheasants found in Asia, 75% are threatened by hunting and habitat loss (Fuller and Garson 2000).

Galliformes, such as the Mikado Pheasant (*Syrmaticus mikado*), are particularly susceptible to hunting pressure, because of their colorful plumage and edible flesh. Flying only to escape predators and to reach roost sites, these primarily terrestrial and ground-nesting birds are also threatened by human introduced predators such as pigs and rats. The decline and extinction of bird species on 36 islands, ranging in size from the North and South islands of New

Zealand (114,500 – 150,200 km^2) to the minute land mass of the Galapagos archipelago, has been attributed to predation by introduced rats, cats and pigs (Atkinson 1985, Veitch 1985).

A newer threat to species survival is global climate change. Climate models predict general increases in temperature and precipitation (see Hughes 2000). Trends have also been observed in the intensity of precipitation (Karl and Knight 1998). Erratic weather patterns over a 20-year period caused variation in survival and reproduction of Darwin's Ground Finches (*Geospiza scandens*) resulting in morphological change (Grant and Grant 1992). Climate change has been implicated in numerous studies documenting the decline and possible extinction of amphibian species (e.g. Blaustein et al. 1994, Lips 1998, Laurence 1996). Changes in temperature and precipitation may also affect galliformes, particularly species such *S. mikado* isolated in temperate montane refugia surrounded by tropical and sub-tropical habitats.

Historically, *S. mikado* has been considered a vulnerable or endangered species. This has been primarily due to the fact that, until recently, the bird was rarely seen (Severinghaus 1977). In 1977, Severinghaus concluded the pheasant was "locally common." It was upgraded to vulnerable in the early 1990's (Groombridge 1993-1994). At that time, the threats listed were hunting pressure (King 1981) and limited distribution (Johnson and Sattersfield 1990). *Syrmaticus mikado* has been listed as safe from the threats of extinction (McGowan and Garson 1995) but is currently considered near threatened (Fuller and Garson 2000, Hilton-Taylor 2000). Within Taiwan, however, it is specifically protected under the Cultural Heritage Conservation Law of 1982 (Yang 1993) and generally protected under the Wildlife Conservation Law of 1989. Despite governmental bans, poaching and habitat destruction continues within the range of *S. mikado*. The actual effects of these threats are unknown.

The purpose of this part is to use the available evidence to evaluate the conservation threat status of *S. mikado*. To be considered vulnerable or in danger of extinction, there must be evidence of restricted range and population decline (IUCN 2001). To address the latter case, I examine encounter data and trends from two research periods within the same study area inside Yushan National Park.

STUDY SITE

Located within Yushan National Park, Taiwan (Appendix: Figure 4.1), the study area is composed of two study sites divided by a ridge. The secondary forest study site (Kwan Kao) is of eastern exposure and the primary forest site (Dwei Kwan) is of western exposure.

In the secondary forest site, clearcutting was discontinued in 1985 when Yushan National Park was created. The Taiwan Forest Bureau gradually decreased maintenance of the Chunta Logging Road (2450 m in elevation) bisecting this site until it was discontinued in 1992. The last motorbike traffic was in 1992. The Taiwan Forest Bureau continues to send crews to the study area to clear firebreaks along the ridge that separates the two study sites. To keep observation conditions similar between the two study periods, my research team resumed maintenance of the road within the study area. This maintenance entailed trimming the vegetation within the roadbed to create a corridor about 3 m wide. This was done no more than twice a year. The cleared road attracted pheasants (see Bridgman 1994), making observations and encounters possible.

Except for the Patunkwan Trail and landslides, the primary forest site is undisturbed. The trail, which bisects the site as it climbs from 2000 to 2600 m, is one of the most famous and best maintained in Taiwan. It was created during Japanese occupation in the late 1800's and is the main hiking trail for east-west passage. In certain seasons, there can be several hundred hikers passing through the study area. These hikers almost never stray from the trail's edge. Maintenance of the trail has slowly declined over the past 10 years. About once a year, Yushan National Park sends a crew to trim the trail, creating a corridor about 1 m wide. Every two or four years, a crew works several months shoring up the trail and reconstructing bridges.

METHODS

Surveys

Trips were made to the study area for most months from July 1989 through July 1992, and July 1996 through June 1999. For the first three years, survey effort was concentrated at Kwan Kao on the Chunta Logging Road (66.1 km to 67.5 km). During this time, the Patungkwan Trail (10.1 km to 14.3 km) within the Dwei Kwan site was surveyed twice a month when traveling between the town of Tungpu and Kwan Kao (Figure 4.1). From July 1989 through June 1991, observations of pheasants within the Kwan Kao site were made from blinds and during surveys of road. Radio-telemetry began September 1991, at which time records of encounters while doing telemetry were included with records from road survey and blinds. This pattern of recording pheasant activity when moving about the study site continued within both study sites from July 1996 through June 1999, with survey effort was between 65.2 km and 68.1 km of the Chunta Logging Road and between 10.1 km and 14.3 km of the Patungkwan Trail (see Part 2).

Although other members of the field team and visitors to the study sites helped with all activities, I have included in this study only those pheasant encounters I saw personally. For each encounter, I recorded the date, time and location of each pheasant observed, associations with other pheasants, and identifying marks. During each day, I recorded encounters with hikers, large mammals, other galliform species, other bird species, locations of passerine nests, discovered traps or snares, and anything else that was of interest.

As I traveled back and forth, monitoring the road and trail, I recorded the beginning and ending times and locations of each survey. During these surveys I triangulated on radio-tagged pheasants, monitored snares, and recorded pheasant activity. Although I kept track of the time spent, I did not include pheasants encountered when mapping and collecting habitat data. Time spent off the road or trail, homing in on transmitters or collecting habitat data, was not included estimates of survey effort because I never encountered a pheasant during these forays.

As the total number of survey hours varied from year to year, I tested for differences in survey effort per hour of day between years using the hourly percentage of each year's total. This percent survey effort was tested for each study site using a Kruskal Wallis Test (PROC NPAIR1WAY WILCOXON, SAS 1990), a non-parametric version of the one-way ANOVA (Daniel 1990). I repeated this analysis to test for yearly differences in percent survey effort for each month.

Indices

All observations of pheasants were made on the logging road or the trail. Relative abundance of *S. mikado* was calculated based on the number of pheasants seen per survey day. I included only those pheasants I observed, myself. Estimates from 1996-1999 were compared to estimates from 1989-1992 to examine population trends. The encounter index was also calculated based on the number of pheasants seen per survey day. Using the data from this index, I plotted the yearly mean and standard error of the mean and used linear regression (PROC GLM, SAS 1990) to test for differences between years. To compare my results with those of Severinghaus and Severinghaus (1987), I also calculated the number of pheasants observed per hour spent looking for them (Severinghaus 1977)

I measured relative productivity between the two study periods (1989-1992 and 1996-1999) by counting the number of chicks or sub-adults encountered during each day in July, August, and September. In addition to counting the number of chicks encountered, I also measured relative productivity using the number of females with broods. These three months were selected because chicks were more visible in July than in earlier months. By October, sub-adults were similar in size to adults, making it difficult to distinguish between female adults and sub-adults.

Hunting intensity was determined by counting the number of snares, gunshots, remains, and maimed animals found or heard during each year. This number was divided by the number of days spent in the field to create a hunting index. Stashes of snares or traps were counted as one unit. This index was calculated for each day because many of the incidences (gun shots) occurred at night or were discovered at the campsites.

I calculated an index for potential predators and large mammals. For large mammals and snakes, the index is based on the number of individuals observed per day. These mammals include the nest predator *Sus scrofa taivanus* (Formosan Wild Boar), predators of adult pheasants which may also target nests: *Mustela siberica davidiana* (Siberian Weasel), and *Martes Flavigula chrysospila* (Formosan Yellow-throated Marten); and ungulates: *Capricornis crispus swinhoei* (Formosan Serow), *Cervus unicolor swinhoei* (Formosan Sambar), and *Muntiacus reevesie micrurus* (Formosan Reeve's Muntjac). The snakes are in the Viperidae and Colubridae families. The index for *Macaca cyclopis* (Formosan Macaque) is based on the number of groups encountered per day. For avian predators, the index is calculated as the number of days with encounters. Avian nest predators included the corvids *Nucifraga caryocatactes* (nutcracker), *Corvus macrorhynchos* (large-billed crow), and *Garrulus glandarius* (Jay). Predators of adult birds also included the raptors: *Spilornis cheela* (Crested Serpent Eagle), *Accipiter trivirgatus* (Crested Goshawk), *Bustastur indicus* (Grey-faced Buzzard), *Falco tinnunculus* (Common Kestrel), *Asio otus* (Long-eared Owl), *Ninox Scutulata* (Brown Hawk Owl), *Strix leptogrammica* (Brown Wood Owl), and *Strix aluco* (Tawny Owl).

Climate

Weather data for 1970 to 1999 was obtained from two of Taiwan's Central Weather Bureau stations (Appendix: Figure 4.1): on the North Peak of Yushan (3858 m in elevation), and at Alishan (2351 m in elevation). While Yushan is the closest weather station, Alishan has the most similar elevation. These stations record average daily temperatures (0.1 C), wind speeds (0.1 m/s), and total daily rainfall (0.1 mm). Each variable was analyzed using a one-way analysis of variance (PROC ANOVA; SAS 1990) for the months of May and June to discern differences between weather station, study period (1989-1992 and 1996-1999) and year. As the earliest sightings of chicks were in May (Bridgman 1994, Yao et al. 1998), weather effects on nest or chick survivorship were expected to occur during these months.

RESULTS

Survey Effort

From July 1996 through June 1999, survey effort was evenly distributed between the two study sites (see Part 3), an average of 60 days per year at Dwei Kwan and 55 at Kwan Kao. There were differences in the number of days spent at each study site from July 1989 through July 1992, an average of 22 days per year at Dwei Kwan and 72 days per year at Kwan Kao.

From July 1989 through July 1992 and July 1996 through June 1999, there were no yearly differences at Kwan Kao (Figure 4.2) in survey effort per hour of day (Kruskal Wallis Chi-Square=0.17, df=5, p=1.00) or month of year (Kruskal Wallis Chi-Square=6.02, df=5, p=0.30). During each day, survey effort generally peaked in the mornings and afternoons. Survey effort was fairly even throughout the year, with slight peaks in some years (1990, 1996, and 1997) in the spring. At Dwei Kwan (Figure 4.3), there were also no significant differences in the hourly distribution of survey effort (Kruskal Wallis Chi-Square=1.55, df=5, p=0.91) or in monthly effort (Kruskal Wallis Chi-Square=2.01, df=5, p=0.84).

