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ECOLOGY AND BEHAVIOR OF THE ASIAN ELEPHANT

John F. Eisenberg

Abstract: The Asian elephant was studied in Sri Lanka from 1967 until 1978. Under the sponsorship of the Smithsonian Institution, six zoologists have addressed themselves to an analysis of the behavior and ecology of the Asian elephant over a period of eleven years (Figure 1). Although elephants were studied in all three national parks found in Sri Lanka, the major effort during the last seven years has been concentrated on Gal Oya National Park. Although the Asian elephant shares numerous behavioral traits with those of the African, differences may be noted. It is proposed that the major differences between the two species in terms of population structure, social groupings, and habitat utilization reflect the longer history of the Asian elephant's adaptation to a forest-grassland ecotone. An analysis of feeding rates and competition among the various large herbivores in Gal Oya National Park indicates that at certain seasons of the year, buffalo and elephants may become strong competitors. Interspecific competition among herbivores varies greatly when patterns of resource exploitation are compared among three national parks. The Asian elephant has declined significantly in recent years and may properly be considered a threatened, if not an endangered, species. Conflicts between man and elephant in Asia have a far longer history than elephant-agricultural conflicts which are developing in Africa. The elephant's survival in peninsular India is a tribute to the adaptability of human culture to accommodate another species.

Introduction

The Asian elephant has been the subject of study by man since the dawn of recorded history. Historical records indicate that the Asian elephant was domesticated over 3,000 years ago. Many papers describing the domestication process (Deraniyagala, 1955), the maintenance of elephants in captivity, diseases of elephants (Evans, 1910), and physiology (Benedict, 1936), as well as numerous anatomical studies have produced an extensive literature (Olivier, 1978). Research on the ecology and propagation of elephants received a renewed impetus in the 60's of this century when conservationists became aware of the fact that the combined impact of landclearing and shooting for ivory had reduced wild elephant populations to dangerously low levels in southeast Asia.

My involvement with Asian elephants began in 1966 with the formation of a team, under the sponsorship of the Smithsonian Institution, to investigate the status of elephants in the national park system of Sri Lanka, formerly Ceylon, (Eisenberg and Lockhart, 1972, see Figures 2 and 3; Kurt, 1974; McKay, 1973). After the initial team efforts of intensive study between 1967 and 1970, several additional studies were conducted by graduate students at the University of Peradeniya, Sri Lanka (Ishwaran, 1978; Nettasinghe, 1973; Vancuylenberg, 1974). These studies plus the recent thesis by Olivier, (1978) based in part on the elephant populations in Malaya, make up the bulk of the recent published material on the ecology of the Asian elephant. Recently Professor M. Gadgil and his associates have initiated an extensive program of elephant studies in South India. Singh (1969, and 1978) has continued with

Figure 1. Current distribution of the Asian elephant and locations of major field studies conducted to date. The names of the principal investigators are keyed to their respective study areas. Major field research on the Asian elephant has been carried out in Sri Lanka. Current range of the Asian Elephant modified from Olivier (1978).

Figure 2. Location of Wilpattu National Park, Sri Lanka, where the author together with M. Lockhart studied elephants from 1968 to 1969. See enlargement of the Park in Figure 3 opposite.

Figure 3. Map of Wilpattu National Park. The major river systems and permanent water sources (Villus) are indicated. Former agricultural activity in the eastern part of the park is demonstrable by the existence of ancient dams which impounded water for rice farming. The areas bounded in black lines indicate the major study areas within the center of the park.

elephant surveys in northern India. What follows will be an attempt to summarize the extant literature and to provide a framework for future studies in Asia.

Current distribution of the Asian elephant

Olivier (1978) has researched the literature concerning the present distribution of the Asian elephant. Figure 1 outlines what we currently accept as the major distribution patterns. As can be seen, elephant populations in India have been reduced to remnants in the northwest but rather substantial herds remain in south India. Northeastern India still supports considerable numbers of elephants. The situation in Burma, Cambodia, Laos, and Viet Nam remains uncertain. The elephant in Malaya has suffered considerable reduction in its range. The limits of its distribution in Borneo are imperfectly understood. Elephant populations are relatively isolated in Sumatra. Figure 1 indicates that most of the efforts in studying the ecology of the Asian elephant have been concentrated in Sri Lanka and south India.

Figure 2 illustrates the major study areas for elephants in south India and Sri Lanka and pinpoints the location of Wilpattu National Park where the author, together with Melvyn Lockhart, conducted an extensive survey in 1968-1969. Wilpattu can be thought of as a typical lowland dry zone habitat for the Asian elephant in the subcontinent of India. Figure 3 outlines the park and the distribution of water within it. As can be seen the park is bounded by a north and south river but contains numerous "villus" or fresh water lakes which vary in extent depending on the season of the year.

The drainage system in the eastern portion of the park was extensively dammed for irrigation purposes from 700 to 1100 A.D. It was abandoned following this period and has reverted to rather mature second growth forests. Yet the silted-in reservoirs provide open areas which support extensive grass growth that in turn are utilized as grazing sites by the ungulates in the National Park. Thus the hand of man some 700 years ago has modified the habitat to favor ungulate grazing patterns at the present time (Eisenberg and Lockhart, 1972).

It is worth noting that many of the extant elephant habitats in the subcontinent have at one time or another been modified by the activities of mankind. In fact, as will be demonstrated later, the very dependence of the elephant on grasses and forbs for a significant portion of its food intake typifies the elephant as an ecotone adapted form. The shifting agricultural patterns of Chena cultivators or the abandoned agricultural areas reverting to second growth can under certain circumstances be a very favorable habitat, not only for the elephant but for wild cattle as well (Wharton, 1968).

In no small measure the intertwined destinies of elephants and man in Asia which led to the domestication of the elephant have helped to protect it. The elephant has taken on a role in the religious, cultural and economic life of the human inhabitants of India, Sri Lanka, Burma, Thailand, and Indochina. The elephant has been exploited as a work animal and as a source of ivory and in former times as an implement of warfare, but it was nevertheless held in high regard as a fellow being. It is this quasi-religious attitude toward the elephant which has served to protect it in Asia. Consider, for example, the fact that the Island of Sri Lanka is scarcely larger than the State of West Virginia, and yet wild elephant populations have continued to exist in a land subjected to intensive agricultural practices from A.D. 100 until the present.

Elephant time budget, feeding and impact on habitats

Mueller-Dombois (1972) found that little damage to trees occurred through elephant feeding activities even though the population exists at a density of $1/km^2$. The terminal parts of branches are fed upon; the browsing activities of elephants distort considerably the growth of shrubs and small trees. In fact, the crown distortion serves as a useful index of the impact of elephants on their habitats.

