FOLIA PARASITOLOGICA (PRAHA) 23: 1—14, 1976

NATIONAL SURVEILLANCE OF VECTORS AND ANIMAL RESERVOIRS*)

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Dedicated to Prof. V. V. Kucheruk on the occasion of his 60th birthday

Abstract. In carrying out the national surveillance of vectors and animal reservoirs in Czechoslovakia the theory of the natural focus infections has been taken into account. In order to achieve a successful surveillance, besides studying the distribution of vectors and vertebrate hosts, the greatest emphasis has been put on the compilation of important data concerning their ecology, ethology and phenology. The author refers to some of the practical results of the national surveillance programme in Czechoslovakia.

In preparing the programme of national surveillance of vectors and animal reservoirs in Czechoslovakia, the ecological aspects of the so-called natural focus infections have been taken into account. (Pavlovsky 1939, 1964, 1965, Rosický 1967, WHO Tech. Rep. Ser. 378, 94—95.)

A natural focus is defined as the larger or smaller portion of a certain landscape consisting of biocenoses in which the pathoergont**) circulates irrespective of the organism at risk but can reach man or his domestic animals occasionally. Hence the natural focus is considered to be a general biological phenomenon, when the pathoergont, being a member of an ecosystem established by evolution or human activities, spread to the species at risk by various routes under favourable ecological conditions. In our case, man is mainly involved. The phenomenon of natural focus is clearly demarcated geographically and seasonally, depending upon certain local fauna.

METHODOLOGICAL PROCEDURES

With multidisciplinary concept in mind, methodological procedures have been developed for the surveillance of vectors and animal reservoirs in natural foci of infections in Czechoslovakia and they have proved to be practical. (Rosický et al. 1959, Engelbrecht et al. 1965 and others).

I would like to emphasize that, apart from the network of health services, the institutes of the Czechoslovak Academy of Sciences as well as departments and institutes of universities and technical schools and museums, and last but not least the research institutes for agriculture and forestry, have

*) Condensed from papers presented at several WHO Inter-regional seminars on methods of epidemiological surveillance.

**) After Pavlovsky (1965) it may be more convenient to call the causative atent (from arboviruses to parasitic worms) by one word with a general meaning "pathoergont" instead of the term "pathogen" which may suggest some genetic relationship not necessarily included in studies of the theory of natural focus diseases.

also participated in the Czechoslovak programme of surveillance of vectors and animal reservoirs. It has been necessary to bring the different scientific branches of entomology, parasitology, zoology, ecology, epidemiology, clinical medicine, veterinary medicine and geobotany together in order to build a long-term organization with meaningful working relationships. As a result, this broad basis for surveillance of vectors and animal reservoirs has made it possible to accumulate data which would have been obtained only with great difficulty through the health service alone. It goes without saying that these investigations must be supplemented by serological and allergic surveys in human population, collection of all available data and others measures provided by contemporary epidemiological and epizootological methods.

The data presented here illustrate only a part of the detailed investigations carried out in Czechoslovakia. The methods used in the surveillance of vectors and reservoir animals are being improved. Some work already done has to be repeated because the natural and economic conditions determining the existence of vectors and reservoir animals are changing constantly. Of the studies which have been published recently, attention is drawn to papers presenting important modern methods of vector surveillance and containing many illustrative examples (Petrishcheva and Olsufyev 1964, Baroyan et al. 1965, Haas 1965, Wilkinson 1967, Tupikova 1969).

As far as animal reservoirs are concerned, attention should be paid to a paper by Formozov and Isakov (1963), presenting methods for the surveillance of the most important animal reservoirs of plague, tularemia and leptospiroses. In all these methods, the population dynamics of reservoir animals is taken into account.

Some of the answers to these problems which can serve as a good foundation for the surveillance of vectors and animal reservoirs are reported in papers to be cited below. However, it should be understood that the methods used may have to be modified to suit particular geographical conditions.

The Surveillance Programme

The following constitute the main aims of the national surveillance programme of invertebrate vectors and vertebrate reservoirs:

A. Faunal survey:

a) To elucidate the species composition of the fauna of animal and vector reservoirs and to study the association of epidemiologically important species with certain biotopes.
b) To establish the distribution and density of the most important vectors and animal reservoirs of diseases in various types of vegetation and to determine the upper and lower limits of their distribution.
c) To investigate the biology, phenology and ethology (behaviour) of vectors and animal reservoirs.
d) To study experimentally under natural conditions the developmental cycle of vectors, especially in relation to life span, hibernation and estimation.

