DESCRIPTION OF THE GIANT MUNTJAC (*MEGAMUNTIACUS VUQUANGENSIS*) IN LAOS

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The giant muntjac (*Megamuntiacus vuquangensis*) was discovered in 1994 in evergreen forests of the Annamite Mountains that border Laos (Lao People's Democratic Republic) and Vietnam. We describe its known distribution in Laos and provide the first detailed description of the species. Comparison of its skull and antlers with those of sympatric red muntjacs (*Muntiacus muntjak*) and other muntjacs support its designation as a distinct species. Morphological and genomic DNA data suggest that the giant muntjac belongs with other muntjacs in the genus *Muntiacus* and not in a genus of its own.

Key words: giant muntjac, Laos, morphology, systematics, *Muntiacus, Megamuntiacus vuquangensis*

Muntjacs, or barking deer, of the genus *Muntiacus* are relatively small and solitary cervids that inhabit thickets and forests in southern Asia from India east to China and Indonesia. Seven species of *Muntiacus* generally are recognized; all occur on the Asian mainland except the yellow muntjac (*M. atherodes*) from Borneo (Corbet and Hill, 1992). Of these, the red or Indian muntjac (*M. muntjak*) has the widest geographic distribution, which includes Laos.

Survey teams from the Wildlife Conservation Society saw unusually large antlers of muntjacs in villages of the Annamite Mountains of east-central Laos near the Vietnam border in January 1994, and a captive male with the same distinctive antlers in a local menagerie in March 1994. The antlers and the large size of the captive animal suggested that it was a new species (Evans, 1995; Evans and Timmins, 1994). During the same period, similar antlers and partial skulls were observed around the Vu Quang Reserve of Vietnam (Scott, 1994), and on the basis of these, Tuoc et al. (1994) published a preliminary description of a new species, the giant muntjac (*Megamuntiacus vuquangensis*). They justified the designation of a new genus on the basis of size and differences in mitochondrial DNA among the giant muntjac, the red muntjac, and the Chinese or Reeves' muntjac (*Muntiacus reevesi*).

One of us (GBS) took part in the survey in Laos in January 1994 and returned in December 1994 and January 1995. Because published information on the giant muntjac provided little detail (Tuoc et al., 1994), we present the first description of a male and female giant muntjac and compare measurements of their antlers and skulls with the sympatric red muntjac (*M. m. annamensis*).

STUDY AREA AND METHODS

We conducted our survey along the border between Laos and Vietnam, which traces the crest of the Annamite Mountains (Fig. 1), a long and narrow range with many ridges >1,000 m in elevation and some peaks >2,000 m. The range consisted primarily of igneous rock that formed rugged, but not precipitous, terrain. Mountains in some areas extended westward in a series of hills and plateaus that were separated from the main massif by valleys and stretches of low-lying terrain. The principal vegetation type in undisturbed areas was a forest of broadleafed evergreens and an understory of bamboo, palms, and tree saplings. Below an elevation of ca. 750

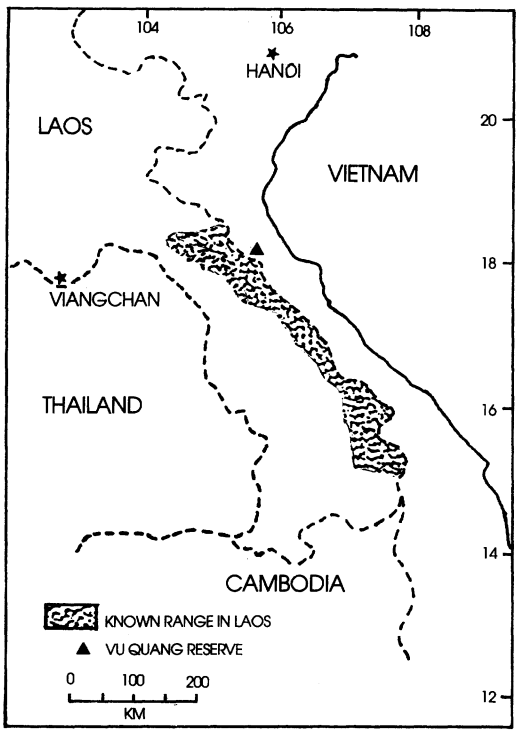

FIG. 1.—The known distribution of the giant muntjac (*Megamuntiacus vuquangensis*) in Laos.

m, wet-evergreen forest was increasingly replaced by dry-evergreen forest and patches of semi-deciduous forest. Cultivation had affected forests, particularly near streams, and created a mosaic of old-growth and secondary forests in various stages of regeneration.