Vancuylenberg (1974, 1977) analyzed the time budget for adult elephants. Figure 4 illustrates an idealized diagram. In general, the elephant has two extensive feeding periods in the 24-hour cycle. Altogether these periods may total 76% of the animal's total daily time budget. Feeding alternates with directed movement and rest or bathing periods. During any feeding cycle, the rate of feeding increases dramatically as the animal approaches an optimum feeding site, tapering off gradually and followed by a movement cycle to an area where the animal may drink, bathe, or rest.

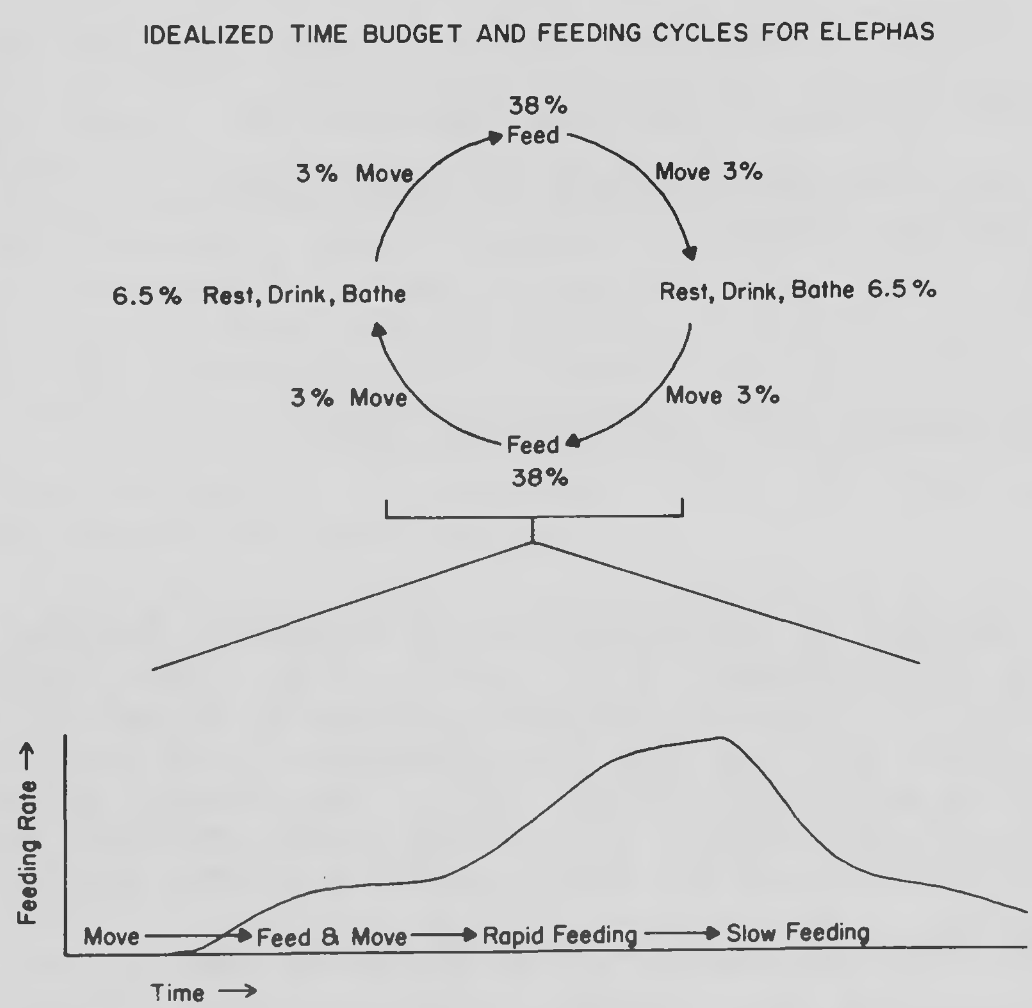

Figure 4. Idealized Time Budget and Feeding Cycles for the Asian Elephant. An average 24 hour activity cycle is illustrated in the top part of the figure. One feeding bout is then schematized in the lower graph demonstrating that a feeding cycle involves initial movement with a gradually increasing feeding rate which then declines and terminates in further movement.

An adult elephant may drink from 10 to 15 gallons of water daily. The amount, of course, will vary drastically depending on local conditions and the interval preceding the last drinking bout. In Table 1, the results from Vancuylenberg (1977) and Ishwaran (1978) are presented concerning feeding activity. When feeding, an elephant may consume up to 7.13 kg (wet weight of vegetation per hour). An average adult elephant feeds approximately 18 hours out of every 24 hour period, and in the course of one 24 hour period may consume an average of 150 kg. of green vegetation. Although an elephant may utilize 60 to 70% of the plant species found in its habitat (McKay, 1973), it has definite preferences. The percent of preferred species of plant material available in the habitat may be as low as 19%. When given a choice an elephant will feed extensively on grasses and forbs in addition to browse. Vancuylenberg has found that up to 50% of the intake during a 24 hour period will consist of grasses and forbs.

Table 1

Salient features of elephant feeding*

$\bar{x}$ Feeding Rate = 7.13 Kg/hr (wet weight)

$\bar{x}$ Feeding Time = 18 hr/day/elephant (≈ 75% of activity/day)

$\bar{x}$ Intake = 150 Kg/day/elephant

% of preferred species of plant available = 18.7%

% of time spent feeding on grasses and forbs ≥ 50%
($\bar{x}$ annual all age classes)

*From Vancuylenberg, 1977, and Ishwaran, 1978

The elephant prefers to utilize areas of secondary forests, scrub and savannah (Eisenberg and Lockhart, 1972; McKay, 1973). The distribution of permanent water within an elephant's habitat profoundly influences the density to which the population can rise and the movements of the population in the course of its foraging activities (McKay, 1973). An elephant generally drinks once every 24 hours and its movement and feeding range generally permits it to drink and bathe at least once, if not twice, within a 24 hour cycle.

The structure of Asian elephant populations

Population densities for the elephant in Sri Lanka were determined for three different national parks by Kurt (1974), McKay (1973), Eisenberg and Lockhart (1972). Olivier (1978) reviews past density estimates, offers his own density estimates for Malaya, and presents a balanced critique of past methods. It is clear that the elephant over most of its range exists at densities lower than those described for some populations of African elephants. Although Asian elephants may reach densities of 1/km^2 and maintain these densities over a considerable period of the annual cycle, this density appears to be near the maximum recorded to date. Of course, short-term feeding aggregations of elephants may vastly exceed this number and such feeding aggregations are highly seasonal and transient (McKay, 1973). Crude densities for Asian elephants within the range of habitats studied probably fall between .12 and 1/km^2. Those areas supporting high densities of elephants generally exhibit an interdispersion of resources including water, grass and low shrubs. Dense primary rain forests, while supporting healthy elephant populations, generally support them at the lower end of the density range (Olivier, 1978).

