# STATUS AND CONSERVATION OF ELD'S DEER (*Cervus eldii*) IN VIETNAM

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## Brief information on Vietnam

Vietnam is located along the eastern coast of Indochinese Peninsula, stretching over nearly 15 degrees of latitude (8°30'N to 22°22'N) and over 7 degrees of longitude (102°10'E to 109°20E). The country covers an area of 329,240 km$^2$ and 3,000 km coastline. Seventy five percent (75%) of the area is mountain or hills.

Vietnam experiences a tropical monsoon climate with a marked wet season in the south and more temperate weather in the north. Biogeographically it is at the intersection of the Indian, South Chinese and Malayan regions. This has resulted in a region of very high biodiversity, with areas in Vietnam being recognized as critical for global conservation with high levels of endemism.

Vietnam support about 12,000 vascular floral species; 275 mammal species, 828 bird species, 180 reptile species, 80 amphibian species, 547 freshwater fish species, 2,033 marine fish species and about 12,000 insect species (WWF/SPAM Project, 2002). The endemicity of the floral and faunal systems is very high with at least 40% of plant species and 78 species and sub-species of mammals, over 100 species and sub-species of birds. Four large mammal species new to science were described during the last decade: Sao la (*Pseudoryx nghetinhensis*), Giant muntjak (*Megamuntiacus vuquangensis*), Truong son muntjak (*Caninmuntiacus truongsonensis*) and Tay Nguyen civet (*Viverra tainguensis*).

The population of Vietnam is over 80 million people. Eighty percent (80%) of the population live in rural areas. Vietnam is undergoing an economic transition towards a more market-oriented economy. Economic growth, infrastructure development, population growth, long wars and development of agriculture, forestry and fishing industries has caused an over-exploitation of Vietnam's natural resource.

In 1943, area of natural forest was about 14,300,000 ha, giving the coverage of 43.0%. In 2002, area of natural forest was reduced to 9,444,198ha (less than 10% primary forest), giving the coverage of about 34.45% (WWF/SPAM Project, 2002). Gross deforestation has been accompanied by a loss of the country's overall biodiversity.

The Government of Vietnam has recognized the necessity for conserving and rehabilitating the natural environment since 1960s. At present, there were 121 protected areas with total area of 2,478,295ha (accounting over 7% of the national area) officially established. Various national legislation documents on forest protection and biodiversity conservation have been adopted. Vietnam has also joined various international biodiversity conservation convention such as Biodiversity Convention, RAMSAR, CITES, etc.

## Status of eld's deer in Vietnam

Eld's deer is poorly studied in Vietnam. The first description of Eld's deer in Vietnam was by Lydekker in 1915 (Lydekker, 1915) based on specimen collected in a province of Central Vietnam (Nha Trang city of Khanh Hoa Province). Latter, studies of Vietnamese scientists found further records of Eld's deer Kon Tum, Gia Lai, Phu Yen, Dak Lak and Lam Dong (Dang Huy Huynh et al., 1994). So historical distribution range of Eld's deer in Vietnam covers southern part of Central Vietnam from ca 10°00'N to 14°30'N (Figure 1).

Before 1975, this area was mostly covered by tropical evergreen forests and Tropical semi-evergreen forest and open deciduous forests, that provided very good habitats for Eld's deer and this species was relatively abundant. As reported by local people and old army officials the animals were often seen in groups of 10 to 20 individuals. After 1975 (end of war), due to demand of the post-war country reconstruction the forests were undergone intensive commercial logging and due to rapid population increase to the area, large forested lands were converted into arable lands and settlement lands, and wildlife was severely hunted for food and trade. As a result, Eld's deer have been seriously reduced in number and have lost a great part of its habitats.

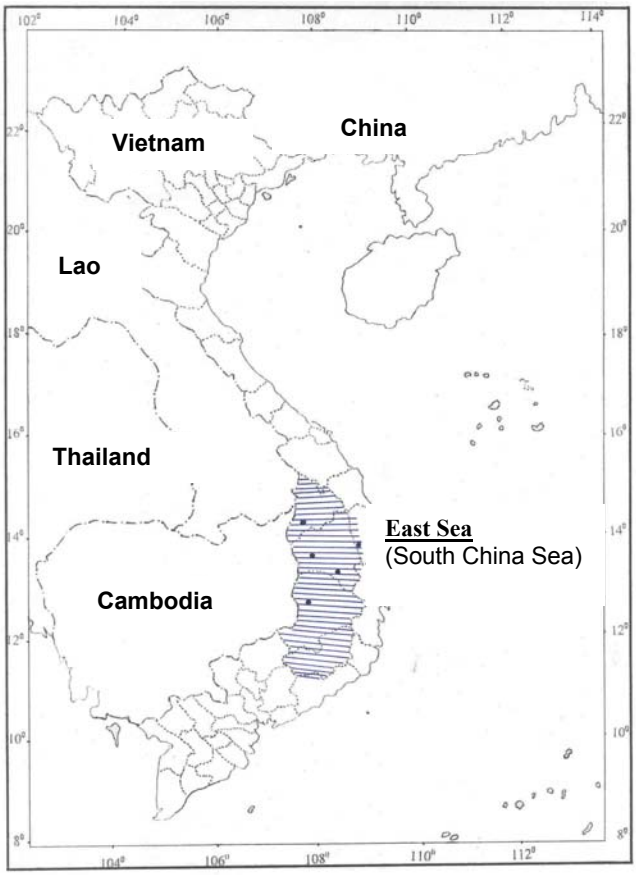


Figure : Distribution of Eld's deer in Vietnam
Distribution range ③ - Recent records

During recent decade there was no systematical investigation on status of Eld's deer in Vietnam, so that our knowledge on its status and distribution is very poor. Few recent records of this species are:

- In 2001, survey team of *Birdlife International in Vietnam* and *Forest Investigation and Planning Institute (FIPI)* conducted survey in A Yun Pa area of Gia Lai Province (13°24'N – 13°38'N; 108°30'E – 108°45E) and recorded the existence of small population of this species through interview of local residents (Tran Quang Ngoc et al., 2001).
- In 2001, the same survey team conducted survey in Chu Prong area (13°18'N – 15°38'N; 107°34' – 107°51') of Gia Lai province where they found a pair of fresh Eld's deer antlers in a farmer house. The farmer reported that in 2000 he saw a group of about 8 Eld's deers and killed one of them. Investigating this location, the survey team found some fresh tracks and droppings of Eld's deer (Tran Hieu Minh et al., 2001).
- In August 2003, Survey team of *Birdlife International in Vietnam* and Institute of Ecology and Biological Resources (IEBR) conducted survey in Yok Don National Park (12°47'N – 13°00'N; 107°29'E – 107°50'E) of Dak Lak Province. The team observed an old antler of Eld's deer collected by the Park's ranger in 2001. One resident informed that in June 2003 he saw a group of 5 –7 Eld's deers in forests in central part of the park (Dang Ngoc Can, Pers. communication).
- During September 2003, authors of this report had a short visit to area of Eld's deer range. Antlers of Eld's deer were found in several shops in Buon Ma Thuot City (Dak Lak province) – about 50 km away from Yok Don NP and Pleiku Town (Gia Lai Province) (see enclosed pictures). The actual provenance of these antlers are not known. While visiting Chu Mom Ray Nature Reserve (14°22'N – 14°36'N; 107°30'E – 107°47'E) of Kon Tum Province, the Reserve director confirmed existence of Eld's deer in reserve with a pair of

antlers collected by his forest guards in the forest 2 years ago. The species is also enlisted in 2001 Revised Management Plan for Chu Mom Ray Nature Reserve (FP&RD Project, 2001).

## Conservation of eld's deer in Vietnam

Eld's deer was enlisted in Red Data Book of Vietnam at highest level of threat – **Endangered**. In Governmental Decree 48/2002/NDCP, dated 22 April 2002, stipulating the list of threatened species and regulation for their management and protection, Eld's deer is listed in **Group IB** – Strict ban of hunting and use.

Nineteen (19) protected areas have been established or proposed in the range area of Eld's deer and recent records of the deer are found in 5 protected area: Proposed A Yun Pa NR (Gia Lai Province), Proposed Chu Prong NR (Gia Lai Province), Krong Trai NR (Phu Yen Province), Chu Mom Ray NR (Kon Tum Province) and Yok Don NP (Dak Lak Province).

**TABLE 1: FOREST AREA AND FOREST COVERAGE IN PROJECT PROVINCES**

| Province | Total land area (ha) | TOTAL FOREST AREA (ha) | NATURAL FORESTS (ha) | Forest plantation (ha) | Forest coverage (%) |
|---|---|---|---|---|---|
| Kon Tum | 961,450 | 631,275 | 602,109 | 29,167 | 65.7 |
| Gia Lai | 1,549,571 | 760,245 | 778,907 | 31,339 | 49.1 |
| Phu Yen | 503,506 | 154,336 | 129,767 | 24,569 | 30.7 |
| Dak Lak | 1,957,644 | 994,482 | 980,975 | 13,507 | 50.8 |
| Lam Dong | 976,220 | 632,281 | 586,487 | 45,794 | 64.8 |
| **Total** | *5,948,391* | *3,172,619* | *3,078,245* | *144,376* | *53.3* |
| ***Vietnam*** | ***32,879,652*** | ***11,784,587*** | ***9,865,019*** | ***1,919,569*** | ***35.8*** |

*SOURCE: DECISION NO 2490/QD/BNN-KL, DATED 30 JULY 2003 OF MINISTER OF MARD ON ANNOUNCEMENT OF FOREST AREA AND FORESTRY LAND OF VIETNAM IN 2002.*

Eld's deer range provinces are among the provinces of highest forest coverage in Vietnam (ranging from 30.7 to 65.7%, Table 1), that give a hope to provide enough habitats for survival and restoration of Eld's deer in Vietnam.

In spite of strong efforts by Vietnam Government on biodiversity conservation, Eld's deer in Vietnam is facing the following threats:

- Illegal hunting for food and for antlers trade
- Habitat degradation by slash-and-burn agricultural practice and non-timber products collecting.
- Habitat disturbance by human encroachment for agricultural production and forest products collecting.
- Forest fire risks

## Conclusion and recommendation

- Eld's deer in Vietnam is seriously threatened and may undergo extinction in the near future unless effective conservation measures are undertaken.
- Status and ecology of Eld's deer in the wild is very poorly studied. Lack of this knowledge causes great difficulties in development of effective conservation measures for this species.
- Vietnam Government spends strong effort on conservation of its biodiversity resources, however, there is no specific conservation activities for Eld's deer.

- In order to improve conservation of Eld's deer in Vietnam following activities must be undertaken as soon as possible:
    - Conduct survey to identify current status of its existing populations and threats to each population to develop appropriate conservation measures
    - Conduct education to increase awareness of residents in Eld's deer range area on importance of the species conservation and governmental legislation on biodiversity conservation.

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# Ecology and Available Habitat of Eld's Deer in Southeast Asia

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## Introduction

This chapter is based on a presentation at the 2003 Eld's Deer Conservation Workshop and draws heavily on previous written work by the author on the subject.

The most abundant of the three subspecies of *Cervus eldi* is *C. e. thamin*, which is now found only in Myanmar. There has been a steady decline in the thamin populations since the 1940s (Yin 1967, Salter and Sayer 1986, McShea *et al.* 1999). A country-wide survey conducted in 1992 estimated that 2200 individuals remained (Aung 1994). The largest population remains in Chatthin Wildlife Sanctuary (CWS), but this population declined 40% between 1983 and 1995. A field survey in 1997 (McShea *et al.* 1999, McShea and Aung 2001) estimated that fewer than 1750 animals remain in the wild. Most of our knowledge of ecology and natural history is derived from observations and studies of thamin. I can only assume that these observations will hold true for the other subspecies.

## Ecology

### *Habitat and seasonal movements:*

The best-studied of the three subspecies, *C. e. thamin*, inhabits small patches of suitable habitat in the central dry zone of Myanmar (McShea et al. 1999). Vegetative cover is a mosaic of cultivation, deciduous forest and scrub, on flat to gently rolling terrain. The predominant forest community consists of several species of deciduous broadleaf trees, with abundant ground cover consisting of grasses and forbs. This forest commonly incorporates grassy glades. Most habitat burns annually during the dry season. Virtually all remaining thamin habitat has been subject to cultivation, selective logging, and livestock grazing for generations. Within their remaining habitat, thamin prefer thin-canopied deciduous dipterocarp forests with grassy ground cover, degraded forests and grassy areas, and avoid closed forests. They are grazers and opportunistic browsers who supplement their diet with fruit and cultivated crops, particularly rice (McShea et al. 2001).

