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THE ROLE OF COMMENSAL RODENTS AND THEIR ECTOPARASITES IN THE ECOLOGY AND TRANSMISSION OF PLAGUE IN SOUTHEAST ASIA*

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Plague has been endemic in the Republic of Vietnam (RVN) since 1898. Prior to 1962, outbreaks of the disease were chiefly confined to the Mekong Delta and to the coastal provinces to the east of Saigon. Since 1962, an alarming increase in the incidence of human plague in RVN has been noted; some 13,417 suspected cases were reported for the period (Table 1). Most of these suspected cases of plague have been reported from areas in which the disease was previously unrecognized.[5,9,10,11,16,19,23,26,33,35]

The isolation of *Pasteurella pestis* from patients seen in outlying epidemics has been greatly facilitated by the use of Cary-Blair transport medium.[4] We have been able to isolate *P. pestis* from 2,478 of 5,517 clinical specimens submitted by various physicians, who collected the specimens from suspected cases of plague. In our study, the criteria of Baltazard et al.,[1] have been nused to identify *P. pestis*. When *P. pestis* could not be isolated for one reason or another, it was often possible to obtain a retrospective diagnosis by serological means[1,6,7,22] — approximately 1,000 additional cases of plague have been so confirmed.

The majority of the cases we have seen have been bubonic plague, although pneumonic plague[25] and asymptomatic pharyngeal plague[16] occur. As the major clinical form of the disease is that of flea-borne bubonic plague, major emphasis has been placed on the determination of those epidemiological factors useful in planning an integrated control program. The results of our studies for the past three years forms the basis of this report.

Vector Fleas

Examination of mounted specimens of fleas collected in various urban plague foci revealed the presence of *Xenopsylla cheopis*, *X. astia* and *Ctenocephalides felis*. Over 99% of the mounted collection has been identified as *X. cheopis* according to the criteria of Hopkins and Rothschild.[13] The population density of *X. cheopis* varied according to the season. The greatest number of fleas infesting rats was found during the dry weather preceding the monsoon. The onset of monsoon rains produced a marked reduction in the flea population, in the mountainous and rice growing lowlands. The influence of the rains on the flea index was less pronounced in the sandy coastal areas where rapid run-off of ground water prevented flooding.[5]

It has not, at this date, been possible to examine many fleas from wild rodents. Those fleas which have been examined have been *X. cheopis*.

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TABLE 1. *Provinces of the Republic of Vietnam Reporting Plague 1961-1967*

Province	1961 [1]	1962 [1]	1963 [1]	1964 [1]	1965 [1]	1966 [2]	1967 (Jan-June) [2]
Long Khanh	8	5	5	4	23	14*	6
Bien Hoa		3	6	2	35	8*	15*#
Phuoc Tuy		14	3	1	13	13	26*
Khanh Hoa		10	78	174	284	134*	152*
Gia Dinh (Saigon)			12	34	466	65*	227*
Long An			1	2	5	2*	
Lam Dong			1	2	13	21*	36*
Binh Duong			4		2		11*#
Tuyen Duc				13	82	53	13*
Tay Ninh				1	6	2*	82*
Darlac				9	539	744*	650*
Hau Nghia					19	14	11*
Binh Thuan					503	32*	244
Pleiku					54	11*	21*
Binh Dinh					1074	234*	1054
Quang Ngai					680	789*	1079*
Phu Yen					647	117*	121*
Ninh Thuan					19	318*	121*
Phu Bon					5	10	13
Quang Nam					19	271*	679*
Quang Tri					1	3*	56*
An Xuyen					2	80#	0
Chuong Thien					10		
Go Cong					2		
Thua Thien						421*	198
Quang Tin						131*	48*
Phuoc Long						55#	14
Kontum							20*#
Quang Duc						62*	
Kien Giang							21*
Total	8	32	110	242	4503	3604	4918

1 1964-1965 Annual Report of these laboratories

2 RVN Ministry of Health records

* Positive cultures secured by USA MRT (WRAIR) V and IP in this area

\# Data from USA MRT (WRAIR) V sources

Xenopsylla cheopis collected in RVN and Thailand have been tested for sensitivity to standard insecticides[5] by World Health Organization (WHO) methods.[2] The results of these tests are given in Table 2. Analysis of data obtained by WHO from world-wide testing of *X. cheopis* has shown that DDT sensitive fleas have LC_{50} values that range from 0.27 to 0.70 percent.[30] Our data show that *X. cheopis* in RVN and Thailand were resistant to DDT.

