

Dog Ecology and Dog Rabies Control

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Dog populations, like other populations, depend on the availability of resources (food, water, and shelter). Humans either make available or deliberately withhold resources for varying proportions of dog populations. Dog-keeping practices and the duties of responsible ownership vary with the cultural setting. Dog populations often attain densities that allow the species to be a main host of rabies. The epidemiology of dog rabies is not well understood, despite the easy access to dog populations. Today dog rabies is predominant in developing countries. In addition to the high rate of exposure of humans to dogs, traditional medical beliefs and practices are the most important cultural factors that lead to high numbers of cases of human rabies. Dog rabies control programs have been successful in the past, but most are failing today. Program development should follow managerial principles and take into consideration the biology of dog populations as well as cultural constraints. Elimination of stray dogs is not an efficient means of controlling either the dog population or rabies, but it may create public awareness.

Wolves were among the first animals to be domesticated. Mutual benefit and tolerance must have determined the nature of the early association between humans and these canids. Their descendants, the dogs, have accompanied humans to every continent and nearly all islands. Today dogs are esteemed in most cultures as companions and supporters of human activities, but the practice of keeping and tolerating dogs is not without problems. Dogs have a high reproductive potential, and dog populations may rapidly grow to such an extent that the health risks for humans become serious and the environment begins to suffer considerably.

The specific health risk to be discussed in this paper is rabies. Of at least 20,000 human rabies casualties per year, >99% are due to rabies transmitted by dogs [1, 2]. The majority of these cases occur in the developing countries of the Third World under cultural and ecologic conditions that are quite different from those in Western industrialized societies in temperate zones. Not only are characteristics of the habitat different, but there are also differences with respect to the keeping of dogs, ideas about ownership and its responsibilities, medical beliefs, and access to treatment.

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Dog Populations

Under optimal conditions a given population of dogs would nearly triple every year. In reality, population growth levels off quite rapidly and an equilibrium is reached at the carrying capacity of the environment, which depends on the pattern of availability and the quality of resources (shelter, food, and water) for the species concerned. The primary difference between wild and domestic animals is that humans either make available or deliberately withhold resources for a large proportion of domestic animals. Carrying capacities for dog populations are therefore related to different habitats, cultures, and social strata of human rural and urban populations. Any reduction in the density of the dog population due to increased mortality is rapidly compensated for by increased reproduction and rate of survival; i.e., when dogs are removed, the life expectancy of survivors increases because they have better access to available resources.

Reliable estimates of dog populations are still rare. Most of the published information considers only dogs that have owners. Their number is established by questionnaires or from licensing records. In general, American and European countries report a dog-to-human ratio between 1:10 and 1:6. We have observed similar ratios in Buddhist and Hindu communities of Southeast Asia and in rural areas of North Africa. A considerably lower number of dogs per inhabitant is found in some, but not all, Muslim communities of Africa and Asia; in this particular social and religious context dogs are considered to

Table 1. Densities of dog populations in southwestern Sri Lanka.

Town	Type of area	No. of dogs per indicated unit		
		Household	Human	Square kilometer of habitation area
Moratuwa	Suburban	0.62	0.11	3,000
Galle	Urban	0.97	0.16	2,700
Kataluna	Paddy cultivation village	0.68	0.13	170
Kuda-Oya	Dry farming village	0.45	0.07	30
Negombo	Fishing village	0.61	0.12	1,700

be unclean, and an important resource—shelter and protection for puppies—is not provided. With use of wildlife census techniques to estimate the number of dogs, it was found that there were ~150 ownerless dogs and unsupervised pets per square kilometer in study areas of North American cities [3–5]. In these cities the ratio of ownerless to owned dogs ranged from 1:2.6 to 1:40.5. We registered high densities of the dog population in rural areas of Sri Lanka—a condition that is due to the high density of the human population (table 1).

Dog populations are more heterogeneous than populations of free-living wild animals. Owned and ownerless dogs, confined and free-ranging dogs, and dogs kept for different purposes have different access to resources. Within a population segment of owned, well-supervised dogs, the reproductive rate is relatively low because many dogs are spayed and females in heat are kept under close control [6]. Shelter, food, and water are provided by humans. The mean age in such a population segment is relatively high (~4.5 years for dogs studied in the United States).

The demographic importance of a second segment of the dog population is quite different. These animals also belong to owners, but they are poorly supervised; they reproduce freely, and the rate of success in their rearing is high, since shelter and protection are provided by their owners. One would expect a rapid turnover in population under these conditions. We were surprised to find that the age distribution of a population of poorly supervised dogs in southwestern Sri Lanka indicated a relatively slow population turnover (table 2). This observation is explained by a low rate of reproduction due to the occurrence of *Brucella canis* and possibly other agents that cause miscarriages and sterility. The spread of several dog-transmitted diseases is influenced by the fact that these animals feed on refuse and garbage. The proportion of food provided by the owners

varies with the cultural setting; in many areas owners provide no food to their dogs.