Although Eld's deer may enter shady forested areas during hot weather, they generally prefer to inhabit open forests (Salter and Sayer 1986). The southwest monsoon results in heavy rainfall (up to 5000 mm) on the fringes of Eld's deer habitat (i.e. the hilly borders of the Irrawaddy plain) to 750 mm in the Eld's deer primary habitats (central Myanmar) (Salter and Sayer 1986). The rainy season range is from mid-May to mid-October. Pristine habitat is non-existent for Eld's deer, and they now inhabit areas that range from dry scrub and thorn forest to open deciduous forest in various stages of secondary succession (Wemmer 1987, McShea *et al.* 1999).

Based on radio-tracking data, the average size of the annual thamin home range was estimated to be 9.04 ± 5.67 $km^2$ for males and 7.25 ± 3.45 $km^2$ for females, and varied greatly among individuals of the same sex (range of 1.85 – 18.37 $km^2$ and 2.6 – 11.11 $km^2$ for males and females, respectively) (Aung *et al.* 2001). There were no significant differences between the sexes in annual home ranges, but there were significant seasonal differences in home range, with larger home ranges observed during the hot-dry season. Both males and females did exhibit site fidelity with seasonal home ranges showing a high degree of overlap.

### *Food habits:*

Detailed studies in CWS (McShea *et al.* 2001) revealed that thamin consumed primarily forbs, grasses and agricultural crops, but also consumed the fruits of 8 common tree species. Thamin used dipterocarp forest, but showed seasonal shifts and distinct individual differences in habitat use. With the exception of the mating season (January-April), females were found more often in degraded forests and closer to crops than males. Sex differences in habitat selection were hypothesized to be due to either female selection of habitats with lower predation risk, or to increased nutritional needs associated with lactation. Males were found more often in *dipterocarp*

forest. Both sexes appeared to avoid mixed deciduous forests and to a lesser degree grasslands. There were no obvious seasonal changes in habitat use. Approximately one-third of CWS was flooded during the rainy season, and pools of water that persisted through the dry season were important sources of water for thamin.

***Sex and age composition**:*

Based on 747 sighting and radio-tracking records (11 adult male and 8 adult female) at CWS, a 0.63:1.0 adult male:female ratio, and a 0.51:1.0 fawn:adult female ratio was observed. Mean group size was variable (range 1.0-5.9 deer) and showed seasonal differences, with smaller groups observed in August-September, and groups of up to 70 individuals in March-April.

Sighting records (Aung *et al.* 2001) indicated that male thamin spent most of the year alone, and females associated only with their fawns. Females were found alone, or with their fawn, 55% (*n* = 394), 84% (*n* = 316) and 80% (*n* = 339) of the time during the hot-dry, rainy and cool-dry seasons, respectively (Aung *et al.* 2001). Of all sighting records where sex could be identified, 29% (*n* = 277) were of a single adult (both sexes), and 15% (*n* = 143) were of a single adult female with fawn. The pattern changed dramatically from the cool-dry to the hot-dry season, when groups of up to 70 individuals were observed. Mean group size peaked in April (5.9 ± 8.3) and decreased slowly to 1.1 (± 0.3) through September (Aung *et al.* 2001). Males were first observed in all-male groups in November, and multi-male mixed-sex groups were found mostly during the late cool-dry and hot-dry season (December through March).

***Breeding season**:*

The annual reproductive life cycle can be inferred from direct observations of (1) antler development in males, (2) group composition, and (3) the timing of fawning. The greatest number of all male groups was observed from November to January, just before the observed peak in mixed-sex group composition. Whereas overt mating behaviour (i.e., mounting and copulation) were not observed in radio-collared males, these males were observed tending females in March and April.

Visual observations of 11 radio-collared males were used to track the annual antler cycle. All males were in hard antler from late December to May, 75% possessed hard antlers during early June, 58% in late June, 14% in early July and none by late July. Thus, antlers were shed between the last week of May and mid-July. Antlers were first observed in the velvet stage during July (21%) and August (86%). All males were seen with velvet antlers in September and October, after which observations of deer with velvet antlers declined steadily; by early December 88% of male thamin were in hard antler.

The ratio of fawns per female was lowest in October, and peaked in February. Fawns were observed first in December, but never at their bedding sites. Six of 8 radio-collared females produced fawns. Of the other two females, one was with a fawn and the other with a yearling male, when first captured. Of those females that were radio-tracked for more than one birthing season (October- December), only one produced a second fawn, and this after an interval of 2 years. Although single adult females were sighted with two fawns, no twins were observed in the radio-collared study population. These data support an estimate of a 60-90 day mating season (February-May) (Aung *et al.* 2001). Observations of wild thamin in CWS appear to match closely the reproductive patterns for captive thamin (see below) that have been maintained in temperate zones for more than 50 years. Thus, it appears likely that thamin have evolved endogenous reproductive rhythms in response to seasonal fire and rainfall – dominant environmental events in the dry forests of southeast Asia.

***Gestation and fawning**:*

Detailed reproductive studies have confirmed that captive hinds are seasonally polyoestrous, spontaneous ovulators, with onset of oestrus occurring in late winter or early spring, followed by a seasonal and/or lactational anoestrus in the autumn (Monfort *et al.* 1990a,b). In captivity, 80 to 90% of all births occur from September to November (Desai and Malhotra 1978, Prescott 1987, Wemmer and Grodinsky 1988). Captive females can conceive as yearlings (mean age at first conception: 469 days) and the interbirth interval is ~365 days, regardless of whether or not fawns were reared in the previous year (Wemmer and Grodinsky 1988). The average oestrous

cycle duration is 18.5 days, and if conception does not occur, hinds may cycle for up to 8 months (Monfort *et al.* 1990a,b, Hosack *et al.* 1997).

The thamin birthing season probably evolved as a trade-off between fawn safety and the energetic needs of the dam and fawn. Birthing during the cool-dry season, when monsoon waters have receded, and dense ground vegetation provides adequate shelter for fawns, ensures that weaned fawns (4-5 months of age at the beginning of the hot-dry season) will have sufficient mobility to reduce vulnerability to predation and to exploit shifting food and water resources (Aung *et al.* 2001). In contrast, widespread fires would compromise fawn survival during the hot-dry season, and would increase vulnerability to predation due to lack of cover, and poor dam nutrition (i.e., lactation stress). Similarly, extensive flooding during the monsoon would increase the risk of infection, and fawns drowning, and wet conditions could impair thermoregulatory function in neonates.

