PLAGUE in the AMERICAS

PAN AMERICAN HEALTH ORGANIZATION
Pan American Sanitary Bureau, Regional Office of the
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525 Twenty-third Street, N.W.
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SECTION A

INTRODUCTION

Since the birth of the Pan American Health Organization, plague has been an important, albeit diminishing, problem of the Member Countries. The initial meeting of the Organization, then known as the International Sanitary Bureau, was the First International Sanitary Convention held in Washington, D.C., from 2 to 4 December 1902. One of the main concerns of the founders was: "The adoption of measures for the disposal of garbage and wastes to prevent the spread of bubonic plague and other diseases."

In the years following, the application of classical methods has driven plague into the endemic foci of today. While current control and containment measures have been more or less successful, it has become obvious that before further progress can be made against plague it will be necessary to undertake a thorough study of the nature of the disease in its present circumstances.

As a first step in a program to include the needed ecological studies, a thorough study and evaluation was begun of all information on plague in the Americas contained in the technical literature, official reports, and other sources. On the basis of these data and observations to be made in the plague foci, there will be designed a series of ecological research studies.

This document contains a summation of the basic information available on plague in Argentina, Bolivia, Brazil, Ecuador, Peru, the United States of America, and Venezuela. The data were obtained from the technical literature and official reports. Included also are a listing of research needs and preliminary outlines of two field research projects, those of Peru and Venezuela. In undertaking the exhaustive studies necessary and in the preparation of this document, the Organization has had the capable services of Dr. Robert Pollitzer, on assignment from Fordham University, and Dr. K. F. Meyer, Director Emeritus of the George Williams Hooper Foundation, University of California Medical Center, together with the secretariat services of Dr. A. N. Bica and Dr. E. C. Chamberlayne.*

* Since April 1964 with the National Institutes of Health, U.S. Public Health Service.

SECTION B

GENERAL REMARKS

As can be gathered from the adjoined tabulations, plague is at present manifest in the western part of the United States as well as in five South American countries, namely, Bolivia, Brazil, Ecuador, Peru, and Venezuela. Generally speaking, the ecology of the disease is of a uniform pattern, characteristic also of other countries with a vast hinterland, as for instance, South Africa, which became plague-infected during the present pandemic: entering through seaports, the infection involved first the rat-populations in the urban areas and soon also in more or less distant cities and towns, the rat epizootics invariably leading to considerable epidemics; however, though often slowly, the infection inexorably spread to rural areas of the hinterland, where owing to the presence of susceptible wild rodent species, it found conditions for its persistence comparable in principle to those in the ancient plague foci of Central Asia. Though in some of the affected South American countries or parts thereof the common rats are still involved in the manifestations of plague, in other foci these rodents have ceased to play a role or have been relegated to a secondary role, becoming but temporarily affected when the disease is rampant among the wild rodents and thus, like the house mice and, more often, the domesticated guinea pigs, serving merely as links in the chain of events leading to a transition of the infection from the wild-rodent reservoir to man (which, however, may also be effected through direct contact with wild rodents or through their fleas).

Thus, as these brief general statements suffice to show, considerable variances in the plague situations in the individual countries, or even in the foci involved, are bound to exist, and these variances are further accentuated by the presence of different wild-rodent and wild-rodent flea species in the various affected localities. Therefore, in order to arrive at an adequate appreciation of the plague situations in the presently involved American countries, it is necessary to deal individually with each of them.

TABLE I

INCIDENCE OF PLAGUE IN THE PRESENTLY AFFECTED COUNTRIES OF THE AMERICAS

DURING THE PERIOD 1946-1963

Country	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
Argentina...	10	4	12	-	-	1	2	-	-	-	-	-	1	-	-	-	-	-
Bolivia.....	13	?	3	3	22	10	55	-	9	45	3	-	-	-	12	20	-	53
Brazil.....	332	88	386	91	55	20	65	10	6	27	4	37	25	16	28	106	36	39
Ecuador.....	45	21	40	19	28	33	44	90	81	85	80	79	22	40	77	105	326	258
Peru.....	126	173	73	116*	77*	73*	60*	163	75	8	24	37	49	33	139	68	164	72
USA.....	-	1	-	-	-	-	-	-	-	-	1	1	-	4	2	3	-	1
Venezuela...	-	-	7	2	5	8	-	1	-	-	3	-	-	-	-	6	1	-
Totals	526	287	521	231	187	145	226	264	171	165	115	154	97	93	258	308	527	423

*Deaths only
-No cases reported.

TABLE II

Plague Incidence in the Americas, 1956-1963

(Figures mainly from the Weekly Epidemiological Record of the World Health Organization)

II.1 Argentina

Year	Plague Incidence
1956	-
1957	-
1958	One plague case recorded in Misiones Province (see Reported Cases of Notifiable Diseases in the Americas 1949-1958, PAHO Scientific Publication No. 48, p. 70).
1959-1963	-

II.2 Bolivia

Year	Plague Incidence
1956	Three cases recorded in Santa Cruz Department, Vallegrande Province (see PAHO Scientific Publication No.48).
1957	-
1958	-
1959	-
1960	Small epidemic (12 cases) recorded at Pucar, Santa Cruz Department, Vallegrande Province.
1961	20 plague cases with 8 deaths recorded from 26 March to 1 April in Villa Serrano, Boeto Province, Chuquisaca Department (WHO Weekly Epidemiological Record 36, 1961, 16:165).
1962	-
1963	53 cases reported during April-May from Santa Cruz Department, Vallegrande Province.

TABLE II, Plague Incidence in the Americas, 1956-1963 (cont.)

II.3 Brazil

Year	States affected	Case incidence: Per state	Case incidence: Yearly total
1956	Pernambuco	4	4
1957	Alagôas	5	
	Bahia	20	
	Pernambuco	12	37
1958	Bahia	25	25
1959	Bahia	16	16
1960	Alagôas	13	
	Bahia	13	
	Rio de Janeiro	2	28
1961	Alagôas	12	
	Bahia	15	
	Ceará	7	
	Minas Gerais	2	
	Paraíba	31	
	Pernambuco	39	106
1962	Alagôas	1	
	Ceará	16	
	Paraíba	3	
	Pernambuco	13	
	Rio Grande do Norte	3	36

TABLE II, Plague Incidence in the Americas, 1956-1963 (cont.)

II.3 Brazil (cont.)

Year	States affected	Case incidence: Per state	Case incidence: Yearly total
1963	Alagôas	3	
	Bahia	14	
	Ceará	13	
	Paraíba	2	
	Pernambuco	7	39

II.4 Ecuador

Year	Localities affected: Provinces	Localities affected: Cantons	Case incidence: Per canton	Case incidence: Per province	Yearly total
1956	Tungurahua	Ambato	18	18	
	Manabí	Jipijapa	12	12	
	Chimborazo			7	
	Loja			43	80
1957	Los Ríos	Vinces	5	5	
	Chimborazo	Guano	12	12	
	Loja			62	79
1958	Chimborazo	Guano	7		
		Riobamba	1	8	
	Loja	Celica	9		
		Calvas	3		
		Puyango	1		
		Macará	1	14	22

TABLE II, Plague Incidence in the Americas, 1956-1963 (cont.)

II.4 Ecuador (cont.)

Year	Localities affected: Provinces	Cantons	Case incidence: Per canton	Per province	Yearly total
1959	Chimborazo	Guano	11		
		Riobamba	10	21	
	Loja	Celica	4		
		Macará	1		
		Loja	7		
		Catacocha	1		
		Paltas	6	19	40
1960	Chimborazo	Riobamba	10		
		Alausi	10		
		Guano	15	35	
	El Oro	Piñas	5	5	
	Loja	Celica	1		
		Paltas	7		
		Calvas	17		
		Macará	12	37	77
1961	Tungurahua	Ambato	8	8	
	Chimborazo	Riobamba	1		
		Guano	1	2	
	Loja	Calvas	2		
		Celica	3		
		Paltas	2	7	
	El Oro	Piñas	9		
		Zaruma	8	17	
	Manabí	Manta	36		
		Portoviejo	23		
		Rocafuerte	10	69	
	Pichincha	Quito City	2*	2	105

* Infected in Manabí.

TABLE II, Plague Incidence in the Americas, 1956-1963 (cont.)

II.4 Ecuador (cont.)

Year	Localities affected: Provinces	Localities affected: Cantons	Case incidence: Per canton	Case incidence: Per province	Yearly total
1962	Chimborazo	Aluisi	21		
		Riobamba	6	27	
	El Oro	Piñas	2	2	
	Loja	Calvas	19		
		Celica	23		
		Macará	10		
		Paltas	1		
		Puyango	3	56	
	Manabí	Chone	13		
		Jipijapa	1		
		Junín	1		
		Manta	86		
		Montecristi	9		
		Portoviejo	26		
		Rocafuerte	16		
		Santa Ana	12		
		Sucre	74		
		24 de Mayo	3	241	326
1963	Chimborazo	Aluisi	57		
		Guano	8		
		Riobamba	2	67	
	El Oro	Piñas	18	18	
	Loja	Calvas	9		
		Loja	5		
		Macará	2		
		Paltas	13	29	
	Manabí	Chone	4		
		Manta	15		
		Montecristi	8		
		Portoviejo	56		
		Rocafuerte	14		
		Santa Ana	7		
		Sucre	22		
		24 de Mayo	18	144	258

TABLE II, Plague Incidence in the Americas, 1956-1963 (cont.)