Wildlife in Laos is so heavily hunted that large mammals are wary and seldom observed. Consequently, we obtained most data by talking with local people and examining crania of muntjacs with attached antlers that were occasionally nailed to walls in huts to serve as hanging racks.

We observed a captive male giant muntjac and took skull and body measurements from an adult female that was killed by hunters on 6 January 1995 as she was being attacked by a dhole (*Cuon alpinus*). Antlers of seven giant muntjacs were measured; one set was attached to an almost complete cranium. Our sample of red muntjacs from Laos consisted of 40 sets of adult antlers with the associated pedicels and top of the cranium and in one instance, most of the skull. Crania of several other species of muntjacs were checked for comparison at the American Museum of Natural History, New York. Skull measurements included: length of beam (distance from bottom of burr along the outside curve to the tip); length of brow tine (point of upper contact with beam along inside curve to the tip); circumference of beam (above junction of brow tine and beam); distance between tips of beams; length of pedicel (lower inside edge of burr to first contact with the cranium); circumference of pedicel (above contact with cranium; specimens in villages often had the top of head and pedicels encased in skin, so our measurements were based on those without skin); length of skull (anteriormost premaxilla to posteriormost occipital condyle); lengths of lower P2–M3 (maximum length lingually at occlusal surface), upper P2–M3 and M1–M3 (maximum lengths buccally at occlusal surface), and upper P2-premaxilla (anteriormost premaxilla to anterior junction of upper P2 and maxilla); width of braincase (maximum width across parietal-temporal suture); height of occipital (top of foramen magnum to top of occipital crest); maximum length of nasal; maximum width of nasal (measured over the curve); length of nasion-premaxilla (posteriormost extent of nasal bones to anteriormost premaxilla); maximum diameter of orbits.

Total genomic DNA was isolated from tissues of one red muntjac and one giant muntjac by phenol/chloroform isolation procedures, and 285-base fragments of the 16S ribosomal segment of the mitochondrial gene were PCR amplified and analyzed (Caccone et al., 1987; Gatesy and Amato, 1992; Gyllensten and Erlich, 1988).

RESULTS

Distribution.—We found antlers of giant muntjacs in villages as far north as the Chat River (18°37′N, 105°04′E) and as far south as the village of Dakchung (15°29′N, 107°16′E), a distance of 450 km (Fig. 1). Although we searched for giant muntjacs only in the northern and southern parts of this range, distribution in suitable habitat probably was continuous and included some of the small mountains bordering the main massif. For example, R. Timmins (pers. comm.) observed antlers between ca. 16°15′N and 16°50′N. It is possible that giant muntjacs in Laos occur south to, and

FIG. 2.—An adult giant muntjac with antlers in velvet in captivity in Laksao, Laos (20 December 1994; photograph by G. B. Schaller).

perhaps into, Cambodia and that they are found at least as far north as 19°20′N. The giant muntjacs may have a similar linear and narrow range on the Vietnam side of the Annamite Mountains. In the southern part of its distribution (Fig. 1), the giant muntjac did not occur beyond the foothills, where evergreen forest was replaced by dry-deciduous forest at an elevation of 200–300 m. In the north where evergreen forests occur west of the main massif, it was found at least to 104°30′E.

According to local informants, giant muntjacs are moderately common to rare or absent depending on the condition of the forest. They are said to occur mainly in old-growth forest, in contrast to red muntjacs that also are common in secondary forest.

