

Distribution, status and conservation of Hainan Eld's deer (*Cervus eldi hainanus*) in China

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Abstract. Hainan Eld's deer (*Cervus eldi hainanus*) was once widely distributed in Hainan Island of China. With the rapid increase of human population and the fast expansion of agriculture in the recent 350 years of Chinese history, the habitat of the deer has been greatly reduced. Habitat loss and hunting have driven the deer to the verge of extinction. The last group of 26 deer was protected at Datian Nature Reserve (DNR) which was founded in 1976. The habitat at present remains only 13.14 km² at DNR, just 4.38–6.57% of that of the 1950's. The deer population increased to over 1,000 individuals in 2003 under the protection of enclosure building along the boundary of DNR. Moreover, an off-site conservation approach for the deer has been launched since 1990. A total of 83 deer from DNR had been accumulatively introduced to establish off-site populations by the end of 2000. The off-site conserved populations had reached 263 by the end of 2002, of which 246 animals were born in captivity or semi-captivity. A new off-site population in the natural environment was founded by introducing 65 animals from DNR during July to December 2003. The deer population still however faces challenges of habitat limitation, decrease of genetic diversity, inbreeding and poaching. Conservation approaches needed to practice immediately have been proposed in this paper.

Key words: *Cervus eldi hainanus*, conservation, distribution, habitat, Hainan Eld's deer, population

Introduction

Eld's deer, or brow-antlered deer (*Cervus eldi*), is limited to the tropical and subtropical region (93°06'–110°35'E, 11°10'–25°41'N) of Asia, populations occur in India, Myanmar (formerly Burma), Thailand, Cambodia, Laos, Vietnam and Hainan Island of China. The species is listed as vulnerable by the World Conservation Union (IUCN) and included in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Three subspecies *C. e. eldi*, *C. e. thamin*, *C. e. siamensis* are commonly distinguished by zoologists (Gee 1960, 1961); but, Chinese zoologists generally consider the population in Hainan Island of China as a unique subspecies *C. e. hainanus* (Xu et al. 1983). The latest study did not necessarily support the designation of Hainan Island population as a distinct subspecies and regarded it as a population of subspecies *siamensis*, but it was characterized by a unique and relatively divergent mitochondrial DNA haplotype (Balakrishnan et al. 2003).

Hainan Eld's deer is a rare and endangered animal in China and listed as a rank I key species of national protection under the Wild Animal Protection Law. Its population was once on the verge of extinction, and only two isolated groups with 46 deer in total were recorded in the field in 1976 when Datian Nature Reserve (DNR; 108°45'–108°50' E, 19°04'–19°08' N) in Dongfang County and Bangxi Nature Reserve (BNR; 109°04'–109°07' E, 19°22'–19°25' N) in Baisha County were established for its protection (Song 1993a). After the deer at BNR were

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finally wiped out by poachers in 1981, DNR and its vicinity became a unique site to harbor the last group of Hainan Eld's deer (Y u et al. 1984).

Research on population dynamics, habitat relationship, food habit, breeding behaviours and conservation has been conducted at DNR since the middle 1980's (Y u a n et al. 1988, 1991, 1993, 2001, S o n g 1990, 1993a, 1993b, 1996, S o n g & L i 1990, 1991, 1992a, 1992b, 1994, 1995, Z e n g et al. 2001, P a n g et al. 2003, S o n g & Z e n g 2003). Results from those studies made considerable contribution to management and conservation of the deer. Population size at DNR has gradually recovered; moreover, deer have been transferred to found off-site populations at several sites in China since 1990. In order to assess the present status of Hainan Eld's deer, we conducted a nation wide data survey for both on-site and off-site populations. In this paper, "off-site population" means one outside DNR and developed from original founders from DNR. In addition, historical information about the deer is presented here.

Methods

Information relating to the historical and present distribution and status of Hainan Eld's deer was obtained from published literature (X u & L i u 1974, W a n g 1979, Y u et al. 1984, L i u 1987), and by interviewing local people who are familiar with this species in its original distribution area from 2002 to 2003. Some data on the population trend of Eld's deer between 1976 and 2000 were extracted from published literature (Y u a n et al. 1993, 2001, L i 2000), but data from 1986 to 1989 were collected by Y.-L. S o n g at DNR (S o n g & L i 1992a). Information on off-site populations was obtained by questionnaire sheets or by site visits by the authors from 2002 to 2003. We classified the living condition of the off-site populations into three classes according to their food resources: (1) captivity (Deer were in an enclosure, and their food was wholly provided by keepers), (2) semi-captivity (Deer were in an enclosure where they could feed on their natural foods or pasture, but supplemented by small quantities of food, such as sweet potatoes), and (3) natural state (Deer ranged freely and fed entirely on their natural food).