TABLE 2. *Insecticide Sensitivity of Wild-caught* Xenopsylla cheopis *Collected in the Republic of Vietnam or Thailand, 1965-1967 (Tests by WHO Method)*

Locale	Insecticide*				
	DDT	Dieldrin	BHC	Malathion	Diazinon
Vietnam**					
Saigon	3.6	0.89			0.001
Nha Trang	2.3	0.10	<0.125	0.023	0.003
Thailand					
Bangkok	>4.0		0.3	0.02	
Korat	>4.0	0.07	0.4	0.02	
Pakchong	>4.0	0.07	0.09		
Ban Pong	1.2				

*LC_{50} in per cent.
**Data from Reference 5.

Mammalian Reservoirs of Plague

For obvious reasons, trapping activities have been largely confined to urban areas, but limited trapping by us and others has provided some information on the rodent population and plague situation in the countryside. Some 22,144 small mammals and their fleas have been examined by pooling methods for the isolation of *P. pestis*.[1] The sera of many of these rodents have been tested for specific *P. pestis* Fraction 1 hemagglutinating antibody.[3,7,11,20] The animals we have examined are listed in Table 3.

In coastal urban areas, 4 mammals were equally involved in the epidemiology of plague. *Suncus murinus, Rattus exulans, R. norvegicus,* and *R. rattus* were infected at a rate of about 4 *P. pestis* isolations per 1,000 animals tested. Fleas *(X. cheopis)* from about 3 animals per 1,000 animals tested were infected with *P. pestis*.[5,17,18]

In the country and around cities, *Bandicota indica* and its fleas *(X. cheopis)* have been found infected with plague. One of the forest rats, *R. nitidus* has also been found infected. The sera of 3/3 *Herpestes javanicus* and 1/1 *Paradoxurus hermaphroditus* collected in a completely sylvatic habitat were reactive for *P. pestis* antibody.[15] Although the present data are admittedly limited, and based on the examination of very few specimens of some of the animals listed in Table 3, the infection of sylvatic as well as urban reservoirs is suggested. In view of the wild rodent population, which consists primarily of Muridae[8,21,28,31,32] the ecology of sylvatic plague in Vietnam may resemble that of scrub typhus.

Seasonal Tendencies

As outlined by Pollitzer,[29] conditions of temperature and humidity appear ideal for the propagation of plague somewhere in RVN throughout the entire year. The mean annual temperature recorded in highland plague foci was 22.1 C with an annual range of 19 - 26 C, ideal temperatures. In lowland foci, the mean annual temperature was 26.8 C with an annual range of 22 - 30 C, not optimal for year-round epidemics. Relative humidity is constantly high, nearly always over 70%. The climatic conditions prevailing in Southeast Asia do not appear to influence either the composition or the relative proportions of species of animals trapped in any given location during the year. However, when tabulating the percentage incidence of human plague. plague infected rodents and fleas, and the flea index on a nationwide quarterly basis, a clear picture of both the seasonal prevalence and epidemiological aspects of plague in RVN become apparent.

TABLE 3. *Observations on Habitat and Plague Infection of Some Small Mammals Collected in the Republic of Vietnam 1964-1967*

Mammal	Observed Altitudinal Range in Meters	Observed Habitat*	Data on Plague Infection		
			P. pestis isolated		*P. pestis* HA Antibody
			Tissues	Fleas	
INSECTIVORA					
Suncus murinus	0-100	1	+	+	+
RODENTIA					
Dremomys rufigenis	50-2000	2,6,7,9			
Menetes berdmorei	5-2000	2,4,5,7			
Rhizomys pruinosus	600	6			
Bandicota bengalensis	400-1300	5			
Bandicota indica	10-450	1,2,3,5	+	+	+
Chiromyscus chiropus	450	9			
Mus cervicolor	10-450	1,2,5			+
Rattus					
Subgenus *Rattus*					
R. argentiventer	10-1700	3,4,5			
R. exulans	0-1500	1,2,4,5,6,7	+	+	+
R. losea	10-2000	4,9			
R. nitidus	450-1500	1,5,7	+		
R. norvegicus	0-450	1,2,4	+	+	+
R. rattus	0-1550	1,2,3,4,5,7,9	+	+	+
R. sladeni	450-1550	5,6,7,9			
Subgenus *Stenomys*					
R. bowersi	1200-1550	5,6,7			
Subgenus *Maxomys*					
R. cremoriventer	450-1500	7,9			
R. fulvescens	600	7,9			
R. niviventer	450-2000	5,6,7,9			
Subgenus *Lenothrix*					
R. moi	450-600	7,9			
R. surifer	50-1500	4,5,6,7,8,9			
Rattus					
Subgenus *Leopoldamys*					
R. edwardsi	1500	7,9			
R. sabanus	50-600	7,9			
Subgenus *Berylmys*					
R. berdmorei	500-1200	5			
CARNIVORA					
Paradoxurus hermaphroditus	100-600	5,7			+
Herpestes javanicus	0-600	2,5,7			+