General description.—The giant muntjac resembled other species of muntjacs in that it had simple antlers on prominent pedicels that extended along the face as ridges (Fig. 2). Preorbital glands and a pair of frontal glands were large, and the female that we examined had pedal or interdigital glands on the hind feet only, as is typical of muntjacs (Groves and Grubb, 1990; Lydekker, 1898). Males have tusk-like canine teeth that project from the upper jaw; canine teeth in our male specimen were 3.4-cm long over the outside curve from the gum line.

The female giant muntjac that we examined weighed 34 kg, or three times the mean female weight of the small Chinese muntjac and at least 25% more than the medium-sized black muntjac (*M. crinifrons*) and red muntjac in China (Table 1). Sheng (1992) reported that one male Gongshan muntjac (*M. gongshanensis*) weighed 24 kg and one male Fea's muntjac (*M. feai*) weighed 21 kg.

Body dimensions of the female giant

TABLE 1.—*Mean body measurements of a female* Megamuntiacus vuquangensis *and females of four species of muntjacs from China (Sheng, 1992).*

Species	*n*	Mass (kg)	Shoulder height (cm)	Length (cm) Total	Tail	Ear	Hind foot
Megamuntiacus vuquangensis	1	34.0	67.0	113.0	17.0	11.9	32.0
Muntiacus reevesi	5–8	11.1	45.4	78.6	12.2	8.4	22.2
Muntiacus crinifrons	29–34	24.3	58.9	106.8	21.4	10.1	32.0
Muntiacus feai	1			100.0	17.5	9.0	30.0
Muntiacus muntjak	4–5	25.4	57.4[a]	99.6	18.8	9.7	27.1

[a] Sheng (1992) provided no shoulder height; we measured this female in Laos.

muntjac were compared generally with similar dimensions for four other species, which were measured somewhat differently (Sheng, 1992). We took height of shoulder and length of hind foot from the tip of hoof rather than in the flat normal stance and measured the head and body over the curves rather than as a straight plane. The female giant muntjac appeared to be somewhat taller and longer than averages of other species (Table 1); however, her tail was relatively short compared to black muntjacs and was broad and almost triangular, unlike the narrow tail of other species.

The captive male was an adult of unknown age. He had bred with a red muntjac in his enclosure and produced three hybrids that were present in the enclosure. His body was gray-brown to dark tan with a pale chestnut hue; not the dark chestnut typical of red muntjacs in the area. His coat had a grizzled appearance because the hairs had black tips followed by a light band; an annulated pattern that is also found in several other species of muntjacs. There was a dark dorsal line on the neck that continued as a diffused grayish area along the shoulder and back and terminated in a dark-gray rump and almost black tail. The lower legs were dark gray, and the forelegs were nearly black above the carpal joint. The male's pelage became darker between late December and late January as growth of his antlers ceased and the velvet dried. The belly, insides of the legs, anal area, and underside of the tail were white. The tail was relatively short, broad, and almost triangular, as in the female. The white tail hairs were long and conspicuously fanned out when he raised his tail. White hairs fringed the tail dorsally, and a white patch occurred above each hoof, as in Fea's and red muntjacs. Unlike other muntjacs, there was a round white spot on each knee (Fig. 2).

Pelage on the male's head lacked unusual features. A black line extended from the frontal gland along the inside of each facial ridge to the end of the pedicel, as in red muntjacs. Hairs on the pedicels were elongated, but there was no frontal tuft. The muzzle was dark gray, and the chin was white. The inside of the broad and pointed ears was whitish; each ear had a tuft of white hair on the lower front margin. The rest of the head and pedicels was of a subdued chestnut color.

The female giant muntjac that we examined was pregnant with a 165-g fetus and one of her four nipples had milk. She lacked a chestnut hue and was a more uniformly dark-grizzled tan and gray than the captive male. Her face was gray and changed to black on the crown. Facial ridges were only slightly developed, and facial lines barely were evident on the gray to black head. Frontal glands were 3.8 cm long and white when slightly everted, which contrasted with the dark pelage. A dark-gray band extended from nape to rump, which was darkest in the center and more diffuse toward the sides. Otherwise, she was patterned like the male, except that she lacked white knee spots and markings above the hooves were tan not white. She had a tuft of hair where pedicels would emerge in a male. Her canine teeth were thin pegs ca. 1 cm long.