Kurt (1969) has analyzed to some extent the mortality trends for elephant populations in southeastern Sri Lanka. During the first six to ten years of life mortality rates are rather high, but begin to decline radically for females as they approach adulthood. Subadult and adult males have higher mortality rates than those for females in comparable age classes (Kurt, 1969). The chief cause of death in adult or subadult males results from interactions with humans, especially where elephant ranges interface with agricultural developments (McKay, 1973).

The social behavior of the Asian elephant

Female elephants appear to show considerable fidelity to the cow herd in which they are born. These herds, or clans, are essentially organized along matriarchal lines. The older cow coordinates movements and acts as the leader. In Sri Lanka the cow herds tend to be rather small, ranging from 8 to 21 animals (Kurt, 1974; McKay, 1973). A cow herd may divide on a daily basis into two or more subgroups. These subgroups may forage within vocal contact of one another, or separate for a day or two at a time. McKay (1973) has noted that subgroups may be functionally divided. Lactating females with very young calves are very frequently in the company of other females with small calves. This can lead to the formation of a functional "nursery unit". Such a subgroup of females with some attendant juveniles can function effectively in protecting infants from predation. In peninsular India the tiger was very probably a significant predator on young calves.

Young male elephants begin to become peripheral to the cow at about six to seven years of age. They become increasingly peripheral with advancing years and may take up with an older bull in a loose association. Bull associations rarely exceed three or four animals (McKay, 1973). Fully adult males tend to be rather solitary in their movements and may show considerable fidelity to a rather limited home range. A cow herd in its movements may pass through the home range areas of several adult bulls. Adult males, when they encounter cow herds, generally interact briefly with females. If a female is in estrus, however, she will generally attract several bulls. Indeed, as she approaches estrus, three to four bulls may be in attendance. A definite dominance order can be discerned among the bulls, however, and only a mature bull which can easily dominate the others will be in close attendance on the cow. Contests of strength among younger bulls or "mock fighting" may increase in intensity at the time they are in association with cow groups.

Reproductive biology of the Asian elephant

Reproductive physiology and behavior of the Asian elephant has been studied in some detail (Eisenberg, McKay and Jainudeen, 1971; Jainudeen, Eisenberg and Jayasinghe, 1971; Jainudeen, Eisenberg and Tilakeratne, 1971; Jainudeen, Katongole and Short, 1972). Although a young male elephant can begin to exhibit spermatogenesis as early as seven or eight years of age, in general, they are neither large enough, nor have a high enough dominance status to actively compete for and breed with adult cows. At ten to twelve years of age the young male is at the beginning of subadult phase if he has been blessed with a good nutritional input for the better part of his ontogeny. Generally, from 14 to 17 years the young male begins to achieve adult stature and exhibit the condition of musth.

Musth is characterized by copious secretions from the temporal glands located on either side of the face between the eye and the ear. At least three stages of secretory activity can be identified (Jainudeen, McKay and Eisenberg, 1972). The tertiary stage characteristically shows a copious flow of fluid from the temporal glands that leaves a stain to the corners of the animal's mouth and even down into the animal's mouth.

Secretory activity of the temporal gland is accompanied by increased plasma testosterone (Jainudeen, Katongole, and Short, 1972); increased frequency of erections; heightened aggressiveness and irritability toward other male elephants; and increased secretory activity from the secondary sexual glands associated with the male genital tract. The condition of musth is confined to the male, and the only cases of female temporal gland secretion are confined to those females which are clearly post-menopausal. Males in full musth can generally dominate a non-musth male even if the musth male is smaller. We know that females in estrus can, upon prolonged exposure to a male, enhance an earlier onset of his musth period. In general, a male only shows one musth period a year and males tend to be quite regular with respect to the season of the year that they show musth. Musth is thus not clearly synchronized in a population of males but may approach synchrony in those populations where climatic extremes, such as prolonged drought period, tend to synchronize plant productivity, and hence synchronize the nutritional status of males in a population (see Eisenberg, McKay and Jainudeen, 1970).

It is true that a male need not exhibit musth to be able to achieve an erection, exhibit mounting behavior or show a complete copulatory sequence with a female. We do know, however, that musth correlates highly with an increased blood testosterone level and, therefore, suggests that a high rate of spermatogenesis may accompany the condition of musth. We hypothesize that musth is analogous to "rut" in north temperate ungulates.

It is worth mentioning at this point the contrast between temporal gland secretion in African elephants and Asian elephants. In African elephants both males and females exhibit secretions from the temporal glands during periods of excitement. It has been clear to us for some time, however, that there are qualitatively different types of secretions when males and females are compared.

Male African elephants exhibit a second type of secretion from the temporal gland which females do not. This secretion is very dark, sticky and, under a condition of full flow, stains the complete side of the male's head and under the chin. Captive observations by Xanten and Perry (pers. comm.) indicate that our male African elephant (at the National Zoological Park, Washington, D.C.), as he passed through puberty, began to exhibit some regularity in strong secretion from his temporal glands on an annual basis. Increased frequency of erections and attempts to mount the female often accompanied these periods of increased temporal gland secretion. Recently, Joyce Poole (1979) has completed a thesis which confirms this condition in the wild African elephant male populations at Amboseli National Park. Thus it appears that a condition analogous to musth is exhibited by male African elephants, but that, in addition, the temporal glands of both male and female African elephants can and do secrete a second substance which apparently serves a different communicatory function.

The female Asian elephant has a variable interval between estrus periods. Although attempts have been made to establish an estrus cycle through vaginal smear techniques, we failed to produce a consistently adequate set of smears. Instead we studied the estrus cycle of cow elephants by measuring the strength of the male's response to cows when they were introduced on successive days (Jainudeen, Eisenberg and Tilakeratne, 1971). Estrus intervals from 16 to 25 days were thereby determined. This does not appear to exceed the range of variation demonstrated by an African female at the London Zoo (Watson and D'Souza, in press; Nevill *et al*., 1976).

In captivity, females may conceive as early as seven to eight years of age. However, in the wild this may be delayed depending on the plane of nutrition which the female has experienced. Reproductive data for captive *Elephas maximus* at the Washington Park Zoo, Portland are summarized in Table 2. The gestation period of the elephant averages around 680 days. The interval between births is a function in part of how long the calf nurses from the mother. Interbirth intervals, where the calf is lost at an early age, may be as short as two years. In captivity if the calf experiences a normal lactation period, then the interbirth interval on the average is 3.74 years. In the wild, the interbirth interval averages about 4+ years (McKay, 1973).