The annual growth rate, r , was calculated as $r = [(N_t/N_0)^{1/t}] * 100\%$, where N_0 = initial population size; N_t = the population size at time t (C a u g h l e y 1977).

Results and Discussion

Distribution and habitat trend

Hainan Eld's deer is only found in Hainan Island, China. It inhabits the tropical plains and hills at less than 200 m in altitude, predominately scrubland and grassland together with sparse trees (X u & L i u 1974, Y u et al. 1984, L i u 1987, S o n g & L i 1994, Y u a n et al. 2001).

Eld's deer was once widely distributed in Hainan (Fig. 1). Historical records by the Annals of Hainan Island (formerly Qiongtai or Qiongzhou) include Chengmai (1672, 1908), Qiongsan (1687, 1811), Lehui (namely Qionghai, 1687, 1822), Dingan (1690, 1878), Yazhou (namely Yaxian or Sanya, 1694), Lingshui (1792), Wanzhou (namely Wanning, 1828, 1891) and Lingao (1891), as well as Qiongzhou according to the local people (X u & L i u 1974, Y u et al. 1984, Y u a n et al. 2001). The species has disappeared from these sites since the 1950's.

In the early 1950's, the species was found in only 20 districts in six counties (Tunchang, Danxian, Baisha, Changjiang, Dongfang and Ledong), and its distribution was estimated at

200–300 km² (Y u et al. 1984). With the rapid increase of human population and the fast expansion of agriculture, the habitat was continually reduced. In the late 1960's and early 1970's, the distribution of Eld's deer rapidly dwindled to only six districts in four counties (Baisha, Changjiang, Dongfang and Ledong) according to the result of a fauna survey for birds and mammals at 30 locations over Hainan (X u & L i u 1974, X u et al. 1983, Y u et al. 1984). Unfortunately, the deer were extinct at Changjiang and Ledong in 1976, and the distribution was reduced to no more than 40 km², only 13.33–20% of that of the 1950's (S o n g 1993a). The deer population was threatened by illegal hunting and habitat loss caused by agricultural encroachment.

Two nature reserves, namely DNR and BNR, 25.33 and 3.70 km² respectively, were established as refuges for the species in 1976. The two reserves however did not protect the deer and their habitat effectively. Poaching had wiped out all of the deer at BNR by the end of 1981. DNR and its vicinity, 25–30 km² in size, had become the unique site harboring the wild Eld's deer population of China (Y u et al. 1984). In 1983, DNR was as large as 21.33 km², but this shrank to 13.67 km² in 1985 and 13.14 km² in 1990 because of agricultural encroachment as well as land usufruct problems with local people (S o n g 1993a, Y u a n et al. 1993). Up to now, the wild population is still restricted to this small patch of only 4.38–6.57% of its distribution in the 1950's.

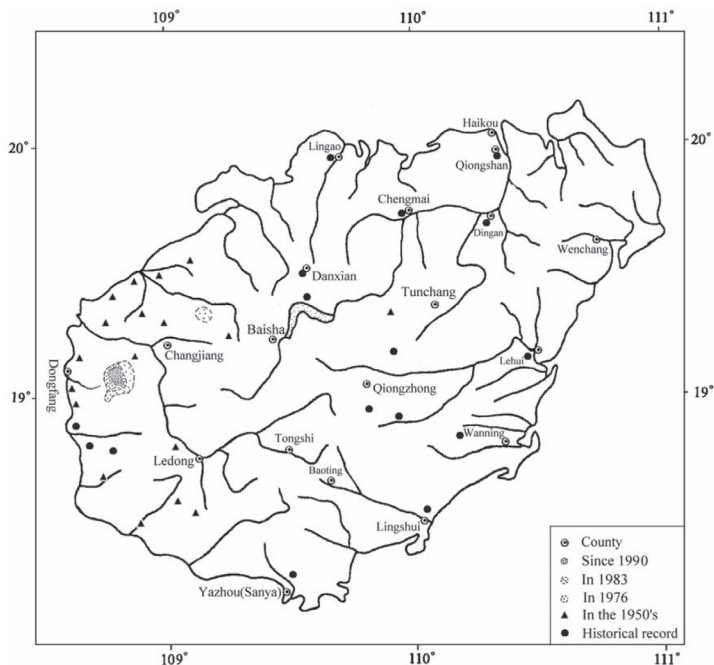


Fig. 1. Historical record and present distribution of Hainan Eld's deer.