Antler and skull measurements.—The antlers of giant muntjacs were considerably larger than those of other muntjacs (Table 2). The beam was 17.0–28.5 cm long, and the brow tine was up to 9.8 cm long. In contrast, our longest antler of the red muntjac from Laos measured 16.0 cm, and the longest brow tine was 3.9 cm; 25% of the animals either lacked a brow tine or had one <1 cm long. In Chinese, Fea's, and red muntjacs, species with moderately long antlers, the beam curved inward and then downward at the tip, sometimes sharply to form a hook, and brow tines projected inward at the base. In contrast, antlers of giant muntjacs curved up and out, and then gradually inward and slightly backward. Brow tines followed the curve of the beam or diverged only a little, and if long, bent inward at the tip (Figs. 3 and 4).

Antlers of giant muntjacs grew on short,

TABLE 2.—*Measurements (in cm) of antlers and pedicels of sympatric adult* Megamuntiacus vuquangensis *and* Munticus muntjak *in Laos.*

Variable	*M. vuquangensis*				*M. muntjak*			
	$\bar{X}$	±	*SD*	*n*	$\bar{X}$	±	*SD*	*n*
Length of beam	23.2	±	3.9	7	10.8	±	2.6	40
Length of brow tine	8.2	±	2.3	3	1.5	±	0.9	33
Circumference of beam	8.4	±	0.6	5	4.8	±	0.8	23
Tip to tip	15.2	±	3.2	6	9.4	±	2.4	35
Length of pedicel	5.8	±	0.7	5	8.2	±	1.0	11
Circumference of pedicel	8.8	±	0.4	3	6.3	±	1.0	10

stout, and hair-covered pedicels that were 8.5–9.2 cm in basal circumference and 4.9–6.7 cm in length. Sympatric red muntjacs had long, slender pedicels that were 5.3–7.9 cm in circumference and 6.9–9.6 cm in length (Table 2, Figs. 3 and 4). However, red muntjacs had unusually long pedicles for a medium-sized muntjac; in contrast, those of black muntjacs average only 4.9-cm long (Sheng, 1992).

We compared two skulls of giant muntjac with the skulls of several red muntjacs (Table 3). The skull of the female giant muntjac was 219 mm long, or longer than any red muntjac in our sample, although two skulls of male red muntjacs from western Malaysia were 226 and 236 mm long and several males from northern Myanmar (Burma) (Groves and Grubb, 1990) were about the same size as the skull of our female giant muntjac. Length of tooth row, width of nasals, and width of braincase of the female giant muntjac were no larger than those of the red muntjacs in our sample, although her skull was longer. The anterior part of the skull was longer in giant muntjacs than in red muntjacs, as shown by the measurements of P2-premaxilla, nasion-premaxilla, and length of nasals (Table 3). Length of nasals of the two giant muntjacs (74 and 78 mm) exceeded lengths from red muntjacs (≤64 mm) in Groves and Grubb (1990) or other species of muntjacs (Sheng, 1992).

Several cranial features distinguish giant and red muntjacs. Giant muntjacs appeared to have lower and wider occipital surfaces than red muntjacs, and temporal lines on the parietal converged less posteriorly. Ventrally, the medial processes of the premaxilla in giant muntjacs did not narrow into a sharp posteriorly directed spur as in red muntjacs, but they maintained their breadth and extended into the anterior maxilla. Nasals of giant muntjacs projected posteriorly into the frontals as sharp central spurs and without any marked development of posteriorly directed flanges lateral to the central spur. In contrast, red muntjacs lacked spurs and tended to have flanges. Anterior nasals of giant muntjacs lacked lateral spurs, which usually were present in red muntjacs (Figs. 3 and 4) and several other species (Ma et al., 1986). The palatine extension in giant muntjacs toward the alisphenoid above and medial to M3 formed a strong, sharp vertical crest, which was not evident in red muntjacs.