Table 2

Synopsis of reproduction data for ***Elephas maximus****

Gestation	622 - 680 days
Interbirth Interval:	
Previous calf survived	$\bar{x}$ = 1,364 d. = 3.74 yrs.
Previous calf died	$\bar{x}$ = 802 d. = 2.19 yrs.
Minimum age at conception (female)	2,979 d. = 8.01 yrs.
Minimum age at conception (male)	~12.0 yrs.

*Courtesy of Washington Park Zoo, Portland, Oregon, based on 12 cases.

The duration of lactation appears to be quite variable but the young calf nurses heavily from the mother for the first six months after its birth. From about six months on, the calf experiments with feeding itself and solid food intake has increased markedly at the close of its first year of life. McKay (1973) suggests that a great deal of learning is accomplished by the young as it feeds with the mother. Food selection, no doubt, is potentiated by the female's feeding activities. Young elephants frequently ingest the feces of adults during the first year of life. This may serve to innoculate their digestive system with the appropriate microbial symbionts. Young elephants are able to take food (browse and grass) from other adults with impunity, but at about the time of four or five years of age they are generally rebuked with kicks or butts and begin to forage more on their own. The group of females with their various aged offspring provides an essential social milieu for the developing youngster and the larger female elephants provide an effective protection against predation.

The elephant in the south Asian ecosystem

Peninsular India, Sri Lanka and southeast Asia differ somewhat in the history of land use patterns, original vegetation cover, and faunal exchanges when compared with Africa. Schaller (1967) made the point that at least since Pleistocene, the Indian subcontinent was probably dominated by a forest climax with the exception of the extreme northwest. To be sure, many different forest types can be recognized and the forest types correlate with variation in the annual rainfall patterns. Contemporary national parks in India and southeast Asia often preserve fragments of the original forest cover, and in many cases the forest cover in these parks is second growth of varying age. Eisenberg and McKay (1974) pointed out that the terrestrial mammalian herbivores of the Indian subcontinent and southeast Asia show reduced diversity in numbers of species when compared with comparable sized areas in East Africa. Indeed, in contemporary peninsular Indian habitats, the biomass of terrestrial herbivores seems to fall somewhat short of that achieved in certain national parks of East Africa. Utilizing data from various sources, Eisenberg and Seidensticker (1976) attempted to construct an imaginary rainfall gradient by arranging Asian national parks according to length of the mean annual drought period experienced. At one extreme, vegetative cover was characterized by dry thorn forests and steppe. Intermediate types of forest cover ranged from dry semi-deciduous forest to tropical, evergreen, multistratial rainforests. As Eisenberg and McKay (1974) pointed out, climax multistratial tropical evergreen forest disfavors high densities of large, terrestrial mammalian herbivores. In fact, the dominant vertebrate biomass components may shift to arboreal forms, and in particular arboreal herbivores such as langur monkeys. Eisenberg and Seidensticker (1976) indicated that complex, mosaic habitats generally associated with alluvial drainage systems resulted in an interdigitation of grass, forests, and shrubs. In inundated areas an excellent interdispersion of water with plant growth could result. This type of habitat once characteristic of the Upper Indus and Lower Brahmaputra and Ganges River basins has now been extensively modified by agricultural pursuits. Yet what fragments of this ecosystem remain indicate that it supports high levels of terrestrial mammalian biomass.

Figures 5 through 7 are abstracted from the tables published by Eisenberg and Seidensticker (1976). We have portrayed five types of vegetational cover arranged in a series of increasing annual rainfall and decreasing prolonged annual drought periods. As can be seen from this portrayal, the ungulate family Bovidae is favored by a habitat showing moderate to low forest cover. In extreme xeric habitats, the genera Gazella, Antilope, Tetracerus, and Boselaphus are dominant contributors to the mammalian biomass component. The Bovidae are highly adapted for a grazing or mixed grazing/browsing strategy, and even xeric conditions with extensive grasslands can favor this taxon.

Figure 6 demonstrates the diversity of the family Cervidae in the Indian subcontinent and southeast Asia. Although mixed feeding strategies have been evolved within this family, in the main, the cervids are adapted for browsing. Thus the cervids were the natural component to have undergone an adaptive radiation in the almost continuous forested conditions of the subcontinent and southeast Asia prior to intense human agricultural pursuits. This diversity is still reflected in the present day distribution and abundance of cervids in the remnant national parks systems. It is the notable absence of bovid diversity correlating with the original lack of extensive steppe and grazing areas that has resulted in the post-Pleistocene faunal impoverishment which characterizes the ungulates of the Indian subcontinent. In East Africa, however, a history of aridity with the development of extensive savannahs promoted and enhanced speciation and diversification of the family Bovidae which are primarily grazers or grazers and mixed browsers. This historical difference probably accounts for the reduced diversity with respect to numbers of ungulate species when south Asia is compared to East Africa.

Figure 7 portrays the relative impact in terms of biomass displayed by the Asian rhinoceros and the Asian elephant across the same series of vegetation cover types. It will be noted that the browsing members of the genus Rhinoceros are adapted to forested habitats or alluvial plains. The elephant apparently has a much broader range of habitat tolerance than does the rhinoceros and, indeed, if we interpret its feeding behavior correctly, its dependence on grass and forbs has led it to be favored in more open second growth conditions or conditions of an ecotone between forests and grassland. Nevertheless, both the rhinoceros and the elephant are limited with respect to the interdispersion of water with the suitable vegetative substrates. The elephant fails to extend into extreme xeric conditions.

Elephant densities under optimum conditions in south Asia can reach a level of $1/km^2$ (Kurt, 1974; Gadgil, pers. comm.). The habitats that they currently occupy and in which they reach such high densities vary somewhat but are usually characterized by moderate tree cover grading into tree savannah in association with permanent sources of water widely interspersed in the vegetational mosaic (see Eisenberg and Lockhart, 1972; McKay, 1973). Extremely dense tracts of forests disfavor high densities of elephants although if sufficient interdispersion of water and grass areas permits grazing, moderate crude densities can be achieved (Olivier, 1978).