II.5 Peru

Year	Localities affected		Case incidence		Yearly total
	Department	Province	Per province	Per department	
1956	Piura	Ayabaca	8		
		Huancabamba	16	24	24
1957	Piura	Ayabaca	9		
		Huancabamba	14	23	
	Ancash	Huaraz	11		
		Recuay	3	14	37
1958	Tumbes	C. Villar	3	3	
	Piura	Ayabaca	24		
		Paita	1		
		Sullana	6	31	
	Lambayeque	Lambayeque	7	7	
	Cajamarca	Hualgayoc	3	3	
	Ancash	Huaraz	5	5	49
1959	Piura	Ayabaca	10		
		Huancabamba	4		
		Paita	1	15	
	Cajamarca	Hualgayoc	18	18	33
1960	Piura	Ayabaca	15		
		Huancabamba	117	132	
	Cajamarca	Hualgayoc	7	7	139

TABLE II, Plague Incidence in the Americas, 1956-1963 (cont.)

II.5 Peru (cont.)

Year	Localities affected: Department	Province	Case incidence: Per province	Per department	Yearly total
1961	Piura	Ayabaca	3		
		Huancabamba	65	68	68
1962	Amazonas	Bagua	25	25	
	Piura	Ayabaca	48		
		Huancabamba	44	92	
	Cajamarca	Jaén	47	47	164
1963	Amazonas	Bagua	34	34	
	Ancash	Casma	6	6	
	Piura	Ayabaca	23		
		Huancabamba	9	32	72

II.6 United States of America

Year	State	County or locality	Cases	Annual total	Remarks
1952-1955	-	-	-	-	-
1956	California	Condado County	1	1	
1957	Colorado	Boulder	1	1	The patient, who fell ill in Texas, had become infected in Colorado

TABLE II, Plague Incidence in the Americas, 1956-1963 (cont.)

II.6 United States of America (cont.)

Year	State	County or locality	Cases	Annual total	Remarks
1958	-	-	-	-	
1959	California	Mono City	1		
		Tolumnoe City	1		
	New Mexico	Bernalillo City	1		
	Maryland	Frederick City	1	4	(Laboratory infection)
1960	New Mexico	Chaves City	2	2	
1961	New Mexico	Santa Fe City	3	3	
1962	-	-	-	-	
1963	Arizona	Apache City	1	1	Died in New Mexico

II.7 Venezuela

Year	State	Localities involved: District	Localities involved: Municipality	Case incidence	Yearly total
1956	Aragua	Ricaurte	Tejerías	3	3
1957	-	-	-	-	-
1958	-	-	-	-	-
1959	-	-	-	-	-

TABLE II, Plague Incidence in the Americas, 1956-1963 (cont.)

II.7 Venezuela (cont.)

Year	State	Localities involved		Case incidence	Yearly total
		District	Municipality		
1960	-	-	-	-	-(a)
1961	Aragua	Ricaurte	Tejerías	2	
			El Consejo	1	
		Mariño	Turmero	3	6
1962	Aragua	Ricaurte	La Victoria	1	1
1963	-	-	-	-	-

(a) The Weekly Epidemiological Record for 1960 (vol. 35, 7:80) stated that evidence of plague in a wild rodent (Sigmodon hispidus hirsutus) was detected on 26 January in the locality last found affected by human plague in 1956.

SECTION C

REVIEW AND EVALUATION OF THE PRESENT STATUS OF PLAGUE IN ARGENTINA

Incidence of the Disease

Dealing with the early history of plague in Argentina, Pollitzer (1954) made the following statement:

"Apparently by-passing Buenos Aires and the Argentinian ports on the Paraná River, plague became manifest first in South America at Asunción, situated far inland in Paraguay, which had been reached in April 1899 by an infected steamer. From this original focus the disease was soon carried back to Rosario and other river ports in Argentina, at the end of the year also to Buenos Aires.

"The initial period of the infection thus established was followed first by a stage during which plague was carried inland by rail, then by further progress of the pest to remote regions in the interior, where wild-rodent foci were created. A wide area, extending from the Provinces of Jujuy and Salta on the Bolivian border in the north, to Patagonia in the south, thus became gradually involved (Sussini, 1939).

"As pointed out by De la Barrera (1942), generally speaking the inland foci of plague in Argentina fell into two groups:

"(a) Those in the central part of the country, particularly in the Provinces of Río Negro, La Pampa, Mendoza, and San Juan, with a sparse population and no agriculture. Since grain stores which might have attracted the rodents to the settlements were absent, contact with infected animals was restricted to chance meetings in the fields, and the incidence of human plague was consequently low.

"(b) Those in the north, especially in Santiago del Estero, Tucumán, and Salta, where accumulations of agricultural products attracted the rodents to the settlements and houses, and the incidence of human cases was accordingly higher."

As estimated by Moll and O'Leary (1945), the number of plague cases in Argentina from 1899 to 1930 amounted to about 6,200. The further incidence of the disease up to 1952 is shown in the following table:

Year	Cases	Deaths	Year	Cases	Deaths	Year	Cases	Deaths
1931	37	24	1938	15	8	1945	?	3
1932	61	19	1939	5	4	1946	10	3
1933	63	25	1940	228	192	1947	4	0
1934	45	40	1941	56	28	1949	12	4
1935	15	10	1942	38	19	1949/50	0	0
1936	31	21	1943	2	1	1951	1	0
1937	20	18	1944	107	63	1952	2	1

Note: In 1940 the Provinces of Santiago del Estero, Córdoba, and Tucumán were mainly involved, in 1944 Salta and Jujuy Provinces.

Though these figures show the trend of the infection rather than the exact incidence of the disease, which was probably higher, they indicate that during the period under review the plague situation was on the whole favorable. The ports remained free after 1931, with the exception of a small outbreak (8 cases with 3 deaths) in November 1946 in Buenos Aires (Moll and O'Leary). Considering the large extent of the areas involved, the morbidity in the rural districts was as a rule rather low and, as is characteristic of sylvatic plague, the human attacks of bubonic plague were usually not grouped together but appeared in numerous foci independent of one another (Outes and Villafañe Lastra et al., quoted by Pollitzer). It must be noted, however, that the incidence of pneumonic plague was comparatively high and that repeated, though usually limited, epidemics of this type were observed. Miyara and his associates (1947) recorded 27 such outbreaks with a death toll of 222 and one instance of recovery for the period 1913-1918.

It is interesting that, whereas early in the period under review the plague incidence was higher in summer, later on there was a notable increase of manifestations recorded in autumn and winter (Villafañe Lastra et al., 1942).

Only two instances of plague have been reported in Argentina from 1952 to date: one recorded in a 1960 PASB report as occurring in 1958 in Misiones Province; and another in Jujuy Province, mentioned without date in a note recently received from De la Barrera, who, referring to both these attacks, stated that "a scrutiny of the scanty existing documentation renders the exactness of their diagnosis doubtful."

It would appear, therefore, that since 1952 Argentina has been practically free of human plague.

Giving in the above-mentioned note an over-all picture of the present plague situation in Argentina, De la Barrera stated that:

1. Infection of the common rats, while frequent in the past, has rarely been met with during the period 1940-1952, and not at all since the latter year.

However, since deratization in the ports and cities is being done irregularly and inadequately, R. rattus and R. norvegicus continue to be abundant (extraordinarily so in some localities). Their most frequent flea in the areas with a hot or temperate climate is Xenopsylla cheopis. In the colder regions Nosopsyllus fasciatus and N. londinensis are present. Generally the flea indices are low.

2. Though since 1942 no exhaustive studies have been made, sylvatic plague has been met with in some localities. The findings of infected animals have been isolated and no reference has been made to epizootics. No new foci of sylvatic plague have been detected.

3. As shown by De la Barrera, the following wild-rodent fleas are capable of conveying plague by their bite:

Polygenis platensis cisandinus
Panallius byturus
Polygenis byturus
Delostichus talis

Foci of sylvatic plague have been found in the following localities:

Locality	Province	Longitude (WG)		S. Latitude	
Chañaritos	Córdoba	65º		30º	30'
	Río Negro/ La Pampa	65º	30'	38º	40'
Telen	La Pampa	66º		36º	
	Mendoza	68º	20'	33º	
Las Toscas	Mendoza	68º	40'	34º	10'
Icaño	Catamarca	65º	10'	28º	50'
Río Seco	Córdoba	63º	30'	30º	30'
	Tucumán/Santiago del Estero	64º	30'	30º	30'
	Salta	64º	30'	25º	35'
Quenquén	Buenos Aires	58º	40'	38º	32'

Ecological Observations

Common Rats

To judge from the compilation of Moll and O'Leary (1945), R. norvegicus was generally predominant among the common rats of Argentina in the towns as well as in the rural areas. R. r. rattus was less common, R. r. alexandrinus least frequent.