Indices

At Kwan Kao, the relative abundance of *Syrmaticus mikado* appears to have declined (Figure 4.4) over the past 10 years. The rate of encounters per day varied among years (linear regression: F=34.24, df=1, p<0.0001), dropping from a mean of >3 pheasants per day in 1989-1992 to <2 in 1996-1999. At Dwei Kwan, there were no differences between years (linear regression: F=0.02, df=1, p=0.89). From 1989-1992, the rates of encounter at Dwei Kwan (mean pheasants per day: 0.4 in 1989 and 1998 to 1.3 in 1991; Figure 4.4) are much less than at Kwan Kao (mean pheasants per day: 3.2 in 1989 to 4.2 in 1991; Figure 4.4). From 1996-1999, the rates between the two sites were similar (Figure 4.4).

The daily rate of encounters with chicks, sub-adults and broods at Kwan Kao (Figure 4.5) declined between the two study periods (chicks and sub-adults: F=28.37, df=1, p<0.001; females with broods: F=27.38, df=1, p<0.001). At Dwei Kwan, the mean number of chicks and sub-adults appeared to decline, but were no significant differences between years (F=3.35, df=1, p=0.07). There were also no significant differences in the number of females with broods (F=0.34, df=1, p=0.56). At Dwei Kwan, there were never more than 10 chicks or sub-adults observed from July through August of each year. At Kwan Kao, chicks and sub-adults were encountered as many as 244 times in 1991. Brood size ranged from one to five chicks per female at Kwan Kao, and one to four at Dwei Kwan.

The overall encounter rate for possible predators increased from an average of 1.96 encounters per day in 1989-1992 to 2.62. Of the predators primarily targeting adult pheasants, the rates of encounters for raptors (Figure 4.6) decreased. Of the predators of *S. mikado*, most of the increase in encounter rate was among the egg predators (from 1.44 encounter per day to 2.16). Of the possible egg predators (Figure 4.6), the increase in encounter rate was greatest for *Mustela siberica*, although rates for *Macaca cyclopis* and corvids also increased. In contrast, the encounter rates for snakes and *Sus scrofa*, often killed by humans from general ill-will (snakes) or for food (*Sus scrofa*),decreased.

Encounter rates for ungulates, which are also targeted for hunting, increased (Figure 4.6). The incidence of hunting more than doubled (Table 4.1).

Climate

Temperature and wind speed differed significantly between weather station ($p<0.0001$), study period (1989-1992 and 1996-1999)($p<0.05$), and year ($p<0.003$), as did interactions among these variables ($p<0.0001$; Table 4.2). Generally, there were slightly warmer temperatures from 1989-1992 (mean monthly temperatures: 10.2 °C vs. 10.0 °C), and slightly less wind (mean monthly wind speed: 2.9 m/s vs. 3.0 m/s). Rainfall data were only significantly different for the interactions of study period with year ($p<0.0001$) and of study period with year and station ($p<0.0001$; Table 4.2).

The pattern of rainfall (Figures 4.7 and 4.8) was similar for both weather stations. Springs of both 1989-1992 and 1996-1999 had weeks of heavy rainfall, with peaks in excess of 170 mm (Yushan weather station) and 370 mm (Alishan weather station) of rain per day. There were peaks of rainfall in late June of 1990 and 1991. Other than this, the springs in this study period were fairly dry. For the second study period, 1996 and 1997 had more days of heavy rain (greater than 50 mm/day) evenly distributed throughout the two months. Whereas 1997 was fairly dry, but with a spell of very heavy rain, peaking at 250 mm per day (Alishan weather station), in the first 10 days of June.

From 1970 through 1999, total rainfall of May and June averaged 971 mm (range: 297 – 1699 mm) at the Yushan North Peak weather station and 1243 mm (range: 420 – 2293 mm) at the Alishan weather station (Figure 4.9). For the months of May and June, the least amount of rainfall was in 1980, the maximum amount in 1977. Overall, 1972 was the wettest year and 1980 the driest (Figure 4.9). Figure 4.10 shows the bi-weekly percentage of rainfall for May and June of each year.

DISCUSSION

From 1989-1992, the daily rate of encounter of *S. mikado* at Kwan Kao has declined from 10 times that of Dwei Kwan, to levels similar to those in Dwei Kwan in 1996-1999. Whether the decline at Kwan Kao is a long-term trend or part of a cyclic pattern remains to be determined. The relative abundance indices for 1986 reported by Severinghaus and Severinghaus (1987) for the same study area are similar to those found in 1996-1999 (Figure 4.11). The fact the Kwan Kao population has declined over the past 10 years warrants continued observation, if only to resolve the patterns and trends.

During the same time period, the *S. mikado* population at Dwei Kwan appears stable (Figures 4.4 and 4.11). In Part 2, microhabitat analysis indicates that *S. mikado* more frequently utilize secondary and disturbed habitats. The stable population at Dwei Kwan, a site composed of primary forest, suggests *S. mikado* might be better adapted to more disturbed habitats. This difference in encounter rate between sites, however, may be the result of variation in pheasant behavior in response to the habitat. Tagged birds were encountered much less frequently at Dwei Kwan, even though estimates of population densities were similar (Part 3). Bridgman (1994) noticed that *S. mikado* use of the road at Kwan Kao varied from season to season.

Whether the decline at Kwan Kao is a long-term trend or part of a cyclic pattern remains to be determined. The relative abundance indices for 1986 reported by Severinghaus and Severinghaus (1987) for the same study area are similar to those found in 1996-1999 (Figure 4.11). The fact the Kwan Kao population has declined over the past 10 years warrants continued observation, if only to resolve the patterns and trends. In addition, this decline has occurred since the creation of Yushan National Park in 1985 and is in contrast to the increases noted for ungulates (Figure 4.6). It is interesting that ungulate populations have increased despite a corresponding increase in poaching activity, especially as *Sus scrofa* has decreased (Figure 4.6). All of these animals are considered food items by Taiwan's aborigines (Takisliniun Lini, personal observation). Although illegal, hunting of ungulates and wild boar continues for commercial reasons, particularly for sale to restaurants (Takisliniun Lini, personal communication). As recently as 1991, *S. mikado* were advertised in restaurants (personal observation).

The increase in predator populations (Figure 4.6) suggests that predation may be a concern. With the probable extinction of *Neofelis nebulosa brachyurus* (clouded leopard), the only remaining candidates for top predators are *Prionailurus bengalensis* (Chinese money cat) and *Martes flavigula*, both of which are extremely rare. *Martes flavigula* was only found once within the study area in 1990 (personal observation). Over the past 40 years, *Mustela siberica*, a human commensal, has expanded its range to higher elevations and to the more isolated parts of Taiwan (Lin 2000). This animal preys upon adult *S. mikado* (unpublished data) and probably targets nests and chicks. Other than *M. siberica*, no other mammalian predators are recorded. Possible mammalian nest predators include domestic dogs accompanying tourists and workers, *Sus scrofa*, and *Macaca cyclopis*. Primarily frugivorous, *M. cyclopis* is known to eat bird's eggs (Wendy Birky, personal communication). Within North America, *Sus scrofa* is a documented nest predator (Wood and Barrett 1979). One incidence of nest predation on *S. mikado* may have involved a domestic dog following human scent (unpublished data). Many members of the corvid family are documented nest predators, as are small mammals such as voles and squirrels (Rodewald and Yahner 2001, review in Chalfoun et al. 2002). Although many of Taiwan's small mammal species were observed daily within the study area, I did not keep track of encounter rates. Loss of a second *S. mikado* nest was attributed to *Corvus macrorhynchos* (Wang 1994). Corvids are present within the study area (Figure 4.6).

The main cause for the decline in *S. mikado* at Kwan Kao appears to be poor survivorship of young, with nest predation a contributing factor. The number of chicks and broods encountered each summer declined precipitously between field periods (Figure 4.5). This is despite observed courtship activity between adult pheasants (personal observation), and brood patches on five radio-tagged females (Bridgman et al. 1999). In addition, none of the six nests discovered since May 1992 (Bridgman 1992-1993, Lin 1994, and Yao et al. 1998) have succeeded in producing chicks. Two of the nests were lost through predation and four were abandoned. Researcher effect on the loss of these nests cannot be discounted. In all six cases, researcher observation and activity was invasive, involved photographing or monitoring with video cameras.

In addition to nest predation, the poor encounter rate of young in 1996-1998 may be due weather conditions, particularly the heavy rainfall and cooler temperatures from mid-May to mid-June (Figure 4.5). All the earliest reports of chicks have been in the last two weeks of May (Yao et al. 1998; unpublished data). Nests have been found in April and May (Yao et al. 1998, Bridgman 1992-1992, Wang 1994). In 1990 and 1991, when productivity was high, most of the rain occurred during the last two weeks of June (Figures 4.3, 4.4 and 4.6), 2 to 4 weeks after most chicks would have hatched. In 1942, Cartwright (1945) noticed a crash in *Tympanuchus phasianellus* (sharp-tailed grouse) and *Perdix perdix* (grey partridge) populations of western Canada, implicating the unusually cold and wet weather during the hatching period. In 1984, Green documented that *Perdix perdix* chick activity was lower under cold wet conditions than in warmer and drier conditions. During the first few weeks of life, *Phasianus colchicus* chicks (ring-necked pheasant) have difficulty maintaining body temperature, needing to be brooded (Hill and Robertson 1988). *Perdix perdix* brooding periods were longer in cold weather (Reitz 1983). Potts (1986) had difficulty correlating *P. perdix* chick mortality with rainfall (>5 mm/day) alone, finding a stronger relationship with temperature, and preferred to cite food (insect) availability as the main source of mortality. The cool, wet, and windy conditions recorded for springs 1997 and 1998 may well have resulted in *S. mikado* chick death due to hypothermia. In addition to the patterns observed in the spring, two large typhoons visited the study area in July and August of 1996. Because of the level of destruction (Chou et al. 2000, personal observation), typhoons such as these undoubtedly affect animal populations, probably resulting in mortality of both *S. mikado* chicks and adults. Typhoons intense enough to uproot trees occur every eight to 12 years (Mabry et al. 1998).

It is possible that *S. mikado* populations, such as the one at Kwan Kao, show some cycling in their productivity: high productivity and high relative abundance in some years, low or no productivity and low relative abundance in most years. At present, just the documentation of the decline in relative abundance and productivity at Kwan Kao is important. Further study is needed to determine whether there is a pattern and how well this pattern coincides with spring weather conditions. Springs of 1974, 1985 and 1987 had rainfall patterns similar to 1990 and 1991 (Figure 4.6), and may also have been productive years for *S. mikado*. From 1970 to 1995, most years had rainfall patterns similar to those experienced from 1996 to 1999.