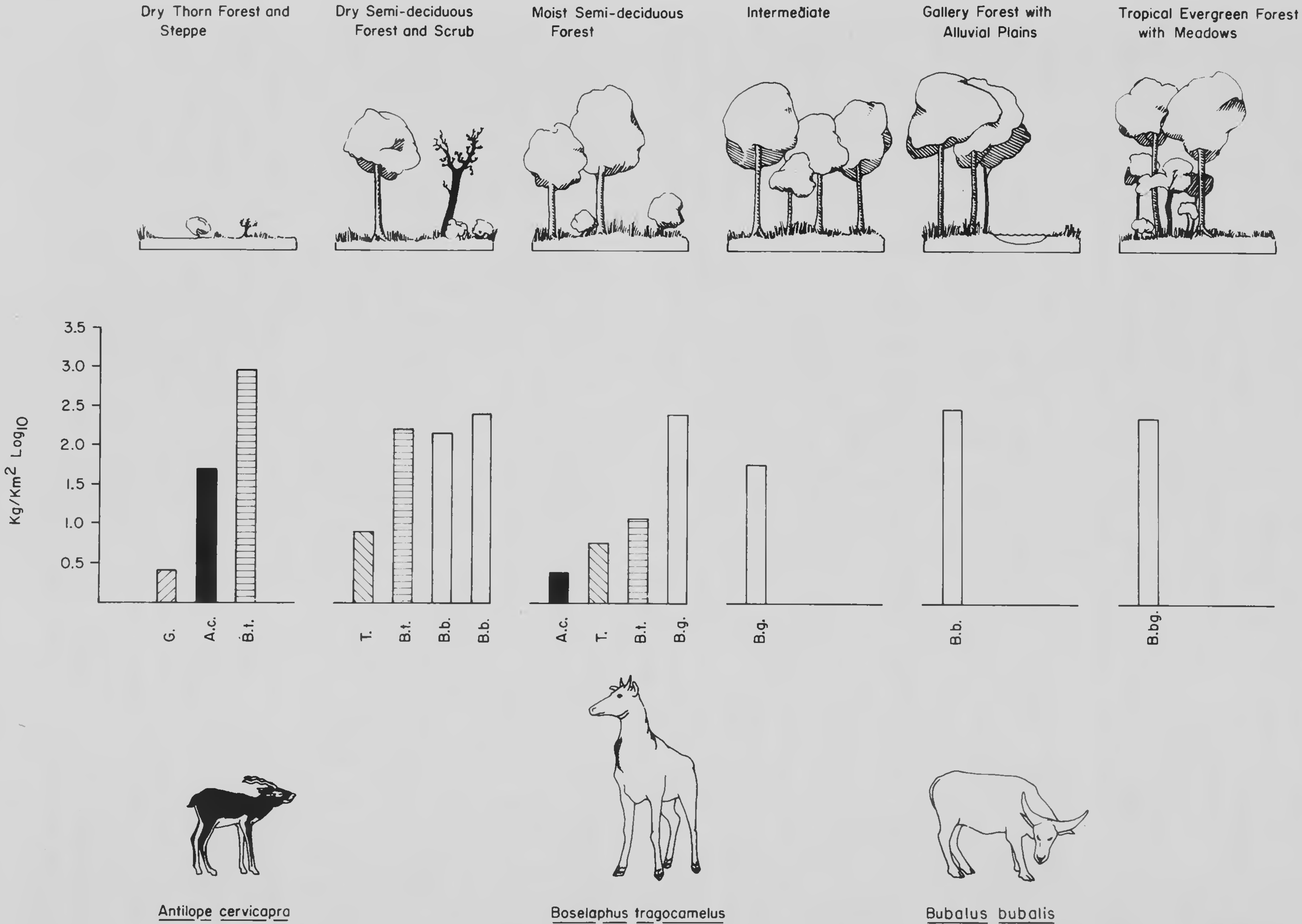

Figure 5. Crude biomass levels attained by bovids for a range of Asian habitat types. Bovids can occupy extremely arid habitats to which <u>Gazella</u>, <u>Antilope</u>, and <u>Boselaphus</u> are well adapted. The wild cattle, <u>Bubalus</u> and <u>Bos</u> are confined to more moist habitats and can reach high biomass densities where forest is interspersed with meadows for grazing. Data abstracted from Eisenberg and Seidensticker (1976). G = <u>Gazella gazella</u>, T = <u>Tetraceros quadricornis</u>, A.c. = <u>Antilope cervicapra</u>, B.t. = <u>Boselaphus tragocamelus</u>, B.b. = <u>Bubalus bubalis</u>, B.g. = <u>Bos (Bibos) gaurus</u>, B.bg. = <u>Bos (Bibos) banteng</u>.

Dry Thorn Forest and Steppe Dry Semi-deciduous Forest and Scrub Moist Semi-deciduous Forest Intermediate Gallery Forest with Alluvial Plains Tropical Evergreen Forest with Meadows