***Mortality**:*

During the 4-year study period, four radio-collared deer were killed by dhole (*Cuon alpinus*), 1 was killed by a hunter, 1 died of unknown causes, two disappeared, and two dispersed out of the study area (a female and yearling male captured together). Most deaths (4 of 6), both dispersals, and both disappearances, occurred during the cool-dry season. Additionally, there were reports of leopards (*Panthera pardus*) by local villagers, but most predation is believed to be from dhole, jackals (*Canis aureus*), or feral dogs. There were nine recorded instances of dhole predation on thamin (combined total from radio-collaring and sighting data), and six of these occurred during the cool-dry season. Poaching is still a major concern, and the greatest threat to Eld's deer is the conflict between the needs of humans and animals for limited resources, but other factors such as the monsoon flooding, fires and predation, are also major factors influencing mortality in thamin.

The primary predators of Eld's deer were tigers (*Panthera tigris*), leopards (*Panthera pardus*), and dhole. All of these predators overlapped the distribution of the Eld's deer across most, if not all of the historic range. Today, tigers and leopards have been eliminated from much of the remaining range of the Eld's deer, and thinly distributed dholes, which forage over much larger areas, are the primary wild predator of the species in Myanmar. In addition, domestic dogs pose a threat to Eld's deer when used by hunters, as coursing with dogs is the primary means of illegal hunting in Myanmar. Fawns of Eld's deer are vulnerable to predation by domestic dogs, which accompany villagers as they pass through Eld's deer habitat in Myanmar.

***Fire***:

Fire ecology is of critical importance to thamin. The dry dipterocarp forest is maintained through extensive fire and the cycle of regeneration for grasses is driven by the frequency and intensity of fire. We do not yet understand the complex cycle between deer ecology, fire frequency, and human agricultural practices.

## Determining suitable habitat in Southeast Asia

From the studies at Chatthin and our countrywide surveys we learned the habitat requirements of Eld's deer in that region. We decied to look at the majority of the historic range of Eld's deer in the Southeast Asian: Cambodia, Myanmar, Laos, Thailand and Vietnam. We know form the previous field studies that Eld's deer reside in dry dipterocarp forest. Myanmar has been reported to contain the majority of remaining Eld's deer in the wild, however there have also been recent sightings in Laos and Cambodia.

This regional analysis was conducted using global coverage data layers that are at no cost to the user in combination with Eld 's deer survey and radio tracking data obtained through prior research. These data sources were used to delineate potential Eld's deer habitat over a large study area using coarse resolution data. Four global data sets were used to generate the Eld 's deer suitable habitat map. The United States Geological Survey (USGS) Global Land Cover Characterization (GLCC) data was used for land cover, USGS Global 30 Arc-Second Elevation

Data Set was used for elevation, the University of Maryland's Continuous Fields Tree Cover Project data was used to delineate percent canopy cover, and the Oak Ridge National Laboratory's Landscan data was used as a measure of ambient population.

## GIS Analysis

It has been determined that lowland dry dipterocarp forest is vital to Eld's deer through a habitat selection study (McShea, 2000). Several criteria were identified in the global data sets that relate to the characteristics of this forest type and deer species in order to identify appropriate areas. As dry dipterocarp forest is a broadleaf deciduous forest, the USGS Global Land Cover Characterization (GLCC) data was used to exclude areas with evergreen and bare landcover. Although dry dipterocarp forest can be found at 1000 m elevation, there have not been any Eld's deer sightings above 400 m. The USGS elevation data set was used to exclude all area above 400 m. Eld's deer have also been observed in areas of low canopy cover, this area fell between 15 and 45% in UMD's continuous fields percent tree cover map. The areas outside of this tree cover were excluded. The Landscan data was used to exclude all areas that had a value of more than 10 people per pixel. This cutoff was determined by the approximate value seen around know Eld's deer locations. These raster data sets were intersected using the map calculator function in the Earth Science Research Institute's (ESRI) Arcview 3.3 (Figure 1).

The created raster layer was smoothed using a 5x5 neighborhood function in ERDAS 8.5. The remaining raster data was then converted to vector for analysis. All patches outside of the five-country study area and all patches smaller than 25km$^2$ were eliminated. Area statistics were then analyzed for each country using the final Eld's deer suitability layer.

**Land cover Databases Used:**
USGS. GLCC (Global Land Cover Characterization) http://edcdaac.usgs.gov/glcc/glcc.html
**Elevation:**
USGS. GTOPO30 (Global 30 Arc-Second Elevation Data Set)
http://edcwww.cr.usgs.gov/products/elevation/gtopo30.html
**Canopy Cover:**
UMD. Continuous Fields Tree Cover Project
http://glcf.umiacs.umd.edu/treecover/index.html
**Landscan:**
Oak Ridge National Laboratory (ORNL), LandScan
http://www.ornl.gov/gist/landscan/index.html

## Results

Suitable forest was found in each range county, but ranged from 738 km$^2$ in Vietnam to 20,680 km$^2$ in Myanmar. As percent of total forest available, Cambodia (13%) had the largest proportion of suitable habitat. It was striking how little suitable forest falls within the current protected area system (1.5%). There are forest patches of sufficient size in each range county, but the largest patches were in Cambodia and Myanmar.

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# Captive Animal Husbandry and Research in the Eld's Deer

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## Historical Perspectives

The Burmese brow-antlered deer, or Eld's deer (*Cervus eldi thamin*), is a sub-tropical, endangered species that is sparsely distributed from eastern India to Indochina (3° to 25°N latitude). The North American, captive population consists of about 230 individuals primarily distributed among 3 herds separated by as many as 4,500 km. This species, and these populations, typify the challenges associated with genetically managing captive, wild hoofstock populations. Eld's deer reproduce well in captivity, but their excitable temperament increases the risk of stress and injury during long-distance transport. Eld's deer have a reputation for displaying self-destructive behaviours in captivity, which has decreased their popularity as exhibit animals and discouraged their routine transport among institutions to maximize genetic vigor. There have been two consequences. The carrying capacity for the species has been reached in North American zoos, and Eld's deer have become inbred within individual breeding facilities.

Zoo managers and biologists now face a dilemma. How can genetic diversity be maintained without increasing animal numbers? Germ plasm cryopreservation, combined with artificial insemination (AI), has potential for overcoming these management problems while providing insurance against further losses in genetic diversity as a result of additional inbreeding, disease or other unforeseen catastrophes. The Eld's deer is prime candidate for demonstrating how "assisted reproductive biotechnology" can be integrated with sound animal husbandry to manage and preserve genetic diversity within fragmented captive ungulate populations. However, the prerequisite for successfully applying these biotechnologies is the development of a strong biological database. Such information can only be obtained when animals are sufficiently tractable to permit detailed scientific studies to be conducted under controlled conditions. Our objective is to describe the intensive management approach used at the Smithsonian's National Zoological Park's Conservation and Research Center (CRC), and to provide an overview of the scientific information we have accumulated using this strategy.