B. Ecological investigations:

a) To detect the range of hosts of the parasitic stages of vectors among various species of vertebrates and domestic animals.
b) To elucidate the population densities and dynamics of vectors and the animals acting as reservoirs; in particular, to elucidate the causes of observed fluctuations in the size of vector and host populations so that densities may be forecast for any given year.
c) To study ecology and population dynamics of some of the most important vertebrate hosts either infested by or attractive to vectors.
d) To study the ecology of the game animals and their pasture habits. Of special importance here are the systems of pasturing domestic animals.

C. Ecological and social conditions

a) Methods of stock breeding; survey of pasturing methods. The numbers of cattle in pasture lands, especially of young animals.
b) The numbers of game animals purposefully raised and their ecology.
c) Survey of diseases afflicting domestic and game animals with relevant services as a possible guidance for ecological studies.

D. Estimation of natural foci and their structure

a) To elucidate the association of the zoocenotic component of natural foci of communicable diseases with certain biotopes, including those resulting from human activities, for example, pastures, irrigation.

b) To establish the biotic and spatial structure of individual natural foci.
c) To elucidate the role played by the migratory components of zoonoses in the spread and maintenance of elementary foci.
d) To localize elementary foci of communicable diseases in a landscape in order to give a forecast of their epidemiological potential as a danger to man.

E. Analysis of all data and evaluation of anti-epidemic measures

a) To detect possible contacts of invertebrate vectors and vertebrate reservoirs with man (including the phenomenon of synanthropization).
b) To select suitable methods of unspecific protection of man.
c) To establish possible pesticide resistance in individual vectors and reservoirs.
d) To propose relevant surveillance and anti-epidemic measures which are based on a detailed knowledge of the ecology and life cycles of both vectors and animal reservoirs.

RESULTS

FAUNAL SURVEYS

Faunal surveys are conducted usually in two phases: 1. a general preliminary survey, 2. detailed biological and zoogeographical studies.

The purpose of the preliminary survey is to determine the vectors and animal reservoir fauna of a given area and to indicate their distribution in broad outline. The area selected for a detailed study and mapping should be representative of all vegetational and ecological zones. If possible, the maps should demonstrate the correlation of the distribution with its environmental determinants, primarily the vegetation zones or particular phytocenoses. Coloured or shaded maps are especially effective in emphasizing some of these factors. As basic material, detailed maps of the given area or region are needed and it is essential to have maps showing also topography, geobotanical units, average annual temperature, precipitation and other such information. For the mapping of external ectoparasites which do not occur permanently either in the nest or on the host's body, but which live in open nature seeking after shelters with a favourable microclimate, the geobotanical basic maps are of great importance.

For the preparation of maps, the programme of collecting potential invertebrate vectors and vertebrate reservoirs should be continued throughout the year to acquire information on their seasonal dynamics, abundance and activity. With ticks and mites, for example, consideration must be given to suitable methods of collecting specimens attached to the animal hosts, both wild and domestic, as well as from the forest undergrowth during the period when they live apart from the host. It is an absolute requirement to record all pertinent data concerning species of vectors and animal reservoirs according to individual specimens; it is also necessary to record data of environmental conditions, both macro- and micro-climatic ones.

For the faunal survey, mapping is an effective way to present both qualitative and quantitative distributional data but a map showing a qualitative distribution should be limited to the one species. Generally it is desirable to use one symbol to indicate the presence and another type of symbol to indicate the absence of certain medically important species within the area examined, but only when the absence of an animal has been actually determined by adequate survey. After securing quantitative information on the prevalence of invertebrate vectors and vertebrate reservoirs in a given area, the mapping should indicate their abundance, scarcity or absence, where possible, in specific terms.

As a basis for mapping serve precise data on the occurrence of separate species of vectors and reservoir animals in the given territory to be mapped. The map scale is chosen according to the extensiveness of the area studied and according to the purpose for which the map is being provided. We mainly distinguish small scale maps, for example 1 : 5 000, 1 : 10 000, 1 : 25 000 etc, or large scale survey maps to a scale of more than 1 : 1,000 000.

There is no need to emphasize the fact that the animal species must be precisely identified according to the most recent taxonomic zoological criteria.

The data are being obtained by collecting the material while using current or special methods. There is a great number of authors dealing with these methods and their descriptions are to be found in most entomological, acarological, theoriological or ornithological compendia. Each collection item is recorded on a catalogue card which serves for further map elaboration. The record, be it of any form suitable for the given purpose (e.g. mapping of various species of vectors in a district, region or the whole country) is an indispensable basis for further procedure in elaborating the map.