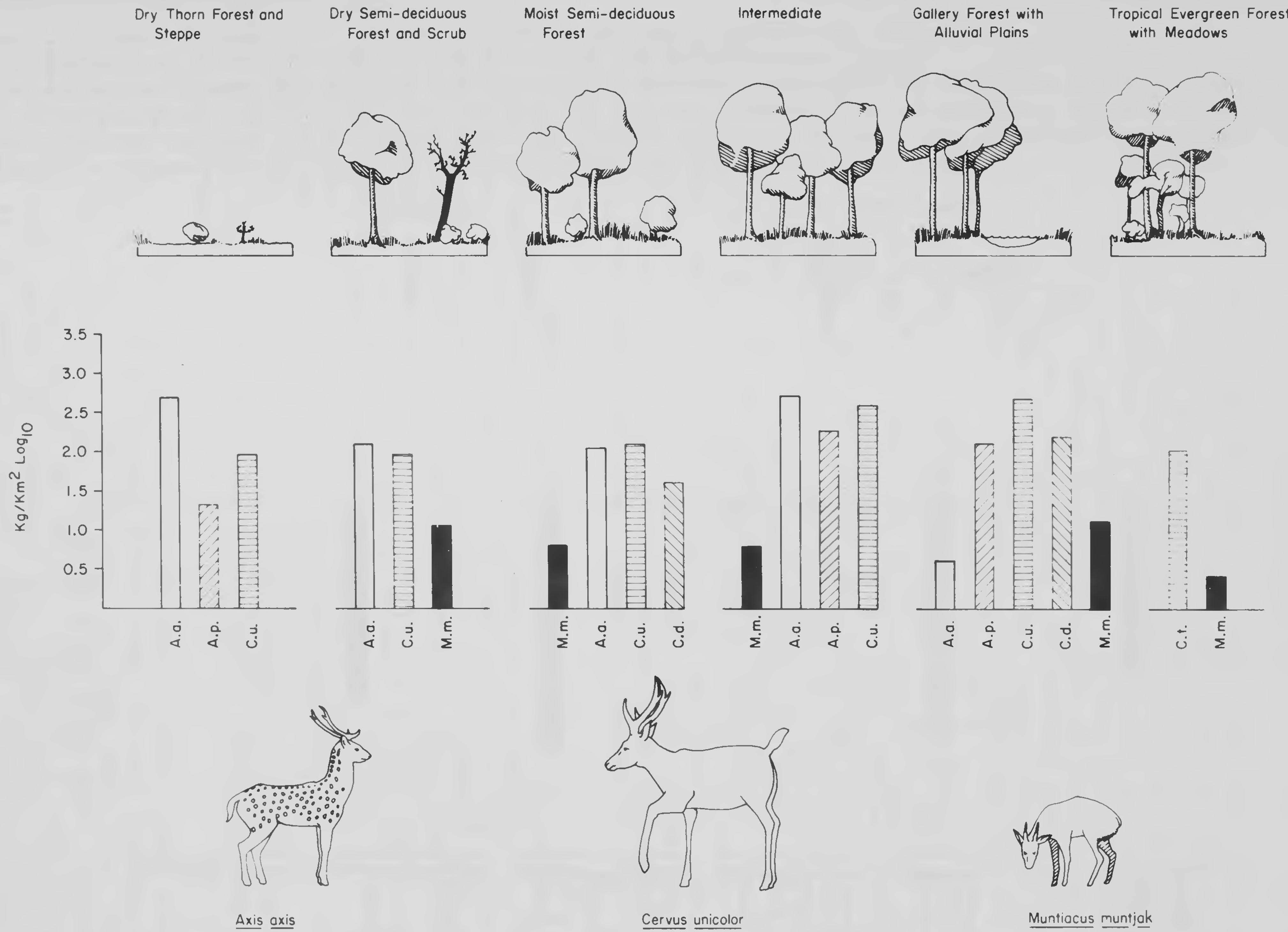

Figure 6. Crude biomass levels attained by cervids for a range of Asian habitats. Note that members of the family Cervidae such as Axis axis are favored in dryer habitats. In general, the cervids are adapted for browsing in forested habitats. The Sambar, Cervus unicolor , has the widest range of habitat tolerances. Data from Eisenberg and Seidensticker (1976).
A.a. = Axis axis, A.p. = Axis porcinus, C.u. = Cervus unicolor, M.m. = Muntiacus muntjak, C.d. = Cervus duvauceli, C.t. = Cervus timorensis.

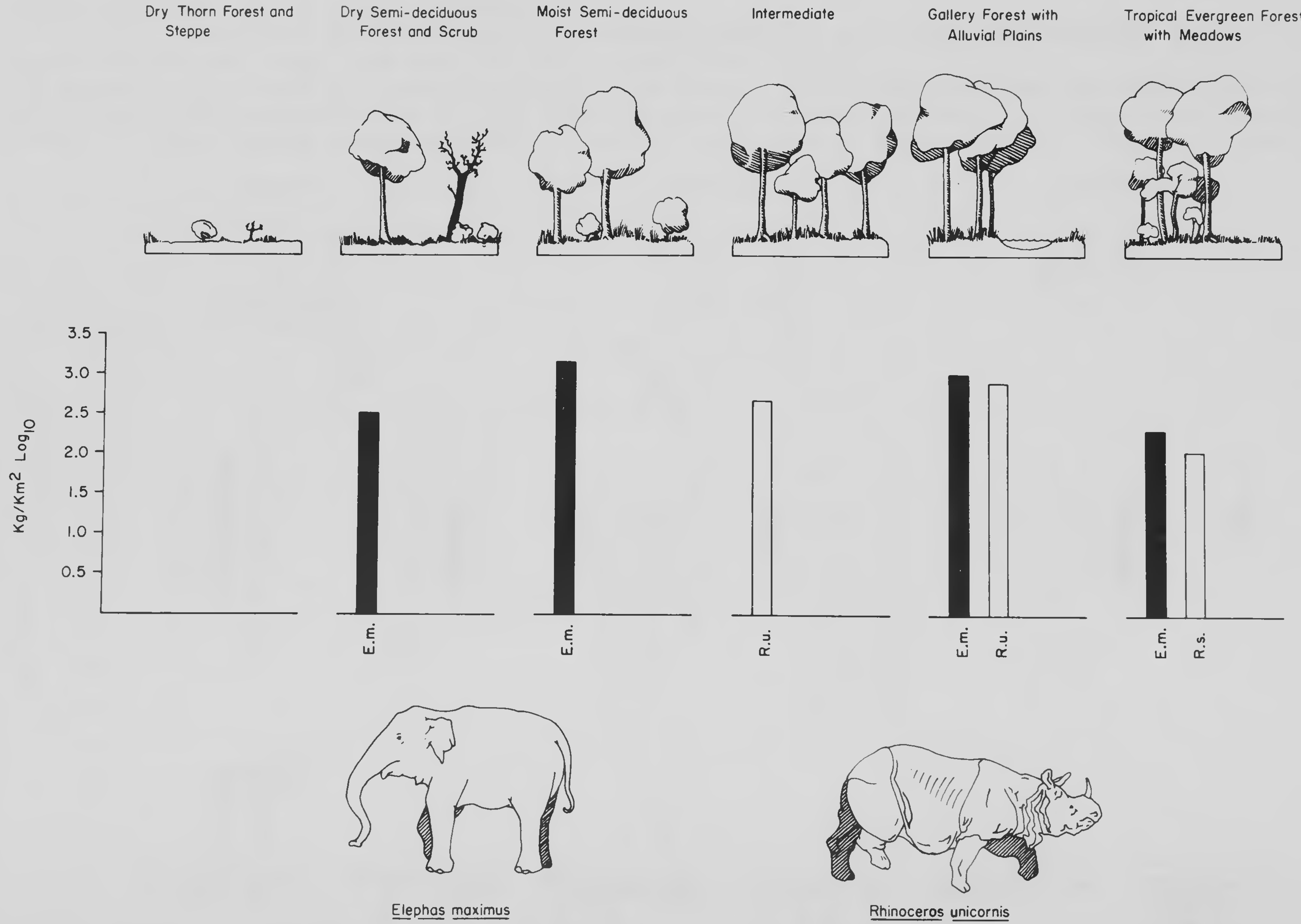

Figure 7. Biomass values attained by the elephant and rhinoceros for a series of Asian habitats. Note that the elephant has a broader range of habitat tolerance whereas the rhinoceros is confined to moist habitats. The elephant can utilize the habitat type which is intermediate between moist, semi-deciduous forest, and gallery forest, however no population data are available for this particular habitat type. Data taken from Eisenberg and Seidensticker (1976).
E.m. = Elephas maximus, R.u. Rhinoceros unicornis, R.s. = Rhinoceros sondaicus.

Conservation

The current status of the Asian elephant has been evaluated in the publication by Olivier (1978). In Olivier's tabulations he frankly admits that the situation in Borneo, Burma, and Indochina is very imperfectly known. Better estimates for elephants in peninsular India, Sri Lanka, Malaya, and perhaps Sumatra are available. I have taken the liberty of examining Olivier's results, and based on my own understanding of India and Sri Lanka, made the following estimations. Probably the minimum number of Asian elephants existing in a wild state today is around 23,000. The maximum number that I believe could be contained within its present range can be no more than 41,000. Clearly the Asian elephant is in far more serious difficulty than the African.