As summarized by Pollitzer (1954), the relative epidemiological importance of the common rats and of the wild rodents in Argentina, as well as the question of a transition of plague from the former to the latter or vice versa, have been the subject of much debate. No doubt can exist that originally the infection spread from the rats (probably R. norvegicus) to the wild-rodent species (Villafañe Lastra et al., 1942), and it is also certain that foci have become established where wild rodents alone are responsible for the causation of human plague as well as for the perpetuation of the infection. However, in other localities a spread of the disease from the sylvatic rodent fauna to the rats was observed and the latter then played a subsidiary or even a preponderant role in the causation of human attacks. De la Barrera (1942) maintained, in this connection, that opportunities for contact between the wild and the commensal rodents were present, especially in the agricultural areas of north Argentina where both were attracted by the grain stores, and a study of the available literature confirmed that an involvement of the common rats in the chain of infection was far more frequently noted there than in the central provinces.

Wild Rodents and Lagomorpha

In an undated reprint of an article entitled "Roedores silvestres infectados por Pasteurella pestis en la República Argentina," published in the book Primeras Jornadas Entomoepidemiológicas Argentinas and recently forwarded to the present reporters, De la Barrera furnished the following excellent list of wild rodents and lagomorpha found naturally plague-infected in Argentina:

First found infected

Species	Year	Locality	Observer
Cavia aperea	1924	Santa Rosa, La Pampa*	Uriarte and González
Cavia pamparum	1942	Necochea, Buenos Aires Province	Alonson Mujica
Microcavia australis australis	1934	Pichi-Mahuida, Río Negro Province	Llosa

* Cavia aperea is not indigenous in this region.

Species	Year	Locality	Observer
Microcavia australis joannia	1939	La Paz, Mendoza	De la Barrera
Microcavia australis salinia	1940	7 de Abril, Santiago del Estero	De la Barrera
Galea musteloides musteloides	1940	Metán, Salta	De la Barrera
Galea musteloides littoralis	1934	Fortín Uno, Río Negro	De la Barrera and Riesel
Galea musteloides leucoblephata	1937	Santa Rosa, Mendoza	De la Barrera and Corica
Lepus europaeus	1935	Fortín Uno, Río Negro	De la Barrera
Sylvilagus brasiliensis	1942	Salta	Alvarado
Graomys griseoflavus griseoflavus	1934	Fortín Uno, Río Negro	De la Barrera and Riesel
Graomys griseoflavus centralis	1942	Río Seco, Córdoba	Savino and Goobar
Graomys chacoensis	1940	El Quebrachal, Salta	De la Barrera
Graomys medius	1940	Pellegrini, Santiago del Estero	De la Barrera
Graomys cachinus	1940	El Quebrachal, Salta	De la Barrera
Eligmodontia morenoi	1940	7 de Abril, Santiago del Estero	De la Barrera
Hesperomys murillus cordobensis	1934	Fortín Uno, Río Negro	De la Barrera and Riesel
Hesperomys launcha	1940	7 de Abril, Santiago del Estero	De la Barrera
Hesperomys venustus venustus	1940	Santiago del Estero	De la Barrera

Species	Year	Locality	Observer
Hesperomys himaculatus	1940	Santiago del Estero	De la Barrera
Akodon dolores	1940	Santiago del Estero	De la Barrera
Lagostomus maximus	1940	Santiago del Estero	Alvarado
Oryzomys flavescens	1940	El Quebrachal, Salta	De la Barrera
Phyllotis darwini vaccarum	1940	El Quebrachal, Salta	De la Barrera
Holochilus balnearum	1940	7 de Abril, Santiago del Estero	De la Barrera

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Details in regard to some of these species furnished by De la Barrera in the above-quoted contribution and in an article published in 1953 in the Bulletin of the World Health Organization were as follows:

... Microcavia australis (Caviinae)--An animal somewhat smaller than an adult guinea pig, distributed all over Argentina west of the 63rd meridian from Santa Cruz to Jujuy, but more abundant in the south than north of Córdoba. Digs burrows, which as a rule are inhabited by 3-8 individuals. Cohabits sometimes with Galea. Herbivorous and diurnal, not penetrating into human habitations, but ventures into their immediate vicinity. Its skin cannot be utilized and its meat is but rarely consumed.

Flea index: 20 in winter, 3 in summer. Most frequent fleas (a) in the north, Craneopsylla wolffhuegeli (43%), Panallius galeanus (36%), Polygenis byturus (19%); (b) in the south, Delostichus talis (45%), Hectopsylla gemina (20%), Dysmicus barrerae (9%), Panallius galeanus (8%), Hectopsylla cypha (7%), Polygenis platensis cisandinus (4%).

M. australis is apt to be decimated by plague epizootics. A transition of the infection from it to man is usually due to direct contact with the carcasses, with which the children often play.

... Galea musteloides (Caviinae)--Occurs in three subspecies showing the same geographic distribution as M. australis, but becomes progressively more frequent toward the north. As noted above, G. musteloides sometimes lives together with the latter rodent, the habits of which it shares.

Fleas: (a) in the north, Tiamastus cavicola (64%), Ph. byturus (13%), P. trypus (11%), Cr. wolffhuegeli (5%) (data for the extreme north); (b) in the south, Panallius galeanus (47%), H. gemina (16%), H. cypha (9%), D. barrerae (8%), P. platensis cisandinus (5%).

G. musteloides suffers from intense epizootics whenever plague is present.

... Cavia pamparum (Caviinae)--This species, which is abundant in the coastal areas of Argentina (Buenos Aires, Entre Ríos, Corrientes, and Santa Fe), does not dig burrows but shelters under sufficiently high vegetations. Diurnal in habits, it shows a lesser tendency than the above-mentioned rodents to approach human habitations. Its meat is rarely consumed.

The flea index for C. pamparum is extremely low (0.04-0.1). Though like the above-mentioned species highly susceptible to experimental infection with P. pestis and abundant in the most plague affected regions, C. pamparum was found but once naturally infected.

... Graomys griseoflavus (Cricetinae)--Two subspecies of this rodent (Gr. gr. griseoflavus and Gr. gr. centralis) are widely distributed in Argentina, from Santa Cruz to Jujuy and from the 62nd meridian to the west, while six other species of the same genus are occurring less abundantly in the center and north of the country. Nocturnal and basically arboreal, Graomys griseoflavus, which is slightly smaller than R. rattus, is prone to settle down in many locations, including hollow trees, nests of birds, burrows of other animals, bushes, and even the thatch of the roofs of rural houses, in which latter it feels as much at home as in the open.

The flea index of Gr. griseoflavus varies from 3 to 12. In the south its flea fauna consists mainly of P. platensis cisandinus (86%), which also abounds in the nests of the animals; other species met with are Cr. wolffhuegeli (11%), Dysmicus hapalus (1%), and Delostichus talis (0.5%); in the north P. platensis cisandinus is replaced by P. byturus (20%), P. galeanus (14%), and Cr. wolffhuegeli (63%)

Invariably involved in the epizootics, Gr. griseoflavus presumably plays a dangerous role in the spread of the infection among the wild rodents and is also apt to convey the disease to woodcutters and other workers in the forests. Moreover, acting on account of its ubiquity as a link between the sylvatic fauna and the rats, this animal is likewise able to take an ominous part in the causation of intradomestic plague manifestations.

... Hesperomys (Cricetinae)--As described by De la Barrera, species of this genus are distributed in Argentina from Chubut to Jujuy, of which four have been found naturally plague-infected. Though these rodents, which are somewhat larger than M. musculus, are said to be arboreal, they are also found in burrows, thus having ample opportunities of coming in contact

with other sylvatic species. It is not surprising, therefore, that they almost invariably become involved in the plague epizootics.

The flea index of Hesperomys (in the north of the country) varies from 2 to 5. Their predominant flea is Cr. wolffhuegeli (51%), followed in frequency by P. byturus (39%) and P. galeanus (8%).

... Oryzomys flavescens (Cricetinae)--This arboreal species, of the same size as the Hesperomys, though widely spread in subdomestic environments as well as in the open, was but rarely found naturally plague-infected. Its flea index was 1-3, with Cr. wolffhuegeli forming 65% of the flea fauna, P. rimastus 22%, and P. pl. cisandinus 5%. However, in the north of the country P. rimastus was found to be replaced by P. byturus (30%).

... Eligmodontia morenoi and E. hirtipes jucunda (Cricetinae)-- These rodents, of the same size and habits as the foregoing species, are met with only in the north of the country. They have been found plague-infected in "pirguas" (rough structures for the storage of maize and other agricultural products), where they are apt to live together with other wild rodents and R. r. alexandrinus.

