

Disease dynamics across political borders: The case of rabies in Israel and the surrounding countries

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SUMMARY

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ABSTRACT

An eco-historical analysis facilitated the identification of the socio-political, demographical and environmental changes that have affected the distribution and abundance of vertebrates living in Israeli and Palestinian territories, their pathogens and the extent of human —animal contacts, all contributing to the risk of rabies, leading to three deaths in the late 90's. There are indications that the implementation of uncoordinated control strategies with a lack of an ecological perspective on one side of the border, such as the destruction of the main reservoirs, led to the emergence of a more potent reservoir coming from the other side, and the creation of an additional one yet to be identified. We analyze the lessons of historical mistakes, aiming at future regional control of the disease.

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Palabras clave: rabia, zoonosis, zorros, reservorio, Israel, West Bank, Palestina.

Keywords: rabies, zoonoses, foxes, reservoir, borders health, Israel, West Bank, Palestine.

1. INTRODUCTION

Rabies poses an important public health problem in the Middle East, where its characterization in dogs dates back to ancient documents from the twenty third century B.C (1). Fluctuations in the temporal and the spatial distribution of the animal reservoir and thereby in potential risk to humans, have been observed in Israel and in the West Bank throughout the twentieth century. In recent times, only few people have become ill or died, however, for Israel, controlling rabies has remained a significant economic burden; about \$5,225,000 were spent for this purpose in 1988 (2). Rabies has no cure; a person exposed will develop symptoms and die unless the person gets immediate post-exposure treatment.

As in the case of all zoonotic diseases, the emergence, spread and maintenance of rabies is related to the geographic distribution of the animals that carry the infectious agent. Humans get infected either by direct contact with the reservoir host or most likely by vector animals that live in close proximity to man, such as the dog or farm animals (Figure 1).

Located at the cross-roads of three continents, the eastern Mediterranean is considered one of the richest regions in the world in terms of its bio-geographical heterogeneity (3). However, since the

(1) TIERKEL, Ernest. Canine rabies. In: George Baer (ed.), *Natural history of rabies*, New York, Academic Press, 1975, pp. 123-137.

(2) YAKOBSON, Boris *et al.* An epidemiological retrospective study of rabies diagnosis and control in Israel, 1948-1997. *Israel Journal of Veterinary Medicine*, 1998, 53 (4), 114-126.

(3) CHERNOV, Eitan; YOM-TOV, Yoram. Zoogeography of Israel. In: Yoram Yom-Tov; Eitan Chernov (eds.), *The zoogeography of Israel: the distribution and abundance of a zoogeographical crossroad*, Dordrecht, DRW Junk Publishers, 1988, pp 1-6.

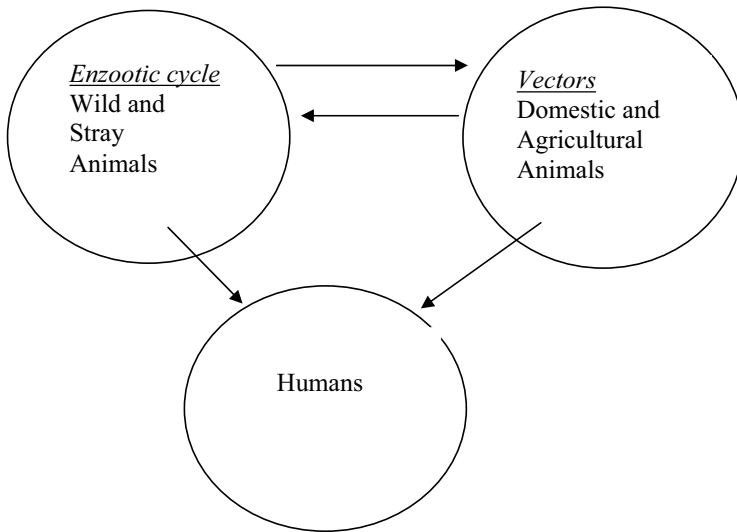


Figure 1.—Routes of transmission

early 20th century the area has undergone constant changes due to population migration, switching of political sovereignties, introduction of new agricultural practices and economical growth. All these developments affected the distribution and abundance of mammals living in the territory(4). Since some of these species are potential reservoirs and vectors of rabies, changes in the ecosystems, that affect these reservoirs and the extent of human-animal contacts, will have an impact on the risk of rabies to humans.

Rabies in the Middle East has been discussed in an ecological context, emphasizing the emergence of the fox as a potent carrier (5); and in a political context emphasizing the role of government in

(4) YOM-TOV, Yoram; MENDELSSOHN, Heinrich. Changes in the distribution and abundance of vertebrates in Israel during the 20th century. *In*: YOM-TOV; CHERNOV (eds.), note 3, pp. 515-547.

(5) BADER, Khalidoun; AWERBUCH, Tamara E.; GREENBLATT, Charles. Reemer

protecting its citizens not just from neighboring enemies but also from diseases that cross political borders (6). The current paper discusses how particular historical pathways have connected events into a complex dynamical system that have sometimes impacted Public Health in counterintuitive ways. Ecological, demographical, political and socioeconomic factors did not directly affect the sudden reemergence of rabies at a particular point in time, nor did they enter the pathways simultaneously. However they strengthen each other even though they occurred at distant time intervals. This approach enables us to analyze the lessons of historical mistakes, which now impact the development of new control strategies. Combining data on reservoirs of rabies in animals and humans throughout the last few decades along with historical markers, enables us to examine the relevant changes in human and animal ecology which had a possible impact on the temporal and spatial distribution of rabies.

Early in the twentieth century and until the mid nineteen-fifties in Israel, rabies was considered enzootic in dogs and jackals (7); while at the same time, in the neighbouring countries, Lebanon, Syria and Jordan (the West Bank included), foxes have been cited as the main reservoir of the disease (8). Before the establishment of the State of Israel in 1948, 3 to 10 human cases were reported annually. The incidence in humans, however, dropped gradually following control programs that affected the ecology of the animal hosts and their pathogens, until no case was seen in Israel after 1960; however, thirty

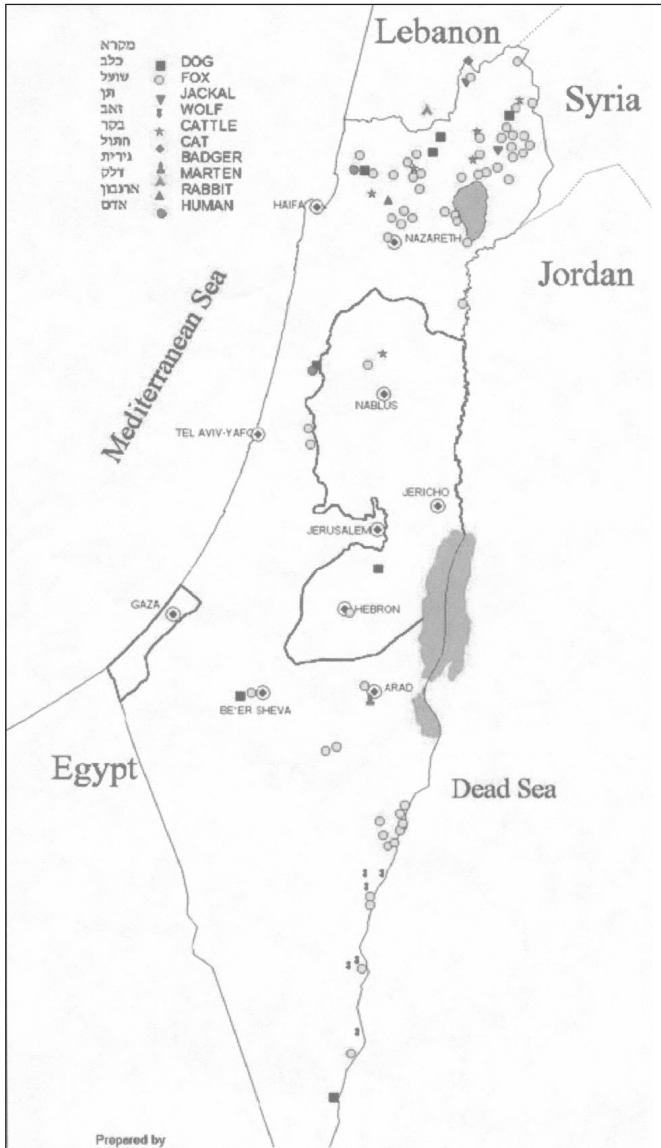
gence of rabies in Israel and the West Bank: the role of the fox. *Infectious Disease Review*, 1999, 1 (1), 20-29.