Population status and conservation

Wild population

No efforts were made to estimate the Eld's deer population before the 1960's; the estimate of "at least 500" in the early 1950's was made by zoologists based on the knowledge of habitat quality and deer

density at Datian district, Dongfang County, from a survey in 1964–1973 (X u & L i u 1974, Y u et al. 1984). During that survey 100 deer were estimated in six districts in four counties (Baisha, Changjiang, Dongfang and Ledong). By 1976, the deer were found only at two isolated sites: 20 individuals at Bangxi district in Baisha County, and 26 at Datian district in Dongfang County.

The deer at DNR increased to 75 individuals in 1983. The extinction of the deer at BNR in 1981 left DNR the last hope. Fences of 2.8 m in height were constructed at DNR to protect the deer from poaching. Due to financial budget restriction, at first only 1 km² in the core area of DNR was enclosed in 1984. Four years later the enclosure was enlarged to 3 km². Finally, it was enlarged to cover the entire region of DNR in 1995.

The enclosure management approach reduced the threat of poaching, and the deer population at DNR increased to 375 in 1993, with an average annual growth rate of 17.46% since 1983. Unfortunately, the population declined to 342 in 1994 due to food shortage caused by a serious drought in that year and also by the extremely high density of 87 deer per square kilometer within an enclosure of only 3 km². Since the entire region at DNR was enclosed, the deer population has increased again with an annual growth rate of 16.70% on average between 1994 and 2000 (Fig. 2). By the year 2000, the population size had reached 864 individuals (Y u a n et al. 2001). Over 1000 deer were estimated in the field at DNR in 2003.

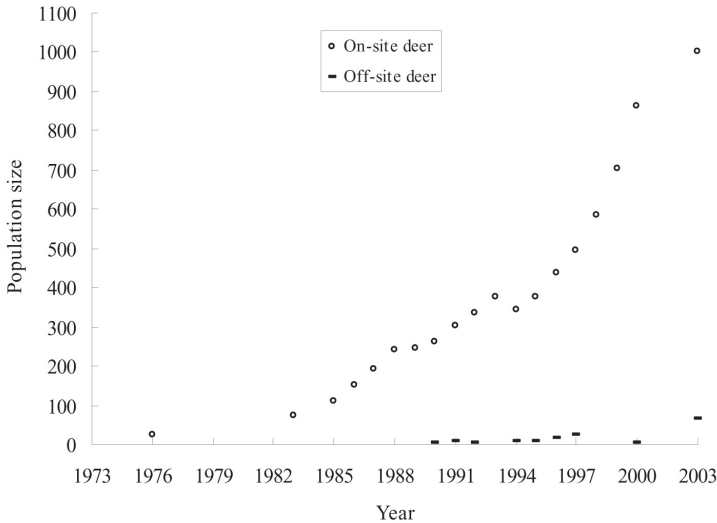


Fig. 2. Population dynamics of Hainan Eld's deer at the Datian Nature Reserve (DNR).

Off-site conserved population

DNR has played a unique role in Hainan Eld's deer conservation and has been a great success. Its limited size, however, did not provide adequate space (S o n g & L i 1995), and population viability analysis showed that environmental variation could drive the deer to extinction (S o n g 1996). In addition, from the view of species conservation it is not sensible to keep the entire population at one site. In order to reduce the risk, an effort has been made to establish off-site populations since 1990.

A total of 83 young deer (2 yrs) from DNR was accumulatively introduced to seven sites as founders of the off-site population from 1990 to 2000 (Figs 2, 3, Table 1). Two animals

were transferred to the eighth site, Guangzhou Zoo, from Jinniuling Park in 2000. Among these sites, six are located in Hainan, two on the mainland of China. Deer at Fengmu Deer Farm, Jinniuling Park and Guangzhou Zoo are in captivity, but at other sites deer are kept in semi-captivity. Off-site conservation for Hainan Eld's deer has been a great success (Table 1). In the third year after the deer were introduced, the breeding rates of the female founders were $63.2 \pm 7.5\%$ ($n=8$) at these off-sites. The deer reintroduced into BNR had increased to 115 individuals from 18 founders up to 2002; the total off-site populations had reached 263 individuals by the end of 2002, 246 of which were born at the off-sites in captive or semi-captive conditions. In order to better protect these off-site populations, our research group is studying the difference of their genetic diversity and the indications of inbreeding in these deer.