## Basic Management Approaches

Several strategies have been used for managing captive, North American populations of Eld's deer. Maintaining animals in a herd within large pastures (2-20 ha) is one option; however, these animals generally revert to "wild", excitable behavior patterns. Under this scheme, even the simplest manipulations necessary for routine health screening or animal translocations can be problematic. Deer must be monitored from all-terrain vehicles and generally observed at long-distances using binoculars. Essentially all procedures require remote anesthetic delivery under field conditions that increases time, expense and the incidence of animal injuries and mortalities.

An alternative, semi-intensive management approach involves maintaining small, intermediate-sized herds (10-20 individuals) within paddocks, holding yards or pastures (0.5-2 ha). In this scenario, Eld's deer can potentially be conditioned to voice commands or to feeding regimens that enable animals to be routinely shifted between yards. Individual hinds or stags can be shifted between groups for breeding purposes or can be mustered into squeeze chutes for routine health-related procedures such as tuberculin skin-testing or blood sampling. This management approach is similar to strategies found in commercial deer farming operations, but is not often used successfully in North American zoological institutions. Although useful for animal propagation, exhibitry or simple behavioural studies, this approach generally is inadequate for conducting detailed biological investigations that require intensive "hands-on"animal manipulations, or repeated collections of biological materials (i.e., blood, urine, feces) or morphometric measurements. Therefore, we have developed an alternative, intensive management strategy involving hand-rearing and conditioning that has permitted performing detailed scientific investigations while minimizing animal stress.

## Housing

Cervid species generally can be housed safely within a managed barn facility in most zoo settings. Because deer typically are excitable and exhibit a strong flight response when threatened, confinement, as opposed to limitless space, can actually simplify the ability to safely manipulate animals. Within the complex, there are two types of barn layouts, each containing unique design characteristics. During winter, the rutting season or during most research studies, males are housed singly indoors. At other times, deer are maintained on pastures in single sex groups to prevent unwanted matings. Hinds can be grouped with minimal inter-animal aggression because dominance hierarchies are established quickly. Males can be maintained together except during the rutting season.

## Husbandry

### Diet

Excellent body condition is maintained by feeding good quality alfalfa hay in combination with alfalfa pellets (12.5% protein) in daily rations consisting of 2-3% of body weight. Within individual stalls, hay is suspended from a hay rack at a height of ~1.5 m, and pellets (1 kg total ration) are placed in a ground-level feed pan. Grouped deer are fed at multiple feeding stations to prevent monopolization of food by dominant individuals. Dietary supplementation with natural browse also is provided, in part, to prevent animal boredom, and trace mineral salt blocks and fresh water are provided ad libitum.

### Lactation and Growth

Milk composition, intake and neonatal growth have been studied in 9 mother-young pairs (C. Wemmer & S. Crissey, unpublished information). Fat, protein and lactose content in the dam's milk remains relatively constant (10.5-11.0%, 6.6-7.7% and 3.6-4.5%, respectively) through the first 21 weeks of lactation. Total milk intake averaged 640 ml/24 h during the first week of life. Intake gradually declined to less than 200 ml/24 h immediately before the fawns were weaned at ~25 weeks of age. There were no sex-related weight differences between fawns through 13 weeks of age. Both male and female fawns weighed 4 to 5 kg at birth, and both weighed ~22 kg by 13 weeks of age. By 27 weeks, average weights for males (36.3 kg) exceeded ($P < 0.05$) those of females (33.1 kg).

### Neonatal Examination and Treatments

Twenty-four to 48 h after birth, a complete physical examination is performed on each Eld's deer fawn. The umbilicus is treated with antiseptic (Neo-Violet®), and 1500 IU tetanus antitoxin and 3 ml clostridium bacterin-toxoid (Clostridium Chauvoei-Septicum-Novyi-Sordellii-Perfringens types C & D bacterin-toxoid) are injected subcutaneously. Supplemental vitamin E (3 ml, 1500 IU) and 2.5 ml prophylactic long-acting antibiotics (penicillin G benzathine and penicillin G procaine, 300,000 IU/ml) also are administered subcutaneously. The eyes are flushed with sterile saline and a broad-spectrum ophthalmic antibiotic ointment (Gentamycin without steroids) is placed within each eye. Blood samples also are obtained by jugular venepuncture and used to generate a complete blood count and serum chemistry profile. A sulfate turbidity test (McEwan et al., 1970; Parkinson et al., 1982) routinely is performed to check for failure of passive transfer of maternal immunoglobulins. The fawn is weighed, ear-tagged for permanent identification, and gross morphometric measurements are obtained (in cm), including: 1) length from tip of nose to the tip of the tail; 2) shoulder height from apex of the scapula to the dorsal hoof margin; 3) chest girth caudal to the shoulder; 4) chest girth at the point of the last rib; 5) tail length; 6) upper neck circumference just below the angle of the mandible; 7) lower neck circumference cranial to the scapulae; 8) circumference of the cranium; and 9) ear length. Once all of these procedures are completed, newborns are reunited with the dam, or if hand-rearing is planned, the fawns are placed in a heated stall bedded with straw.

## Hand-rearing

When fawns are hand-reared, information concerning sire and dam identification, whether the fawn suckled the dam, weight at removal, and general physical condition are recorded on a hand-rearing record. Ingestion of colostrum within the first 24 h after birth is critical for neonatal survival (Robbins et al., 1987). The absorption of immunoglobulins is maximal at 12 h after birth and is completed by 24 h (Robbins et al., 1987). If failure of passive transfer of maternal immunoglobulins is suspected, and less than 24 h has elapsed since birth, frozen conspecific colostrum, or soluble colostrum powder should be provided. The fawn's weight is recorded daily for the first 3 weeks, and daily records of food intake, weight gain and general health include date, time, body weight, amount and composition of the milk formula offered, amount of milk consumed and occurrence of urination or defecation. The condition of the stool is graded on a scale of 1-5 (1 = liquid to 5 = hard). Activity patterns (sleeping, recumbent or standing, and either active or inactive) also are recorded at the time the animal handler enters the fawn's stall for feeding.