- (6) AWERBUCH, Tamara E.; BADER, Khaldoun; GREENBLATT, Charles. Ecological continuum and disease transmission across political borders between Israel and its neighbors. *In: Proceedings of the Fourth Nordic Conference on Middle Eastern Studies: The Middle East in a Globalize World*, Oslo, 1998. Available at <<http://www.hf.uib.no/smi/pao/awerbuch.html>>.
- (7) STEELE, James H. Rabies in the Americas and remarks on global aspects. *Reviews of Infection Diseases*, 1988, 10 (Suppl. 4), S585-S597.
- (8) WINKLER, William G. Fox rabies. *In: George Baer (ed.), Natural history of rabies*, New York, Academic Press, 1975, pp. 3-21.

six years later, in the winter of 1996, a new case was reported (9), and two more in 1997 (10). The last case in the West bank was reported in 1971 (11). In recent years Israel has established a policy to alert its citizens as soon as rabid animals are found in proximity to human settlement by declaring the area a «risk zone», as it happened in July of 1996 during an outbreak of dog rabies in Petach Tikva (west to Tel-Aviv). Similarly, the area in the central Arava (south of Israel bordering with Jordan) was declared a risk zone following the discovery of rabid wolves, foxes and domestic animals in June of 1997. (see Map 1)

Control of human rabies has been based on the Rabies Ordinance formulated in 1934 (12); it was revised a few times since then and includes control measures such as annual dog vaccinations which became compulsory in 1957, destruction of stray dogs and cats, and quarantine of suspected rabid animals. However the major accomplishments in rabies control could be partly attributed to two main National Programs: one assisted by the World Health Organization in the early nineteen fifties, introduced a parenteral live-virus vaccine for dogs; and the other, carried out in 1964, was based on systematic poisoning of jackals (*Canis aureus*) —one of the few mammals not protected by the Wild Animals Protection Law enacted in 1954, for the purpose of reducing their damaging effect on agriculture (13). Nevertheless, as mentioned above, the risk to humans never disappeared, nor did it disappear among domestic animals, as its prevalence stayed static over the past 30 years (14). The question is: why?

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- (9) A tragedy of errors: a soldier bitten in the tent died. *Maariv Daily Newspaper*, 1996, November 16.
- (10) DAVID, Dan *et al.* Antemortem detection and virus characterization of three human rabies fatalities in Israel between 1996-1997. *Israel Journal of Veterinary Medicine*, 1999, 54, 66-72.
- (11) BADER, Khaldoun. *The epidemiology and control of rabies in Nablus and the West Bank*. The Hebrew University, (Masters Thesis, School of Public Health), Jerusalem, 1996.
- (12) RABIES Ordinance, 1934. *An ordinance to provide for the prevention of rabies*. <<http://www.israel-embassy.org.uk/web/pages/rabord34.pdf>>.
- (13) YOM-TOV; MENDELSSOHN, note 4.
- (14) YAKOBSON *et al.*, note 2.



Map 1: Geographic distribution of rabid animals in 1997.

Geographic distribution of rabid animals found in Israel and the West Bank. Israel's area: 20,600 sq. km.; 27,800 sq. km. including areas under Palestinian self-government. Length of political borders: 1,060 km.

2. DATA SOURCES

Data on human cases were obtained from records of the Israeli Ministry of Health and the Palestinian Ministry of Health. Data on animal rabies were obtained from the Israeli Veterinary Department within the Ministry of Agriculture, the Nature Reserve Authority, the Palestinian Veterinary Department, and from analyses of questionnaires filled out by residents of the Nablus District (15).

Before the establishment of Israel records were kept initially by the Jerusalem Pasteur Institute established in 1913 and later by the Department of Health of the Government of Palestine (16).

Human data used in our study include information on date, species and location of biting animal. Animal data include information on animal species, starting from 1930, and their geographic distribution in the eighties and nineties. The data is based on results of examination of animals suspected of being rabid which were brought for testing to a central laboratory at the Kimron Veterinary Institute. The Kimron Veterinary Institute established as a small diagnostic laboratory during the British mandate in 1928 and since the establishment of the State of Israel in 1948 has been the main reference laboratory in the country (17). The animal population which was tested, consisted of animals that were killed following biting incidents, that died by poisoning and those that were found dead on the roads (communicated personally by Frankenberg 1996 about his experience working as Chief Biologist for the National Reserve Authority).

Information about control activities was obtained from the monthly reports of the Veterinary Department. We use descriptive methodology to analyze the raw data and no attempt is made to use summary statistics.

(15) BADER, note 11.

(16) YAKOBSON *et al.*, note 2.

(17) YAKOBSON *et al.*, note 2.

3. FINDINGS

3.1. *Characteristics of the animal population involved in the transmission cycle*

3.1.1. *Temporal patterns of rabid animals*

In Figure 2 we present data on animal species diagnosed annually with rabies starting from 1930, some of which are: i) involved in the enzootic cycle in charge of maintaining and amplifying the reservoir and transmitting to domestic animals, agricultural ones, and men; and ii) animal vectors involved in transmitting the disease to domestic and agricultural animals and men as well. These data are an underestimate, because the reporting especially in the case of the wild canids, by and large depends on actually finding the rabid animals in the field. It is likely that most of the wild canids are found because once they become rabid their normal behavior of keeping distant from people is changed and they aggressively approach human settlements (18). On the other hand, it is possible that there are rabid animals that are never found because of their smaller size and because they are active mainly at night.

The profile of all rabid animals show annual fluctuations until the early sixties, then a long period of relative low numbers seen until the early eighties (Figure 2a).

A) Rabies in the wild life

Although more than seven different species in the wildlife have been reported to carry rabies including mongoose, marten and rabbit

(18) MENDELSSOHN, Heinrich; YOM-TOV, Yoram. Canidae. In: Azaria Alon (ed.), *Plants and animals of the land of Israel*, Tel-Aviv, Ministry of Defence, 1984, vol. 7, pp 180-199. [Hebrew].

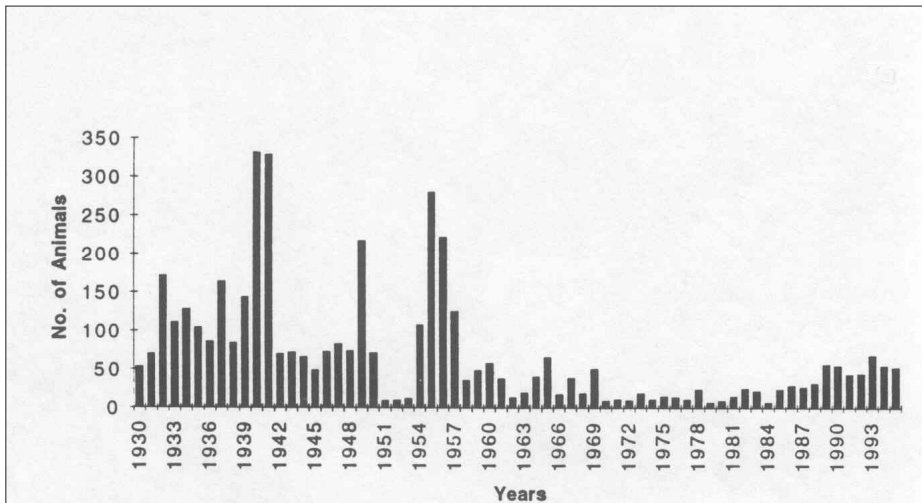


Figure 2a.—Total number of rabid animals found in Israel and the West Bank.

(see Maps) we only present Figures on the annual cases of the main reservoirs (all canids): Jackals, Wolves and Foxes.

Jackals and wolves (Figures 2b and 2c), although they appeared in small numbers early in the thirties, did peak in 1940 and in the late forties; then disappeared completely from the early sixties on. Jackals re-emerged in the late eighties and their numbers were still growing. Rabid wolves, which appeared to be numerous only early in the twentieth century, were not found at all after 1949. Then they re-emerged in July 1997 in the Arava (the desert area in the south of Israel) (see Map1); of six suspected wolves four were killed and confirmed as rabid. Foxes show a third pattern (Figure 2d). They appeared only as singular examples until 1972, and thereafter show a fairly dramatic rise, becoming the main carrier of rabies virus in Israel.

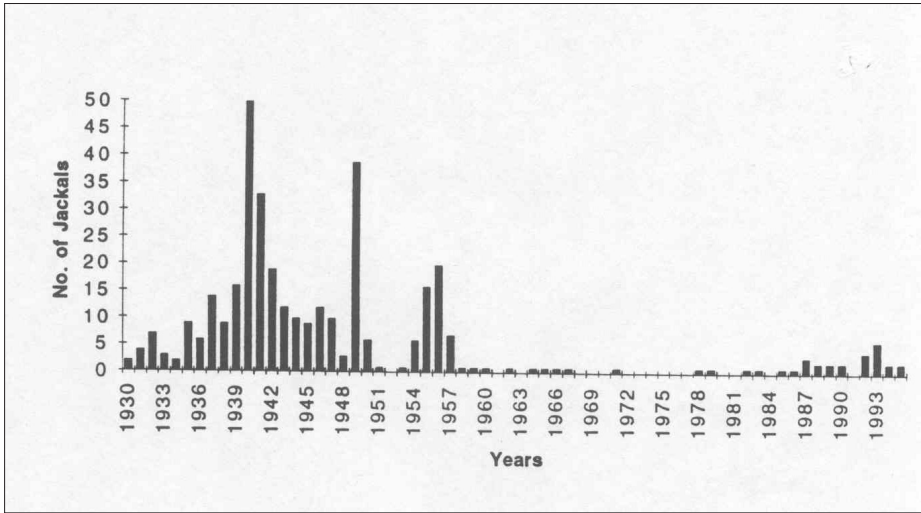


Figure 2b.—Total number of rabid animals found in Israel and the West Bank: Jackals.