If such population cycling occurs at the Dwei Kwan, then it is of very low magnitude. Although the rate of encounter with *S. mikado* at Dwei Kwan may not be correlated with the increase in poaching and in predator populations or changes in weather patterns, all of these threats do affect this population. These threats are matters of concern because the overall productivity of *S. mikado* at Dwei Kwan is lower than that at Kwan Kao, as indicated by smaller brood size and the very low rate of encounters with broods and chicks. Mean productivity (chicks and sub-adults per day) has declined over the past 10 years, the fact this decline is not significance may be a function of sample size, the low rate of encounter.

It may well be that the survival of *S. mikado* depends on the longevity of its adult population. In the field, banded *S. mikado* have survived and continued to breed for as long as nine years (Bridgman 1999). As *S. mikado* attempt to breed every year, it may be on only the drier and warmer years that the next generation is produced. All of the pheasants for which there are longevity data (three males and one female) were born in warmer and drier years of 1990-1991 (unpublished data). Female *S. mikado* can successfully rear five chicks on good years (Severinghaus 1977, Bridgman 1994, Yao et al. 1998), with recorded clutch sizes of one to eight eggs (Severinghaus 1977). The pattern of stable survival of adults with juvenile survival varying according to environmental conditions has been well documented for ungulates (see Gaillard et al. 1998).

For birds in particular, there is a pattern of older and experienced birds having more successful clutches (Martin 1995, Curio 1983, but see Part 1995). This has been documented regardless of environmental effects (Daunt et al. 1999) and for many bird species (blackbirds: Descrochers and Magrath 1993; barnacle geese: Forslund and Larsson 1992; Seychelles warblers: Komdeur 1996; gulls: Pyle et al. 1991; wandering albatross: Weimerskirch 1992; white-tailed and willow ptarmigans: Wiebe and Martin 1998; but see wood ducks: Hepp and Kennamer 1993; common terns: Wendeln and Becker 1999). An age advantage in fecundity and successful rearing of offspring is not limited to birds (Alaskan caribou: Adams and Dale 1998; roe deer: Gaillard et al. 1992).

Syrmaticus mikado was one of the focuses of poaching during both study periods, despite the fact that all hunting is illegal within Taiwan’s national parks and the pheasant is specifically mentioned in Taiwan’s conservation laws (Yang 1993). Pheasants trapped within the study area were most likely consumed in the field (personal observation). Whether for consumption or for research purposes, pheasants were usually trapped using snares. Although I repeatedly found snares in both the primary and secondary study sites (Table 4.1), actual evidence of pheasants caught and consumed were rare. Two types of snares were used, those targeting *S. mikado* and those targeting ungulates such as Formosan Serow (*Capricornus crispus*). Most of the gunshots occurred at night, primarily targeting Formosan Reeve's Muntjac (*Muntiacus reevesei*) and several species of flying squirrel. The fact that snares are the main hunting method is disturbing as snares are indiscriminate and continue trapping animals long after the hunters have left the area (Lewis and Alpert 1997).

Trimming the road was necessary for research activities, and provided some consistency in habitat between study periods. *Syrmaticus mikado* are frequently observed using roads (Severinghaus 1977, Severinghaus and Severinghaus 1987, Alexander et al. 1990, Bridgman 1994, Yao 1998) and have adopted the use of freshly constructed trails (Bridgman 1994). Unfortunately, clearing the road helped to make the secondary forest site more accessible to hunters. The statistically significant decline in *S. mikado* at Kwan Kao is not due to increased accessibility as compared to Dwei Kwan, as poachers must travel through Dwei Kwan to reach Kwan Kao. Poaching activity occurs in both sites, with almost all hunting activity, including snares, on or adjacent to the road or trail. As hunters placed snares wherever they went, probably hoping to capture something by the return trip (Takisliniun Lini, personal communication), some snares were found more than 500 meters distant from the road or trail in places with no other signs of human activity (personal observation). Most of the snares within the study area were set in the winter, targeting adult pheasants. If there is, in fact, a correlation between pheasant age and successful reproduction, the trapping of adult pheasants may be a concern. This may be even more of a problem if reproduction is correlated with yearly weather conditions, resulting in periods of low productivity.

For now, the data indicate that *S. mikado* be considered vulnerable to extinction. The IUCN Red List (IUCN 2001) gives five criteria for classification as vulnerable. While two of these are appropriate to *S. mikado*, only one need apply: restricted range less than 20,000 km^2, or population reduction of 20% over the past 10 years. *Syrmaticus mikado* has a restricted range and fragmented range, and available habitat may be decreasing (Part 3). The threats of predation and poaching are increasing. Finally, there is strong evidence that the population of mature and sub-adult pheasants has declined in Kwan Kao over the past 10 years. Even though relative abundance at Dwei Kwan appears stable, at Kwan Kao it has declined by 65% over the past 10 years. Until we can identify whether this is decline is part of a long-term trend or a function of population cycling, *S. mikado* should be considered vulnerable to extinction.

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APPENDIX

Table 4.1: Hunting Index: the rate at which signs of hunting were encountered within the study area inside Yushan National Park, Taiwan, for each year from July 1989 through July 1992 and from July 1996 through May 1999.

Year	1989	1990	1991	1996	1997	1998
Snares	2	1	9	15	9	10
Remains	0	2	1	3	4	2
Gunshots	2	0	0	1	6	14
Total	4	3	10	19	19	26
# Days	55	43	147	98	69	112
Encounter/Day	0.07	0.07	0.07	0.19	0.28	0.23

[1] Snares include pheasant neck snares, pheasant foot snares, leg-hold snap traps, wire neck snares, dead animals in snares, and maimed animals, specifically, those missing a foot. Stashes of snares were counted as one unit.
[2] Remains include feathers, bones, and skins found at camp sites.
[3] Each gunshot was counted as one unit.

Table 4.2: One-way Analysis of Variance tests on Temperature, Wind Speed, and Rainfall during May and June for Taiwan weather stations (Alishan and Yushan), study period (1989-1991, and 1996-1998) and year.

Average Daily Temperature

	DF	Sum of Squares	Mean Square	F Value	Pr > F
Station	1	861423.94	861423.94	3991.06	<.0001
study period	1	934.33	934.33	4.33	0.0378
Year	5	13477.53	2695.51	12.49	<.0001
station*study period	1	1036.39	1036.39	4.8	0.0288
station*year	5	1295.70	259.14	1.2	0.3071
study period*year	-1	0.00	0.00	0	<.0001
station*study period*year	-1	0.00	0.00	0	<.0001

Average Daily Wind Speed

	DF	Sum of Squares	Mean Square	F Value	Pr > F
Station	1	287861.01	287861.01	1197.75	<.0001
study period	1	941.12	941.12	3.92	0.0482
Year	5	4519.63	903.93	3.76	0.0023
station*study period	1	602.32	602.32	2.51	0.1138
station*year	5	4700.90	940.18	3.91	0.0017
study period*year	-1	0.00	0.00	0	<.0001
station*study period*year	-1	0.00	0.00	0	<.0001

Total Daily Rainfall

	DF	Sum of Squares	Mean Square	F Value	Pr > F
station	1	549890.65	549890.65	3.73	0.0538
study period	1	142.61	142.61	0	0.9752
year	5	316869.64	63373.93	0.43	0.8278
station*study period	1	10443.54	10443.54	0.07	0.7902
station*year	5	346608.45	69321.69	0.47	0.7985
study period*year	-1	0.00	0.00	0	<.0001
station*study period*year	-1	0.00	0.00	0	<.0001

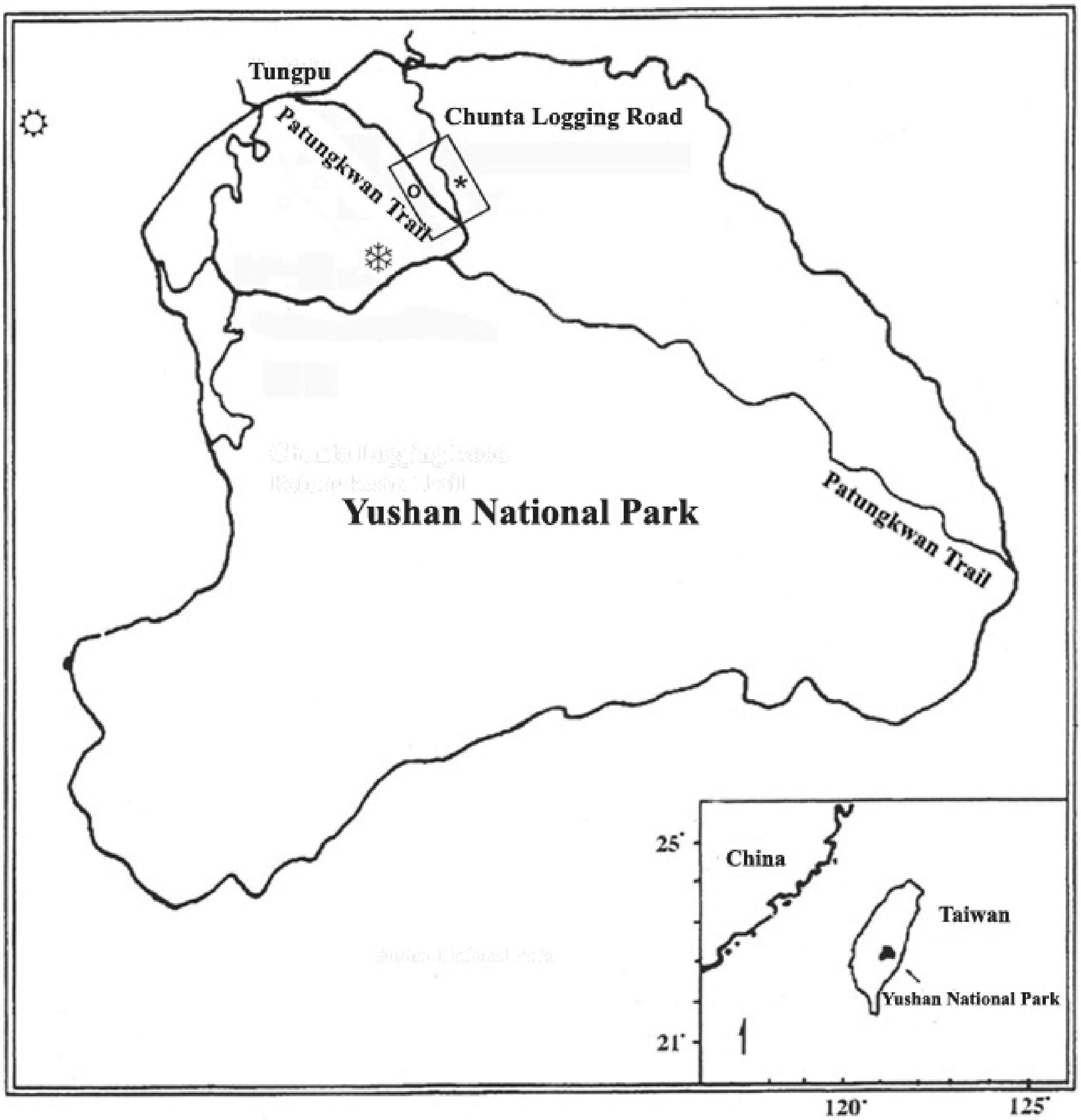
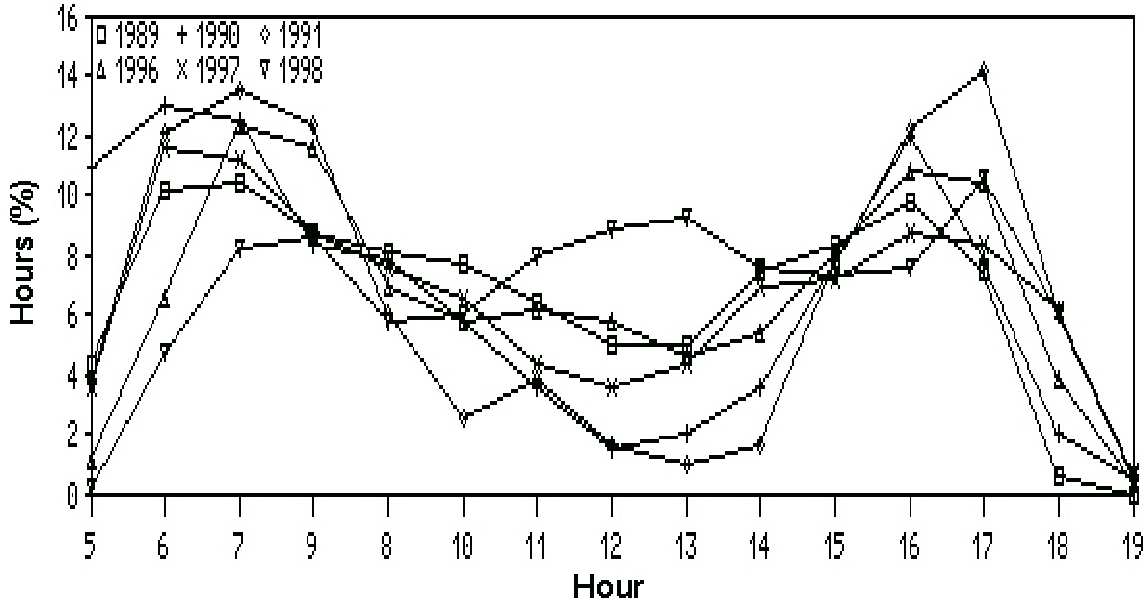