... Phyllotis darwini vaccarum (Cricetinae)--Somewhat smaller in size than Graomys and of arboreal habits, this species also occurs only in the north of Argentina, where it has been found plague-infected in maize "pirguas." Its flea fauna is unknown.

... Holochilus balnearum (Cricetinae)--This rodent, of the same size as Phyllotis, though of aquatic habits, is encountered also on firm ground, where it is apt to penetrate into the storages of cereals kept near the houses. It has been found naturally plague-infected in these locations. Its fleas have not been determined.

... Akodon dolores (Cricetinae)--This species, of the same size as M. musculus, abounds in the center of Argentina, living in small burrows or below shrubs, but was only on rare occasions found plague-infected. Its fleas include Cr. wolffhuegeli (64%), P. byturus (28%), and Panallius galeanus (7%).

... Lagostomus maximus (Chinchillidae)--As stated by De la Barrera: "This large rodent is represented by three subspecies distributed over the whole country from the 40th degree latitude to Jujuy. Strictly nocturnal, herbivorous, burrowing, it is an agricultural pest. Does not approach the houses. The young animals are sometimes hunted for the sake of their skins and meat."

Found but accidentally plague-infected, this species does not seem to be involved in the conveyance of the infection to man. It is much infested by fleas (index 10-30, comparatively highest in old animals). The fleas found on Lagostomus are: in the south and center, P. irritans (73%),

Hectopsylla stomys (25%); in the north, Panallius galeanus (66%), P. irritans (21%), Hectopsylla stomys (11%).

... Lepus europaeus (Lagomorpha)--This cosmopolitan species of hares abounds everywhere in Argentina, where it is much hunted for the sake of its skin and meat. It is slightly flea infested, almost exclusively by P. irritans.

These hares have been invariably found plague-affected in the course of the epizootics, but their infection rate was always low. For this reason human infections due to the skinning of the carcasses of the animals were also not numerous.

... Sylvilagus brasiliensis (Lagomorpha)--This animal, which is a little smaller than a rabbit, is found only in the north of the country (Salta, Jujuy, Formosa, Misiones). Only two instances of plague infection have been detected in this species up to 1952. Its flea fauna has not yet been investigated.

As has been stated in earlier parts of these reports, De la Barrera, no doubt influenced in the first line by his long and ample experiences in Argentina, postulated that all wild rodents and lagomorpha found plague-affected in South America are equally susceptible to the infection, their comparative importance in the maintenance and spread of the disease depending solely upon differences in their population density and ecology. The present reporters had to point out, however, that observations made elsewhere, for instance in the United States, proved or at least suggested that a distinction had to be made between (a) species or races of wild rodents or lagomorpha serving mainly or solely as fuel for the spread of plague, and (b) those which, possibly because more resistant to infection with P. pestis, were capable of acting as permanent reservoirs of the disease. The question of whether such differences existed also among the plague-affected species in South America was, in the opinion of the present reporters, still sub judice. They considered, in this connection, the probability that during the interepizootic periods plague might be restricted to territorially quite limited strongholds of the infection and pointed out that the detection and thorough investigation of such localities would go a long way to establishing which species of rodents or lagomorpha were instrumental in bridging over the gaps between the manifestations of epizootics.

It might appear at first glance that Argentina, where plague is now at low ebb, might be a suitable locale for such studies. However, due account has to be taken of the disproportion between the enormous size of the potentially still-affected areas and the now apparently rare and rather unpredictable reappearance of quite limited manifestations of sylvatic plague.

Concluding Remarks

Reassuring as the recent absence of plague in man and apparently even in the common rats of Argentina is, one should not forget that in view of the undoubtedly continued existence of sylvatic plague, however little manifest at present, the possibility of a recrudescence of the disease cannot be altogether excluded.

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SECTION D

REVIEW AND EVALUATION OF THE PRESENT STATUS OF PLAGUE IN BOLIVIA

Incidence of the Disease

The tabulations of the plague outbreaks in Bolivia from 1921 to 1948 furnished in a report by De la Barrera (1955) and, in a more elaborate form, by Macchiavello (1959), plus reports of the Ministry of Health and from other sources, may thus be reproduced in a somewhat modified form:

Year and month	Locality*	Cases/ deaths	Observations on epizootics	Comments
1921 I-VI	Padcaya, Arce Prov., T.	1,525/642	None	One report listed 1,525 cases with 842 deaths from January to August.
1921-22 XII-V	Padcaya, Arce Prov., T.	?375/300	None	
1928 V-VII	Vallegrande Prov., S.C.	?300/88	None	
1929	El Filo, Cordillera Prov., S.C.	??	None	
1930	Mataral, Florida Prov., S.C.	??	None	
1932-33	Huayrahuasi Grande, Tomina Prov., Ch.	1,500/800	None	An outbreak began in this locality in December 1932.
1933 VIII	Mataral, Florida Prov., S.C.	??	None	

* S.C.=Santa Cruz Department.
Ch. =Chuquisaca Department.
T. =Tarija Department.

Year and month	Locality	Cases/ deaths	Observations on epizootics	Comments
1933				
XI	Mosquerillas (?), Florida Prov., S.C.	? ?	None	An outbreak took place from November 1933 to January 1934, in Padilla, Tomina Province, extending from there as far as the Azero River.
XII	Montecanto, Tomina Prov., Ch.	10/12	None	
1934	Pampas del Tigre, Boeto Prov., Ch.	? ?	?	
	Postrevalle, Vallegrande Prov., S.C.	16/?	None	
1934-35				
X-II	Yanakurko, El Rosal, Tomina Prov., Ch.	56/34	None	
1935	Postrevalle, Vallegrande Prov., S.C.	12/9	None	Huayrahuasi Grande, Tomina Province (19 cases).
VI	Villa Serrano, Boeto Prov., Ch.	? ?	None	Pencal, Vallegrande Province.
1936	Entre Ríos, T.		In Rattus	First evidence of disease in rats.
1937				
I	Villa Serrano, Boeto Prov., Ch.	? ?	None	
I-II	Montecanto, Tomina Prov., Ch.	? ?	None	
1937-38				
XI-IV	El Tapial, Tomina Prov., Ch. (?)	? ?	None	
XII-III	Entre Ríos, O'Connor Prov., T.	106/?18	In Rattus	
1938	Monteagudo, Azero Prov., Ch.	56/34	None	

Year and month	Locality	Cases/ deaths	Observations on epizootics	Comments
1938				
IV-VII	El Palmar, Gran Chaco Prov., T.	?100/?50	In Rattus	
VIII-X	Choreti and Camiri, Cordillera Prov., S.C.	151/63	"	One report recorded a case incidence of 290 in these two localities ("end of July").
IX	Various places of Tomina Prov., Ch.	? ?	None	Sachapera, Palmar, Aguayrenda, 90 cases in May.
	Abopó and Cabezas, Cordillera Prov., S.C.	? ?	Apparently present	Cuevo, Cordillera Province, 35 cases in December.
IX-X	Carahuaycho, Cordillera Prov., S.C.	? ?	In Rattus	
IX	La Herradura, Cordillera Prov., S.C.	1/0	"	
1938-39				
XII-I	Entre Ríos, O'Connor Prov., T.	6/1	None	
XI-II	Muyupampa, Luis Calvo Prov., Ch.	16/10	In Rattus	
XII-III	Cuevo, Cordillera Prov., S.C.	36/23	"	
1939				
I	Taperillas, or Esperillas, Cordillera Prov., Ch.	1/1	None	
II	Vaca Guzmán, Luis Calvo Prov., Ch.	2/?	None	
	Camatindi, Cordillera Prov., S.C. (?)	3/3	None	

Year and month	Locality	Cases/ deaths	Observations on epizootics	Comments
1939				
VII-X	Llactonsillos, Tomina Prov., Ch.	8/4	In Cricetinae	
?IX	Contadero, Belleza, Tomina Prov., Ch.	12/7	None	
XII	Charagüa (Ovai and Ovaicito), Cordillera Prov., S.C.	5/3	In Rattus	
1940				
I, XII	Cuevo, Cordillera Prov., S.C.	2/0	None	
III	Tholaorcho, Tomina Prov., Ch.	?1/1	None	
III	Entre Ríos, O'Connor Prov., T.	2/?	None	
VII-VIII	Ivo, Luis Calvo Prov., Ch.) Boyuibo, Cordillera Prov., S.C.)	16/10	In Rattus	
VIII-IX	Aguayrenda, Gran Chaco Prov., T.	3/1	None	
IX-X	Misión Santa Rosa, Santa Rosa de Cuevo, Luis Calvo Prov., Ch. (?)	18/15	In Rattus	
XI-XII	Camiri, Cordillera Prov., Ch.	2/1	"	
1941-42	Ipitá (?), Cordillera Prov., S.C.	?/?	None	
1942-43				
X-I	Sipotendi and Karikari (?), Boeto Prov., Ch.	42/45	None	Another report recorded 41 cases at "Sipotendi" and Karikari."
X-III	Gutiérrez, Cordillera Prov., S.C.	?25/?	None	