Formula consists of Carnation® canned condensed milk mixed with equal parts of previously boiled (and then cooled) water. Milk is placed in a 3 liter bottle containing 4 to 5 drops of a soluble multi-vitamin supplement (Poly-Vi-Sol®), 0.25 gram of table salt and 400 IU Vitamin E per day. During the first week of life, bottles containing 180 ml lukewarm milk (3 to 4% of fawn body weight) mixture are offered 4 times per day (0730, 1130, 1530 and 1930 h). After separation from the dam, the first feeding is delayed several hours to increase the fawn's appetite and improve bottle acceptance. Conversion to a bottle can be difficult, often requiring considerable encouragement such as expressing small amounts of milk from the rubber nipple into the fawn's mouth. This is done cautiously to avoid potential problems associated with tracheal aspiration and secondary pneumonia. While the fawn is nursing, a warm, damp sponge is used to stroke the ano-genital region to stimulate the suckling, urination and defecation reflexes.

Fawns are given daily food rations equivalent to 18 to 20% of their body weight. After the first week of life, the proportion of milk is gradually increased 15-20% per week, until by 3 weeks, only undiluted condensed milk plus vitamins and salt are being fed. If the proportion of milk in the formula or the absolute amount of formula offered are increased too rapidly, fawns experience diarrhea. In such cases, the proportion of milk and the absolute amount of formula is reduced to a level that previously was unassociated with diarrhea. A pediatric electrolyte solution also can be substituted for water in the formula to facilitate rehydration and electrolyte replacement. Although there is individual variation, fawns generally receive 300 to 400 ml per feeding (4 times per day) at 1 month of age, 400 to 500 ml per feeding (3 times per day) at 2 months, and 700 to 800 ml per feeding (2 times per day) at 3 months. Alfalfa pellets and hay are offered to fawns ad libitum beginning at 1 week of age, but solid food consumption generally does not begin until ~3 weeks. At this time, 50 to 60 gm of alfalfa pellets, pre-soaked in warm water, also are combined with milk formula as supplement. Bottles and nipples are sterilized between feedings, and different animal handlers rotate nursing duties to enhance fawn socialization with humans. Fawns are encouraged to lick a trace mineral block and are not prevented from consuming small amounts of dirt that can provide a valuable source of supplemental iron and rumen microflora (Robbins et al., 1987).

## Training for Effective and Safe Management

Conditioning to the barn setting and training of movement routines begins whenever a neonate or new adult is added to the collection. It is important to acclimatize animals to novel stimuli, thereby minimizing flight responses. Initially, an unfamiliar keeper spent 30 to 60 min per day positioned immediately outside of each animal's indoor stall (separated by chain-link fencing). Confinement within high-walled stalls actually minimized the chance of animals exhibiting a flight response and precluded serious animal injury. A soothing voice combined with vegetable treats (carrots, apples) were used as positive reinforcement. Acclimation gradually occurred over 4 to 6 weeks. Whenever an individual animal became overly excited, the keeper simply moved away. Eventually, each deer began to exhibit a reduced flight distance, and within 4 to 6 weeks, the keeper was able to work within the stall while the animal had the option of remaining within the stall or moving to their outside run. Once acclimated to the primary caretaker, the animal was exposed regularly to other animal keepers, volunteers, researchers and maintenance personnel. Deer also

were increasingly exposed to other novel stimuli including vehicles, horse trailers, lawn mowers, wheelbarrows and associated noises. Finally, radio music also was played at a medium volume 24 h per day to further acclimate the deer to background noises. In summary, our overall management strategy is one that minimizes self-destructive behaviors by conditioning animals to a diversity of stimuli. Consistency of demeanor and verbal commands among barn workers is critical for effective control of deer of all ages.

## Preventive Medicine

Routine herd health screening includes biannual assessment of fecal samples for endoparasites and appropriate treatment with antihelminthics. Pre- and post-shipment quarantine procedures include intradermal tuberculin skin-testing using avian and mammalian tuberculin (PPD) injected at 2 sites on shaved regions of the cervical neck, and mammalian old type (OT) is administered in the caudal tail fold. Neck inoculation sites are visually inspected daily, and the skin thickness overlying the inoculation sites is measured using calipers 72 h post-inoculation; the inoculation site within the caudal tail fold is palpated. All animals are vaccinated annually using clostridium bacterin-toxoid (Clostridium Chauvoei-Septicum-Novyi-Sordellii-Perfringens types C & D bacterin-toxoid; 2.5 ml, s.c), tetanus toxoid (1 ml, i.m.), rabies (Imrab®, 2 ml, i.m.) and dewormed prophylactically with 1% Ivermectin (Ivomec®, 2.0 ml, s.c.). Eld's deer generally are vaccinated while physically restrained, however, sedation also can be used for vaccine administration, tuberculin skin-testing, hoof trimming or blood sampling using only xylazine hydrochloride (Rompun®, 0.3 to 0.5 mg/kg, i.m.). A surgical plane of anesthesia is achieved in tame Eld's deer using combined ketamine hydrochloride (Ketaset®, 2 to 3 mg/kg body weight ) and xylazine hydrochloride (0.3 to 0.4 mg/kg body weight) administered i.m. This drug combination has been used successfully for minor surgical procedures, placement of chronic indwelling catheters, electroejaculation and laparoscopic intrauterine insemination (Monfort et al., 1993a-c).

## Reproduction

Environmental factors act as proximate cues modulating onset and cessation of reproductive activity in most seasonally breeding mammals, like the Eld's deer. Although subjected to an extended rainy season (mid-May to mid-October), Eld's deer are not exposed to wide seasonal oscillations in photoperiod in their native sub-tropical habitats (Wemmer & Grodinsky, 1988). There is a general consensus that cervid species living between 20° N and 20° S latitude experience little seasonality in their native habitats and remain reproductively aseasonal even when translocated to temperate zones (Lincoln, 1985; Loudon & Brinklow, 1992). However, Eld's deer are unique, demonstrating a seasonal reproductive rhythm in native sub-tropical habitats and failing to exhibit a latitudinal shift in the timing or duration of their annual reproductive rhythms, even when translocated to temperate latitudes.