Figure 4.1: The location of the study area (box), within Yushan National Park, Taiwan: (O) Dwei Kwan, the primary forest study site; (✱) Kwan Kao, the secondary forest; (❄) Yushan North Peak weather station; and (☼) Alishan weather station.

A) Kwan Kao: Survey Effort per Hour



B) Kwan Kao: Survey Effort per Month

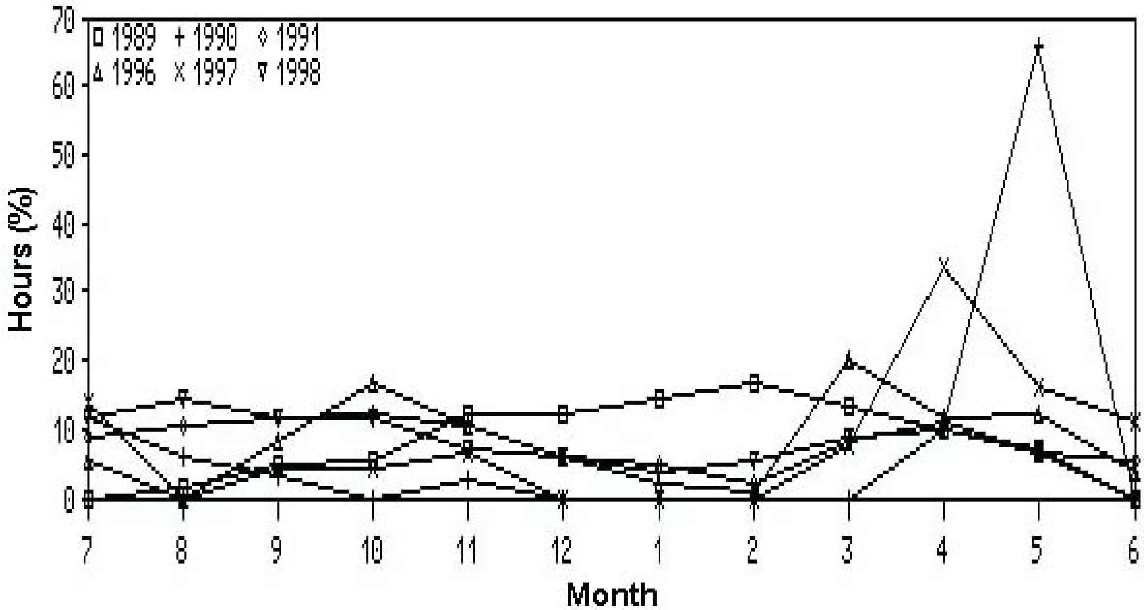
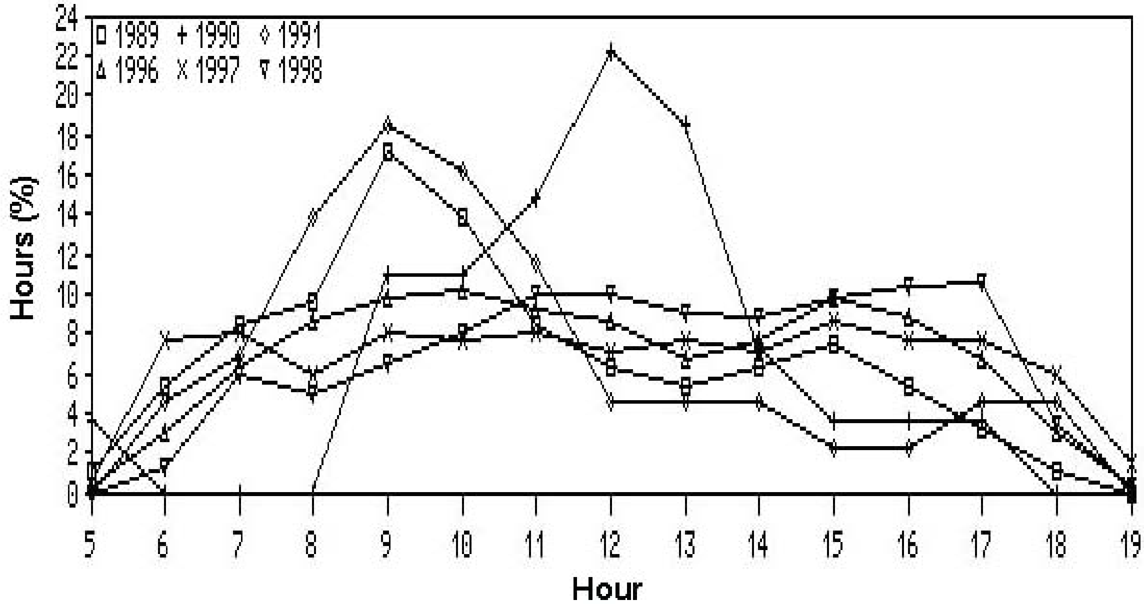


Figure 4.2: Survey effort at the Kwan Kao study site inside Yushan National Park, Taiwan, from July through June 1989 for each year 1989-1992 and 1996-1999: A) % effort per hour (Kruskal Wallis Chi-Square = 0.17, df = 5, p = 1.00) and B) % effort per month (Kruskal Wallis Chi-Square = 6.02, df = 5, p = 0.30).

A) Dwei Kwan: Survey Effort per Hour



B) Dwei Kwan: Survey Effort per Month

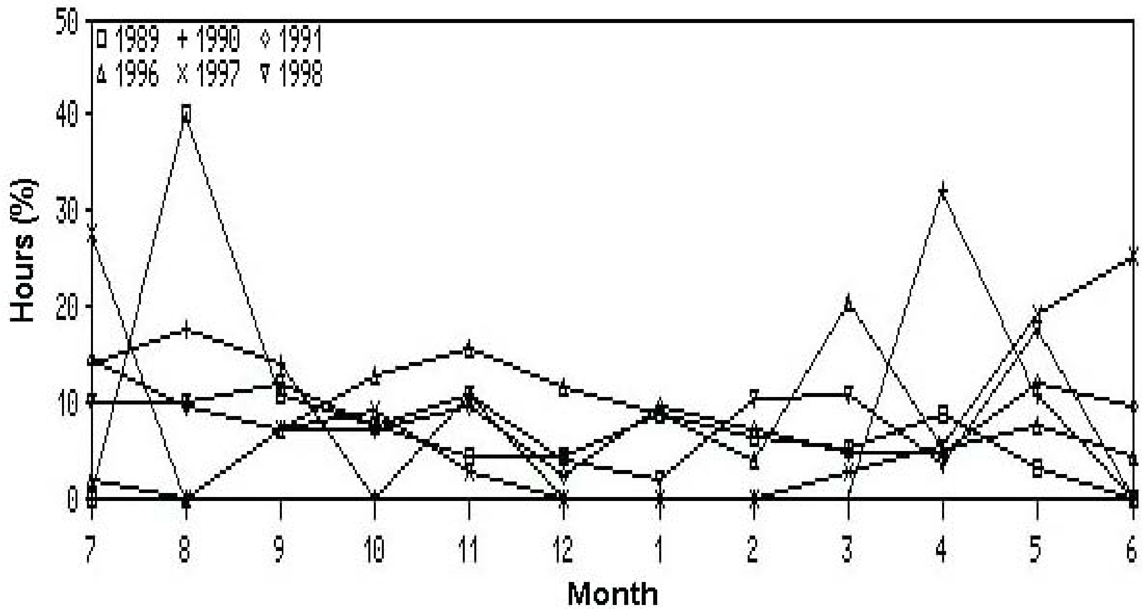
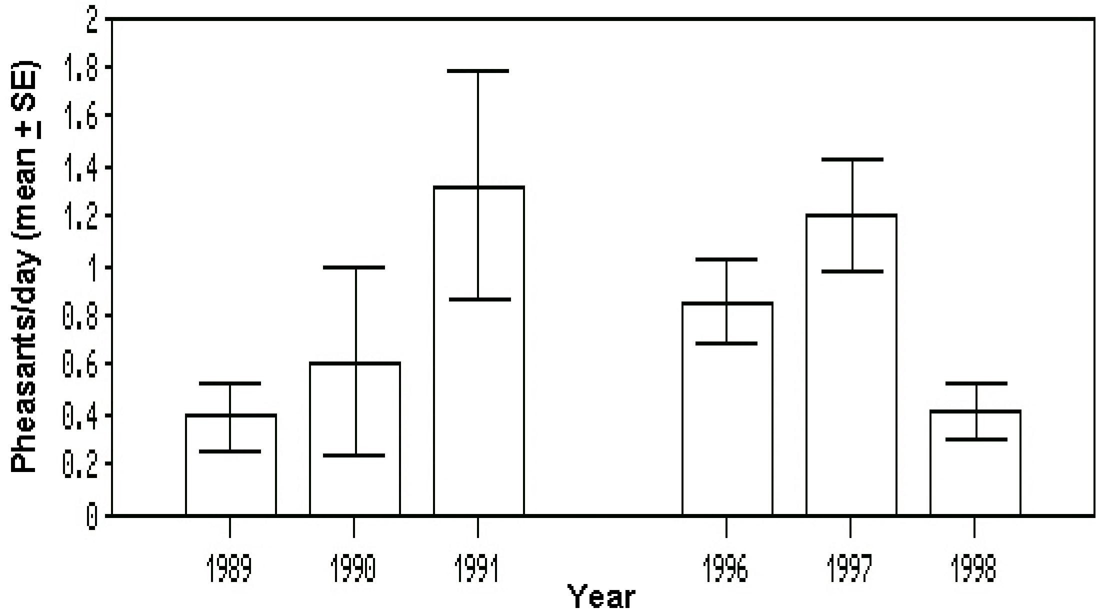


