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COMMENTS ON RABIES CONTROL

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Abstract: The possible effect of a change in habitat on the number of foxes and hence on rabies has been examined by comparing the areas of abandoned farms and the number of cases of rabies in foxes for Georgia from 1930-1969. The relation was postulated from the observed abundance of foxes in recently abandoned farms in Georgia. Abandoned farmland in Georgia increased greatly around 1945-50, and an epidemic of rabies occurred in foxes. This correlation suggests that trends in use of land should be considered among the factors influencing future epidemics of rabies in wildlife.

For three decades rabies in wildlife has presented a complex and intractable problem in public health. In contrast, rabies in dogs, due to the use of vaccines, has essentially disappeared from urban and even rural areas. While canine rabies no longer presents a serious problem, rabies in wildlife continues and every decade seems to include more complications.

Thorough studies on the role of gray foxes in rabies were conducted in Georgia 1950-55.[3] At that time, the significance of the type of vegetation in governing the number of foxes was noted. Around that time, efforts at control of foxes were developed in New York[4,6,12] and in Virginia.[9] The current situation in rabies has been summarized.[10] In recent years, other species have been involved, such as skunks[13] and raccoons.[6] Rabies outbreaks in these species are generally more localized and fade out after a few years, as for example, in Ohio (see CDC Zoonoses Surveillance—Rabies). Rabies in bats has presented even more complex problems, but no evidence has been found in the past 15 years that rabies, at least of colonial bats, is associated with epidemics in terrestrial wildlife.

The control of rabies has been attempted by trapping programs in spite of the fact that the basic principle for the control of a species is to manage the habitat. Trapping is emphasized in part because of an action program is appealing to the public and in part because the control of fox habitat presents considerable practical difficulties. Unfortunately, the results of trapping have rarely demonstrated a decrease in rabies or even a decrease in the number of foxes. For example, although 5727 predators were removed[9] from seven counties and rabies declined, the authors made "no attempt to establish causal relation of trapping and reduction of rabies in the seven counties." While there r.ght be a relation, the data do not demonstrate one, perhaps due to the great variability within each county. Trapping in New York[7] produced no reduction in foxes and more significantly showed that removal of 65% annually would allow complete recovery of the fox population each year. The numbers of foxes[12] were greater in areas that lacked rabies, but there was much variation. The authors felt that rabies had reduced the fox population but were unable to marshall data to prove the point. Various studies of bounties, offered to reduce predaceous foxes in an effort to increase game, have likewise fai'ed to indicate that removal affected the population. For example, payment of bounties on 333,000 foxes in 13 years was ineffective[2] and in another area paying $148,000 was not justified.[14] However, an earlier study[1] in reference to stocking pheasants suggested that intensive trapping of foxes from

1947-49 reduced their population to one-fourth the number in the reference area. Also, in Germany,[18] while intensive hunting had no demonstrable effect on numbers, nevertheless an intensive program of gassing burrows did reduce the number of foxes. Information on wolves[11] indicates that when control started in Wood Buffalo Park, a change in age composition of the wolf population occurred but no change in numbers. At least 50% of the adult wolves must be removed each year to alter the population.

Two species of foxes are involved. In northern USA the red fox *(Vulpes fulva)* predominates but in southeastern USA the gray fox *(Urocyon cinereoargentatus)* predominates sometimes to the exclusion of the reds. Differences occur between the species even when living in the same area in behavior and habitat preference. The epidemiology of rabies may also vary between the species in various habitats but the differences may be the result of habitat rather than species. In this article no distinction is made.

Tables 1 and 2 illustrate the number of foxes that needs to be removed to reduce the population using two sets of assumptions about mortality rates (A and B).[10] It is, of course, obvious that a very intensive trapping or poisoning program *can* reduce the population. The question is how many must be removed. The tables make some simplification, principally that all the young are born on March 1. Another simplification is the assumption that the population is stationary from year to year.