Especially critical to conservation of Elephas is the fact that: although national parks have been established in Malaya, Sumatra, India, Sri Lanka, and Thailand, in many cases the parks are not particularly large and the number of reproducing females present in a protected population may be below 30. Such a low number of females and the tendency for the Asian elephant to be somewhat polygynous in its reproductive pattern can set the stage for extensive inbreeding. Prolonged inbreeding in herbivores can lead to reduced fecundity (Ralls et al., 1979). As reserves become smaller and more fragmented, and the distance separating reserves increases, then the potential for a disastrous decline in wild elephant reproduction becomes an ever closer reality. Much more attention must be paid to adequate size for elephant reserves in south Asia, a size commensurate with the density that is normally supported by elephants given the cover type of the reserve. Population geneticists will have to work more closely with park planners to ensure that these management ideals become a reality.

Conflicts between elephants and man will continue to accelerate in parts of Asia as former elephant range is converted to agricultural land. Herds which occupy land to be converted for agricultural purposes should not be translocated to existing national parks and reserves unless adequate studies have been made within the reserves to determine how closely the resident elephant and ungulate populations approximate the carrying capacity. Ishwaran (1978) has made some initial attempts to estimate carrying capacity in Gal Oya National Park, Sri Lanka. Similar studies must be undertaken in other national parks in south Asia to assess the feasibility of translocation. Translocation of herds should only be undertaken after carefully weighing the alternatives. Should elephant populations reach higher levels in some of the south Asian national parks, I fear that carrying capacity might be exceeded and degradation of the vegetation be set in motion with ultimate consequences for the entire ungulate community.

The development of hydroelectric projects in south India and Sri Lanka also has serious impacts on elephant populations. Careful consideration should be given with respect to the placement of dams and their height. The protection of watersheds lying upstream from dam sites enhances forest preservation, but often if the dam is constructed with a high elevation, then suitable grazing habitat for elephants will be destroyed. Often a dam when constructed at an appropraite height will not completely destroy suitable elephant habitat, but may even enhance the carrying capacity by providing not only a permanent source of water but suitable grazing conditions as the water level drops behind the dam site in the dry season during the course of irrigation. More careful cooperation between engineers and wildlife biologists would ensure a compatible utilization of riverine systems by both elephants and man. A thoughtful consideration of alternatives during the development of hydroelectric power projects could prove fruitful if the appropriate dialogue between wildlife biologists and engineers could be establisned (see Figure 8 below).

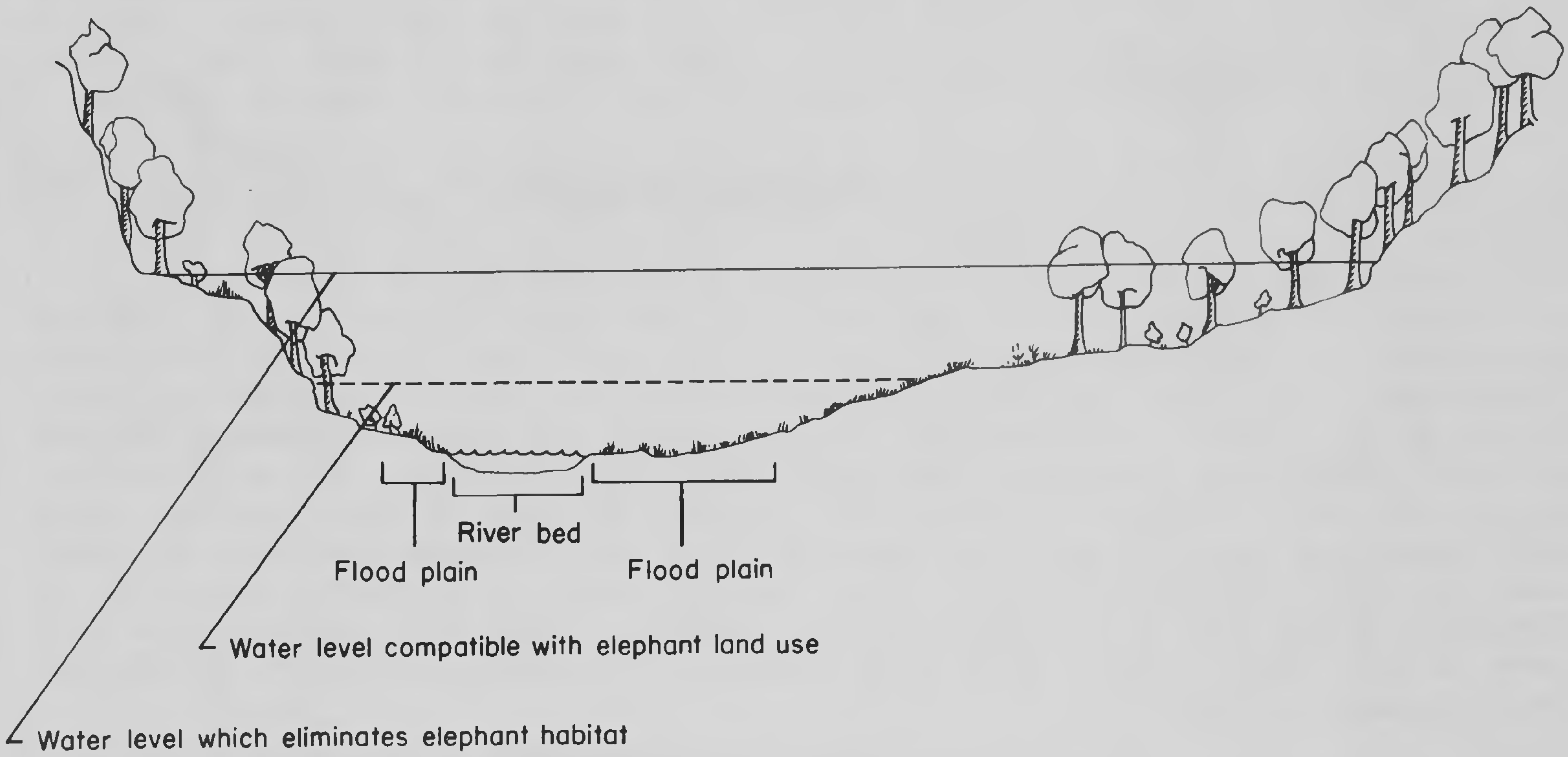

Figure 8. Diagram illustrating the effect of high dams versus low dams on available elephant habitat. In this hypothetical drawing it can be seen that a high dam will generally eliminate all potential grazing habitat for elephants whereas a dam of a lower height can still preserve some habitat for elephant foraging.