Figure 4.3: Survey effort at the Dwei Kwan study site inside Yushan National Park, Taiwan, from July through June 1989 for each year 1989-1992 and 1996-1999: A) % effort per hour (Kruskal Wallis Chi-Square = 1.55, df = 5, p = 0.91), B) % effort per month (Kruskal Wallis Chi-Square = 2.01, df = 5, p = 0.84)

A) Dwei Kwan



B) Kwan Kao

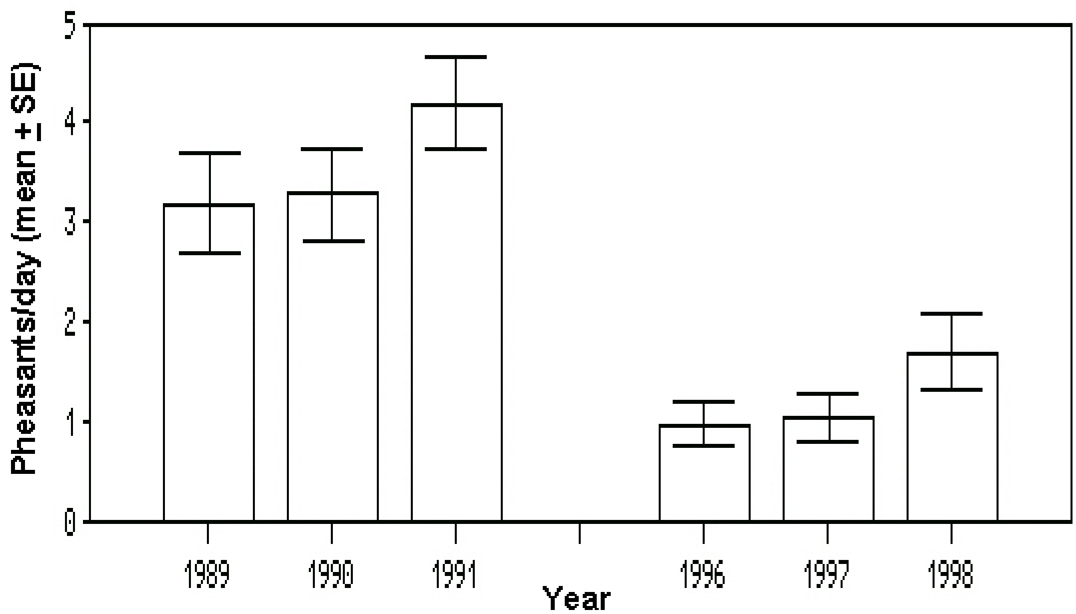


Figure 4.4: Relative abundance of *Syrmaticus mikado* based on the daily rate of encounter (mean and standard error) in 1989, 1990, 1991, 1996, 1997, and 1998: A) At Dwei Kwan, linear regression analysis showed no significant differences between years in the rate of encounter ($F=0.02$, $df=1$, $p=0.89$); B) At Kwan Kao, linear regression analysis showed significant differences between years in the rate of encounter ($F=34.24$, $df = 1$, $p<0.0001$).

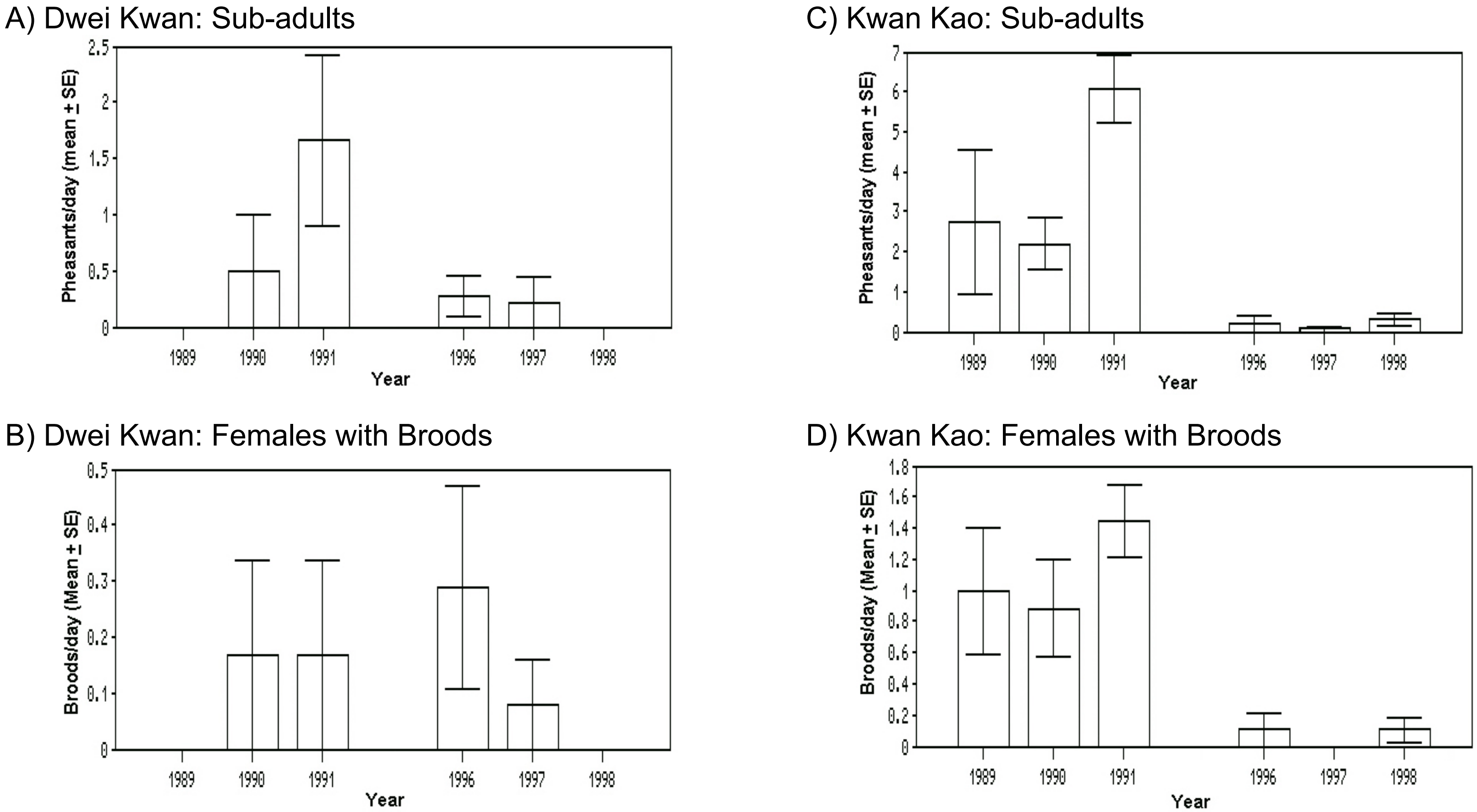
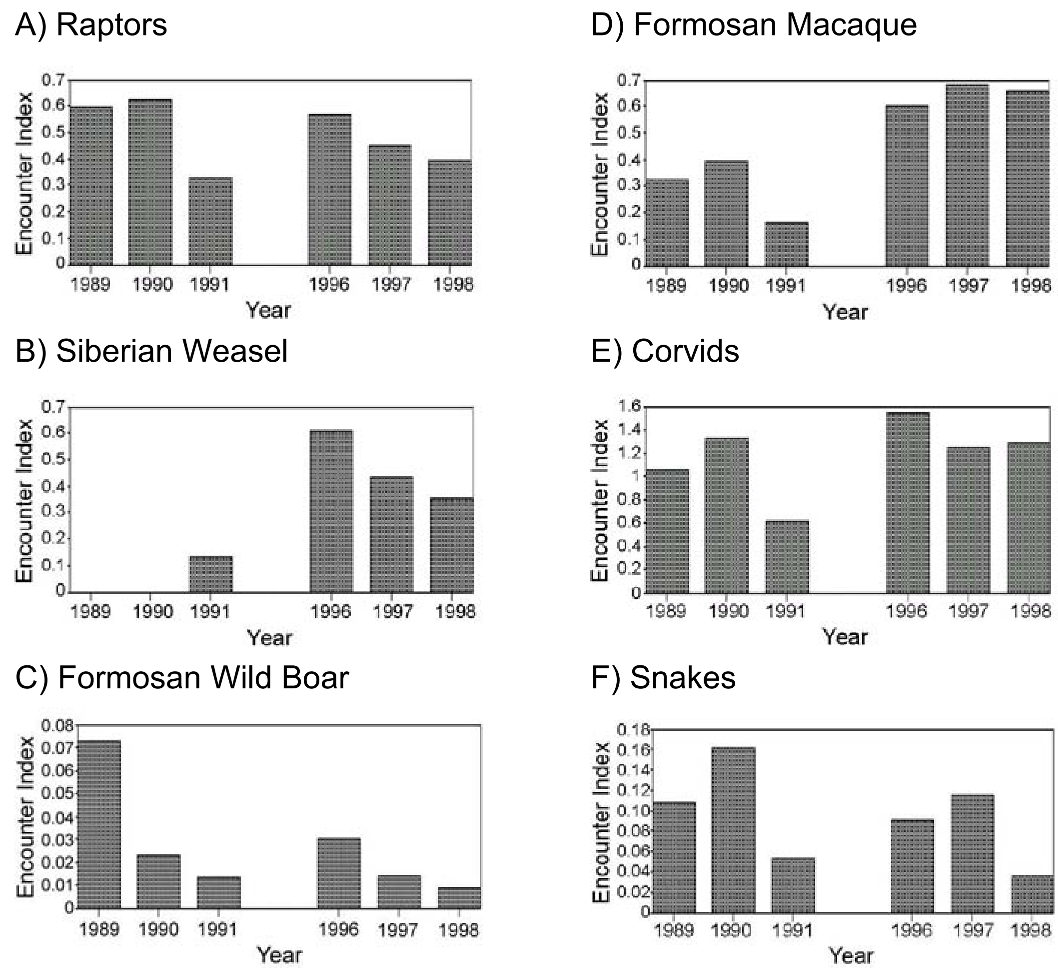


Figure 4.5: Relative abundance of chicks and sub-adult *Syrmaticus mikado* based on the daily rate of encounter (mean ± standard error) in July, August and September in 989, 1990, 1991, 1996, 1997, and 1998. At Dwei Kwan, linear regression analysis resulted in no significant differences between years in the rate of encounter with A) sub-adults ($F=3.35$, $df=1$, $p=0.07$), or B) females with broods ($F=0.34$, $df=1$, $p=0.56$). At Kwan Kao, linear regression analysis showed significant differences between years in the rate of encounter with C) sub-adults ($F=28.37$, $df=1$, $p<0.0001$) and D) females with broods ($F=27.38$, $df=1$, $p<0.0001$).