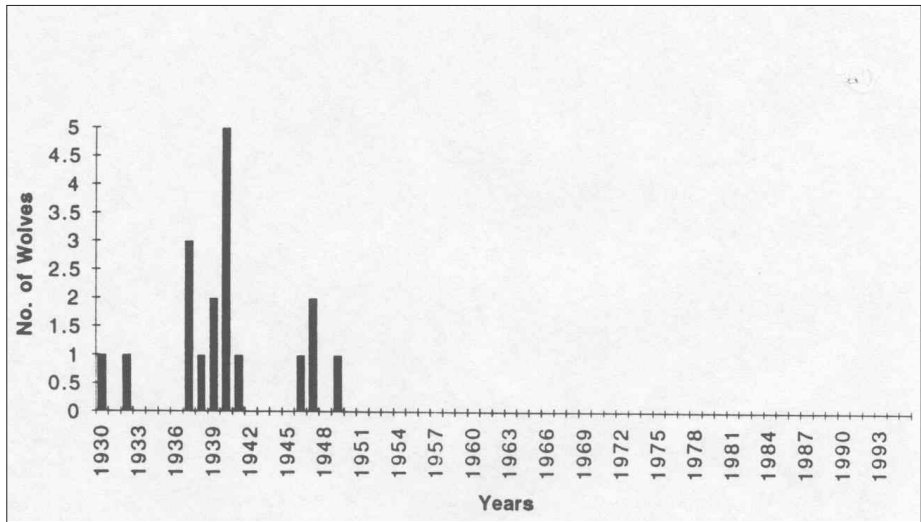


Figure 2c.—Total number of rabid animals found in Israel and the West Bank: Wolves.

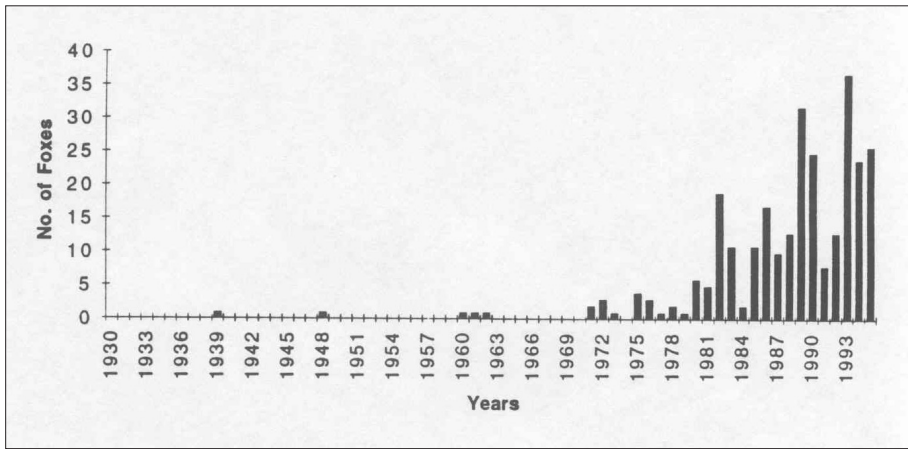


Figure 2d.—Total number of rabid animals found in Israel and the West Bank: Foxes.

B) Domestic and farm animals

Statistics conducted by the Kimron Veterinary Services show that over the past fifty years dogs comprised 50% of the animals diagnosed as rabid (19). However, there were highs and lows as shown in Figure 2e, with most of them diagnosed before 1958.

Cats, both domestic and wild, also appear as a prominent group of the rabid animals from 1930 until the end of the nineteen fifties, but after 1960, only one or two cases sparsely appeared (Figure 2f). Since 1993, although in small numbers, they have constantly found in all last years.

For domestic animals we observe high numbers until about 1948 and then a distinct peak ca. 1954-7 with a lull in between. It is possible that during war times such as the war of independence (mid to late nineteen forties) and the Suez Crisis (the mid nineteen fifties), control programs such as vaccination, quarantine of suspected animals, and

(19) YAKOBSON *et al.*, note 2.

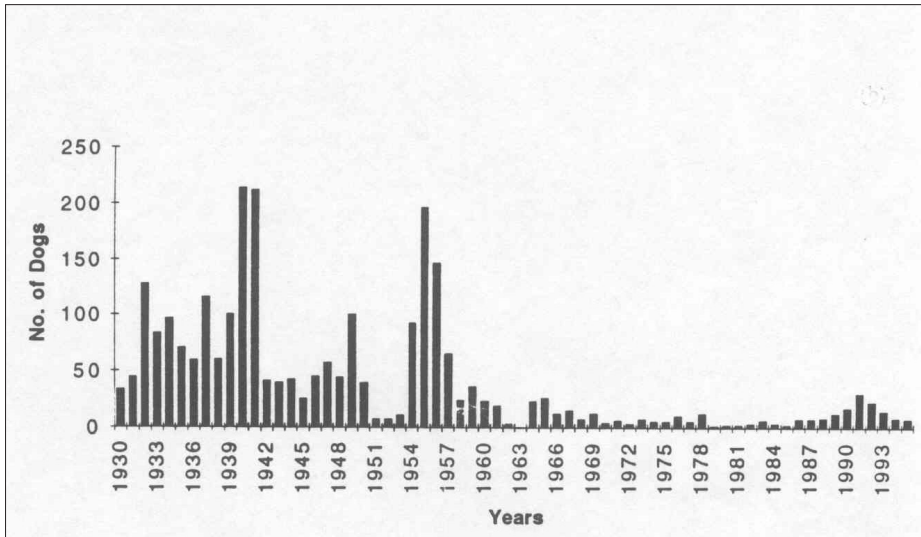


Figure 2e.—Total number of rabid animals found in Israel and the West Bank: Dogs.

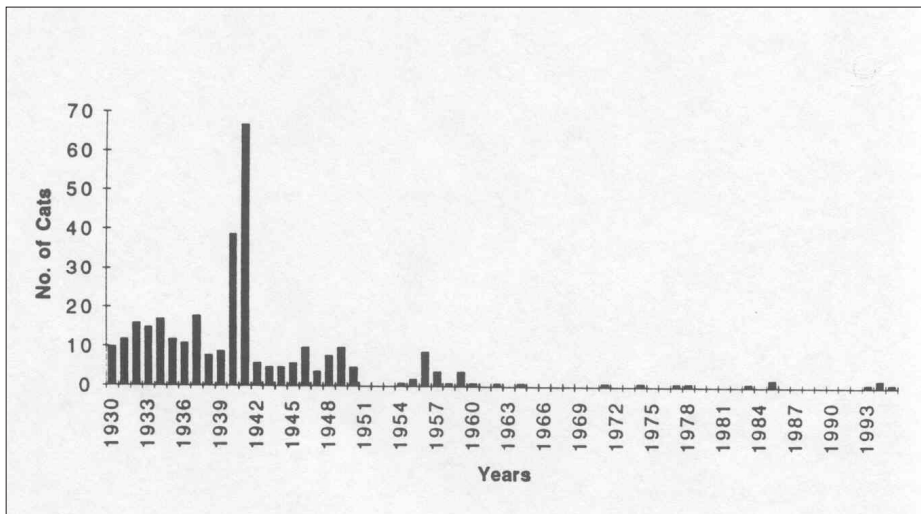


Figure 2f.—Total number of rabid animals found in Israel and the West Bank: Cats.

destruction of stray ones were not readily implemented because of shifting priorities to other national causes.

Agricultural animals (cows, horses, camels, donkeys and sheep) were also among the species affected by rabies. The number of rabid agricultural animals was high even during the nineteen sixties when the total number of rabid animals seemed to be going down, comprising a significant percentage (49.2%) of the total. (Figure 2g). This is consistent with the seasonal exploratory analysis showing that the number of rabid agricultural animals surpassed that of the wild animals involved in biting and transmission (20). The same can be observed in the Map of 1997 (Map 1) where two rabid foxes are found next to a high concentration (eight) of rabid cows and two rabid dogs in the north of the country between Haifa and Nazareth. Probably one wild rabid animal approaching an agricultural settlement is enough to attack a few agricultural and domestic animals.

A comparison between this figure and figure 2a (showing the temporal distribution of the total number of rabid animals) demonstrates that the pattern of highs and lows in the mid fifties are very similar; in 1954 the agricultural animals accounted for about 25% of the total number of rabid animals. This probably coincides with the post-independence rapid agricultural development in Israel. Cows were first brought from Germany to Israel by the Templar Christians in the 19th century. Then the pioneers in the 1920s tried to raise Syrian cows, disease resistant and of good temperament but poor milk producers. Other breeds were introduced to improve the yields. But it was not until 1948 when massive immigration started to pour into Israel (600,000 just in 1948) that the necessity to feed the new comers prompted Israel to augment its efforts to improve this industry. Canadian and US Holstein breeds were imported then to supply milk for the country's growing population (21).