The surplus offspring of the poorly supervised, owned dogs increases the population of ownerless animals. These ownerless dogs are often tolerated, but are fed rarely and irregularly [3, 5]. They seek shelter in uninhabited structures and occasionally in natural structures. The rate of successful breeding is relatively low, in part because of the lack of adequate protection for puppies [3, 9].

Dog Keeping and Services Rendered by Dogs

Dogs are kept for various reasons—as pets and companions, for hunting, as guard dogs or draft animals, for food, or for commercial trade. There are special breeds for certain tasks. Dogs may fulfill other beneficial roles. They may constantly clean and permanently guard a settlement while performing other duties, such as hunting and pulling vehicles, only occasionally. The reasons for the association of people and dogs are frequently obscure. The complicated relations in Polynesia between humans and dogs—with dogs used as food, gifts, and offerings and traded for other items of value—have been described by Luomala [10]. Dogs are kept as pets more often than is evident from the literature. The function of the pet is difficult to define. The psychological im-

Table 2. Composition of age groups of owned dogs in different geographic areas.

Location	Percentage of dog population in indicated age group (y)				
	0–1	1–3	3–5	5–7	7–16
Ohio [7]	19	25	19	12	25
California [8]	13	25	22	16	24
Bern, Switzerland	8	20	17	17	37
Galle, Sri Lanka	24	28	21	14	13
El Kef, Tunisia	36	34	16	9	5

portance of owning a pet is well documented for industrialized societies. To own a pet as a companion may also be more important in hunter-gatherer and peasant societies than has been recognized so far.

On the other hand, dogs may be rejected because they are unclean (in a religious or a hygienic sense), because they bite, or because they are pests, nuisances, or vectors of disease. There are qualitative and quantitative differences between what people think the functions of dogs are and what dogs really do. In certain cultures dogs are thought to be supernatural or related to supernatural powers, either as divine beings or as evil spirits [10–12]. In areas where this is believed, unknown dogs are either treated with respect or avoided.

Frank's monograph [11] concerning the role of dogs in African cultures makes it clear that attitudes toward dogs vary from tribe to tribe, a condition that also has been documented with respect to South America [12]. Some tribes despise and mistreat dogs; others venerate the dog as a cultural hero, as the mythical bringer of fire or grain. In a few areas it is an offense to kill a dog. This is certainly the case where the dominant religion (e.g., Hinduism or Buddhism) prohibits the killing of any living being. But quite often the way dogs are treated is not in accordance with the merits of their mythical ancestors.

Culture and the Responsibilities of Ownership

Attitudes concerning dog ownership and its attendant responsibilities are quite variable, as are thresholds of tolerance for dogs. In industrialized nations the law and the public attitude give people the right to own dogs, but also oblige owners to care for them. Care of an animal must include, but is not limited to, the provision of adequate shelter and of wholesome food and water. The owner of a dog is responsible for ensuring that the dog does not damage public or private property; defecate on public or private property; create unsanitary, dangerous, or offensive conditions; cause disturbance by excessive barking; chase vehicles; or molest, attack, or interfere with persons or other domestic animals.

In other cultures the obligations of dog owners are often considerably less restrictive, but ownership and responsibilities may still be regulated by more or less complicated rules. In the Tlingit (Native American) tribe of northwestern North America, dog ownership is an individual matter, but responsibility for the dog is controlled by the clan. If a dog

bites someone, the owner of the dog is required to compensate the victim only if the injured person belongs to another clan [13]. In another northwestern Native American tribe, the Bella Coola, dog names are clan property and no two dogs may bear the same name at the same time [14].

In rural Hindu and Buddhist areas in Southeast Asia, we observed that the majority of dogs have access to several households where they receive shelter and food. For a limited number of these dogs, a specific household takes some responsibility—for instance, bringing them for vaccination during a rabies immunization campaign; residents often object to the removal of these dogs.

Epidemiology of Dog Rabies

It has long been known that the dog is the principal transmitter of rabies to humans [15]. It is reasonable to distinguish between areas in which dogs are the main hosts of rabies, and areas where reservoirs of rabies are maintained by populations of wild animals—a situation found in America north of Mexico and in Europe, where only 0.1%–5% of the total number of animal rabies cases reported annually involve dogs [16, 17]. In these areas, three factors may account for the low prevalence of the disease in dogs: (1) a large proportion of the dog population is restricted in its movements (i.e., dogs are kept indoors or in enclosures and are kept on a leash when outside); (2) dog vaccination is strongly recommended or even compulsory; and (3) it is possible that strains of virus that are adapted to wild species are not well suited for propagation within dog populations. There is no recent evidence that a wildlife epizootic has given rise to epizootics in stray dog populations in urban areas of the United States or in Europe.