A conservation program of building a new wild population for Hainan Eld's deer has been launched recently. Twenty deer (7 males with 2–5 yrs and 13 females with 3–6 yrs) from DNR were released to field of 12,215 hectares with an elevation range of 110–933 m at Mihouling, Dongfang County on 3 July 2003 (Fig. 3, Table 1). Another thirty deer (14 males with 2–3 yrs and 16 females with 2–3 yrs) and fifteen deer (9 males with 2–5 yrs and 6 females with 2–4 yrs) from DNR were transferred to this region on 11 October 2003 and 20 December 2003 respectively. A reserve station, namely Mihouling Reserve Station (MRS; $109^{\circ}02'45''$ E, $18^{\circ}57'56''$ N), has been established to manage those trans-located and free-ranging deer to ensure the species' conservation. Meanwhile, the technique of radio-tracking is being used by our research group to study the home range and activity status of the population in its natural environment, to study home range formation, habitat use and space requirements of the deer in their new habitat; our aims are to clarify the behavioral reactions and strategies of ecological adaptation of the deer after the change of habitat. It is hearkening that there is no indication

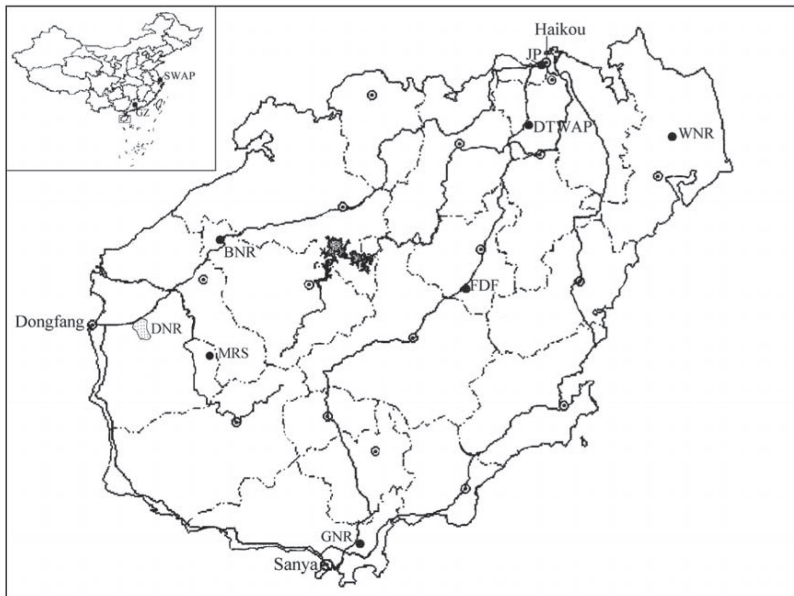


Fig. 3. Locations of off-site populations of Hainan Eld's deer. BNR – Bangxi Nature Reserve, DNR – Datian Nature Reserve, DTWAP – Dongshanhu Tropical Wild Animal Park, FDF – Fengmu Deer Farm, GNR – Ganshailing Nature Reserve, GZ – Guangzhou Zoo, JP – Jinniuling Park, SWAP – Shanghai Wild Animal Park, WNR – Wenchang Nature Reserve, MRS – Mihouling Reserve Station.

of disease in these animals so far. Eight fawns had been born and had survived in the MSR by the end of 2003.

Table 1. Locations and size of off-site populations of Hainan Eld's deer.

Sites*	Locations	Years introduced	Numbers introduced	Source*	Conditions	Deer numbers in 2002
BNR	Baisha, Hainan	1990–1992	18	DNR	Semi-captive	115
FDf	Tunchang, Hainan	1994	10	DNR	Captive	23
SWAP	Shanghai	1995	10	DNR	Semi-captive	18
DTWAP	Qionghshan, Hainan	1996	15	DNR	Semi-captive	4#
GNR	Sanya, Hainan	1997	20	DNR	Semi-captive	41
JP	Haikou, Hainan	1997	4	DNR	Captive	8
WNR	Wenchang, Hainan	1999	16#	DTWAP	Semi-captive	50
		2000	6	DNR		
GZ	Guangzhou, Guangdong	2000	2@	JP	Captive	4
MRS	Dongfang, Hainan	2003	65	DNR	Natural state	/