(20) YAKOBSON *et al.*, note 2.

(21) CADOGAN Stephen. Israeli milk yield is envy of dairy world. *Irish Examiner.com*, 2005, March 17. Available at <<http://www.irishexaminer.com/>>

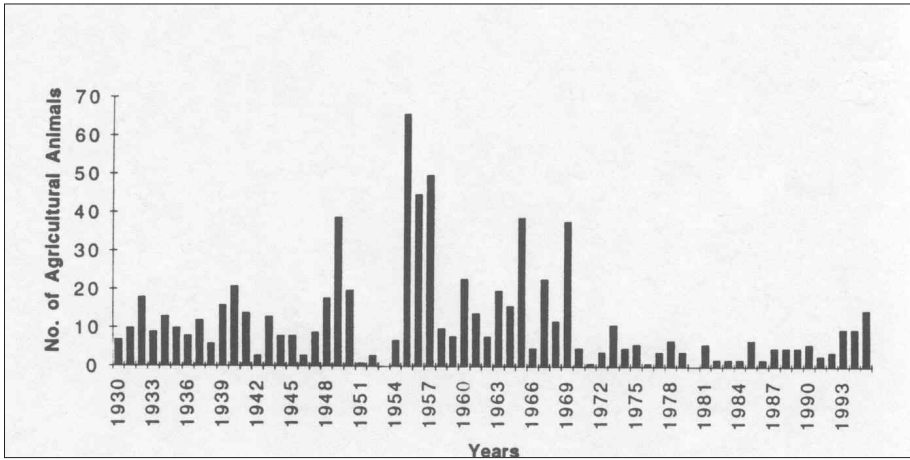
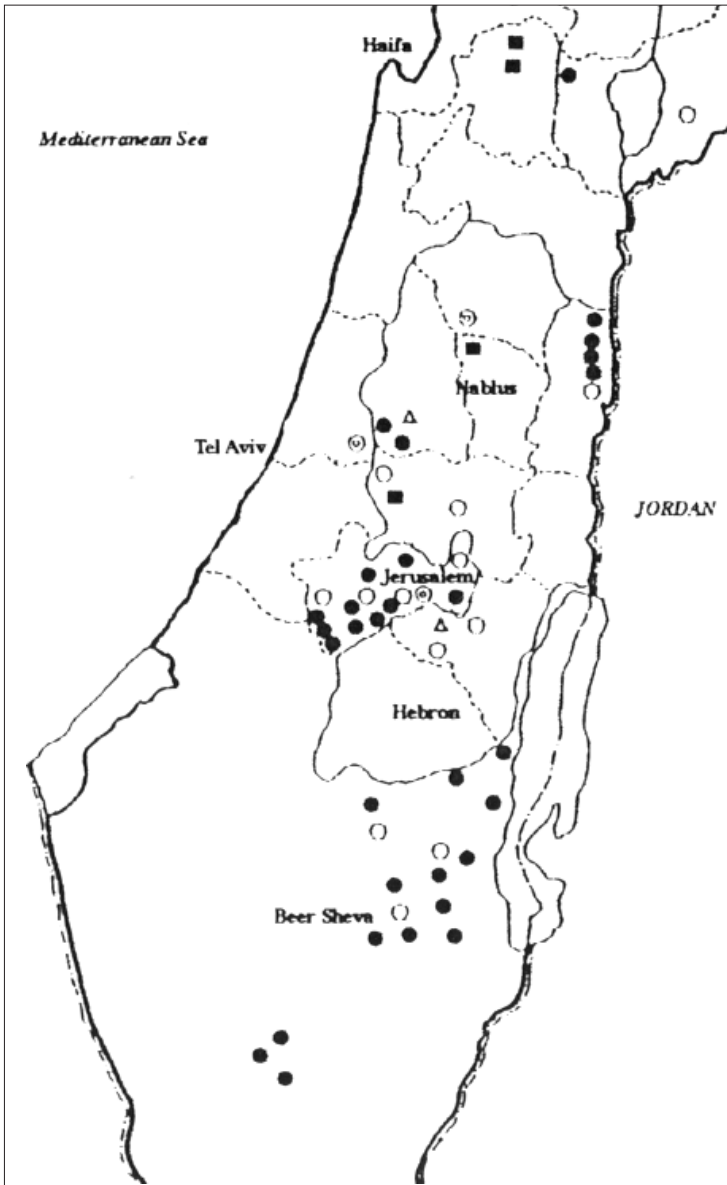


Figure 2g.—Total number of rabid animals found in Israel and the West Bank: Agricultural animals.

This breed adapted well and has been expanding through the fifties and there after. Through improvements in breeding, nutritious feeding and mechanization of milking, Israel has achieved the world record for milk production. Since cows acquired rabies through the reservoir among wild animals, the destruction of the jackals (the main reservoir) in the early sixties led to a reduced number of rabid agricultural animals as compared to the mid fifties.

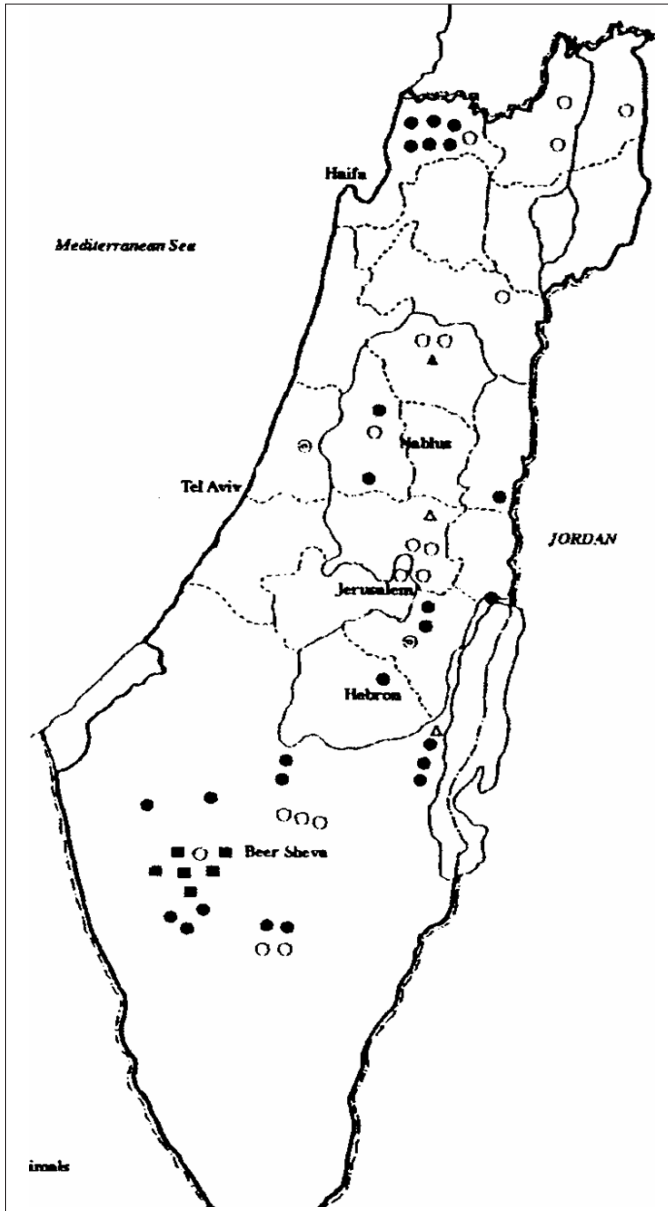
3.1.2. *Spatial distribution of rabid animals*

The rise and fall in the number of rabid animals over time is not equally distributed throughout the territory. Although in the years 1989 and 1990 almost the same number of rabid animals were reported (58 and 56 respectively), they differ in their geographic distribution. While in 1989 there were three main foci: along the Jordan River, around Jerusalem and in the Central Negev, east to Beer Sheba, in 1990 they were found in the Northern Galilee next to the Lebanese border and in the Central Negev, west to Beer Sheba. (Maps 2 and