Over large parts of Asia, Africa, and Latin America, rabies virus circulates within dog populations, in which $\geq 95\%$ of all diagnosed cases of rabies occur. In some areas that are not as well studied, wild carnivores may represent a reservoir for the virus. There are also places where a domestic dog population alone maintains the disease. This is certainly true in Madagascar and on some smaller rabies-infested islands, where there are no wild carnivores.

Despite the ease of access to dog populations, not much is known about the epizootiology of canine rabies. Incidence, prevalence, and eventual recovery

rates still need to be recorded, and spatial and temporal patterns await thorough analysis. From the few relatively detailed descriptions available [18–21] one gets the impression that dog rabies is highly enzootic, with only moderate fluctuations of prevalence. The disease is spread from dog to dog by bite, and other routes of infection appear to have little importance. The social context that allows the transmission of virus from an infectious dog to a susceptible one is not known.

Human Rabies and Rabies Prophylaxis in Developing Countries

Human rabies has become rare in Western industrialized societies, where the rabies mortality rate is ≤ 0.005 per 100,000 inhabitants. To a considerable extent this low rate is due to high standards of health education and relatively easy access to postexposure treatment with potent vaccines. The situation is quite different in developing countries, in some of which the number of cases of human rabies recorded annually exceeds 0.5 per 100,000 inhabitants. A variety of cultural factors other than dog-keeping practices and high rates of exposure are responsible. Traditional medical systems and beliefs are incorporated in cultural contexts to explain natural processes (including disease and death) and to relieve anxieties in an essentially hostile world [22]. If supernatural powers exercised by divine beings, demons, and human witches are often incriminated as causes of disease, exorcism may be believed to be the appropriate cure. Rabies and nonfatal diseases may be considered to be a single disease entity by a local diagnostician. There is no doubt, either, that Western physicians and veterinarians are apt to make false diagnoses when they must rely entirely on clinical symptoms and case histories. Rabies is not always thought to be invariably fatal, so an astrologer may foretell the outcome of the infection and give recommendations for treatment. The persons who might be involved in the treatment of a dog bite of a Buddhist Sinhalese patient in Sri Lanka are listed in table 3 (see also [23, 24]). In rural areas of many developing countries, the traditional healer is among the first persons to be consulted for any health problem. The healer represents traditional beliefs and is locally available; a rabies treatment center might be much more difficult to reach. Since dog bites in general rarely lead to clinical rabies and death, the success rate of a traditional healer may appear to

Table 3. Persons that may be involved in curing a dog bite in Buddhist Sri Lanka.

Person	Services rendered
Household member	Wound treatment, application of folk medicine (leaves of drumstick tree)
Buddhist monk	General advice
Ganitaya, kendra-kariya	Soothsaying, advice
Vederala	Application of ayurvedic medicine and advice on nutrition and daily activities
Aedura, katta-duiya, etc.	Exorcism
Dog bite specialist	Application of drugs to induce a rabies-like clinical syndrome and healing of this prematurely induced disease
Western physician	Postexposure treatment with human diploid cell strain vaccine for those who can afford it, free treatment with goat brain vaccine for poorer people

be superior to the efficacy of a physician who is trained in Western medicine and who has at hand only potentially dangerous animal-brain vaccine of poor quality. A healing ceremony can also bring psychological relief, an aspect often neglected in Western medicine.

Control of Enzootic Dog Rabies

The final goal of rabies control is the prevention of cases of human rabies. This can be achieved by reducing the rate of exposure of humans to rabies and by ensuring easy access to potent treatment after exposure. The best way to reduce the rate of exposure is by controlling the disease in its main host, the dog. The classic methods of achieving this are control of the dog population and the vaccination of dogs — methods that were successful in a number of countries in the 1940s and 1950s [2]. Efforts directed toward control of dog rabies have not been as successful recently because of the lack of adequate programs that take into account the biology of dog populations and because of cultural and structural constraints. The planning of control programs is a management task in which geographic coverage, manpower development, and provision of materials and facilities must be coordinated [1]. The size of the dog population in the project area must be

known. The accessibility of dogs for a particular control measure and the proportion of animals to be reached by this measure for the achievement of the desired effect must be taken into consideration [25]. This information allows decisions concerning strategies for the management of the dog population (e.g., stray dog control, reproduction control, habitat control, and vaccination) to be made. It cannot be stressed sufficiently that removal of stray dogs is usually an ineffective method of population control; however, the elimination of those animals that are not in compliance with regulations helps to create public awareness and may promote responsible dog ownership practices. It is clear that the implementation of dog population management and rabies control schemes has cultural constraints. Every program must be in accordance with local practices and beliefs. In nearly all instances, education and information are at least as important as law enforcement.

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