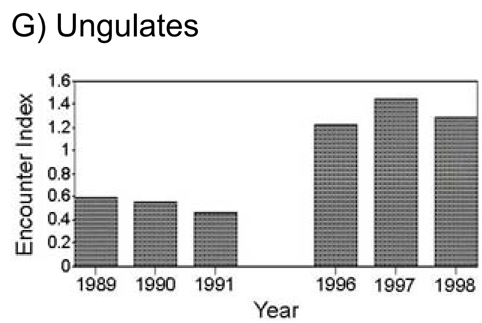
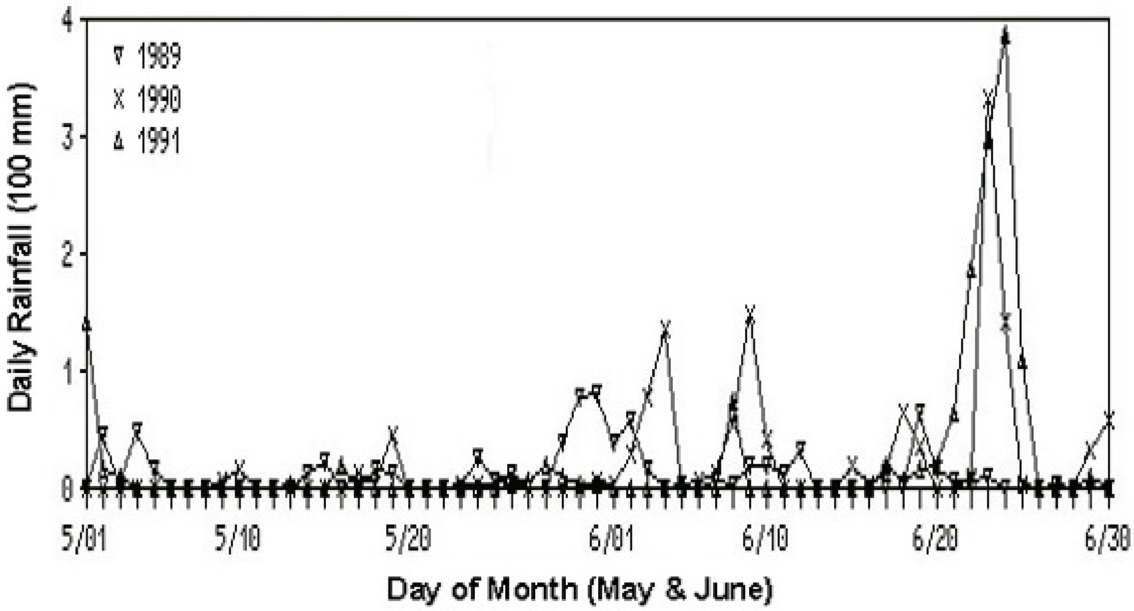


Figure 4.6: The relative abundance of predators and ungulates encountered within the study area inside Yushan National Park, Taiwan, in 1989, 1990, 1991, 1996, 1997 and 1998. Predators of adult *Syrmaticus mikado* are A) Raptors: including *Accipiter trivirgatus* (Crested Goshawk), *Spilornis cheela* (Crested Serpent Eagle), *Bustastur indicus* (Grey-faced Buzzard), *Falco tinnunculus* (Common Kestrel), *Asio otus* (Long-eared Owl), *Ninox scutulata* (Brown Hawk Owl), *Strix leptogrammica* (Brown Wood Owl), and *Strix aluco* (Tawny Owl). Known to prey on adult pheasants, B) *Mustela siberica davidiana* (Siberian Weasel), may also be a nest predator. Possible nest predators include: C) *Sus scrofa taivanus* (Formosan Wild Boar); D) *Macaca cyclopis* (Formosan Macaque); E) Corvids: *Garrulus glandarius* (Jay), *Corvus macrorhynchos* (Large-billed Crow), *Nucifraga caryocatactes* (Nutcracker); and F) Snakes (including Viperidae and Colubridae). G) Ungulates: *Cervus unicolor swinhoei* (Formosan Sambar), *Capricornis crispus swinhoei* (Formosan Serow), and *Muntiacus reevesie micrurus* (Formosan Reeve's Muntjac).

A) Alishan 1989-1991



B) Alishan 1996-1999

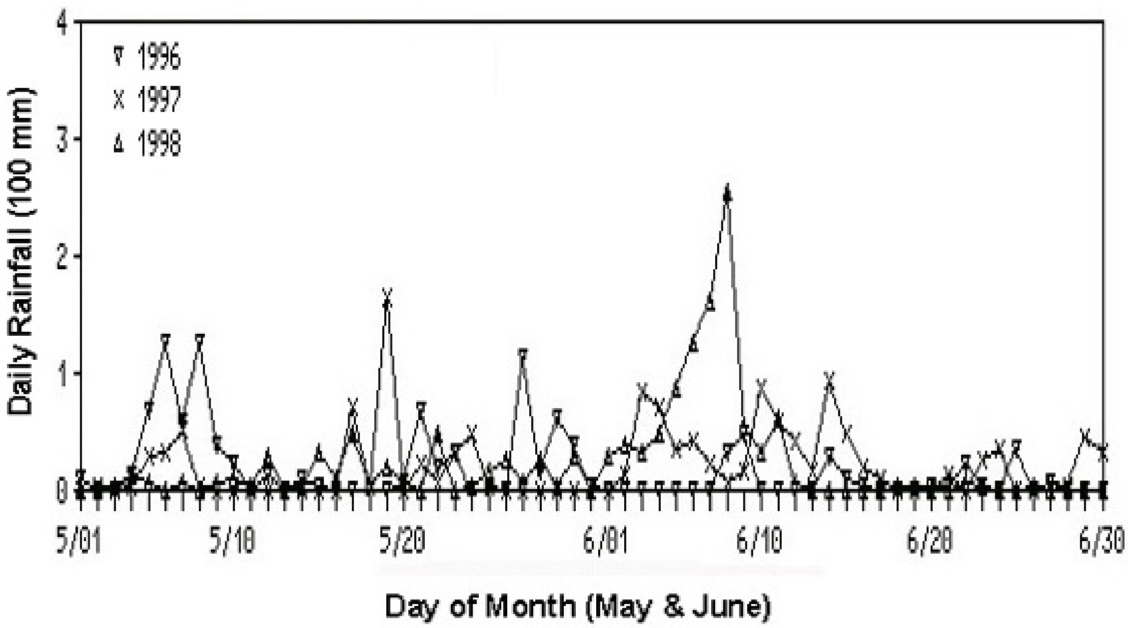
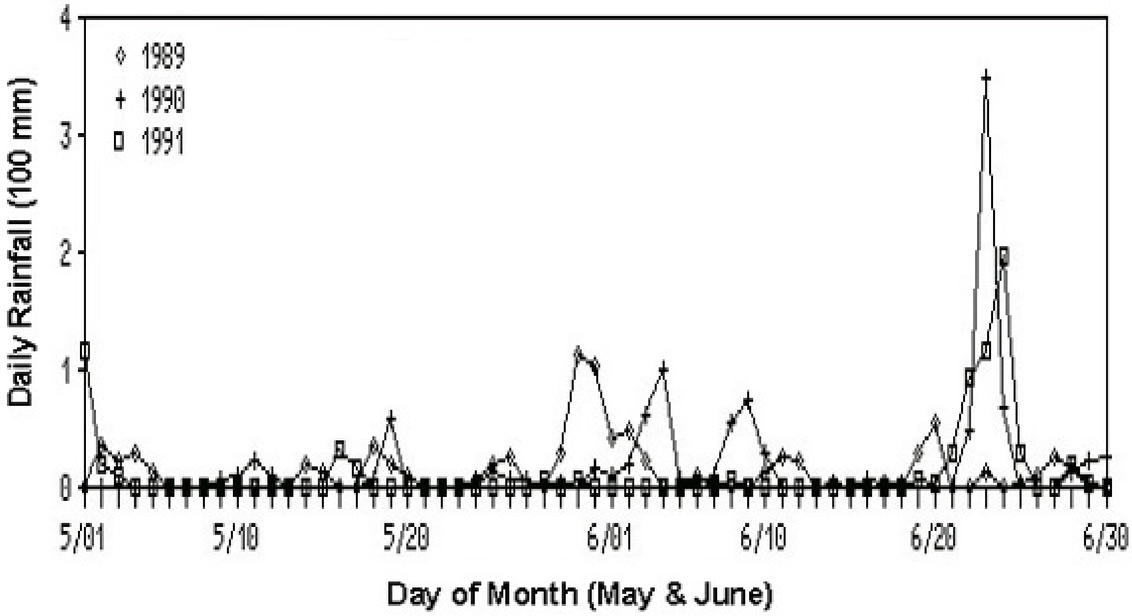


Figure 4.7: Daily rainfall patterns at the Alishan weather station, Taiwan, for May and June: A) 1989-1991 and B) 1996-1998.