It stands to reason that the epidemiologist is interested in determining the distribution area of potential invertebrate vectors or reservoir vertebrates in the given territory. In the first stage he must try to obtain data for the determination of a general outline of the area and its borders. The distribution area of a certain species is the whole territory occupied by a certain animal species.

It must be borne in mind, however, that in nature there are no continuous distribution areas inhabited by certain species of vector or reservoir animal. A species occurs within the distribution area only in habitats (biotopes) corresponding with its ecological properties. Therefore, while defining separate localities attention is focused to records on the outer environment in which the species has been found. This fact facilitates a further deep evaluation of the whole problem. The given species, on the other hand, need not always occur in a favourable biotope. Some species are distributed in many biotopes of the area (e.g. *Ixodes ricinus*), others occur only sporadically here and there (e.g. Argasidae).

While elaborating a map two basic approaches exist:

a) Territorial approach according to recorded localities. The occurrence of vector or reservoir animal is marked on the map by means of certain symbols (points, squares etc), often of different colours, which are chosen or agreed upon in advance. This method is currently used in epidemiology for qualitative and quantitative recording of disease incidence. In some cases the record of a finding or findings in a certain locality is transferred to the relevant administrative-territorial units, in which the given territory is divided (cadastre or settlement, area of district, region, county etc).

When the extreme points or areas in the map are connected together they form the outlines of the range of a certain species of invertebrate vector or reservoir vertebrate. This method is especially suitable for recording the occurrence of biomedically important species in extensive territorial wholes.

b) The approach according to geographical or biological indicators. The preceding approach according to recorded localities gives an objective picture about the association of the occurrence of vectors or reservoir animals with certain environment. A map elaborated according to indicators represents a combination or comparison of findings of separate species with territorial extension of biotopes (or higher ecological units of landscape, biomes or types of biomes). While mapping the vectors their occurrence can be associated with a basic map depicting the distribution of their hosts. A comparison between the range of an invertebrate vector or reservoir vertebrate and a certain landscape has proved to be most suitable. The occurrence of certain animal species also agrees very well with the distribution of a certain plant communities — phytocenoses. Such communities may have either original plant composition, usually in regions intact by man, or they may be considerably modified by his agricultural or industrial activities.

From this aspect the epidemiologist engaged in national surveillance is also interested in the so-called geobotanical maps which exist today in different countries in different scales. A sample of such a geobotanical map to the scale of 1 : 250 000, has been elaborated by the Botanical Institute of the Czechoslovak Academy of Sciences. It is a so-called reconstructive geobotanical map in which the original plant cover is also recorded. The geobotanical maps are a synthesis of landscape elements and to a certain extent a synthesis of geological, pedological, climatic and hydrological maps. They are therefore very suitable to use as indicators for mapping the distribution of invertebrate vectors and reservoir vertebrates. These are associated with vegetation because it serves them as food, shelter, breeding places, or environment where their life cycles take place etc.

Table 1. Occurrence of *Aedes* mosquitoes in two regions of Czechoslovakia (August)

Species	Drnholec[1]) SM[3])			Třeboň SB[4])		
	No. of mosquitoes	%	Positive[2]) isolations	No. of mosquitoes	%	Positive[2]) isolations
Ae. cantans	1 841	8.6	1	343	1.6	—
Ae. cinereus	300	1.4	—	3 427	16.5	—
Ae. excrucians	—	—	—	417	3.4	—
Ae. punctor	—	—	—	1 500	7.2	—
Ae. sticticus	50	0.2	—	13 961	67.5	—
Ae. vexans	19 223	89.8	13	798	3.8	—

[1]) natural focus of the Ťahyňa virus; [2]) Ťahyňa virus; [3]) SM — Southern Moravia; [4]) SB — Southern Bohemia.

Table 2. Investigations of mosquitoes at Drnholec in 1962—1965[1])

Species	1962 the 2nd half of August	1963 the 1st half of August	1964 the 2nd half of July	1965 May—June
Ae. vexans	12555/62/2[2])	6668/31/LL	2312/11/2	—
Ae. cantans	734/5/0	1107/8/1	1109/6/0	1515/10/0
Ae. cinereus	300/2/0	—	—	—
Ae. sticticus	50/1/0	—	—	29166/97/0
Ae. communis	—	—	—	630/4/0

[1]) Danielová et al. (1966).
[2]) Number of mosquitoes /number of isolations/ number of positive findings.