Year and month	Locality	Cases/ deaths	Observations on epizootics	Comments
1942-43 X-V	Mosqueras (?), Vallegrande Prov., S.C.	2/?	None	
1943 V-IX	Moreta, O'Connor Prov., T.	8/6	?	
1944 III	Arrayán, Boeto Prov., Ch.	4/?	None	
	Alisos, Arce Prov., T.	6/2	In Caviae	3 cases recorded during 26 May-3 June.
III-VIII	Muyupampa, Luis Calvo Prov., Ch.	4/2	None	Recorded 8 cases in July at Yacuiba (? Tarija Dept.).
VII	Campo Grande, Gran Chaco Prov., T.	8/4	None	
VIII-XI	Vallecito, Luis Calvo Prov., Ch.	2/?	None	
VIII-IX	El Fraile, Florida Prov., S.C.	9/?7	None	
	Temporal, Boeto Prov., Ch.	?/?3	None	
X-XII	Santiago Chico, Boeto Prov., Ch.	13/?2	None	
1945 I-IX	Lagunillas y Pueblito, Cordillera Prov., S.C.	25/12	In Rattus	
	Muyupampa, Luis Calvo Prov., Ch.	1/0	"	
IV-VI	Vallegrande, S.C.	76/33	"	Same outbreak recorded as occurring in Vallegrande, with 61 cases and 34 deaths.

Year and month	Locality	Cases/ deaths	Observations on epizootics	Comments
1945				
XI-XII	Piraimiri (?), Vallegrande Prov., S.C.	29/7	In Rattus	
	(?) Hornos, Vallegrande Prov., S.C.	6/6	"	
1946				
V	El Arrayán, Boeto Prov., Ch.	1/?	"	
IX-X	Temporalcillo, Boeto Prov., Ch.	8/5	None	
1947				
II	Muyupampa, Ch.	2/2	In Rattus	
	Tomina Prov., Ch.	9/7	None	
VI	Morebeti, Cordillera Prov., S.C.	1/0	In Rattus	
VII	Al sur de Lagunillas, Cordillera Prov., S.C.	?/7	"	
X	Floripondio, Florida Prov., S.C.	5/4	In Cricetinae	No rats, Graomys prevalent.
	Gutiérrez, S.C.	2/0	None	
	Choreti, Cordillera Prov., S.C.	1/0	None	
1948				
VIII	La Cueva	3/?	None	8 cases recorded elsewhere.

More detailed data on the plague incidence in Bolivia during the period from 1949 to 1960, recorded by Torres Bracamonte and González Moscoso (1961) may be summarized as follows:

Department	Province	Canton	Locality	Year	Month	Cases	Deaths
Tarija	Gran Chaco	Caraparí	Común	1950	VIII	3	0
		Sanandita		1957	XI	2	0
Chuquisaca	Tomina	Padilla	Tholaorcho	1949	XII	3	2
			Muyu Orcko	1952	X-XI	14	6
			El Tabacal		X-XI	3	1
			Huaycopampa	1954	XI	5	5
			Monte Cantu		XI	3	1
			Asterillo		XI	1	0
			El Salto		XI	2	1
			Angostura		XI	1	1
			Garganta Khasa		XI	1	1
	Luis Calvo	Vaca Guzmán	El Pincal	1951	XI	1	0
	Zudañez	Mojocoya	Bella Vista	1951	IX	9	6
		Presto	Tapirani	1955	VIII	1	0
	H. Siles	Fernández	Pumamayu	1959	XII	5	3
			Cañamayu		XII	1	0
			Pumamayu	1960	I	4	1
			Cañamayu		I	5	1
			El Rodeo		I-II	2	1
Santa Cruz	Florida	Cuevas	Agua Hedionda	1950	I	2	1
			Novillos	1950	VI-VII	8	2
	Ichilo	San Carlos	Quebrada Seca		IX	2	2
			Pozo Verde		IX	2	2
			Rasca Buchi		IX	5	3
			Chacos		X	2	1
			Quebrada Seca	1951	II	2	2
	Vallegrande	Alto Seco	La Hoyada	1952	IX-X	7	5
			Jaboncillo		IX-X	1	1
			Fernández		XI	2	1
		Pucará	El Zapallar		XI-XII	10	8
			Tranca Mayu		XI-XII	1	1
			El Potrero	1955	X	7	7

Department	Province	Canton	Locality	Year	Month	Cases	Deaths
			Piedra Palta	1955	XI	2	1
			Duraznillo		XI	1	1
			Mecho Comido		XI	8	5
			Tranca Mayitu		XII	9	5
			Tranca Mayu		XII	2	0
			Cañas		XII	4	3
			La Higuera		XII	1	0
			Quesillo Pampa		XII	2	1
			El Abra		XII	1	0
			Guayabilla		XII	1	0
			Misko Loma	1956	I	1	0
			Cañas		I	1	1
			La Torre	1960	XI	12	4
	Cordillera	Choreti	Yapuy	1952	XII	3	2
				1954	X	14	3

Addendum: According to the WHO Weekly Epidemiological Record for 1961 (Vol.36, No.16, p.165), 20 plague cases with 8 deaths were recorded from 26 March to 1 April in Villa Serrano, Boeto Province, Chuquisaca Department. This, and PASB Health Statistics, (Vol.XI, Nos.1-4, January-December 1962), are the latest reports available as of 31 December 1962.

As can be gathered from the first of the above-inserted tabulations, plague was first recorded in Bolivia in 1921 in the Department of Tarija which, lying in the extreme south of the country, borders on Argentina. Then, after an apparently quiescent period, the presence of the disease was again reported in 1928 in Vallegrande Province of Santa Cruz Department, situated about 400 km north of the first affected area and, as asserted by De la Barrera, not in direct communication with it.

Discussing this quite extraordinary sequence of events, that observer and Macchiavello were in agreement that the initial appearance of plague in Bolivia was the result of a spread of the infection from Argentina, but were not in accord in regard to the manner in which this invasion took place. Referring to this problem in the concluding parts of this report, De la Barrera unequivocally maintained:

> "The country was invaded by the disease in 1921, when it existed already twenty years previously in Argentina and Paraguay. Plague began in an area where the domestic rat exists and probably came with the rat from the Argentinian border zone."

Macchiavello, claiming that in 1920 and 1921 a serious plague epidemic was present in the border Province of Jujuy and in other parts of Argentina, considered it as possible that the infection might have been imported by

fleas hidden in a bundle of silk clothes brought in for commercial purposes by the first patient affected by the disease in Bolivia. On the other hand, in his opinion it was:

> "also probable that the zone of Padcaya was the seat of an epizootic among wild guinea pigs, propagated by continuity from the enzootic zone of the above-mentioned rural plague area in Argentina. This seems to be indicated by the seasonal recrudescence of plague and its quiescence during the cold months from July to November, (followed) by a reappearance in December during the hot and rainy season."

It is true that later on, at the time of the 1944 outbreak at Alisos mentioned in the table, the presence of plague in the wild guinea pigs of the Tarija focus had been confirmed. Nevertheless, on the whole it appears more likely that, as assumed by De la Barrera, the common rats were instrumental in bringing the infection from Argentina into Bolivia. It is significant to note, in this connection, that Macchiavello (a) ascribed the appearance of plague in Vallegrande Province in 1928 to the importation of infected rats from Argentina in cargoes destined for the Standard Oil Company installations in that area, and (b) similarly held that the road-building operations and the intensified traffic caused by the Chaco war (1933--or, one should rather say, 1932--to 1935) were responsible for a transport of plague-affected rats or rat-fleas into Tomina in 1932. He emphasized, however, that since both these areas were not inhabited by common rats, a spread and perpetuation of plague could take place only in the wild-rodent populations. It is certain that purely sylvatic plague foci have become established in both provinces. Still, it is not easy to reconcile the quite exceptionally high incidence of plague in the Tomina Province in 1932-1933 (1,500 attacks with 800 deaths) with the concept of a wild-rodent nature of this outbreak. For this and other reasons one cannot claim that the problem of the early history of plague in Bolivia has been fully elucidated.

While venturing no definite statement regarding the origin of wild-rodent plague in that country, De la Barrera felicitously stated:

> "Murine plague has followed a regular route of invasion, as is the rule by the most easy way, first from west to east, then from south to north. As always, it followed the routes of human traffic from the Argentinian border over Padcaya, Tarija, Entre Ríos, Villa Montes, meeting there with another current, probably also of border origin, from Yacuiba via Aguayrenda and Sachapara. The Chaco war accelerated its progress, carrying it as far as Abapo and Cabezas on the Río Grande in 1939. The last outbreak was recorded in 1952."

As De la Barrera added, except at Padcaya all murine outbreaks took place at altitudes of less than 1,300 m and in a warm and semi-dry climate, i.e., an environment suitable for X. cheopis.