A) Yushan 1989-1991



B) Yushan 1996-1999

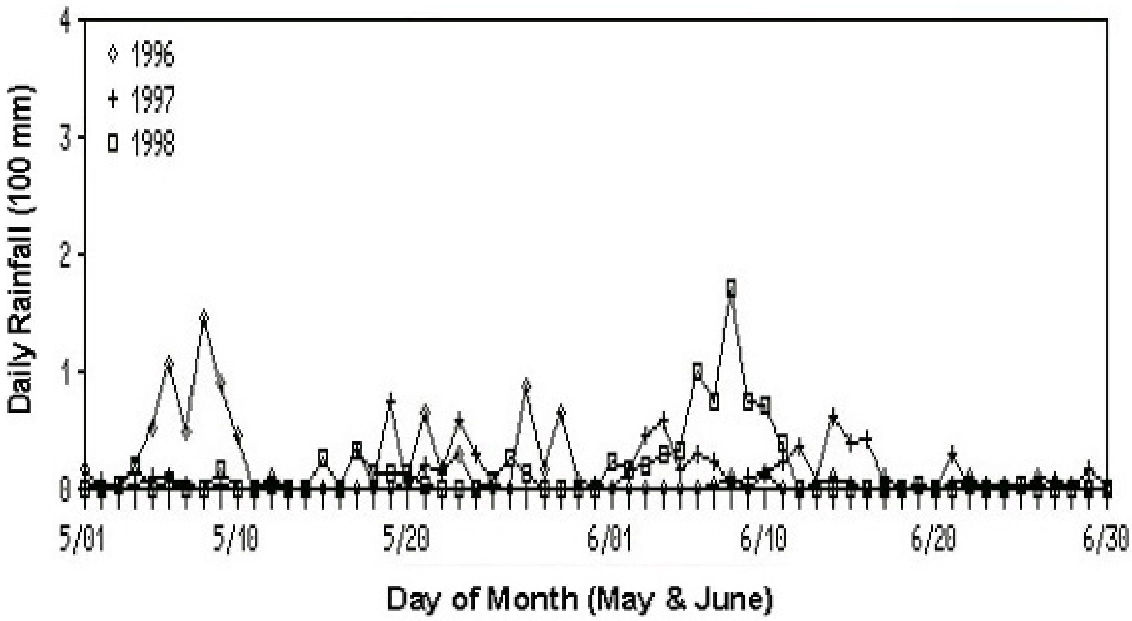
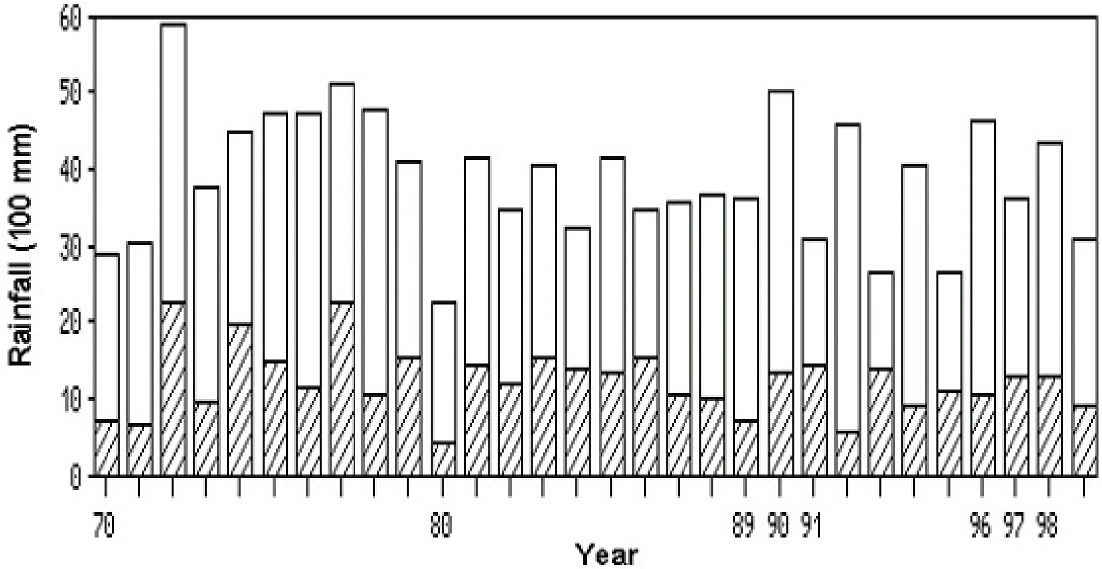


Figure 4.8: Daily rainfall patterns at the Yushan weather station, Taiwan, for May and June: A) 1989-1991 and B) 1996-1998.

A) Alishan



B) Yushan

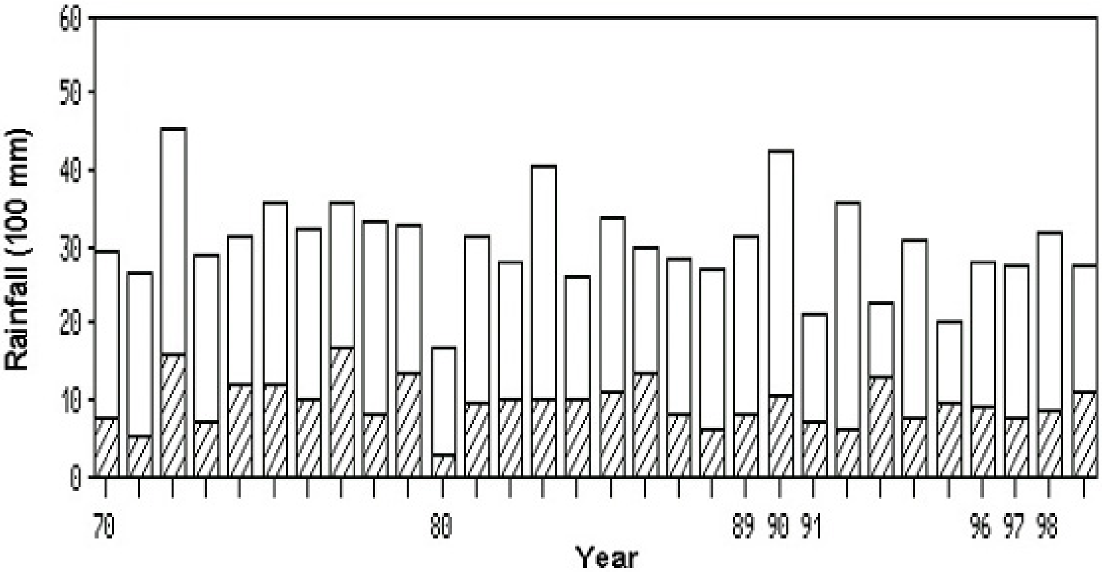


Figure 4.9: Rainfall in Taiwan for each year 1970 – 1999 from A) the Alishan weather station and B) the Yushan north peak weather station. Height of bar indicates total rainfall for each year. May and June rainfall indicated by the shaded areas.

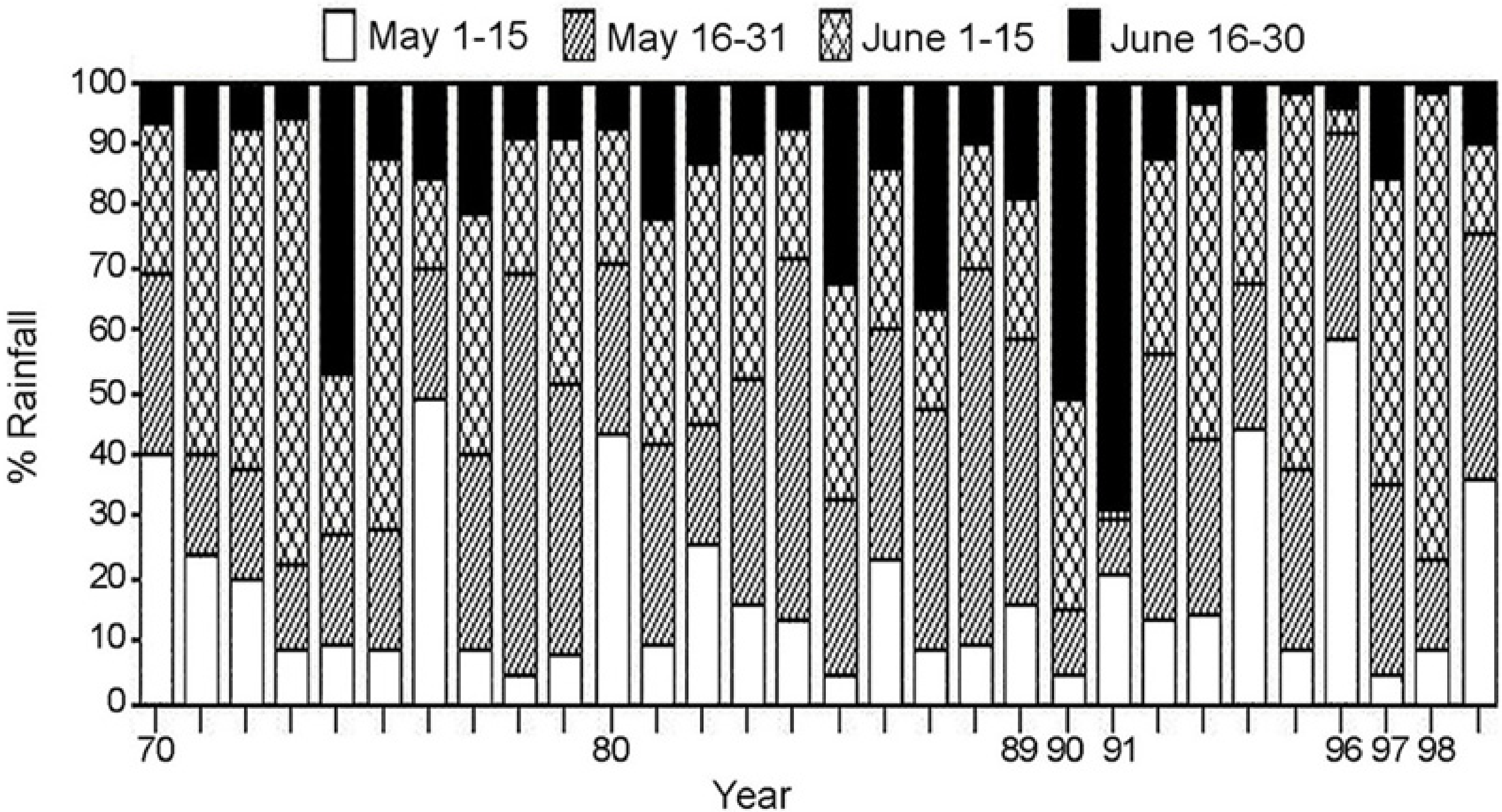
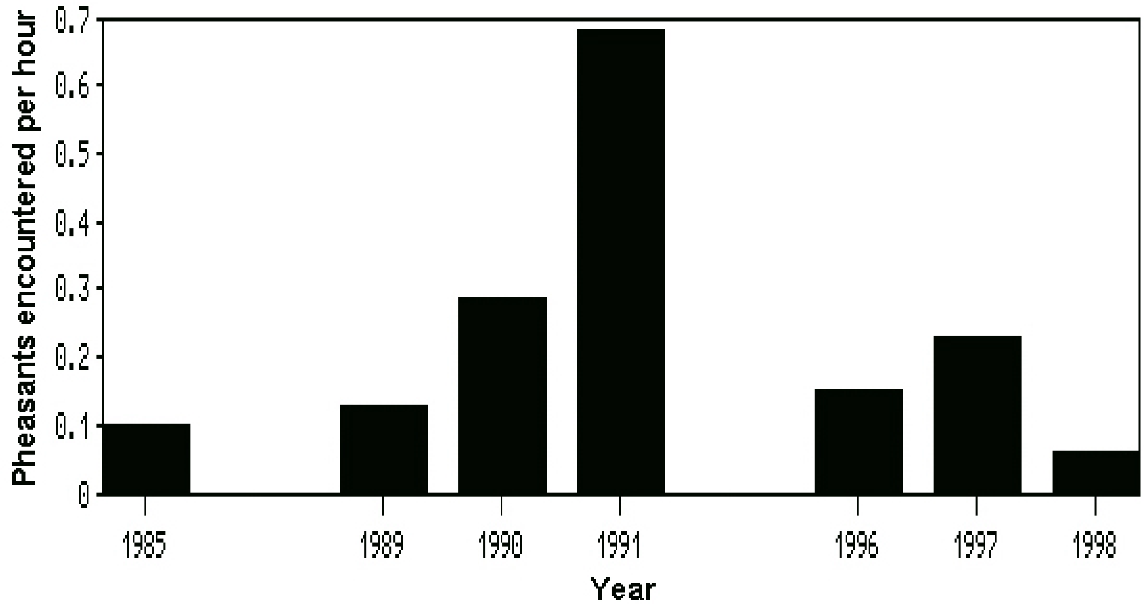