These facts are very important to know during the epidemiologist's surveillance of potential vectors and reservoir animals, because in this way the boundaries of the range of possible occurrence of invertebrate vectors and reservoir vertebrates can be defined, as shown in the indicated transparent of the map. This method also makes it possible to give a scientific forecast of the occurrence of an infection transmitted by an invertebrate vector or harboured by a maintenance vertebrate in the suspect area. During an epidemiological surveillance it must always be kept in mind that the prepared maps be derived from the ecological properties of the object, the degree of its mobility and the character of its relationship with certain territory.

In Czechoslovakia the main purport of the proposed programme has been to map the most important vectors and to accumulate basic data on the distribution of potential vectors and animal reservoirs. The following may serve as examples:

(a) a survey of malaria mosquitoes, (b) a survey of regions with high densities of *Aedes* mosquitoes which are both human pests and potential vectors of Ťahyňa virus (Table 1, 2), (c) investigations into the occurrence of fleas in the natural foci of tularemia and tick-borne encephalitis in southern Moravia (Table 3), (d) studies of the distribution of trombiculids and other mites, according to biotopes, in the natural foci of haemorrhagic nephrosonephritis (Table 4).

As far as the animal reservoirs are concerned, the following work is worthy of record: (a) the mapping of the distribution of *Apodemus agrarius* in Czechoslovakia; (b) the study of the distribution of *Ondatra zibethica* in the natural focus of the tularemia in western Slovakia, and (c) the results obtained by the central pest service of the Ministry of Agriculture in dealing with the irruption of *Microtus arvalis* in Czechoslovakia (Kolman 1965).

These few examples show that surveys of the fauna of vectors and reservoir animals are the source of the basic information needed for mapping the distribution of individual animal invertebrate or vertebrate species.

The mapping of vectors and animal reservoirs is not an end in itself but is a means for drawing conclusions and making forecasts concerning the species of vectors and animal reservoirs present, as well as for effective measures of control.

Apart from the mapping of the distribution of vectors and animal reservoirs, it is necessary to obtain good information on the biology, ethology and phenology of particular species which are of epidemiological importance and which take part in the maintenance of natural foci.

Table 3. Fleas from the winter nests of the common mole (*Talpa europaea*) in the South Moravian natural focus of tularemia

(a) Flea species in various habitats of the natural focus (in %)

Habitat	Species								
	C. agyrtes	*C. bisoctodentatus*	*C. assimilis*	*C. solutus*	*H. talpae*[2])	*P. soricis*[3])	*P. similis*	*N. fasciatus*[4])	Other species
Fields	0.4	15.2	83.4	—	0.6	0.1	—	0.3	—
Meadows	0.6	11.1	86.8	0.01	1.0	0.1	0.1	0.2	0.2
Scrub	7.9	17.7	70.8	0.1	1.7	0.1	0.3	1.0	0.3
Forest outskirts	9.8	26.3	56.3	0.6	3.9	0.6	0.9	0.5	0.1
Forest	29.0	20.4	35.1	2.5	1.3	2.2	5.7	0.4	3.4

(b) *Ctenophthalmus assimilis* in various habitats

Habitat	*C. assimilis*[1])		%	Other species %	Total number
	♂	♀			
Meadows	2 095	4 620	86.8	13.2	7 757
Fields	814	2 171	83.4	16.6	3 588
Scrub	656	1 203	70.8	29.2	2 626
Forest outskirts	348	608	56.3	43.7	1 704
Forest	120	192	35.1	64.9	886

[1]) *Ctenophthalmus*, [2]) *Hystrichopsylla*, [3]) *Palaeopsylla*, [4]) *Nosopsyllus*.

The developmental cycle of *I. ricinus* has also been studied in detail under natural conditions in Central Europe (Černý 1958, Nosek et al. 1967). The average length of the cycle in Central Europe is three years and all developmental stages, including the eggs, can survive the winter. This is an important finding as, under natural conditions, the developmental cycle of ticks, as well as of other arthropods, may differ substantially from that occurring under laboratory conditions.

Simultaneously with the survey it is reasonable to undertake concurrent laboratory studies for rearing arthropod and mammalian species for life cycle information and examining specimens for viral, rickettsial, bacteriological, parasitological or other infections. It helps to delineate species of medical and veterinary significance and permits the planning of related and subsequent ecological surveys.