In the starting year (table 1) we do not distinguish between adults and yearlings and hence include yearlings among adults. By November 1 on assumption A, 50 adults and 84 pups will die, and similarly by February 28, 26 more adults and 120 pups (now yearlings) will die.

TABLE 1. The number of foxes that are born and die during a year in a stationary population using 2 sets of assumptions[10] labeled A and B about rates. In assumption A summer mortality rates are low but in B are high. The birthrates are the same.

		Foxes by age		Total Foxes		Die	
March 1	Year 1	A	B	A	B	A	B
	adults	128	173	408	548	—	
	pups	280	375				
Nov. 1	Year 1						
	adults	78	78	274	274	50	95
	pups	196	196			84	179
Feb. 28	Year 2						
	adults	52	52	128	173	26	26
	yearlings	76	121			120	75
March 1	Year 2						
	pups born	280	375	408	548		
Nov. 1	Year 2						
	adults*	78	78	274	274	50	95
	pups	196	196			84	179

* *Includes yearlings from Feb. 28 which are now indistinguishable from adults.*

These natural deaths give an idea of the magnitude of mortality and hence what additional mortality is necessary to reduce the population. An important complication is that compensation may occur through a reduction in natural mortality when foxes are artificially removed, as explained in the lower part of table 2. If compensation is 0%, then removal of zero foxes will allow the population to remain stationary. If compensation is 33%, then the removal of 93 foxes will still allow the population to remain stationary because these 93 foxes will not be removed by natural mortality. Similarly, if compensation is 67%, removal of 186, and if compensation is 100%, removal of 280 will allow a stationary population. Unfortunately, we have no data on the extent of compensation in foxes, but evidence from other mammalian populations indicate that it probably is rather substantial. Thus, it might be that the removal of 280 foxes from a population, which on March 1 was 408, would nevertheless allow the population to remain the same. Note that this figure is essentially 70%, which is very close to the figure of 65%.[7]

It is obvious that a very large number of foxes must be removed from an area each year to reduce the population. Now, if the population is reduced, a further change occurs. The reduction of effects from density-dependent factors may allow increased production of young and decreased mortality of young and of adults. Thus, an even larger number of foxes would have to be removed due to an increase in birth rates and a decline in death rate. Furthermore, this high number would have to be removed year after year on a sustained yield basis.

TABLE 2. Number of foxes that must be removed to maintain stationary population (Using only assumption A from table 1).

1. Number of adults	March 1		52
2. Number of yearlings	March 1		76
3. Number of pups produced	March 1		280
Probability of dying:			
4. Adults and yearlings		0.60	
5. Pups		0.73	
Deaths during year:			
6. Adults and yearlings		76	
7. Pups		204	

Results of varying extent of compensation (if a fox is removed one less will die from natural causes). To reduce the population below the stationary level more than X foxes must be trapped.

	When Compensation of adults is	Must trap x foxes: adults	pups	Total
8.	0%	0	0	0
9.	33%	25	68	93
10.	67%	50	136	186
11.	100%	76	204	280

Thus, while intensive removal *could* reduce the numbers of foxes, the effort would be extraordianry. A more effective procedure is to manage the habitat so that the capacity to maintain foxes would decrease and the numbers would decline to a level that hopefully would not maintain transmission of the virus. Gray foxes live in abandoned farm land, bushy ravines and hedgerows, that provide a supply of mice, grasshoppers, berries and other food as well as thick cover for resting sites and for the pups. Reduction of such habitat will reduce gray fox numbers.