## Female Reproduction

Females can conceive as yearlings (mean age, 469 days) and the interbirth interval is ~380 days regardless of whether fawns are produced and reared in the previous year (Wemmer & Grodinsky, 1988). Monitoring urinary oestrogen conjugates and/or pregnanediol-3□-glucuronide (PdG) has confirmed that hinds are seasonally polyoestrous, spontaneous ovulators with onset of estrus occurring in late winter or early spring (January to March) followed by a seasonal and/or lactational anoestrous beginning in autumn (August to October) (Monfort et al., 1990). Cyclic fluctuations in PdG correspond to progesterone concentrations measured in peripheral blood circulation (Monfort et al., 1990). The average duration of the estrous cycle is 18.5 days (based on urinary PdG profiles) and if conception does not occur, hinds may cycle for up to 8 months (Fig. 2) (Monfort et al., 1990). Some females can exhibit prolonged oestrous cycles, as long as 62 days, presumably reflecting abnormally prolonged corpus luteum progesterone secretion (Monfort et al., 1990). Hinds exhibit behavioral estrus consisting of scent marking the buck, animal handlers or inanimate objects with preorbital scent glands. Oestrus usually lasts 12 to 24 h, and hinds may

exhibit increased activity patterns and a clear-to-milky vaginal discharge (Wemmer & Grodinsky, 1988). Copulation is characterized by an ejaculatory thrust in which the male's rear feet leave the ground (Wemmer & Grodinsky, 1988). The average (± SEM) gestation lasts ~8 months (33.5 ± 0.4 weeks), and 80 to 90% of births in captivity occur between September and November in France (48° N latitude, Prescott, 1987), the United States (38° N latitude, Wemmer & Grodinsky, 1988) and India (25° N latitude, Desai & Malhotra, 1970). Nearly of all captive births are singleton (97.5%), and sex ratios do not deviate significantly from 50:50 (Prescott, 1987; Wemmer & Grodinsky, 1988). Pregnancy can be diagnosed based on markedly elevated urinary PdG excretion by 12 weeks of gestation and urinary oestrogen conjugates can be used to estimate the expected date of parturition during the final month of gestation (Monfort et al., 1990).

## Male reproduction

Stags are fertile at 1 year of age and exhibit sexual and aggressive rutting behaviors during late winter and early spring in Southeast Asia (Salter & Sayer, 1986) and the United States (Wemmer & Grodinsky, 1988; Monfort et al., 1993a). Unlike most temperate, 'short-day' breeding cervids, maximal testicular growth, antler development and behavioral aggression occur in Eld's deer during the winter and spring, as day length increases (Monfort et al., 1993a,b). Serum luteinizing hormone (LH, from the pituitary) concentrations peaked in autumn (October), 3 months before follicle-stimulating hormone (FSH, from the pituitary) and testosterone (from the testis) peaked in early winter (January) (Monfort et al., 1993a). Marked circannual variations in circulating prolactin (from the pituitary) also suggested that Eld's deer may use photoperiodic cues to modulate seasonal fertility. Although antlerogenesis corresponded to circannual fluctuations in LH, FSH and testosterone, the hormonal rhythms were shifted 6 months out-of-phase relative to most temperate deer species (Suttie et al., 1984). Antler length, body weight and chest girth were maximal during pre-rut (December to January). Maximal scrotal circumference and combined testes volume were observed in mid-winter (February), whereas peak neck girth and behavioural aggression occurred 1 to 3 months later (March to May). This seasonal pattern in morphometric measures presumably reflected endogenous metabolic processes that occur independent of gonadal steroid secretion and ad libitum food intake (see review, Loudon & Brinklow, 1992). Typical of all cervids, Eld's deer stags exhibit a notable increase in voluntary food intake during the autumn and winter that presumably maximizes their body condition before the spring rut.

Semen samples also have been collected quarterly by electroejaculating anaesthetized males using a standardized protocol (Monfort et al., 1993a). Motile sperm were produced in all seasons, however, the number of motile sperm/ejaculate ($213\pm131 \times 10^6$/ml) was lowest during the autumn and peaked ($P < 0.05$) in the winter (winter, 1603±370; spring, 800±302; summer, 760 ± 246 x $10^6$ per ml). The percentage of structurally-normal spermatozoa per ejaculate was more than 4-fold higher ($P < 0.05$) in the winter and spring (85.7% and 91.6%, respectively) compared to the autumn (18.2%). Eld's deer semen is routinely cryopreserved in BF5F cryodiluent containing 4% glycerol over dry-ice. Upon thawing, greater than 70% of spermatozoa are motile as well as, maintain intact acrosomal membranes. Recent studies have demonstrated a dependence on increased calcium in the culture medium to complete in vitro capacitation (Harnal et al., 2000).

## Artificial Insemination

Captive propagation is important for preserving rare taxa when *in situ* conservation efforts are incomplete, fragmented or likely to fail (Soule, 1991). When *ex situ* tactics are used to manage small populations, a primary goal is to maintain adequate genetic variability and to avoid inbreeding depression. Artificial insemination, *in vitro* fertilization and/or embryo transfer, can be used to enhance captive breeding of rare species; however, these "assisted techniques" have not yet proven to be consistently useful for producing offspring from any endangered mammalian species (Wildt, 1992; Wildt et al., 1993). For wild taxa, AI could be particularly valuable for (i) ensuring reproduction between genetically valuable but behaviourally incompatible pairs, (ii) eliminating the risks of animal transport and (iii) providing an avenue for infusing genes between wild stocks and captive populations, many of which are genetically stagnant (Wildt, 1989).

Multiple pregnancies were produced in Eld's deer by artificial insemination using frozen-thawed spermatozoa (Monfort *et al.,* 1993c). Intravaginal progesterone-releasing devices (CIDR-type G, 9% progesterone) were used to synchronize estrus and ovulation in adult hinds. CIDR devices were removed after 14 d and each hind was anaesthetized 70 h later for transabdominal, intrauterine insemination under laparoscopic observation. We also can successfully synchronize oestrous cycles among females and monitor the efficacy of such efforts using noninvasive urinary hormone monitoring techniques (Monfort *et al.,* 1993c)

Our success provides an excellent example of how readily an assisted reproduction technique can be applied to an endangered species if the procedure already is working well in a taxonomically-related "model". Although some refinements may be necessary because of unique species attributes, we anticipate that this approach may have broad applications to other rare cervid species. It is important to emphasize that this study was preceded by a strong preemptive effort to establish an integrative database for both female and male Eld's deer before AI was attempted. Certainly detailing basic life history variables, behavior, seasonality, estrous cyclicity, gametogenesis and semen freezing (Wemmer & Grodinsky, 1988; Monfort et al., 1990; 1993a-d) helped ensure a higher rate of success. For example, detailed information on seasonality ensured that hinds were not inseminated too early or late in the breeding season, a factor that severely decreases AI success in fallow deer (Asher, 1986). Similarly, seasonal evaluations of males indicated the time of year most likely resulting in peak semen quality and sperm freezability (Monfort *et al.,* 1993a).