Table 4. Incidence of chigger larvae in the natural focus of haemorrhagic nephrosonephritis (Ruská Poruba, Eastern Slovakia) according to habitats[1])

Species of chigger	Total number	Individual habitats									
		Gully between fields		Marshy ground		Ridges		Fields		Forest	
		abs.	p.c.	abs.	p.c.	abs.	p.c.	abs.	p.c.	abs.	p.c.
Neotrombicula autumnalis	5 070	292	18.6	16	9.1	4 098	32.7	446	64.1	218	65.1
Neotrombicula talmiensis	8 617	328	20.9	110	62.8	7 877	62.9	241	34.6	61	18.2
Cheladonta costulata	226	6	0.4	2	1.2	214	1.7	4	0.6	0	—
Neotrombicula zachvatkini	1 361	944	60.0	45	25.7	325	2.6	5	0.7	42	12.5
Myiatrombicula muris	5	1	0.05	0	—	4	0.03	0	—	0	—
Leptotrombidium europaeum	5	1	0.05	2	1.2	2	0.02	0	—	0	—
Ascoschoengastia latyshevi	14	0	—	0	—	0	—	0	—	14	4.2
TOTAL	15 298	1 572	100.0	175	100.0	12 520	100.0	969	100.0	335	100.0

[1]) Daniel (1961).

ECOLOGICAL INVESTIGATIONS

As an example in solving these ecological problems, a solid basis for national surveillance of vectors of tick-borne encephalitis was created. The relevant studies were not limited to the mere mapping of ticks but involved the recording of all characteristic features of *Ixodes ricinus* L., the main vector important to the epidemiology of tick-borne encephalitis (TBE). The main ecological results achieved are:

The most characteristic feature in the ecology of ticks in Central Europe is the fact, that ticks are members of biogeocenoses (ecosystems) which have been influenced by man for thousends of years or have even been man-made (shaped by his activities). Therefore all further facts must be regarded from this aspect.

While investigating the trophic relationships existing in nature between ticks and vertebrates, a wide host spectrum has been detected for most Central-European ticks. In Central Europe the main vector of the TBE virus was found on more than 150 species of vertebrates. Detailed studies, however, have shown that only certain host species, namely small terrestrial mammals, are important as genuine maintenance hosts of the TBE virus. Regardless to this fact, also other ecological groups of vertebrates, of course, are important to whole populations of ticks as blood source for their development. Some of them (e.g. domestic animals giving milk), under favourable ecological conditions and due to neglect of some hygienic rules in dairies, can cause epidemiological complications (e.g. Rožňava epidemics). Other hosts, mainly birds and ungulates can play an important role in transporting (either virophorous or non-virophorous) ticks to places repeatedly originating by succession and suitable for the ticks' existence. Recent studies have proved that the fauna complex on which the virus of the Central-European TBE depends, is very ancient by its development (insectivores — ancient types of ticks such as *Haemaphysalis inermis* and the genus *Ixodes*).

Studies have been directed at the daily activity, seasonal dynamics of ticks and observations of the long-lasting dynamics in particular years are still being carried out. Nearly in all localities the curve of seasonal dynamics has a two-peak form (with a distinct spring peak and a lower autumn peak (Rosický 1954, Černý 1957). But the character of the curve in particular years may change to such a degree, that the autumnal increase of tick numbers may be missing. Places with the same microclimate exhibit the same course of the dynamics curve. The places which differ in microclimate (including other properties) may show a different curve of dynamics in the same year, in spite of the fact that they are situated in one locality. This is

Table 5. Occurrence of the first maximum of nymphs according to the altitude above sea-level[1])

Altitude in m	Number of areas	Maximum reached in				Approximate ratio
		IV	V	VI	VII	
200—400	118	14—11.9 %	70—59.3 %	28—23.7 %	6—5.1 %	2 : 10 : 4 : 1
400—600	86	13—15.1 %	48—55.8 %	21—24.4 %	4—4.7 %	3 : 12 : 5 : 1
600—800	36	2— 5.5 %	15—41.7 %	13—36.1 %	6—16.7 %	1 : 8 : 7 : 3
TOTAL	240	29—12.1 %	133—55.4 %	62—25.8 %	16—6.7 %	2 : 9 : 4 : 1

[1]) Černý et al. (1965).

obvious in localities with a very uneven relief and variegated vegetation and with cultivation considerably marked by man.