DNA analysis.—Sequences of total genomic DNA of giant and red muntjacs were similar enough to be aligned by eye. Giant muntjacs differed at 26 sites on the 16S ribosomal segment of the mitochondrial gene from red muntjacs.

DISCUSSION

The giant muntjac is unusually large, but measurements of the skull and body indicate that the red muntjac may be equal in size in some areas. One male red muntjac from north of Hanoi, Vietnam, weighed 36.5 kg (Dang, 1986). In Java, male red muntjacs may weigh 30–35 kg and have a length of head and body of 120–130 cm,

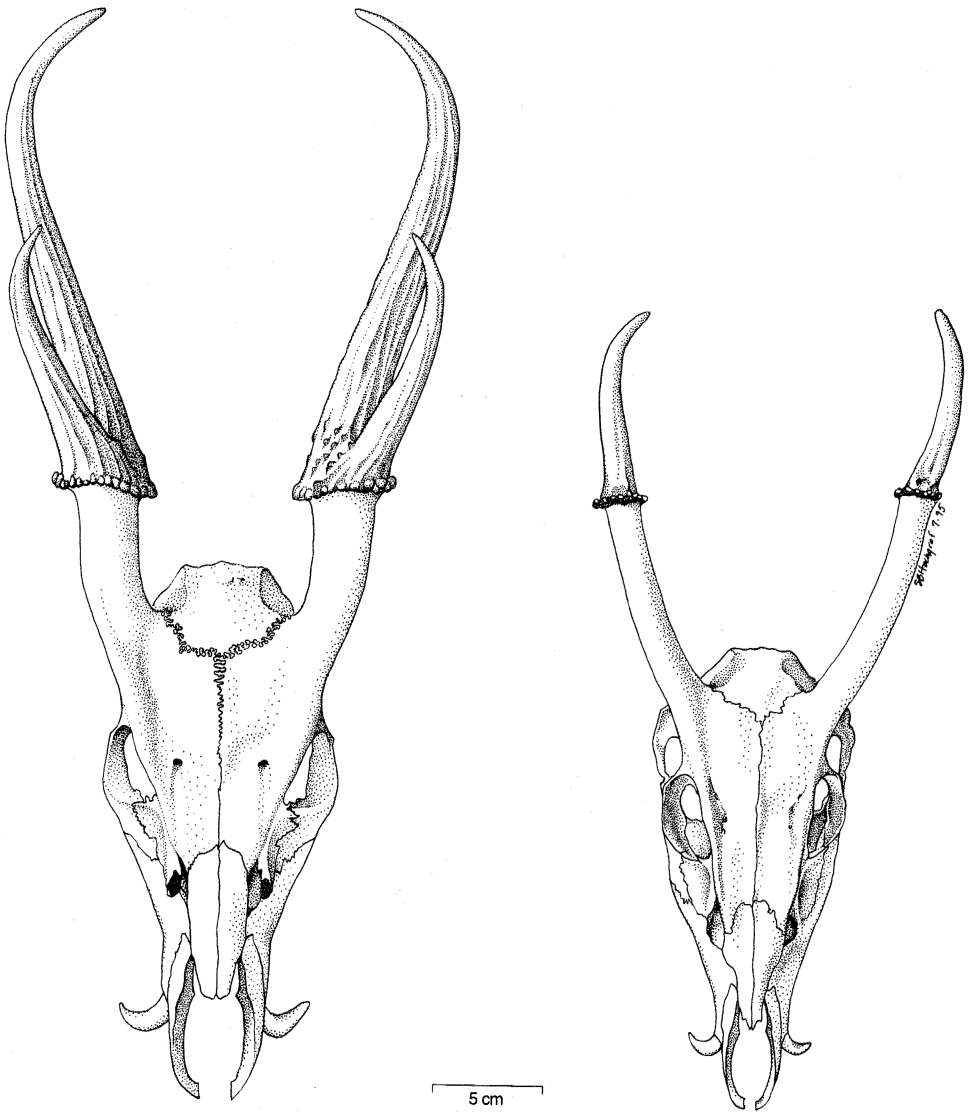

FIG. 3.—Frontal view of an adult male giant muntjac (left) and sympatric adult male red muntjac from Laos (the red muntjac lacked a brow tine; medial processes of the premaxilla were missing in both specimens).