Unfortunately management of habitat of a carnivore throughout a state is also very difficult and in a practical sense, impossible. But some understanding of the history of rabies and hence some possible predictions can be derived from an examination of agricultural changes for the past 30 years. Observations[17] indicated that foxes lived in cultivated areas rather than pine woods or mixed woods. The relation of fox numbers to cultivation requires explanation. The foxes of course do not thrive in a plowed field or in one actively cultivated. However, foxes thrive along the edges of a field and in the field during the months of the year that cultivation is not practiced. When a field is abandoned, it provides excellent habitat for about 5 years, after which the pines succeed the herbaceous vegetation and soon dominate the vegetation. Thus, abandoned cropland is excellent habitat for about 5 years and good habitat for another 5 years. Some land is devoted to pasture after a crop or after a few years of abandonment. Pasture, especially in extensive tracts, is poor habitat for foxes.

Analysis of the data for the amount of cropland in Georgia from 1930 to 1969 (Table 3) shows that from about 1944-1952 the amount of abandoned cropland was very great and the number of cases of rabies was very high. After 1952, the amount of abandoned land declined and the percent of land in farms declined indicating that land was becoming forest, or in some cases, pasture. The number of cases of rabies declined until at the present time the number is small. Of course, in the decade around 1930-35 the amount of cropland abandoned was also high, but data on rabies in foxes were both sketchy and confused with canine cases. While this table should not be taken as highly accurate, since a number of assumptions have been made in its

TABLE 3. History of agricultural changes and numbers of rabid foxes in Georgia. Data for agriculture from USDA Census for 1969; Data for rabid foxes in Georgia from Wood[15] and Dr. G. Winkler, Center for Disease Control (USPHS).

Year	Percent of land in farms	Abandoned Cropland [1]	Estimated Foxes [2]	Total Cropland [1]	Estimated Foxes [2]	Rabid Foxes [3]
1930	58.7	844	13300	4571	71400	—
1935	67.3	870	13600	4712	71500	—
1940	63.2	550	8620	4676	71500	41
1945	63.2	814	13000	4257	67500	115
1950	68.8	846	13250	4195	67400	77
1954	64.2	560	8760	3570	55700	89
1959	52.7	494	7760	2983	46600	47
1964	48.0	560	8760	2547	39800	7
1969	42.5	538	8750	2734	43200	7

[1] Given in thousands of hectares.

[2] Based on figures from Lord[8] of 1.6 foxes per km² of cropland.

[3] Average for 5 (or 4) year period around given year.

preparation, nevertheless, it illustrates the overwhelming importance of habitat in the control of populations of foxes. Other explanations, such as differences in reporting, are possible but seem unlikely.

Considering the future of rabies in foxes and indeed in other species, it seems especially desirable to consider agricultural trends as useful for planning long range programs. If one expects large areas to be abandoned or altered in their uses, then one might seriously consider the possibility that rabies would increase. In contrast, intensive agriculture or forestry practices will result in a decline in rabies in foxes. A similar principle should be applied to rabies in raccoons and in skunks, but here the details of their habitat requirements are inadequately known. Careful studies of their habitat need to be conducted to serve as a guide for the planning of public health measures. For example, skunks seem to thrive in some highly cultivated area and raccoons do well in many suburbs. In general, public health programs concerned with zoonoses should consider likely changes in habitat. For example, the vectors of encephalitis depend on land use.[5] At present it seems unlikely that management of habitat can be practiced on a sufficient scale (e.g. an entire state) to reduce fox populations. But a prediction of trends due to changes in use of land may be helpful in planning a public health activity.

The viewpoint expressed here is based on the recognition that trapping programs, while having a great cosmetic effect, have little influence on the numbers of cases of rabies in foxes. However, very intensive removal programs at specially vulnerable areas such as camp sites and picnic grounds would probably reduce human exposure if carried out each year in the spring before people invade the site or at any time that rabies is found in the wild mammals. In planning such a program, the calculations of tables 1 and 2 should serve as a guide to indicate how many foxes must be removed to reduce the numbers. An hypothetical case may be helpful. Suppose a case of rabies appears in a state park of 26 km^2. This area may support 40 foxes in the fall, of which 28 must be removed before any real reduction can be expected. The plans and budget for a removal program must include consideration of the necessary intensity.

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