As a result of the above-described progress of the rat-caused infection and of a wide spread of the disease among the wild rodent populations, plague eventually involved an extensive area between the 18th and 22nd degrees of southern latitude and the 63rd and 65th meridians west, in the three Departments of Tarija, Chuquisaca, and Santa Cruz (Macchiavello, 1959). As estimated in a report by the Director of the Pan American Sanitary Bureau published in 1958, the regions involved had a size of 10,036 square miles, stretching from the Argentine border in the south to the Province of Ichilo in the north, and from Cordillera Province in the east to Zudañez Province in the west.

Emphasizing the seriousness of the plague situation in Bolivia in their 1961 publication, Torres Bracamonte and González Moscoso pointed to (a) the appearance of the disease in the hitherto unaffected cantons of San Carlos (Ichilo Province of Santa Cruz Department) in the north, and Mojocoya (Zudañez Province of Chuquisaca Department) in the northwest, in 1950 and 1952, respectively; and (b) the 1955 invasion of Presto Canton, still farther west in the Province of Zudañez. More disquietingly still, the two authors stated that, to the area proven to be plague-affected:

> "it is even possible to add that of the Provinces Tahuamanu and Abuná of the Pando Department, and that of Vaca Diez in the Beni Department, in which according to almost certain data sporadic human cases and big epizootics among the domestic rodents occur--a not strange phenomenon if one considers their vicinity with the frontier localities of Brazil, in which these rodents abound."

As will be further discussed below, it would be most important to establish the authenticity of this claim.

Discussing the ecology of plague in Bolivia, De la Barrera subdivided the affected area into the following four zones:

(1) Eastern zone, extending from the cordillera of Incahussi over Cuevo to Cabezas. Though inhabited by common rats infested with X.cheopis, plague was also found in wild rodents of this zone. Many of the urban centers within it had lost the importance they had during the Chaco war, but others, like Camiri and Chcreti, had gained in importance owing to the exploitation of oil-wells.

(2) Southern zone, really consisting of two regions--one in the west around Padcaya, invaded by plague in 1921, and an eastern one, which became infected 15 years later. Both these regions are infested with rats and X. cheopis, which, however, is less frequent in the highly situated western region.

(3) Central zone, free of rats, extending from the Azero River in the north to the Iñao mountain range in the south.

(4) Northern zone, situated in the environs of Vallegrande and also free of rats.

Following a somewhat different system, Macchiavello distinguished between (a) a southern zone, comprising Tarija Department; (b) an eastern zone, encompassing parts of Luis Calvo and Azero Provinces (Chuquisaca Department) as well as Cordillera Province of Santa Cruz Department; (c) the sylvatic plague zone of Tomina (Chuquisaca Department), comprising, besides the Province of Tomina, those of Azero and Boeto; and finally (d) the sylvatic plague zone of Vallegrande (Santa Cruz Department), including, in addition to the province of that name, parts of Florida and Ichilo Provinces and some adjacent localities of Cordillera Province.

In contrast to De la Barrera, Macchiavello upheld that plague in the oriental zone was exclusively murine in character, but that on the contrary the southern zone:

> "corresponds in part to murine, in part to sylvatic plague, being really an extension of what the Argentinian authors called for many years peste rural."

Macchiavello admitted that as a rule there existed in the southern zone a relation between the urban murine plague and the sylvatic manifestations in Caviae and Cricetinae. He maintained, however, that independent foci of sylvatic plague existed in some localities. Thus, as already mentioned above, at the time of the 1944 outbreak at Alisos (Tarija), plague-affected wild guinea pigs had been found in a region free of rats as well as in epizootics among the Cricetinae. Generally speaking, Macchiavello was of the opinion that the subsequent prevalence of rat-plague detracted attention from the sylvatic origin of the infection in the southern area. However, as has been noted above, the validity of the views held by him regarding the invasion of this zone is open to considerable doubt.

Observations on Rodents and Lagomorpha

Common Rats

Investigations made by De la Barrera on a sufficiently large scale showed an entire absence of R. norvegicus in the rat-infested part of the Bolivian plague areas, all the rats caught belonging to the subspecies R. r. alexandrinus. To judge from the results of trapping and from the damage they caused, the population density of these animals was alarmingly high. In the rural areas they showed little tendency to leave the houses or their immediate vicinity.

M. musculus

As can be gathered from Macchiavello's report, M. musculus was encountered not only in the rat-infested zones of the Bolivian plague area, but also in the Tomina and Vallegrande regions.

Visiting a group of houses situated at a short distance from the town of Padilla, where about two weeks previously a plague outbreak involving 12 persons had terminated, De la Barrera found one plague-infected house mouse. Since common rats were absent from this locality but nevertheless the outbreak was of a familial character, affecting six persons in one compound and four in another, De la Barrera inclined to the belief that M. musculus played a causal role in this instance. As no clear-cut evidence of a wild-rodent epizootic could be found, it could not be established in what manner the mice had become infected. Likewise, since the houses had been energetically treated with DDT before De la Barrera's arrival, it could not be ascertained which fleas had spread the infection among the mice and conveyed it from them to man.

Wild Rodents and Lagomorpha

As can be gathered from a table inserted in the article of Macchiavello (1959), he found the following rodent and lagomorpha species in the four Bolivian plague zones distinguished by him:

Southern zone (Tarija, Entre Ríos,) (Yacuiba)	Oriental zone (Choreti, Camiri,) (Cuevo, etc.)	Tomina zone (Monteagudo, Padilla,) (Sucre, Zudañez, Tomina, etc.)	Vallegrande zone (Vallegrande, Floripondio,) (Buen Retiro, etc.)	The following species have been found naturally plague-infected in Bolivia:
R. rattus	R. rattus			R. rattus
M. musculus	M. musculus	Mus musculus	Mus musculus	M. musculus
Cavia sp.	Hesperomys fecundus	Hesperomys venustus H. fecundus	Hesperomys venustus	Dasyprocta variegata boliviae
Galea musteloides	Oryzomys sp.	Oryzomys flavescens	Oryzomys yunganus	Galea musteloides
Sylvilagus brasiliensis	Cavia sp.	O. legatus O. yunganus O. laticeps O. wavrini O. sp.	O. chaprensis O. mamorae O. stolzmanni O. sp.	Graomys griseoflavus
Dasyprocta	Guerlinguetus sp.	Rhipidomys leucodactylus Rh. collinus	Rhipidomys collinus	Hesperomys fecundus
		Akodon sylvanus pervalens	Akodon sylvanus pervalens A. varius	H. venustus
		Phyllotis wolffsohni	Graomys griseoflavus G. gr. domorum	Oryzomys flavescens
		Oxymycterus paramensis	Oxymycterus paramensis	Oxymycterus paramensis
		Cavia sp.	Phyllotis wolffsohni Ph. lutescens	Phyllotis wolffsohni
		Dasyprocta	Dasyprocta	Rhipidomys leucodactylus
		L. viscaccia		Sylvilagus brasiliensis gibsoni
				Sylvilagus sp.

Besides R. rattus and M. musculus, De la Barrera (1955) encountered the following species of rodents and lagomorpha in Bolivia:

Species	Found in
Graomys griseoflavus	All the plague areas
Gr. medius	Padilla, Zudañez
Eligmodontia hirtipes hirtipes	Zudañez
Eurysygomatomys spinosus	Floripondio
Phyllotis wolffsohni	Vallegrande, Samaipata
Ph. nogalaris	Serrano, Ladera
Proechimys longicaudatus longicaudatus	Buen Retiro, Agua Hedionda, Floripondio, Novillos
Akodon mollis	Vallegrande, Pucara, Quirusillas
Oxymycterus doris	Agua Hedionda, Lagunillas, Río Grande, El Fraile
O. paramensis	Padilla, Cuevo, Vallegrande, Serrano, El Rosal
Rhipidomys leucodactylus	Padilla, Serrano, Camiri, Entre Ríos
Rh. collinus	Padilla, Agua Hedionda
Holochilus chacarius	Buen Retiro, Lagunillas, Padilla
Oryzomys legatus	Padilla, Serrano, Vallegrande, Villa Montes
O. sp.	Serrano, Lagunillas, Gutiérrez, Río Grande, Pucara, Vallegrande, Samaipata, Cabezas
Oryzomys longicaudatus longicaudatus	Tarija
O. boliviae	Trinidad
Olygoryzomys stolzmanni	Pucara
O. sp.	Buen Retiro
Hesperomys fecundus	Entre Ríos, Villa Montes
H. muriculus	Buen Retiro, Agua Hedionda, Samaipata, Padilla, Serrano, Camiri, Villa Montes
Oecomys mamorae	Buen Retiro, Trinidad
Sylvilagus brasiliensis	Buen Retiro, Agua Hedionda, Camiri
Leptosciurus leucogaster	Buen Retiro, Samaipata, Agua Hedionda
Guerlinguetus ingrami	Buen Retiro, Floripondio, Novillos
Lagidium viscaccia	Cuesta de Monos, Zudañez
Lagostomus maximus immolis	Nueva Esperanza
Dasyprocta variegata boliviae	Buen Retiro, Agua Hedionda, Trinidad, Samaipata, Lagunillas, Gutiérrez, Pirirenda, Curiche, Novillos, Floripondio
Cuniculus paca	Buen Retiro, Trinidad, Puerto Céspedes
Galea musteloides (? G.m. demissa)	Vallegrande, Pucara, Samaipata, Aiquile, Totora, Zudañez, Cuevo, Quirusillas, Padilla
Cavia tschudii atahualpae	Trinidad

Referring to observations made in the case of a few of the previously mentioned species, De la Barrera recorded the following data:

(a) Graomys griseoflavus. Confirming the findings previously made in Argentina, De la Barrera proved the occurrence of natural plague in this rodent species during a 1954 epizootic at Pucara (Vallegrande Province), in which Galea musteloides also was implicated. As in Argentina, G. griseoflavus, leading partly a sylvatic and partly a domestic existence, functioned as a dangerous liaison animal between the wild and the intradomestic rodent fauna.