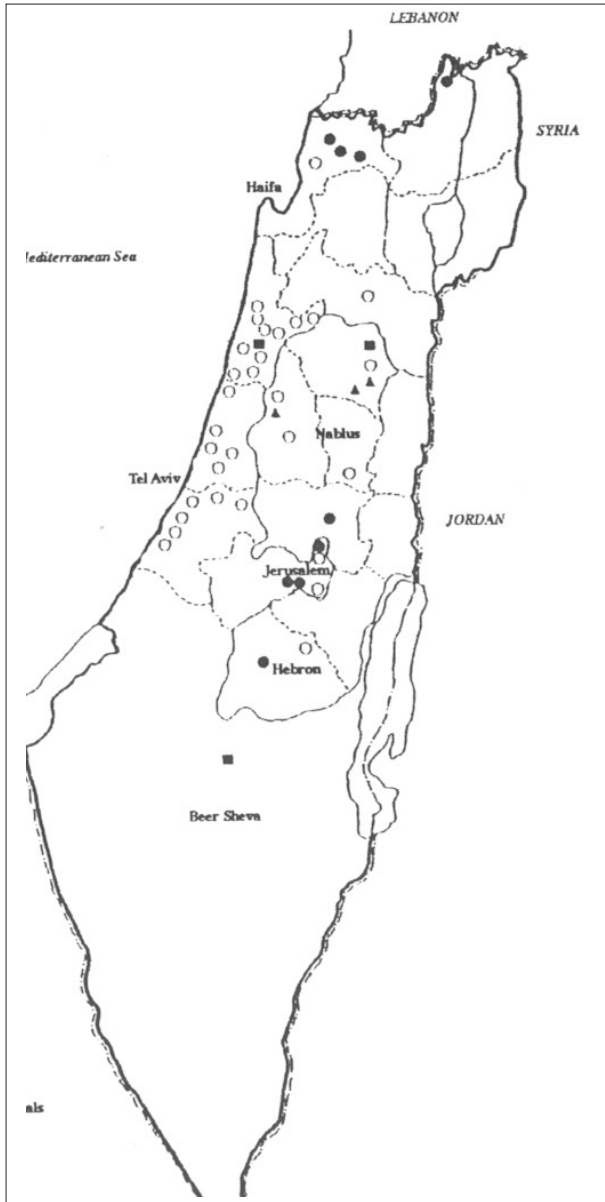
Map 2: Geographic distribution of rabid animals in 1989.

● Fox, ● Jackal, ○ Dog, △ Deer, ▲ Donkey, ■ Agricultural animals.



Map 3: Geographic distribution of rabid animals in 1990.

● Fox, ◎ Jackal, ○ Dog, ▲ Deer, ▲ Donkey, ■ Agricultural animals.



Map 4: Geographic distribution of rabid animals in 1990.

● Fox, © Jackal, ○ Dog, △ Deer, ▲ Donkey, ■ Agricultural animals.

3). All these foci include a relative high number of foxes, but because they are segregated geographically it is likely that they carry different types of the virus —as a molecular and antigenic characterization from various areas in Israel has shown, that at least 5 genotypes of the virus, each particular to a geographical locations, are involved in the epidemiology of rabies in Israel (Map 5) (22). Although each focus might have evolved independently, genetic analysis of all the Israeli variants in the various foci show great similarity to the variants in other neighbouring countries such as Southern Lebanon, Iran , Oman and Saudi Arabia, indicating that animal migration is a vehicle for the spread of rabies (23).

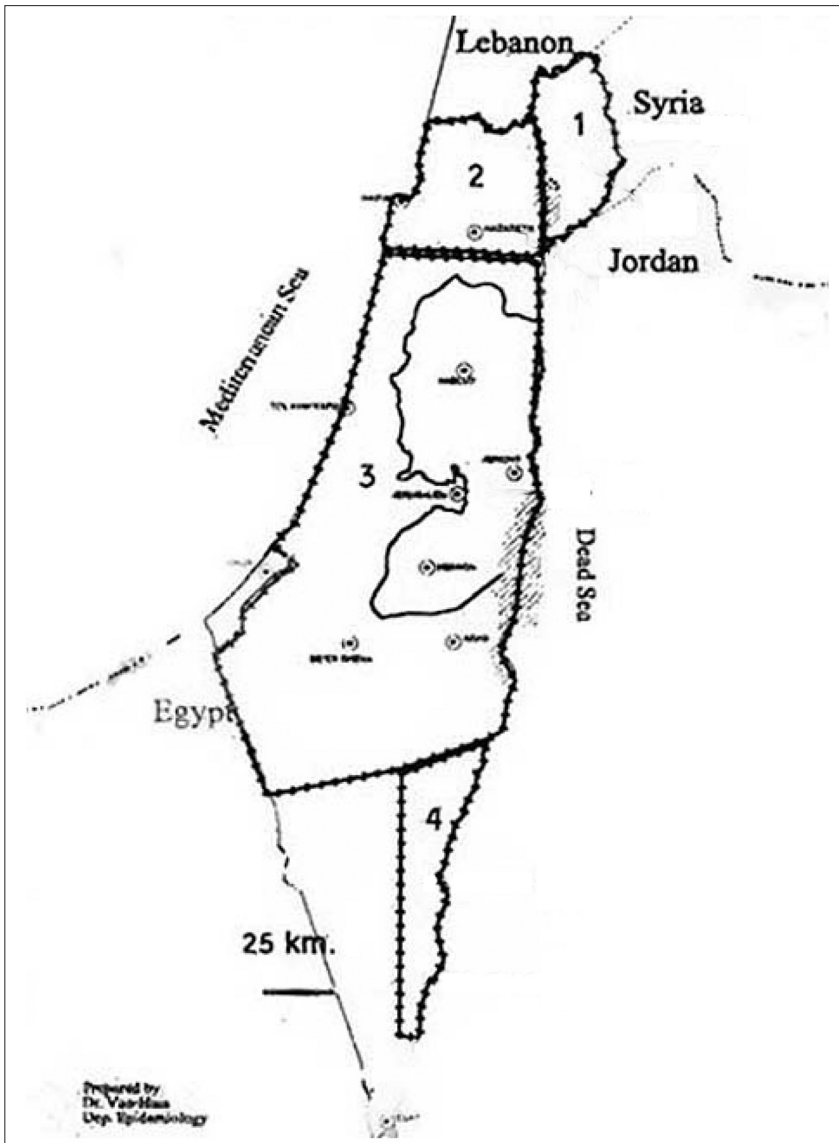
A particular species may be more abundant in one year than another and clusters appear in more than one site. For example, the year 1989 was abundant in rabid foxes compared to 1988 (32 vs 13) with three main clusters as described above, while in 1988 there was only one cluster, around Jerusalem.

The Israeli Veterinary Services noted that 1991 was an unusual year in its geographic and species distribution of rabid animals. From 1979 until 1991, rabies was sylvatic (circulating mainly within the local fauna); however in 1991, for the first time in many years the dogs contributed nearly 70% to the total number of rabid animals. They were found mainly along the coastal plain which has the highest human population density in Israel (Map 4). This phenomenon was attributed to the Gulf war which prompted the migration of people from highly populated urban areas to rural ones, leaving behind unvaccinated dogs which were exposed to feral ones that were free to enter the semi-abandoned cities (24). In 1992 the situation reversed to the previous pattern of predominantly sylvatic rabies, following an elimination campaign against stray dogs.

(22) DAVID *et al.*, note 10.

(23) DAVID *et al.*, note 10.

(24) SHIMSHONI, Arnon. Epidemiology of emerging zoonoses in Israel. *Emerging Infectious Disease*, 1997, 3, 229-238.



Map 5: Distribution of rabies virus isolates in Israel based on molecular approach. Source: David, D. *et al.* Molecular epidemiology of rabies virus isolates from Israel and other Middle and Near-Eastern countries. *Journal of Clinical Microbiology*, 2000, 38 (2), 755-762.

3.2. Risk of rabies to the human population

Criteria for rabies prophylaxis have been established by the World Health Organization (WHO) as presented in Figure 3.

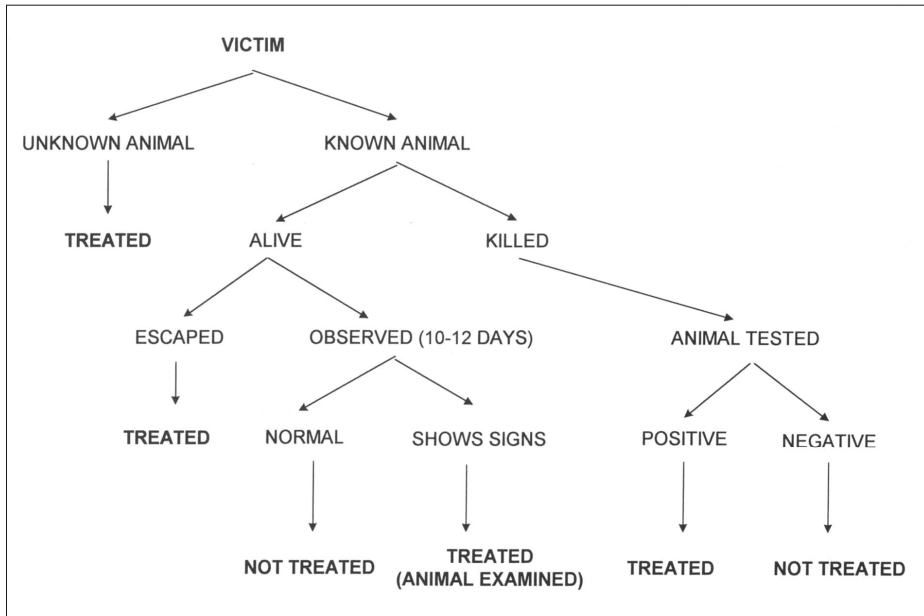


Figure 3.—Flow chart representing criteria for post exposure treatment starting with a victim bitten either by an unknown or a known animal. Source: WHO, Guideline for dog rabies control. Geneva, 1987. VPH/83.43 Rev. 1.