* 1 Human habitation
2 Coastal vegetation
3 Rice paddy
4 Brush
5 Grass
6 Bamboo
7 Second growth
8 Dipterocarp
9 Primary growth

TABLE 4. *Correlation of Suspect Human Cases, Isolation of* P. pestis *from Mammalian Reservoir Hosts and Flea Vectors, and Presence of HA Antibody in* R. norvegicus, *Accumulated by Quarter of Year for 1965-1967, Republic of Vietnam*

Quarter of Year	Suspected Human Cases		*P. pestis* Isolations				HA Antibody in *R. norvegicus*		Flea index of *R. norvegicus*
			Reservoir Hosts		Fleas				
	No.	(% of Total)		(% of	No.	(% of Total)	No. reactive/ Total Tested	(% of No. reactive)	
I	3938	(52)	26	(39)	15	(44)	113/1290	(40)	2.98
II	1999	(26)	13	(20)	6	(18)	92/1342	(33)	3.08
III	1103	(14)	11	(17)	4	(12)	23/944	(8)	0.97
IV	611	(8)	16	(24)	9	(26)	53/1584	(19)	1.07
Totals	7651	(100)	66	(100)	34	(100)	281/5160	(100)	

These data are given in Table 4. Peak incidence of human and epizootic plague occurs in the first quarter of the year. Both human and epizootic plague then decline through the second and third quarters. In the fourth quarter, a continued decline in the incidence of human plague is observed while epizootic plague shows evidence of increased activity.

Control

Integrated plague control *per se* is non-existent and probably impossible to achieve under present circumstances. The facilities of existing sanitation agencies are largely inadequate to cope with the present day needs of cities populated with masses of individuals living under exceedingly low socio-economic conditions. The situation is further aggravated by constant, increasing refugee problems.

Tremendous rat and shrew populations are found in the urban areas of RVN and these rodents in turn support large populations of the highly efficient plague vector, *X. cheopis*. There is an intermixing of commensal and peridomestic rodents at the edge of the towns with species of both groups harboring *X. cheopis*. *Pasteurella pestis* has been isolated from both groups and their respective fleas.

Under the constant threat of re-introduction of plague infected fleas and rodents from the countryside, a continual program of flea control is the only feasible approach to plague control in RVN at this time. DDT has been widely used for this purpose; however, it appears to have been unsuccessful. It must be concluded that, based on testing and experience, the flea vectors in RVN are resistant to DDT. When, however, insecticides shown by test to be effective in killing *X. cheopis*, were used to control limited plague outbreaks (Diazinon in two outbreaks and a combination of Diazinon and Dieldrin on one outbreak), the epidemics promptly stopped. Due to the short residual life of the effective organophosphate insecticides, repeated applications must be made to prevent recrudescence of the human epidemic initiated by the re-introduction of infected animals and vectors.

Discussion

Plague is widespread in RVN. The major flea vector, *X. cheopis*, is, by test and experience, resistant to DDT. Extensive and continuing applications of DDT dust have not controlled or modified the course of plague in numerous foci.[5,19,33] By contrast, use of Diazinon or Dieldrin or combinations of the two insecticides to which the *X. cheopis* are, by test, susceptible, has achieved prompt control in three limited outbreaks.

Initially, DDT was highly effective in plague control.[2,12,20,229,34] Now, DDT resistance appears to be rather widespread. Saenz Vera[29] recorded failure with DDT in foci where DDT had previously

achieved control. Patel *et al.*,[21] reports the presence of DDT resistant *X. cheopis* in India in an area which had been subjected to extensive spraying with DDT. The above observations may be analagous to those we have made in RVN and Thailand, both areas having received widespread applications of DDT under various malaria eradication programs. A program of testing indigenous flea vectors for insecticide resistance permits the selection of effective insecticides for plague control. Such programs are recommended for plague receptive areas.

It is, perhaps, proper to recall at this time that the last great plague pandemic which infected all of the plague receptive areas on earth originated in Southeast Asia.[20] The present day situation in RVN is such that a definite potential for international spread exists. Rats and fleas, infected with plague, have been collected in and around most of the major ports and airports and an important plague reservoir, *R. exulans*, is being found on an increasing number of ships and aircraft arriving in the U.S.A. from RVN.[27] Present day jet travel is capable of carrying infected rats, fleas, and human beings to any part of the world within a few hours.

Immediate reduction of rat harbourages and the proper disposal of wastes should be carried out as thoroughly as possible in and around centers of plague activity in RVN. These procedures, integated with the timely and repeated application of effective insecticides should do much to alleviate, but not eliminate the problem. The extent of the plague problem now existing in Vietnam indicates that control measures will be required for a long period of time to come. The proven involvement of commensal, peridomestic, and feral rodents forecasts the need for constant attention to prevent re-infection of areas in which control is achieved.

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