The problem of exact measurements of microclimate (temperature and humidity), in various microhabitats of *I. ricinus* requires new methods at present. An attempt in this respect has been made by Daniel and Černý (1967). Only on the basis of such continuous measurements it will be possible to find out the true causes of the mosaic-like distribution of *I. ricinus* in nature. It stands to reason that also other limiting factors (light, hosts etc.) are involved in the discontinuous and in the mosaic-like distribution of *I. ricinus* (and other tick species) in Central Europe.

In this connection the phenomenon North-South, which is of epidemiological importance, cannot be omitted. In harmony with the same phenomenon observed in other animals belonging to the faunal complex of the European deciduous forest *I. ricinus* in the southern part of Europe occurs at higher altitudes than in the more northern area of its distribution.

Phenological data for Bohemia and Moravia have been obtained by extensive co-ordinated and synchronous investigation of the tick population dynamics, during the three years 1960—1962, at 114 experimental sites at altitudes ranging from 200 m—700 m (Table 5) (Černý et al. 1965). These studies have shown that from April to October, *I. ricinus* in an active state is to be found regularly on vegetation; under favourable climatic conditions this period is longer, lasting from March to December. The maximum population density of adult ticks and nymphs occurred in May and June and was about 261 nymphs or 55 adult specimens per 100 m². The build-up of the tick population did not always take place at the same time in the whole area investigated and differed according to particular regions. Furthermore, the proportion of adult ticks and nymphs in particular regions varied considerably. These findings have confirmed the observed fluctuations that take place in the number of *I. ricinus* in any given locality (Table 6). Another lesson that can be drawn from this study based on a relatively large area is the need for observations, following standard methodology, of the dynamics of *I. ricinus* in still larger territories.

The distribution of ticks in the entire country has been determined and their quantitative occurrence in the most important regions in particular years has been studied (Rosický 1954, Radvan et al. 1960, Černý et al. 1965, Nosek et al. 1967).

Table 6. Range of changes in numbers of nymphs in various regions in the years 1960—1962[1])

Region	Range of changes	Differences
Beroun	2.0—7.8	5.8
Písek	2.3—3.9	1.6
Klatovy	1.2—3.1	1.9
Jihlava	1.8—6.6	4.8
Opava	1.3—2.2	0.9
Hodonín	1.1—4.5	3.4

The first number — the lowest ratio of yearly maxima for nymphs of one area of a given region in the years 1960—62, the second number — the highest reached ratio.

[1]) Černý et al. (1965).

ECONOMIC AND SOCIAL CONDITIONS

While evaluating the occurrence of invertebrate vectors and vertebrate reservoirs also the conditions under which the farming, primarily stock fattening, is being acomplished, should be taken into consideration. Moreover, it should be borne in mind whether a certain region is used for game keeping. During our studies we paid attention to the fact that in the western region of Czechoslovakia cattle is primarily kept in barns; in the eastern part of the Republic there are still extensive pasture lands. In evaluating the wildlife domesticated animals can by no means be omitted from ecological studies, and the method of animal husbandry or its possible technological changes determining the capacity of animals to carry zoonoses, cannot be ignored either. The data of veterinary service should be fully utilized.

It was necessary to establish the significance of animal husbandry in the maintenance of vectors. A test carried out in a pasture locality infested with ticks has yielded astonishing results, although they need not be applied to every geographical region. In the open pasture the engorged females died of desiccation and as far as they laid eggs, no larvae hatched from them. On the other hand, even isolated bushes offered favourable conditions to the females (Černý 1959). It was necessary to elucidate exactly all factors limiting the occurrence of *I. ricinus* in individual biotopes and in this way also restricting its topic distribution.

We could conclude from our studies that the development of pasturing on poorly tended pasture lands (Table 7) and intentional game-keeping, offer exceptionally favourable conditions to ticks (Table 8). Such are the antropogenous factors responsible for the existence of the natural foci of TBE prevalent in many parts of Czechoslovakia. In brief, the incidence of ticks may be said to be inversely proportional to the degree of cultivation of a landscape (Rosický and Hejný 1959).

Table 7. Tick infestation of cattle on two pastures in Ruská Poruba (Eastern Slovakia)[1]

Month	IV	V		VI		VII		VIII		IX	
10 day period	3	1	3	1	3	1	3	1	3	1	3
No. of examined cattle	22	14	30	16	31	17	34	17	34	26	8
No. of attached female ticks	1 237	768	608	400	185	99	66	20	49	60	20
Ø[2] on cattle	56.2	54.9	20.3	25.0	6.0	5.8	2.0	1.2	1.4	2.3	2.5

[1]) Černý (1960).
[2]) Average per 1 head.