(b) Hesperomys muriculus. This rodent, which partly led an arboreal existence, was less agile than Graomys but was nevertheless apt to penetrate into the houses, usually during the night. Like Graomys, it was mainly infested by fleas belonging to the genus Polygenis.

(c) Galea musteloides. As noted above, this rodent, which belongs to the family of Caviidae, was found plague-affected at Pucara. Being much hunted for the sake of its meat, it was potentially rather dangerous. Still, no definite information was available that the hunting of these animals and the handling of their carcasses formed an important source of human plague infection in Bolivia. Of the fleas found on G. musteloides, 97% belonged to the species Tiamastus cavicola.

(d) Dasyprocta variegata boliviae, an animal of comparatively large size, was also intensively hunted for the sake of its meat. Though living in burrows situated in the open spaces, this "Jochi colorado" was apt to enter the plantations. It appeared to have been implicated in the plague manifestations at Buen Retiro (Vallegrande zone) in 1950. It is important to note that the fleas found on this rodent included, besides P. irritans, Tiamastus cavicola, and Rhopalopsyllus species, some belonging to the genus Polygenis.

(e) Cuniculus paca, an animal of nocturnal habits which was also much hunted, had thus far not been found involved in the plague epizootics. Its fleas included, besides Rhopalopsyllus species, Polygenis roberti beebei and Adoratopsylla (Tritopsylla) intermedia oxyura.

(f) Domesticated guinea pigs. As can be gathered from De la Barrera's report: (a) breeding of guinea pigs in the houses was less general in Bolivia than in some of the other South American countries; and (b) no detailed information was available regarding a participation of these animals in the plague manifestations. Since, however, the presence of X. cheopis was proved in the case of the few specimens examined by De la Barrera, the domesticated guinea pigs are at least potentially rather dangerous.

Information on the role played by the various species of wild rodents and lagomorpha found naturally plague-infected in Bolivia (see last column of the table on p. 35) in the perpetuation and spread of the

infection is still deplorably scanty. Macchiavello merely mentioned, in this connection, that investigations made from 1941 to 1944 in the Tomina zone and at Alisos (Arce Province) had proved the existence of sylvatic plague in Caviae and Cricetinae and, as has been discussed above, considered it as possible that the former animals were the fons et origo mali in the southern Bolivian plague area. Some further information may be culled from the brief reports on a few subsequent plague outbreaks rendered by De la Barrera, whose statements in point may be summarized as follows:

Locality and time of the outbreaks	Observations on human plague	Observations on rodent and lagomorpha
Floripondio (Vallegrande Prov.) 1947	5 cases (3 in one house)	Graomys griseoflavus was found to be predominant among the wild rodents.
Buen Retiro (Vallegrande Prov.) Aug.-Oct. 1950	15 victims, most of whom contracted the infection in the fields.	The human outbreak was preceded by a most intense epizootic in the wild rodents which, however, was apparently not investigated. According to the subsequent observations of De la Barrera, Hesperomys muriculus was the most numerous wild-rodent species, while Graomys griseoflavus was less frequent. Both of these rodents were apt to penetrate into the houses. Also found were Oecomys mamorae and Olygoryzomys sp. The presence of Dasyprocta, Cuniculus, and Sylvilagus seems to have attracted attention during the 1950 epizootic.
Pucara (Vallegrande Prov.) August 1954	9 suspicious cases	Epizootic involving Graomys griseoflavus and Galea musteloides, in both of which the presence of plague was confirmed by De la Barrera.
Padilla (Tomina Prov.) Feb.-Mar. 1955	12 bubonic cases (6 in one house, 4 in another)	Information on the presence of an epizootic not conclusive. The rodent species subsequently found by De la Barrera included, besides M. musculus (found plague-infected as stated above), Hesperomys venustus, Graomys griseoflavus, Oryzomys legatus, and Galea sp.

De la Barrera emphasized that the few wild rodents dissected by him (apparently three Graomys and one Galea), though showing an abundance of P. pestis in their organs, exhibited hardly any macroscopic signs of plague, having thus evidently been the early victims of an overwhelming infection. It would not seem justified to conclude from these few observations, made during an acute epizootic, that the two species invariably develop this type of the disease and thus, because highly susceptible to plague, are incapable of serving as the reservoir of the infection. However, it would be equally unwise, rashly to exclude this possibility until systematic field and laboratory studies on the role not only of these but also of the other wild-rodent and the lagomorpha species found in the Bolivian plague foci have been made.

Observations on Fleas

Rat and Mouse Fleas

While the occurrence of X. cheopis was naturally restricted to the zones infested by the common rats, it would appear that L. segnis, the specific flea of the house mouse, was met within the plague-affected regions of Bolivia in general. Macchiavello recorded the presence of this flea not only on its specific host but also (no doubt occasionally) on wild rodents (Hesperomys, Graomys griseoflavus), while De la Barrera enumerated L. segnis among the fleas met with on the common rats. Other species found by him on the latter included, besides X. cheopis, P. irritans, Ctenocephalides canis, Ct. felis felis, Craneopsylla minerva, Neotyphloceras crassispina hemisus, Polygenis byturus, and P. tripus. Since no doubt Polygenis fleas play an important role in the conveyance of plague in Bolivia, the occurrence of representatives of this genus on the common rats deserves great attention.

P. irritans

To judge from the data furnished by De la Barrera, P. irritans was encountered throughout the plague-affected Bolivian areas. It apparently abounded in the houses, but was found to infest not only the common rats, the domesticated guinea pigs, dogs, and cats but also some wild rodents, including Dasyprocta variegata, Graomys griseoflavus, Oligoryzomys sp. and Rhipidomys collinus.

Fleas of Wild Rodents and Lagomorpha

Exact data on the flea infestation of a few species of rodents or lagomorpha, specimens of which could be procured through shooting or digging out the animals from their burrows, were recorded by De la Barrera as follows:

Galea musteloides*

	Number	%
Tiamastus cavicola	865	97.4
Neotyphloceras cr. hemisus	8	0.9
- " - crassispina	5	0.5
Polygenis platensis cisandinus	4	0.4
- " - byturus	1	0.1
- " - n. sp.	2	0.2
Tunga penetrans	1	0.1
Craneopsylla minerva	1	0.1
Tiamastus n. sp.	1	0.1
	888	99.8%

Dasyprocta variegata boliviae*

	Number	%
Rhopalopsyllus australis tamoyus	255	86.1
Rh. lugubris	35	11.8
Rh. crypturi	1	0.3
Tiamastus cavicola	2	0.6
Pulex irritans	1	0.3
Polygenis klagesi samuelis	1	0.3
P. roberti beebei	1	0.3
	296	99.7%

Cuniculus paca

	Number	%
Rhopalopsyllus lugubris	35	77.7
- " -austr. tamoyus	3	6.6
Adoratopsylla int. oxyura	4	8.8
Polygenis roberti beebei	2	4.3
Neotyphloceras crassispina hemisus	1	2.2
	45	99.6%

Lagidium viscaccia

Tiamastus sp. n.	55 (98.2%)
Dysmicus simonsi	1 (1.7%)
	56 (99.9%)

Lagostomus maximus immolis

Pulex sp. n.	13 (100%)

The flea species found on other rodents and lagomorpha of actual or potential ecological importance were recorded by De la Barrera as follows:

Graomys griseoflavus* — Craneopsylla minerva, Hectopsylla eskeyi, Polygenis byturus, P. klagesi samuelis, P. roberti beebei, P. tripus and two new Polygenis species, Pulex irritans, Tiamastus cavicola.

* Found naturally plague-infected.