shoulder height of 70–90 cm, and maximum length of antlers of 24–27 cm (Hoogerwerf, 1970), which are similar to those of giant muntjacs. Although general dimensions of giant muntjacs are not unique among muntjacs, the animal does exhibit several features that support its designation as a distinct species. These include short and extremely stout pedicels, size and conformation of antlers, skull characters including the length and shape of the nasals, and a triangular tail.

Giant and red muntjacs are sympatric in old-growth forests in the Annamite Mountains. The red muntjac can readily be distinguished from the giant muntjac by its small size, its long, thin pedicels with short antlers, and its dark-chestnut coat with hairs that lack an annulated pattern (except on the muzzle). Differences in size and skull char-

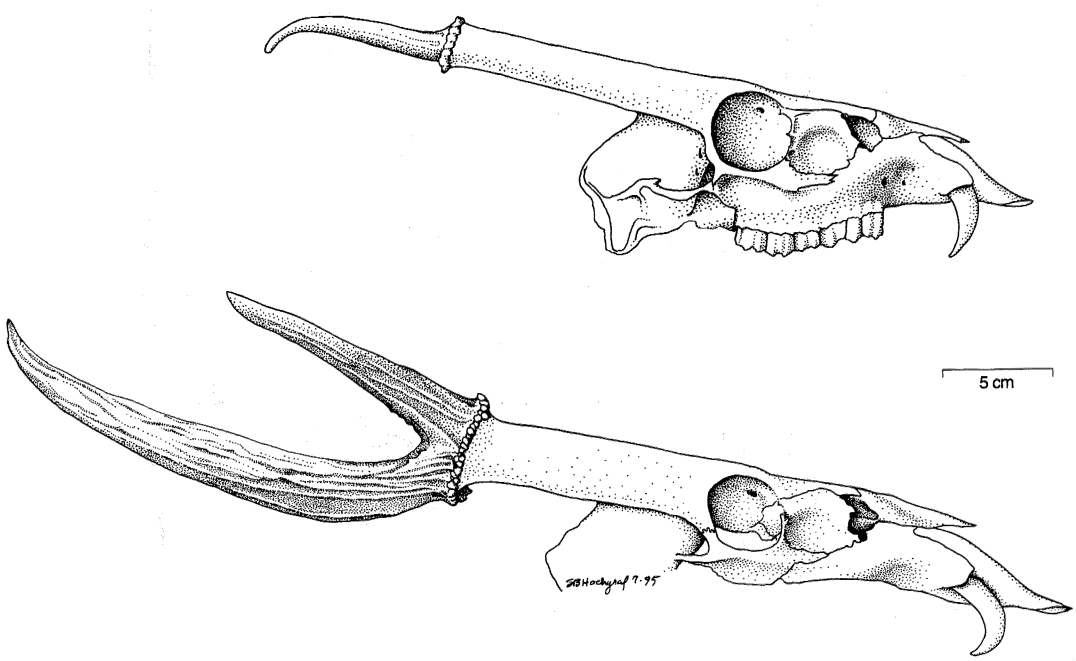

FIG. 4.—Lateral view of a male giant muntjac (bottom) and a male red muntjac from Laos; the giant muntjac lacked dentition.

acteristics between the two species cannot be ascribed to allometric consequences of body size. The question then arises as to how closely the two species are related to each other, particularly because they may hybridize in captivity. Because we lacked an adequate sample of skulls of giant muntjacs for cladistic analysis, we were only able to provide preliminary morphological comparisons. The DNA analysis showed a level of sequence divergence that was within levels estimated for mitochondrial vari-

TABLE 3.—*Selected skull*[a] *measurements (in mm) of adult* Megamuntiacus vuquangensis *and* Muntiacus muntjak.