Our results clearly established the utility of urinary hormone monitoring as an important adjunct to this assisted reproduction strategy. Repeated anaesthesia or restraint for blood collection and ultrasonography usually is impractical in deer living under zoo conditions. In fact, for many species, urinary and/or fecal steroid monitoring are the only alternatives for assessing longitudinal endocrine rhythms. As such, these approaches often provide considerable promise for improving success rates of artificial breeding in other stress-susceptible species. Monitoring urinary hormonal metabolites permitted tracking the efficacy of estrous synchronization and diagnosing pregnancy by Week 12 of gestation.

This provides a clear example of how advanced reproductive biotechniques can be combined with sound management and husbandry to produce genetically valuable offspring. Offspring now have been produced from 32 mammalian species using AI with frozen-thawed spermatozoa (see review, Wildt et al., 1993). Seven of these species have been cervids (white-tailed deer, fallow deer, red deer, wapiti, reindeer, axis deer and Eld's deer). Thus, the technology now exists to implement genetic management plans for maximizing the genetic diversity of small captive populations of rare cervid species.

Responsible zoo management must focus on efforts to maintain or enhance genetic diversity within captive populations. Unfortunately, traditional captive breeding/management of wild ungulates often have failed to integrate even regional zoological collections into a single population for genetic and demographic management. For stress-susceptible ungulates, an approach that combines traditional husbandry and management with advanced reproductive biotechniques may be the only realistic hope to maintain genetic diversity without increasing animal numbers to unmanageable levels. Although performed on a limited scale, our studies represents one of the first examples in which prospective sire and dam selection, germ plasm banking, AI and urinary hormone monitoring have been used for a specific conservation goal in an endangered species. These results were made possible by an intensive management scheme that permitted detailed physiological studies to be conducted under controlled conditions.

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# Designing training programs for restoring wild Eld's deer populations.

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Eld's deer (*Cervus eldi*) is a critically endangered species with a global population estimated at <2,500 (Wemmer 1998). In Myanmar, the stronghold of the species, the remaining 1,000 animals are essentially restricted to one protected area (McShea and Aung 2001). In China, the Hainan Island population numbers around 800 but severe inbreeding depression may have reduced the evolutionary viability of the population (Balakrishnan et al. 2003). Subpopulations in India and Indochina (Cambodia and Lao PDR) number in the hundreds (Johnson et al this volume; Weiler this volume; Sovanna et al. this volume). Eld's deer is now extinct in the wild in Thailand (Wemmer 1998).

If the species is to survive in the wild, serious efforts need to begin now in all range states to address the key threats to survival, hunting and habitat degradation. For example, where it occurs, Eld's deer is restricted to mixed deciduous forests dominated by dipterocarp trees (McShea et al. 1999). It is predictably present where a large enough core area of this kind of forest exists. Throughout its range Eld's deer habitats have been fragmented and lost so the species now persists in scattered and reduced populations. While the creation of parks may lead to the arrest of habitat clearance or result in increases in habitat area (Bruner et al. 2001), restoring links between fragments is usually prohibitively expensive or impossible, so the best option is close management of animals in the fragmented populations.

Eld's deer habitats tend to be highly accessible and being a large conspicuous animal, it is a target for poachers. Despite national regulations that prohibit harvest of Eld's deer, meat is locally consumed and hides and horns are illegally traded as trophies. In some parts of its range this trade may take place across country borders in violation of CITES regulations. For example, Eld's deer horns are regularly seen in markets on the Thai-Myanmar (Tachilek-Mae Sai) and Thai-Cambodia (Poipet-Aranyaprathet) borders. In Indochina particularly where populations are already very small, every deer lost to hunting makes the harvest increasingly unsustainable.

Wildlife habitat protection programs in South and Southeast Asia traditionally focussed on protected areas, with ranger patrols conducted in areas close to guard posts and other management facilities. But in 89% of its range, Eld's deer occurs outside of formally protected areas (McShea pers. comm.). In places where Eld's deer are present, the limits of their populations need defining, and divided into patrol zones. Staff need to be identified to assume roles in protection, whether they be park rangers, police, military or community rangers. To be maximally effective, enforcement efforts should be extended to all parts of the deer range, and made systematic by mobilizing protection staff to the field on regular schedules. Patrols should give special attention to sensitive habitats e.g. those subject to fire, and important feeding areas e.g. waterholes, grasslands.

Eld's deer love rice and agricultural products (McShea and Aung 2001) and reach their highest densities when some people are present in an area (McShea et al. 1999). Because deer and people live close together, and damage to crops can be mitigated by simple means, protection efforts must be done hand-in-hand with conservation awareness training. If deer are worth more

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alive than dead to local people, they have a chance of survival. Programs dedicated to exploring options for incorporating deer conservation in local economies, such as nature-based tourism will be needed. Eld's deer form part of local folklore and religion and, in Myanmar for example, they are protected around temples.

People who can be mobilized to help with deer conservation activities need training and motivation to provide them with the basic skills and interest needed to conduct enforcement and education activities (Boonratana 2002). In many places jurisdiction over areas with Eld's deer are held by multiple agencies so that interagency cooperation will be needed. Ranger training programs are underway in several parts of current and former range of Eld's deer in Asia. These involve technical inputs from conservation agencies and government enforcement agencies such as the Thailand and Cambodian police forces and US Fish and Wildlife Service. Lessons learnt from wildlife protection programs such as those developed at Khao Yai, Thailand, and Bokor and Mondulkiri, Cambodia, which focus on other endangered species and habitats, might be applied in Eld's deer conservation areas.

Aside from this, Eld's deer populations need to be verified in previously inaccessible areas such as the tri-border forests at the Lao PDR-Cambodia-Thailand interface. In areas known to support the species, standardized monitoring systems (Clements 2003; Lynam et al. 2003) need to be established to detect trends in deer populations, and thereby assess and compare the effectiveness of field management actions across sites (Salafsky and Margoulis 1999).

Standard sets of skills for protection, population survey and monitoring and environmental interpretation have been developed for Southeast Asia staff (Appleton et al. 2003), and along with training modules that address site-specific conservation issues, these will provide the foundations for conservation training programs.

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