Since rabies is fatal, increasing awareness and education of the risk of rabies in recent years have led to an increase of the number of exposed people seeking post exposure treatment (Figure 4). The high peak in 1992 requires special attention. It reflects a possible response to the increase in rabid dogs attributed to the Gulf war in 1991. A similar pattern has been seen in the Nablus district of

the West Bank (25). These data are an overestimate of the real risk of rabies because most probably not all people receiving treatment were indeed bitten by a rabid animal since in many cases the biting animal was not available for testing (Figure 3).

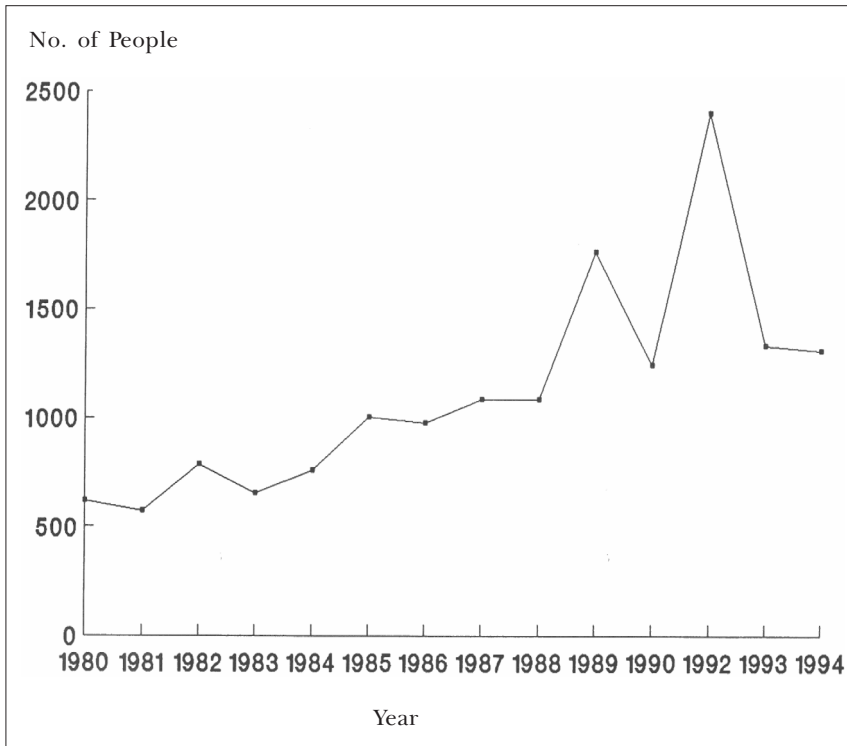


Figure 4.—Number of people receiving post exposure treatment.

The distribution of animals found to bite humans that received post-exposure treatment between the years 1990 and 1996 in Israel is presented in Table 1.

(25) BADER, note 11.

TABLE 1
*Distribution of animals that had bitten people who received post-exposure treatment
 1990-1996*

<i>Animal</i>	<i>Number of People</i>	<i>% of People</i>
Dog	6869	78.4
Cat	1487	16.3
Cattle	153	1.7
Foxes & Jackals	185	2.0
Others	412	4.5
Total	9106	100.0

Most of the treated people in the state of Israel were at risk of rabies through dog bites, on average 78%; so was the case in the West Bank, 64.1% respectively (26). Wild canids (foxes and jackals) were not responsible for a significant number of human bites; on average 2%. In the West Bank, donkeys were responsible for 15.8% of the bites and rats for 11.2% (27) while in Israel, cats assume a more important role: on average 16.3% of treated people were bitten by cats (Table 1).

4. DISCUSSION

Although the occurrence of the disease in people was reduced due to the partial success of dog vaccination programs in the nineteen fifties, dilution of the wild animal reservoir and interventions targeted towards exposed individuals, transmission required to maintain the reservoir was never interrupted. This is supported by the fact that infected animals have been found throughout the years. Moreover, since the early 1970s there has been a growing trend (28). In parallel, the number of people receiving post-exposure treatment, has been growing as well (Figure 4).

(26) BADER, note 11.

(27) BADER, note 11.

(28) BADER, note 11. YAKOBSON *et al.*, note 2.

It is interesting that each of the last three episodes of human deaths due to rabies in Israel (reported in December 1996 and 1997) was the result of an infected bite or scratch by a small unidentified animal (29). The first young victim, a soldier, was bitten while camping in the north, did not get the whole regimen of post-exposure treatment and died. The virus recovered from the patient was analyzed and found to be the same variant as the one isolated from foxes in the north-eastern part of the country (Map 5) (30) despite the fact that it was not a fox that bit the victim.

Dogs and Foxes constituted the majority of infected animals in Israel and the West bank, found to be infected with rabies. However while foxes and dogs equally contributed to the infection load among animals in the West Bank between the years 1986 and 1994, the percentage of rabid foxes in Israel over the same years was much higher than rabid dogs (Table 2).

The data shows that, although a high percentage of wild animals are involved in rabies transmission (Table 3) (31), the great majority of people in Israel and the West Bank who were treated for rabies were bitten by dogs, while wild canids contributed very little to human exposure between 1990 and 1996 (Table 1). This suggests that although a reservoir is maintained within the wild animal population, the main vector for transmission is the dog. This is consistent with findings that dogs account for most of the human cases world wide and for most of the post-exposure vaccination (32). Nevertheless, in our region they account for 64% to 78% of the cases while world wide the dog contribution is a lot higher, reaching 95%. This might be related to cultural differences in the relations between humans and animals which have an impact in the pattern of exposure. For example, in the West Bank, donkeys accounted for 15.8% of the bites, probably

(29) DAVID *et al.*, note 10.

(30) DAVID *et al.*, note 10.

(31) YAKOBSON, Boris. *Rabies in Israel, 2003*. Available at <http://www.israel-mbassy.org.uk/web/pages/isr_rab.htm>.

(32) BADER, note 11.

TABLE 2
*Annual percent of animal species diagnosed with rabies in West Bank and Israel
 from 1986 to 1994*

WEST BANK		
<i>Year</i>	<i>Dog Percentage</i>	<i>Fox Percentage</i>
1986	11.1	77.8
1987	37.5	50.0
1988	50.0	33.3
1989	29.4	23.5
1990	36.8	36.8
1991	45.4	18.2
1992	50.0	35.0
1993	40.0	50.0
1994	33.3	53.3
Total	37.8	39.5

ISRAEL		
<i>Year</i>	<i>Dog Percentage</i>	<i>Fox Percentage</i>
1986	38.6	47.6
1987	25.0	30.0
1988	13.0	43.0
1989	19.5	65.8
1990	30.5	48.6
1991	73.5	20.6
1992	50.0	23.0
1993	18.0	51.7
1994	18.6	52.6
Total	28.6	45.8

TABLE 3
Mean annual number of rabies cases in animals and humans, 1948-1995

<i>Years</i>	<i>No. of years</i>	<i>Domestic animals</i>		<i>Wildlife</i>			<i>Fauna (%)</i>	<i>Human cases</i>
		<i>Dogs</i>	<i>Cats</i>	<i>Foxes</i>	<i>Jackals</i>	<i>Other fauna</i>		
1948-1957	10	72.0	3.9	0.1	9.9	0.4	12.0	23
1958-1966	9	19.4	0.9	0.3	0.8	0.1	5.6	2
1967-1978	12	8.6	0.3	1.3	0.3	0.16	16.5	2
1979-1990	12	6.2	0.25	12.6	1.25	1.3	70.1	0
1991-1992	2	27.0	0	11.0	2	0	32.5	0
1993-1995	3	14.25	1.25	35.25	4	4	72.2	0

Source: <http://www.israel-embassy.org.uk/web/pages/isr_rab.htm>

because donkeys are used there as one of the means of transportation mainly in agricultural settings(33), On the other hand Israeli agriculture relies less on animal labour and more on agrotechnology. It has been reported that in order to develop cost effective agricultural production, meaning increase high quality yields at minimal cost, innovative machinery has been designed, manufactured and widely used in Israel(34).

In Israel the high percentage of cats that bit people who received post-exposure treatment, despite the fact that few cats were reported rabid, indicates that there is close contact between these animals and humans. Indeed, approximately eight thousand cats are annually destroyed by the veterinary services(35).

It is reasonable to think that transmission of rabies to agricultural animals is due to either direct exposure to the wild animal reservoir or to dogs that were bitten by rabid wild animals. Wild animals are likely to enter agricultural settlements in search of food in garbage dumps placed usually at the periphery of the settlement. Unrecorded anecdotes tell that in some instances one single rabid jackal was able to infect several agricultural animals once it entered the settlement(36).

Such a situation is exemplified in the 1997 Map (Map 1), where in the north of the country between Haifa and Nazareth, two rabid foxes are found next to a high concentration (eight) of rabid cows and two rabid dogs.

The main goal of a rabies control program from a Public Health perspective is to prevent as many human cases as possible. This goal

(33) BADER, note 11.