In Africa when elephant populations greatly exceed the carrying capacity, a cycle of environmental degradation can be set in motion. This has been well documented by Laws et al. (1975). The solution to this problem usually involves a culling of elephants, and schemes have been worked out in Africa for the utilization of ivory, meat and hides in an economical manner. In Asia the tradition has been quite different. A form of elephant culling and management had developed over the years which involved the capture of elephants for use as draft animals. This trend in cropping should be encouraged in those areas of south Asia where elephants exceed the carrying capacity. The elephant still can serve as a useful draft animal in selective logging operations. As petroleum resources shrink and as third world countries find it increasingly difficult to pay for gasoline and expensive logging machinery, the elephant may well again come into its own as the animal of choice for providing energy for the extraction of hardwoods from tropical forests (see Figure 9).

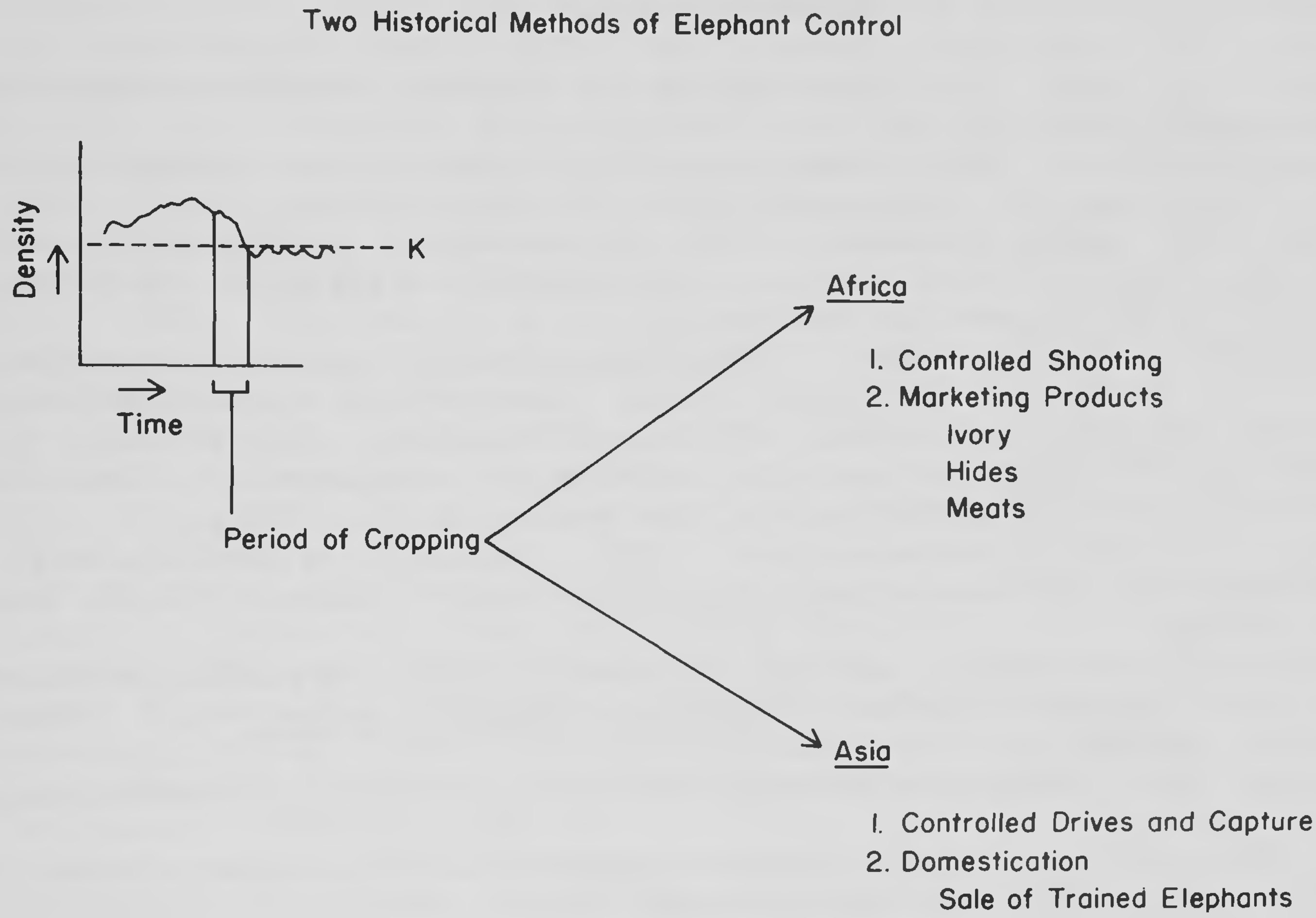

Figure 9. Generalized diagram illustrating two classical methods of elephant control employed in Africa and Asia. Although ideal conditions are seldom met, in general, when elephants begin to exceed their carrying capacity (k) and impinge on human habitat, sentiment develops for the exploitation of the elephant. In Africa, the classical method has involved direct utilization of elephant meat, hides and ivory for trade. In Asia, the elephant has often been utilized as a domesticated animal. Of course, over-exploitation is usually the case rather than the ideal, as diagrammed, and the Asian elephant within historical times was exploited for ivory as well as its utility as a domestic animal.

I am not completely pessimistic about the status of the elephant in south Asia or southeast Asia. As pointed out before, the record for elephant conservation in these countries prior to the last 70 years has been excellent. An awareness of the elephant's utility and a place for the elephant in the folklore of the people has reserved for it a very special status--not to be compared with anything found in contemporary Africa. It is nothing short of a miracle that the Asian elephant has survived as well as it has in southern India and on Sri Lanka, given the pressures of human populations and their very real needs. Our colleagues in Asia are to be congratulated on what they have been able to accomplish so far and we should be more than willing to extend every means of assistance to them for continuation of their enviable efforts.

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Appendix*

World numbers of Asian elephants

Area	Minimum	Maximum
India		
No. East	4,000	8,000
Central	1,500	2,000
So.	2,400	4,400
No. West	200	400
	8,100	14,800
Burma	5,000	6,500
China	150	200
Thailand	2,600	4,450
Indo-China	3,500	5,000
Cambodia	?	?
Laos	?	?
Vietnam	?	?
Borneo	?	2,000
Malaya	1,500	3,000
Sri Lanka	2,000	4,000
Sumatra	250	350
	Total 23,100	Total 40,300

*Modified from Olivier, 1978.

Editor's note: This paper by John F. Eisenberg was reviewed by J.C. Daniel and John Seidensticker. Reviewers' comments were incorporated in the paper. Seidensticker's comments regarding management problems were: "Land use planners are always asking why do we have to conserve the elephants here when there are 23,000 to 41,000 alive. This is the problem with the 'total-numbers approach,' which does not tie the elephants to the habitat situation. The real question is: what is happening to the habitat where they live in terms of fragmentation and quality. The endangered status of the elephant in Asia is a result of the trend in habitat loss, and the difficulty that there is in stabilizing the situation to include corridors and essential habitats."