Table 8. An example of the number of main hosts of *Ixodes ricinus* in a country with a high level of game management[1])

Species	1951	1973
	Bohemia and Moravia	
Cervus elaphus	3 316	8 209
Capreolus capreolus	50 982	87 008
Lepus europaeus	896 976	1 117 827
Phasianus colchicus	242 313	1 191 430
	Slovakia	
Cervus elaphus	2 256	9 444
Capreolus capreolus	1 658	12 879
Lepus europaeus	136 269	308 590
Phasianus colchicus	8 338	192 384
	Czechoslovakia	
Cervus elaphus	5 572	17 653
Capreolus capreolus	52 640	99 887
Lepus europaeus	1 033 245	1 476 417
Phasianus colchicus	250 651	1 383 814

[1]) Official data of the Czechoslovak Ministry of Agriculture, numbers of animals hunted during individual years.

In cooperation with geobotanists extensive investigations were carried out in this respect and are still in progress. It has been demonstrated that the tick numbers in secondary formations of Central Europe, which predominate here irrespective of the fact whether they have originated by complex processes of devastation of ancient growths resulting from various activities of man (pasturing, ploughing, game-keeping etc.) or his intentional silvicultural activities, may be very high and may even surpass calculations for the original Central-European forest (Table 9). The development of pasturing on poorly tended pasture lands and intentional game-keeping for sporting and recreational purposes offer exceptionally favourable conditions to ticks of different Central-European species. This anthropogenous factor is responsible for the exsitence of severe valent natural foci of TBE in many places in Czechoslovakia.

This complicated and long development of game-keeping is responsible for a stockpile of ticks in nature (which may reach in some theriodic tick-infested habitats of Central Europe as many as 3000 specimens per 100 m^2), i.e. an accumulation of both unfed and engorged specimens, which represents not only an important factor in the dynamics of *I. ricinus*, but must also be taken into account in the epidemiology of tick-borne diseases and the tick control measures, because specimens capable to attack hosts are being unceasingly supplied from this stockpile.

ESTIMATION OF NATURAL FOCI AND THEIR STRUCTURE

The assessment of the distribution and roles of vectors and animal reservoirs in Czechoslovakia is based mainly on the occurrence of tick-borne encephalitis, tularemia, leptospiroses, Q-fever, toxoplasmosis and listeriosis. These human infections have been

Table 9. Enrichment of Central European biotopes by hosts of the female of *Ixodes ricinus*[1] over an area of 1,000 ha

Species	Bohemia	Moravia	Slovakia	Branden-burg	Silesia	Saxony	The virgin forest of Beloveza
Lepus europaeus	126	130	43	30	50	50	sol.
Capreolus capreolus	5.4	7.6	1.4	6.4	×	6.2	sol.
Cervus elaphus	0.5	0.5	0.5	×	×	×	0.07
Sus scrofa	×	×	×	×	×	×	0.08
Phasianus colchicus	45.6	67.5	9.3	×	×	×	0

sol = numbers too low to be recorded
× = no data available

Table 10. Occurrence of the common tick *I. ricinus*[1]) in inundated lowland forests of Southern Moravia

Forest	Number of ticks				Number of collections	∅ [2])	% of infested exp. areas
	Males	Females	Nymphs	Total			
Inundated	4	3	33	40	359	0.11	6.1
Dry	17	16	116	149	176	0.8	32.4
In hills	77	88	1 544	1 709	240	7.1	89.8

[1]) On 100 m^2 areas (by flagging), [2]) Average number of ticks per one flagging.

known in Czechoslovakia ever since they were diagnosed for the first time in Central Europe and in certain of them Czechoslovak researchers themselves have carried out the pioneer work. Although the incidence of the infections mentioned is much lower than that of some anthroponoses current in Central Europe, nevertheless, in some years hundreds of patients may suffer from these diseases which entail a convalescence and an incapacity for work of long duration. The infections mentioned also occur in neighbouring countries, as shown by surveys of natural foci using epidemiological as well as biocenological indices. Their present level of occurrence in natural foci situated in various territories need not necessarily reflect their true public health importance but should be regarded rather as an indication of the degree to which a given territory has been studied.

In natural foci of TBE, dependence on biotic factors is seen from the association of ticks with certain plant formations (Table 10). This is mainly due to their microclimatic requirements for the development of eggs (Table 11), for investigations of these relationships have been carried out in co-operation with geobotanists (Hejný and Rosický 1965). It has been demonstrated that the density of the ticks and their vertebrate hosts in secondary plant formations of Central Europe may be very high and may even surpass estimates for the indigenous Central European forest. The association of particular species of external ticks and also of small terrestrial mammals with relevant plant formations permits a scientific forecast to be made of their distribution and certain plants may serve as indicators of the potential incidence of TBE infection (Rosický and Hejný 1962).