(34) FEDLER Jon, Israeli agriculture: Coping with growth. *Israel Ministry of Foreign Affairs*, 2002, July 12. Available at <<http://www.mfa.gov.il/mfa/history/modern%20history/israel%20at%2050/israeli%20agriculture-%20coping%20with%20growth>>.

(35) YAKOBSON *et al.*, note 2.

(36) Communicated personally by the late Dr. Goldblum in 1997, an infectious disease scientist at the Hebrew University, who observed this phenomenon while working in a kibbutz, in the nineteen fifties.

can be achieved by intervening at any point of the transmission route illustrated in Figure 1.

Interruption of viral transmissions from wild animals to humans and domestic animals could be achieved by a reduction of the wild animal population to a size beyond the threshold needed to maintain the natural infection cycle. Although this strategy of population management by hunting and poisoning (which affected also species not involved in rabies transmission), implemented in Israel until the mid sixties might have temporarily reduced the probability of human contact with biting animals (thereby lowering exposure to infection), the main goal of population reduction to a level that does not support the viral reservoir was never achieved. Instead, although the anti jackal campaign in the sixties managed indeed to reduce the number of jackals and wolves, it created a new niche for the foxes, shifting the ecological balance and enhancing the role of the fox in maintaining the transmission cycles of the rabies agent (Figure 2b, 2c, and 2d).

There was a combination of factors affecting the population size of jackals and wolves, reflecting their contribution to the number of rabid animals found throughout the years until the early sixties. Changes in agricultural practices after the establishment of Israel, such as the prohibition of disposal of offal and dead animals, made food less available to scavengers, jackals and wolves among them. Also the wide use of chemicals in agriculture, which was introduced after the Second World War, had its most noticeable effect in the 50s and 60s; residues of thalium sulfate and fluracetamid, used mainly against rodents, accumulated in bodies of secondary consumers such as predatory mammals, having a major impact on their abundance, reducing their numbers. Then, in 1964 the jackal population in Israel was targeted for eradication, as it was incriminated for damaging plastic sheet used to cover crops (37). The massive campaign was based on the systematic poisoning of jackals through the introduction and dispersal of poisoned chicks. This campaign had an effect on the

(37) YOM-TOV; MENDELSSOHN, note 4.

other mammals as well, all of which, however, except the wolf and the jackal, recovered within a few year (38). The population of jackals started to reappear in the late eighties in areas where tourists made food leftovers available and where garbage was not readily disposed. This is reflected in the reemergence of rabid jackals (Figure 2b). In 1997, a total of 3 rabid jackals were found in the north (Map 1).

It is reasonable to think that the jackals which had predominated in the region and were destroyed as described above made room for foxes which migrated from neighboring countries, where they had been recognized as a major rabies reservoir and vector (39). Moreover, the general fox population in the region might have increased in the last decade as a consequence of changing economies. Presumably, the large unemployment in the West Bank enhanced by the Intifada (the Palestinian uprising during the late 1980s and early nineties), resulted in a stagnant economy. Deprived of reasonable employment, mainly in Israel, Palestinians turned to develop their own micro-economy. Thus, many residents in the West-Bank decided to raise chicken in their newly started farms, which attracted foxes that harboured rabies and spread it to other neighbouring areas (40). Also foxes are known to be more sensitive to contracting rabies than other species (41), thus the numbers in Figure 2d might represent not just a growing population of foxes but an increase in the prevalence of the disease in their population.

Calculations have shown that an epizootic wave of fox rabies can move at a rate of 30-60 Km per year depending on many factors such as population density, immune level, seasonal dispersion, animal behavior and territorial barriers (42). Thus, the particular geographical shape of

(38) YOM-TOV; MENDELSSOHN, note 4.

(39) WINKLER, note 8.

(40) PALESTINIAN National Authority, State Information Service. *Agriculture in the Palestine during the first Intifada (1987-1993)*. Available at <<http://www.pnic.gov.ps/english/agriculture/agri27.html>>.

(41) AUBERT, Michel F.; MASSON, E.; ARTOIS, Marc; BARRAT, Jacques. Oral wildlife rabies vaccination for field trials in Europe with recent emphasis on France. *Curr. Top. Microbiol. Immunol.*, 1994, 18, 219-243

(42) WINKLER, note 8.

Israel, with long political borders and narrow width (see distances in caption to Map 1) makes the country especially vulnerable to disease invasion, in particular where there is an ecological continuum across its political borders. At the time the wild animal control programs were implemented, the West Bank was part of Jordan; Israel and its neighboring states had no diplomatic relations and no coordinated control policies; in fact, control policies in Israel were designed and implemented independently of those in neighboring countries; and therefore the results were counterproductive as demonstrated above.

Foxes have recently adapted to exploiting food from garbage dumps. Thus they modified their behavior as a response to human activity, a behavior promoted by a deficiency in garbage collection as part of deterioration in the infrastructure in some parts of the West-Bank—one of the consequences of political unrest during the last decade. This suggests that habitat manipulation by keeping food away from wild animals might be another way of population control.

A possible strategy for the control of rabies transmission among the wild life is an oral vaccination program that will reduce the prevalence of infection among these animals. Such a program, was successfully implemented in 14 European countries against the red fox (43). In 1998 an inter-ministerial national task recommended the implementation of such a program in Israel as well. As a result, funds were made available to the Kimron Veterinary Institute, for full-scale laboratory and field trials. Field trials initiated in 1999 in the North of the country, which included baiting from the air in the designated area of approx. 400 sq. km (2% of the area of Israel), in Central Galilee, were expanded in 2000 to include additional areas in the Northern and Central parts of Israel. Following the implementation of this vaccination program a gradual decrease in the number of infected animals was observed in the treated areas, dropping to zero in the year 2002 (see Map 6 of 2002 vs. Map 1 of 1997).

(43) YAKOBSON *et al.*, note 2.

Although 40 foxes were reported rabid during the year 2000, none was seen in the treated area, suggesting that this immunization was sufficient to interrupt the transmission cycle in this region(44).

Another target for control is the interruption of transmission from vectors to humans aimed at reducing vector to human contact. Despite of the high percentage of wild canids found among rabid animals in Israel and the West Bank (Table 2), dog bites were the most likely cause of transmission to humans. This is based on the observation that dogs comprised 78% of diagnosed animals in Israel that had attacked people who subsequently received post-exposure treatment (Table 1) and 64.1% in the West Bank(45). One can only speculate that the feral dog which is responsible for human bites is the connecting link between the wild canid reservoir and the human victim. In some ecological settings however, dogs can achieve densities that will allow them to maintain a reservoir(46) and perhaps enrich the wild one (Figure 1). It is not clear that this is the case in the region and further research has to be conducted in order to either establish or rule out this possibility. Controlling human-dog contact is usually achieved by limiting the size of the domestic and stray animal population or by restricting the movement of this population(47).

In Israel, the stray dog population is controlled by systematic destruction carried out by personnel of the Nature Reserve Authority; stray dogs found within half a kilometer of any human settlement (village, town, or city) are immediately shot(48). Thousands of dogs are annually destroyed by this method. From 1976 to1997, an average of 18,320 dogs was annually destroyed. This policy is in accordance with the WHO guidelines for dog rabies control(49). The domestic

(44) YAKOBSON, note 31.

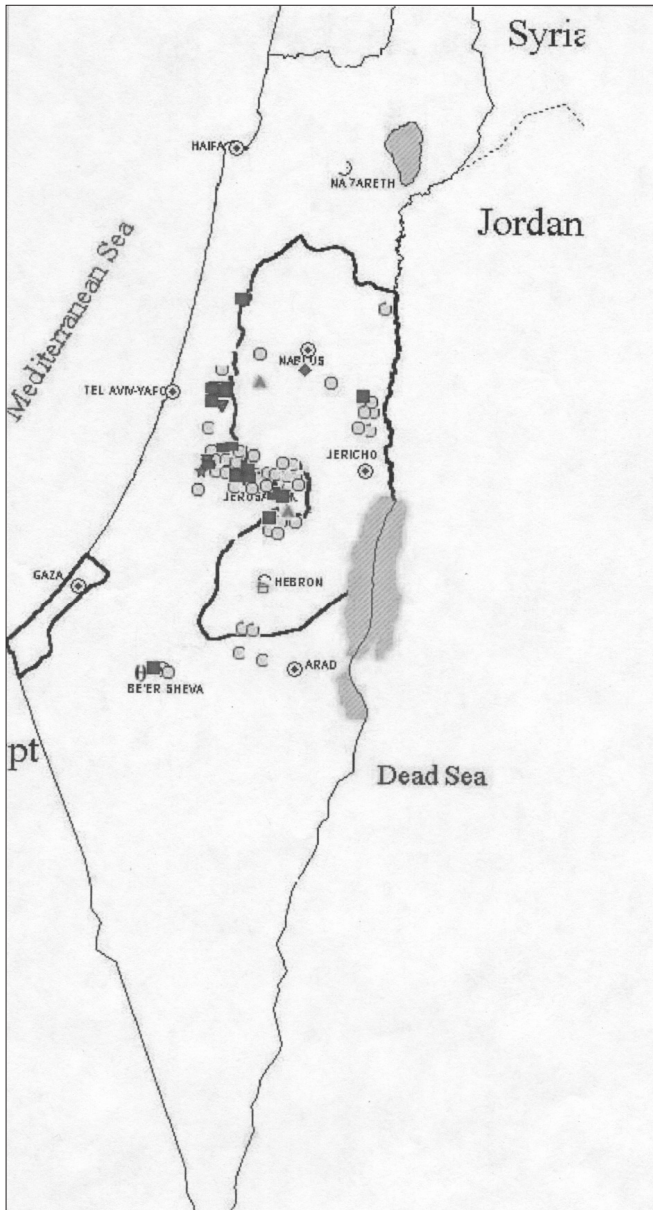
(45) BADER, note 11.