Figure 4.10: Percent rainfall for every two weeks in May and June from 1970 through 1999 at the Yushan North Peak weather station, Taiwan.

A) Dwei Kwan



B) Kwan Kao

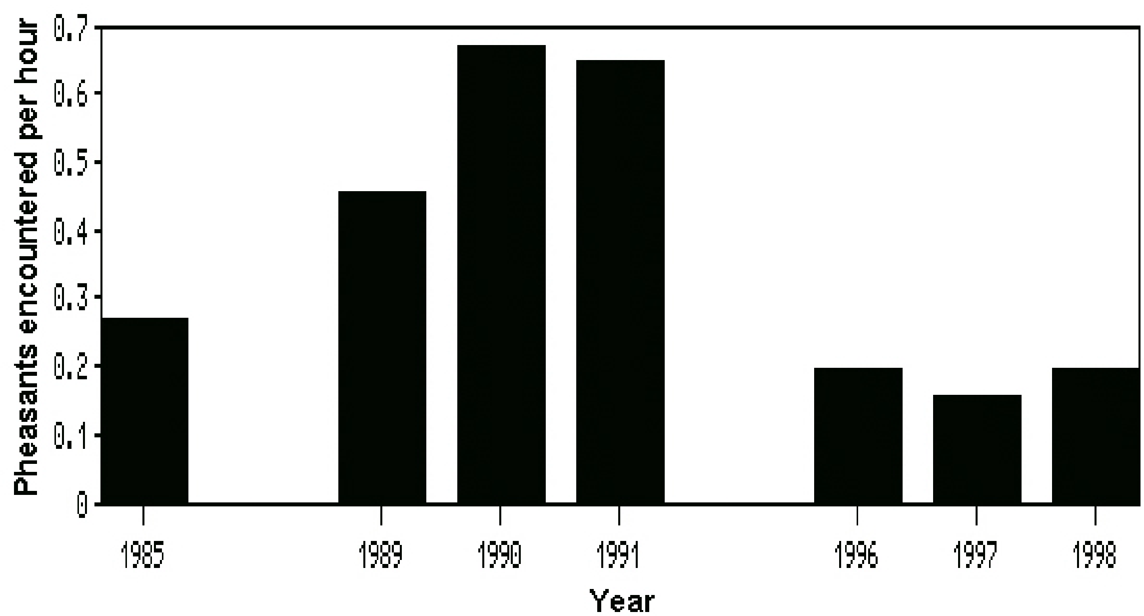


Figure 4.11: Relative abundance of *Syrmaticus mikado* based on the hourly rate of encounter at A) Dwei Kwan and B) Kwan Kao for the following years: November 1985 to December 1986 (Severinghaus & Severinghaus 1987), and July through June for each year 1989-1992 and 1996-1999.

PART 5

CONCLUSION AND RECOMMENDATIONS

Is *Syrmaticus mikado* threatened with extinction? The species is currently classified as near-threatened world-wide (Fuller and Garson 2000), but it has been considered both safe (McGowan and Garson 1995) and threatened with extinction (Groombridge 1993-1994). These shifts in the conservation status of *S. mikado* are not due to improved conservation measures or increasing population size, as the basis of these classifications has been Severinghaus and Severinghaus (1987). These shifts reflect adjustments in the criteria used for classification (Species Survival Commision 1994, IUCN 2001). Within Taiwan, this endemic pheasant is still considered endangered (Yang 1993). In this dissertation, I have examined the pheasant's use of habitat, availability of habitat, and population trends from 1989 to 1999. This information is necessary to identify the risk status of *S. mikado* and determine whether it deserves listing as a threatened species.

Syrmaticus mikado lives and reproduces in both primary and secondary habitats. In Part 2, I reported that pheasants living in primary forests utilize patches with secondary forest characteristics. The association of *S. mikado* activity with secondary forest may be due to selective pressure from topography. The elevations within which this pheasant occurs are distinguished by landslide activity. The fastest growing habitats within Yushan National Park are landslides, with some growing too quickly to allow for forest regeneration (Chou and Wang 1995). Small landslides are frequent, providing exposed soil and light gaps for rapid regeneration. Under certain conditions, this natural disturbance helps create and maintain secondary forest habitats within what is otherwise primary forest. Landslides and typhoons have been important forces in the development of Taiwan's vegetation (Wang 1962, Mabry et al. 1998). Some of the habitat lost, however, is the result of disturbance from logging and construction activities (Chou et al. 2000).

Based on the data presented Part 3, *S. mikado* may be considered vulnerable to the risks of extinction. The extent of occurrence is about 10,000 km^2 and the area of occupancy is about 900 km^2 (Lee Pei-Fen, personal communication). To be listed as vulnerable, the extent of occurrence must be less than 20,000 km^2 or the area of occupancy less than 2000 km^2 (Species Survival Commission 1994). Many of Taiwan's endemic species have an extent of occurrence similar to that of *S. mikado*. Considering only the area of Taiwan's mountainous regions, all of these endemic species could be classified vulnerable to extinction. To use extent of range as a criterion for classification as vulnerable, however, there must also be evidence of population decline and severe fragmentation of either habitat or populations (IUCN 2001). One of the models used in Part 3 shows severe fragmentation of habitat, as does the distribution of known populations (Lee et al. 1998). This habitat fragmentation, combined with the small home ranges and lack of movements for individual *S. mikado* even from one study area to the next, suggests poor colonization ability and genetic isolation. Evidence of population decline is given in Part 4. Adding the evidence for population decline to the fragmented nature of the habitat, and the extent of occurrence of 10,000 km^2, *S. mikado* qualifies for vulnerable, even though 39% of its range is protected within parks and reserves.

Syrmaticus mikado has evolved in a dynamic landscape. It should be able to tolerate some changes in habitat. Unfortunately, the population within the study area inside Yushan National Park has declined by 65% over the past 10 years. To be listed as vulnerable, there must be an estimated reduction of at least 30% over the past 10 years (IUCN 2001). To be listed as endangered, the decline must be at least 50% (Species Survival Commission 1994). This 65% decline, alone, is enough to classify *S. mikado* as an endangered species. The main reason for the decline is poor productivity. Clutches, if laid, and chicks, if hatched, are not surviving. This is probably due to an increase in the population of nest predators and to the effect of cooler weather with heavy rainfall during the hatching period. Poaching, which targets mature birds, has also increased over the past 10 years, despite the fact the study area is within a national park. With such poor productivity, the survival of this population depends on the longevity of mature birds.

The most suitable classification for *S. mikado* is vulnerable. The population decline at Kwan Kao is huge, but the population at Dwei Kwan appears stable. At both sites, there are active breeding populations. What is not known is whether the decline at Kwan Kao is part of a long-term trend or part of a cyclic pattern related to weather conditions and predator populations. The status and trends for other populations of *S. mikado*, is unknown. As *S. mikado* lives in forest at elevations naturally disturbed by landslides, habitat is probably not a limiting factor. If there are limiting habitat requirements for the survival of *S. mikado*, those requirements are likely to be for nest and roosting sites. To better understand this decline in *S. mikado* population, I recommend continued monitoring of nest and chick survivorship as well as investigation into the sociology of poaching.

It is disturbing that the incidence of hunting has apparently doubled since 1989. The use of snares is especially dangerous because snares continue to trap animals long after the hunter has left the area. Therefore, I recommend that Yushan National Park investigate the incidence of hunting within its borders. The types of hunters (economic and educational status, place of employment and residence) should be examined. The motivation, targets, and methods of hunting should be identified. This sociological study will reveal information needed to implement the policy and programs needed to control hunting within the park and other protected areas.

Productivity is very important for maintaining or increasing Mikado Pheasant populations. This study has determined that the Mikado Pheasant population is not growing and may actually be declining, primarily due to lack of recruitment. For three years, almost no juveniles have been added to the populations at Kwan Kao and Dwei Kwan. For an animal that lives three to 10 years (as have the pheasants in this study), a period of three years without recruitment could damage the health of the population. It is important that yearly productivity in Mikado Pheasants be monitored on a long-term basis. Therefore, I recommend that Yushan National Park implement a long-term productivity survey: 1) The Dwei Kwan and Kwan Kao study sites should each be visited for about one week each year during July and September; 2) The Chun Ta Logging Road (67.5 km to 66.0 km) and the Patungkwan Trail (14.3 km to 10.1 km) should be slowly walked each day between 0600-1000 and 1400-1800, with careful record made of the time and distance surveyed; 3) The time and location of all observed pheasants should be recorded with special note of groups of females with chicks and the number of chicks per female; and 4) The condition of the trail and road (e.g. herb height, visibility) and of the weather during the survey should also be recorded as these conditions affect pheasant encounter rate. This methodology is simple, and the amount of effort is small. If this survey can be made each year for 20 years or more, it will be possible to document the patterns of productivity and the effect of weather on the health and stability of these populations of *S. mikado*.

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VITA

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