* Notes of BNR, DNR, DTWAP, FDF, GNR, GZ, JP, SWAP, WNR and MRS are the same as Fig. 3

16 deer were transferred to WNR from DTWAP in 1999

@ Be transferred from JP

Reasons of habitat loss and population decline

Conflict between deer with people was clearly the reason for the decline in their distribution. The typical habitat of Eld's deer in Hainan Island is scrubland and dry grassland together with sparse trees in hills below 200 m in altitude. It is also a suitable environment for agriculture. The decrease of deer from eastern part of the Island before 1950 coincided with the rapid immigration of people from the mainland during the Qing Dynasty (1644–1911). The human population of the Island in 1952 (2.59 million) was nearly as twice that in 1820 (1.38 million), and more than 7 times higher than that in 1391, in the Ming Dynasty (0.375 million; Cao 2000, Lu & Teng 2000, Hou 2001). Most of immigrants settled in the eastern part of the Island and practised agriculture. As a result, almost no habitat remained in the northeast of the Island by the year of 1700 (Xu 1988). It is not surprising that agricultural encroachment drove the deer from its habitat in the eastern part (Fig. 1).

The further loss of habitat in the west was associated with immigration from 1950 to 1982, when 0.83 million people arrived and settled in the Island (Xu 1988). The rapid increase in human density must have resulted in increased residential and commercial activity, and an ever deteriorating environment. More than 50% of the remaining of the deer habitat in the west and middle-west were converted to rubber plantation, sugarcane, sesame, and other economical valuable plants (Yu et al. 1984). Habitat loss caused serious reduction of range and population size for the deer during the recent 350 years of Chinese history, and in the last 50 years.

Hunting is another important reason for local extinctions of Eld's deer in Hainan. Antlers, blood, bones, penises, tails, as well as other parts of deer are used widely in Chinese traditional medicine. Products made from Eld's deer parts paid 10 times the price compared to those from any other deer species. As a result, the hunting pressure on Eld's deer has been extremely great across the region. For instance, 19 deer were killed during one hunting case in 1972 (Wang 1979). Poaching was even detected in nature reserves. The killings at BNR between 1976 and

1981 were the symptom of the heavy hunting pressure. The number of killed deer was summarized from limited information in Table 2. The main reason for building the enclosure at DNR was to protect deer from poaching. Poaching has, however, still occurred within the enclosure; a total of 42 deer were illegally killed from 1995 to 2002 (Table 2). The purchase of Eld's deer parts by the local people will be a threat to the sole wild deer population.

Table 2. Summary of deer numbers killed by local people.

Year	Location (District/County)	Numbers of Killing
1960–1970	Qianjia /Ledong; Bangxi/Baisha	> 100*
1972	Xinjie/Dongfang	19@
1976–1981	Banxi Nature Reserve	> 20*
1985–1987	DNR	7#
1988	DNR	2#
1989	DNR	2#
1990	DNR	6
1991	DNR	13
1992	DNR	5
1993	DNR	7
1994	DNR	9
1995	DNR	6
1996	DNR	7
1997	DNR	6
1998	DNR	4
1999	DNR	5
2000	DNR	6
2001	DNR	5
2002	DNR	3

The data were from Datian Nature Reserve (DNR) except the marks.

* Yu et al. (1984); @ Wang (1979); # Song (1993a).

Further conservation approaches

The size of the deer population at DNR has increased to nearly 40 times that in 1976 by protection over many years, but we are still not able to say with confidence that the deer will be safe from extinction. A small population size would accelerate the loss of genetic variation due to inbreeding, which could decrease the fitness of individuals and might even result in population extinction (Shaffer 1981). Recent study showed no genetic variation in 550bp of the mtDNA control region in 55 Hainan Eld's deer (Pang et al. 2003). Reduction of genetic diversity resulting from a population bottleneck contributes a potential threat. In addition, the population viability analysis showed that the environment variation caused by limitation of habitat availability had an even larger impact than mortality on the deer fate (Song 1996). For effective protection, the following three conservation approaches are needed immediately: first, to purchase more land adjacent to DNR for the wild deer population; second, to manage all the on-site and off-site deer populations as a meta-population to avoid a further genetic decline by genetic drift effect; and third, to stop poaching by enforcing protection laws in the deer distribution region.

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