(46) BERAN, George W.; FIRTH, M. Domestic animal rabies control: an overview. *Reviews of Infectious Diseases*, 1988, 10 (Suppl. 4), S672-S677.

(47) WANDELER, A. I. *et al.* Dog ecology and dog rabies control. *Reviews of Infectious Disease*, 1988, 10 (Suppl. 4), 684-688.

(48) Frankenberg, 1996, personal communication.

(49) YAKOBSON *et al.*, note 2.



Map 6: Geographic distribution of rabid animals in 2002

The symbols representing different rabid animals are the same as in Map 1.

dog population is required to be registered and vaccinated by law (50) although the rate of compliance is estimated to be rather low —60% only, which is lower than the 70% required by the WHO (51).

In the West Bank, poisoning by the strychnine baits was used as the main control strategy of dogs. It was estimated that at best only 11.7% of the total dog population in 1994 was destroyed by this method. This percentage is very far from being effective as it should reach 50-80% in order to achieve maximum control (52). Destruction of only a small percentage of the dog population by any method could act adversely on control efforts since this will provide the remaining stray dogs with better living conditions favoring their reproduction.

In the West Bank there is no vaccination program in action, and the number of vaccinated animals is very low and insignificant (53). In the years 1991-1992, the dogs comprised a higher percentage of diagnosed animals. This increase was probably a result of developments during the Gulf War, as rabies spread among dogs in Israel which moved freely to the West-Bank.

The fact that there has been no human case from 1960 until 1996 in Israel, despite the fact that rabies has been sylvatic in the region and people were exposed, is due to the success of Post-Exposure Treatment and the high awareness of the human population living in close proximity to possible domestic reservoirs animals (54). However, the emergence of the last three human cases is due to a growing sylvatic reservoir. All three were bitten or scratched by unidentified nocturnal animals while sleeping outdoors (55).

(50) BERAN; FIRTH, note 45.

(51) YAKOBSON *et al.*, note 2.

(52) BERGER, Stephen A. *Infectious Diseases of Israel*, Jerusalem, Gefen Publishing House Ltd., 1991, pp. 85-87.

(53) BADER, note 11.

(54) COHAVY, A.; DAVIES, A.M Animal bites in Israel. An epidemiological analysis with special reference to the problem of rabies. *Journal of Tropical Medicine and Hygiene*, 1960, 63, 251-257.

(55) DAVID *et al.*, note 10.

5. CONCLUSIONS

Rabies remains a main Public Health problem in Israel and the West Bank; without all the efforts to prevent rabies during the last few decades by the Israeli veterinary services, we would have seen many more human casualties than the three we observed in the late nineteen nineties. However, the decision to destroy the jackals in the early sixties, mainly because of the damage they caused to agriculture, vacated a niche for other species. Lacking an ecological perspective, the Ministry of Agriculture failed to foresee the effect of this intervention on the emergence of rabies. Interestingly, such knowledge was not new at the time. The concept of the «ecological niche» introduced by Grinnel in 1917 (56) and later expanded and discussed by Elton in 1927 (57) and Gause in 1934 (58) had been widely studied and used in biological research.

Given the accepted ecological wisdom, it should have been possible to predict that the disturbance in the ecological balance by destroying one species would make room for another, in this case coming from the other side of the border, and to anticipate the emergence of rabies in the region. However, this did not happen, perhaps because the policy makers did not have a formal education in Ecology, and therefore Ecology was not part of their conceptual thinking. Even if this were not the case, perhaps lack of political communication with neighboring countries would have prevented co-ordinate activities. Only recent awareness of past failures prompted the Ministry of Agriculture to intervene in different ways, such as by introducing an oral vaccine affecting rabies in the wilderness (map 6).

It is important to point out that though rabies among animals was well monitored by the Ministry of Agriculture, and its emergence could have been used to alert the Ministry of Health in charge of

(56) GRINNELL, J. The niche-relationships of the California Thrasher. *Auk*, 1917, 34, 427-433.

(57) ELTON, Charles. *Animal ecology*, London, Sidgwick and Jackson, 1927.

(58) GAUSE, Georgyi. F. *The struggle for existence*, Baltimore, Williams and Williams, 1934.

protecting humans, it failed to do so, resulting in the three human cases in the late 90s.

As we saw from the patterns of rabies emergence and spread in Israel and the West Bank, implementation of controls on one side of the border will strongly affect the emergence of the disease coming from the other side. Thus, a control strategy will be effective only if it is based on regional cooperation, including: epidemiological surveillance, interruption of transmission through population management and control, the development of an oral vaccine, registration and immunization of domestic animals, education and implementation at all levels of the political organization, from the community level to the ministerial one. So far, none of these elements have been pursued completely. In view of the new peace prospects in the Middle-East, it is expected that the ministries of agriculture and health in the region will form appropriate committees, to develop policies based on an ecological approach, to prevent the emergence of infectious diseases, and respond promptly and efficiently if they emerge. An effort of this sort to control infectious diseases transmitted by mosquitoes and flies that periodically cross national borders in the region was made in August 1994 following the Oslo accords through «the First Middle East Regional Coordinating Workshop on IPM of Insects Harmful to Agriculture and Public Health» held in Taba, Egypt. Participants from Israel (headed by Joel Margalit), Jordan (headed by Munther Haddadin) and the Palestinian territories (headed by Jamal Safi), with American representation (headed by Andrew Spielman) and USAID funding met with enthusiasm about the prospect of cooperation (59). Munther Haddadin announced right at the start that although he brought with him the king's blessing, he would disagree to make public announcements or submit press releases. The formal Washington Peace Declaration was signed by Jordan and Israel only a year later, on 25th July, 1994 (60). Memoirs of the meeting and reports about

(59) AWERBUCH-FRIEDLANDER, Tamara. The author of this paper was a participant.

(60) *TREATY of Peace, between the State of Israel and the Hashemite Kingdom of Jordan*. October 26, 1994. Available at <<http://www.jewishvirtuallibrary.org/jsource/Peace/isrjor.html>>.

the scientific aspects of the project were never published. The project was funded for a few years, and although in terms of scientific work and policy making, not too much was accomplished, it created the foundation for future communication and cooperation mainly between Israel and the Palestinians (Dr. Jamal Safi and Dr. Joel Margalit do meet frequently). In contrast, a multilateral working group on water resources in the Middle East, established as a component of the Peace Process based on Declaration on Principles for Cooperation Among the Core Parties on Water-Related Matters and New and Additional Water Resources, assisted by the Norwegian Government, has been meeting periodically and amicably to lead, monitor, and evaluate the project (61).

In overview, the unilateral Israeli policy of destroying the main rabies reservoir, has been successful in drastically reducing the number of human rabies for a few years. But the analysis in this paper shows that the particular intervention in the 60s backfired with an unpredicted come-back many years later.

A coordinated surveillance system that will monitor any changes in the components involved in transmission (Figure 1) could help establish the magnitude of the problem on both sides of the border and provide the rationale for the establishment of guidelines for its control. This has particular relevance and significance in the region where the population is expanding due to natural birth and massive immigration, and which is undergoing constant development affecting the ecology of the animal reservoir and vectors through changes in their habitats (such as garbage disposal in national parks, acquisition of domestic animals, formation of landscapes that promote the growth of species susceptible to rabies, and changes in canid behaviour becoming less timid in approaching human dwellings).

Following the Madrid Conference of October 1991 where the Middle East Peace process was initiated, five working groups to focus on areas of common regional concern were established: 1) The Environment,

(61) *Second World Water Forum*, The Hague, March 17-22, 2000. Available at <www.jewishvirtuallibrary.org/jsource/Peace/waterdec.html>.

2) Water resources, 3) Economic Development, 4) Refugees, 5) Arms Control and Regional Security (62). Missing is a working group on Transmission of Infectious Diseases Across Political Borders. A lesson we learn from the historical analysis presented in this paper is the urgency in forming a regional working group on this topic, which surprisingly was not a component of the multi lateral track established as part of the peace process.

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(62) The multilateral negotiations-Diagram, Guide to the Mideast peace process. *Israel Ministry of Foreign Affairs*. Available at: <<http://www.mfa.gov.il/MFA/Peace%20Process/Guide%20to%20the%20Peace%20Process/The%20Multilateral%20Negotiations-%20Diagram>>.