Table 11. Survival and laying of eggs of *I. ricinus* females in various microhabitats of a pasture[1])

Microhabitat	No. of exposed females	No. of females laying eggs	Laying fully finished	Hatching larvae
Grass only	38	4	0	0
5 cm in soil (grass)	8	8	0	0
Shrubs without litter	28	25	16	19
Shrubs with litter	23	23	22	23
Inundated meadow	3	0	0	0

[1]) Černý (1959), Ruská Poruba, Eastern Slovakia.

The biotic factors thus influence the spatial structure of the natural focus in which the so-called elementary foci (Rosický 1967) are closely connected and where the TBE virus is being maintained between epidemics (epizootics). The elementary focus*) is a basic element of the natural focus of TBE. In cultivated landscape the area of the natural focus is often so broken up by the economic activities of man that the elementary focus proper is the only existing form of the natural focus (Radvan et al. 1960). Under such circumstances, elementary foci can be easily localized and subjected to epidemiological surveillance.

Although the ticks, mainly *I. ricinus*, were eliminated by man's activities in some biotopes, their numbers remained high in others. In some places even better conditions for their existence were created (pastures, theriodic places) than in regions left intact by man. This is the reason why TBE has been maintained in landscapes cultivated by man for long periods.

ANALYSIS OF ALL DATA AND EVALUATION OF ANTI-EPIDEMIC MEASURES

All data obtained in the mentioned studies must be carefully collected, mutually compared with regard to relevant infections. The data may be obtained from smaller or larger territories. Of course, the ecological data must be analyzed together with epidemiological and epizootological ones in one centre or by one team; when the research work is being done separately an exchange of data and prompt comparison must be secured. It is also important to supply all interested institutions of public health and veterinary services with the information obtained immediately. The data obtained on the fauna, its ecology and natural foci serve primarily for the elaboration of preventive and anti-epidemic measures and a permanent surveillance of transmissive diseases.

*) An elementary focus is a certain limited area within the natural focus, in which a long-term, but not necessarily continuous circulation of the pathoergont takes place among host populations.

Also in the field of vector and reservoir control Czechoslovakia has achieved remarkable results. In some regions sectors of TBE natural foci have been mapped and an attempt has been made to forecast their occurrence.

According to our observations the onset of the *I. ricinus* population increase was connected with a high number of the main blood source for larvae and nymphs, i.e. an abundance of small mouse-like mammals (Havlík 1954). More recent investigations, however, have demonstrated that the prediction of the onset of a population increase of ticks following periods of high numbers of small mammals, as well as a forecast of the population numbers of *I. ricinus* according to their population density in autumn, is limited to a certain probability only (Havlík et al. 1960, Černý 1961, Kolman 1965). The prediction of the occurrence of increased numbers of cases of TBE infection is even more complicated.

In the majority of the infections mentioned, except tularemia, we must rely more upon the control of vectors and animal reservoirs than upon specific measures of prevention such as vaccination. In Czechoslovakia, for example, control of mosquitoes has been carried out on a large scale and the first steps have been taken to control ticks. Disinsection and deratisation is supervised by the hygienic and epidemiological services of the Ministry of Health. For the protection of individuals repellents are widely used. Different original procedures have been elaborated.

Inevitably, many differing methods of surveillance of vectors and animal reservoirs are used in different parts of the world, because national surveillance must be adapted to the local geographic, economic and social conditions. However, the problem of comparability of the observations between countries should always be borne in mind. The determination of basic criteria essential for comparability is one of the objectives of international cooperation.

ГОСУДАРСТВЕННЫЙ НАДЗОР ЗА ПЕРЕНОСЧИКАМИ И ЖИВОТНЫМИ-РЕЗЕРВУАРАМИ

Б. Росицкий

Резюме. При проведении государственного надзора за переносчиками и животными-резервуарами в Чехословакии во внимание была принята теория природной очаговости болезней. С целью осуществления успешного надзора, кроме изучения распространения переносчиков и позвоночных хозяев, большое внимание уделялось обработке важных данных по их экологии, этологии и фенологии. Автор упоминает о некоторых практических результатах полученных по программе государственного эпидемиологического надзора.

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Received 27 August 1975.

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