	M. vuquangensis		*M. muntjak*					
Variable	Laos ♂	Laos ♀	Laos ♂	Laos ♂	Thailand ♂	China ♂	Java ♀	Bali ♀
Length of skull		219.0			189.0	172.0	199.0	174.0
P2-M3 (lower)		69.5	73.8	65.5	64.5	56.4	64.8	61.0
P2-M3 (upper)		64.7	67.6	62.3	59.5	53.0	62.2	54.7
M1-M3 (upper)		36.6	39.5	37.0	34.7	30.5	35.5	31.8
P2-premaxilla (upper)		73.3		67.8	63.8	57.0	66.6	56.5
Width of braincase		63.2	59.7	61.1	60.3	53.5	60.3	54.7
Height of occipital		32.4	32.5		34.0	38.3	33.3	27.8
Length of nasal	74.3	78.0	56.0	55.7	56.2	42.0	52.8	46.1
Width of nasal	37.0	36.0	39.0	38.0	38.0	31.0	33.0	28.0
Nasion-premaxilla	114.7	115.7		93.0	90.4	80.0	91.5	83.3
Diameter of orbit	44.5	39.5	37.0	35.2	36.0	35.0	35.7	33.4

[a] The first three skulls were collected by G. B. Schaller; the remaining skulls were American Museum of Natural History specimens 87604, 60767, 34254, 102079, and 102132. The lower number of female than male skulls of *M. muntjak* was determined by availability in the collection of the American Museum of Natural History.

ation in other genera of cervids (Cronin, 1989). This, together with the morphological data, suggests that giant muntjacs belong in the genus *Muntiacus,* not in a genus of its own.

There are other endemic ungulates in the evergreen forests in and adjoining the Annamite Mountains. In 1995, we found a third species of muntjac, which is small, dark brown to black, and sympatric with the other two (Schaller, 1995); its genomic DNA differs from red and giant muntjacs (G. Amato, pers. comm.). The saola (*Pseudoryx nghetinhensis*), a bovid, was discovered in Vietnam in 1992 (Dung et al., 1993) and in Laos in 1993 (Schaller and Rabinowitz, 1995). The Vietnamese warty hog (*Sus bucculentus*) vanished from the scientific world after its first description (Heude, 1892), but was rediscovered in Laos in 1995 (C. P. Groves et al., in litt.). Horns of an unknown bovid were recently found in Vietnam (Peter and Feiler, 1994).

This striking endemism occurs in a small area. Local climate in the Pleistocene (Ferguson, 1993; Zhang, 1984) and Holocene (Jarvis, 1993) varied between warmer and moister during interglacial phases and cooler and drier during glacial phases. Such climatic changes probably resulted in recurrent fragmentation of forests in Laos and Vietnam, particularly in topographically diverse areas. Today, dry-deciduous to semideciduous forests cover plains along the southern one-half of the Annamite Mountains in Laos; hilly terrain extends westward in the north and is (or was) covered with forests of broadleafed evergreens. The Vietnam side of the Annamite Mountains has more rainfall than the Lao side, and evergreen forests once extended across the narrow strip of country to the South China Sea. During dry phases of the Pleistocene, forests of broadleafed evergreens may have persisted mainly along the upper slopes of the Annamite Range, which provided refugia and may have been centers of speciation.

In November 1994, the giant muntjac was protected under Appendix I in the Convention on International Trade in Endangered Species (CITES). Although the giant muntjac has a limited distribution, it appears to be widespread in the evergreen forests within its range, but it remains vulnerable because of heavy hunting and deforestation. Fortunately, the Laotian government established several National Biodiversity Conservation Areas in and near the Annamite Mountains. Recent surveys noted the presence of antlers of giant muntjacs in villages in four of these areas, totalling ca. 7,750 km^2. The Nakai-Nam Theun Conservation Area is contiguous with the Vu Quang Nature Reserve in Vietnam. This and other parts of the border provide an opportunity for Laos and Vietnam to cooperate in protecting and managing transfrontier forests to assure the survival of the giant muntjac and other endemic species.

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