Hesperomys muriculus	Craneopsylla minerva, Hectopsylla eskeyi, Neotyphloceras crassispina hemisus, Polygenis byturus, P. klagesi samuelis
Oryzomys sp.	Polygenis byturus, P. tripus
Olygoryzomys sp.	Ctenocephalides felis felis, Polygenis bohlsi bohlsi, P. roberti beebei, Pulex irritans, Tunga penetrans
Oxymycterus paramensis *	Neotyphloceras crassispina hemisus, Polygenis byturus
Rhipidomys leucodactylus *	Craneopsylla minerva
Sylvilagus brasiliensis *	Ctenocephalides felis felis, Polygenis klagesi samuelis
Eligmodontia hirtipes hirtipes	Polygenis byturus
Euryzygomatomys spinosus	Craneopsylla minerva, Polygenis atopus, P. roberti beebei, P. n. sp. (prox. byturus)
Lagidium viscaccia	Dysmicus simonsi, Tiamastus n. sp.
Lagostomus maximus immolis	Pulex n. sp.
Leptosciurus leucogaster	Polygenis bohlsi bohlsi, P. n. sp. (prox. byturus) P. n. sp. (prox. litargus)
Oecomys mamorae	Polygenis bohlsi bohlsi, Tiamastus cavicola
Oryzomys legatus	Polygenis tripus
Phyllotis nogalaris	Neotyphloceras crassispina hemisus
Proechimys longicaudatus	Craneopsylla minerva, Polygenis bohlsi bohlsi, P. klagesi samuelis, P. roberti beebei
Rhipidomys collinus	Craneopsylla minerva, Pulex irritans

* Found naturally plague-infected.

These observations leave little room for doubt that Polygenis fleas play the main role in conveying plague among the wild rodents and, since the latter often penetrate into the human habitations, are also apt to initiate plague manifestations in the intradomestic rodent fauna or directly in man. Pending further investigations it is uncertain, however, whether these fleas are also responsible for the frequent intradomestic spread of the disease. As has been discussed in the report on Peru, this is a problem which can be solved only through a systematic study of all potentially involved fleas, including the subspecies of P. irritans.

Epidemiological Observations

To judge from the incomplete available information, the human plague outbreaks in Bolivia were usually of the bubonic type. The only known exception was the epidemic in the Department of Tarija lasting from December 1921 to May 1922 (375 attacks with 300 deaths), during which the presence of pneumonic features attracted attention. It is, however, not certain whether all of the 87 patients showing signs of lung involvement suffered from primary pneumonic plague.

To judge from De la Barrera's report, the occurrence of human plague manifestations has been notified in Bolivia in all months of the year. However, outbreaks of murine origin took their onset most often during the period from July to December (especially in July-August and in December), those of wild-rodent origin from July to November, with clear periods in February and again in May-June.

As has been stressed already, a characteristic but still unexplained feature of the Bolivian plague manifestation was the frequent intradomestic spread of the infection, leading to the successive appearance of several attacks of the disease in one and the same household.

Dealing in the introduction to his study with the various geographic zones of Bolivia, Macchiavello spoke inter alia of a Zona de selvas y llanos tropicales (zone of tropical forests and plains) which comprised, besides the Departments of Tarija in the south and Santa Cruz in the east, those of El Beni and Pando in the northwest, and he claimed that common rats and X. cheopis were present in all these areas.

Reference to the Amazonian zone of Peru was again made by De la Barrera in the following important statement:

> "The technical workers of the Bolivian Health Service have considered the possibility that the Amazonian zone will soon be reached by plague infection.
>
> Since we have studied preferentially the zone which is today the extreme northern limit of the spread (of plague) and have dealt also, though less intensively, with the region which extends as far as Trinidad, we consider that we do not have sufficient information to attempt a prediction about

> the future of plague. However, we can say that as far as is known, the climatic and telluric conditions as well as those of the fauna and flora in the Amazonian zone offer no obstacle to a diffusion (of the infection). The periodic inundations of vast stretches exert a double influence upon the fauna of the small rodents: on the one hand they diminish the populations of the rodents, and on the other hand they concentrate the animals in the areas inhabited by man. Only large field studies, the foundation of which will be the repeated determination of the density of the species, will shed light upon the respective influence of these two factors, antagonistic as far as the diffusion of plague is concerned.
>
> Murine plague has its natural reservoir, the domestic rat, and its vector, Xenopsylla cheopis, abundantly distributed in the zone. The traffic by river is the most probable route of access.
>
> As far as sylvatic plague is concerned, it will continue its spread toward the north, capriciously and uncontrollably as always."

As has been stressed in the first part of the present report, in their 1961 article Torres Bracamonte and González Moscoso claimed that parts of the Pando and Beni Departments had been reached by plague, the infection having become manifest in the form of large rat epizootics and sporadic attacks in man.

Pending a confirmation of this still somewhat vague information, it would be premature to consider a plague invasion of the Amazonian basin as a certainty. However, that the possibilities for such a spread of the disease exist, is undeniable and the present reporters would fail in their duty if they did not stress the urgent necessity of a survey to assess the imminence of this great potential danger. Though presumably in view of the safeguards created by the international sanitary regulations an entrenchment of plague in the Amazonian basin would not be dangerous for the world at large, it would undoubtedly lead to most dire consequences for the local populations.

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SECTION E

REVIEW AND EVALUATION OF THE PRESENT STATUS OF PLAGUE IN BRAZIL

Incidence of the Disease

As summarized by Pollitzer (1954), it is generally accepted that plague, imported by the sea route, first appeared in 1899, when Santos and a few months afterwards São Paulo, lying inland from that port, became infected. From then onwards up to 1906 Rio de Janeiro, Fortaleza in the State of Ceará, Pernambuco, Rio Grande do Sul, and other ports successively became involved. From 1907 onwards the infection began to spread to inland cities and towns but beginning in 1934 disappeared rapidly from these centers while persisting in rural areas which remain in part involved to date (Barreto and Castro, 1946). The total incidence of the disease from 1899 to 1949 is shown by the following approximate figures (Moll and O'Leary, 1945; A. Castro, communication to the WHO Expert Committee on Plague, 1950; and from 1949, WHO Epidemiological and Vital Statistics Rep. 13, 1960, No. 8):

Period	Cases	Period	Cases	Deaths
1899-1929	5,638	1935-1939	1,223	490
1930-1934	535	1940-1944	812	205
		1945-1949	1,090	195
			3,125	890

Details of the plague incidence in Brazil from 1935 to 1949 are given in the following table (A. Castro, loc. cit., and for 1949, the above-mentioned WHO statistical report):

Year	São Paulo		Rio de Janeiro		Minas Gerais		Northeast		Total	
	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths
1935	2	1	-	-	-	-	569	232	571	233
1936	31	21	-	-	-	-	328	115	359	136
1937	1	0	-	-	-	-	35	15	36	15
1938	-	-	12	8	-	-	134	53	146	61
1939	4	2	-	-	-	-	107	43	111	45
1940	-	-	-	-	-	-	255	53	255	53
1941	-	-	7	4	-	-	295	83	302	87
1942	-	-	-	-	3	0	32	7	35	7
1943	-	-	-	-	-	-	66	22	66	22
1944	-	-	-	-	-	-	154	36	154	36
1945	-	-	-	-	-	-	192	42	192	42
1946	-	-	-	-	34	23	298	48	332	71
1947	-	-	-	-	7	3	81	8	88	11
1948	-	-	-	-	-	-	386	54	386	54
1949	-	-	-	-	-	-	91	17	91	17
1935-49	38	24	19	12	44	26	3023	828	3124*	890

* One recovering case in Sergipe in 1946 not included.

The trend of the infection in the northeastern states during the period under review is illustrated by the following tabulation:

Period	Alagôas		Bahia		Ceará		Paraíba		Pernambuco		Piauí		Total	
	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths	Cases	Deaths
1935-39	74	23	79	31	317	95	14	6	673	297	16	6	1173	458
1940-44	256	36	126	39	108	21	-	-	312	105	-	-	802	201
1945-49*	53	8	319	48	249	44	23	3	354	53	-	-	998	156
1935-49	383	67	524	118	674	160	37	9	1339	455	16	6	2973	815

* Until June 30.

From statistics recorded in the PASB Informe Epidemiológico Semanal for 1950-1956 and for 1962 (up to 5 September), and from the summaries on the incidence of plague published in the 1958-1962 volumes of the WHO Weekly Epidemiological Record, the following figures on the plague incidence in Brazil from 1950* onwards can be culled:

	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
Alagôas	19	-	41	2	-	-	-	5	-	-	13	12	1	3
Bahia	15	4	1	3	4	20	-	20	25	16	13	15	-	14
Ceará	2	6	-	-	-	4	-	-	-	-	-	7	16	13
Paraíba	5	-	-	-	-	-	-	-	-	-	-	31	3	2
Pernambuco	7	6	16	6	2	3	4	12	-	-	-	39	13	7
Minas Gerais	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Rio Grande do Norte	-	-	-	-	-	-	-	-	-	-	-	-	3	-
Rio de Janeiro	-	-	4	-	-	-	-	-	-	-	2	-	-	-
Totals:	48	16	62	11	6	27	4	37	25	16	28	106	36	39

* In the case of some years these figures are slightly lower than those published in other WHO records. The statistics quoted were preferred, however, because they could be supplemented by information on the plague incidence in the municipios (counties) of the various states, thus giving a detailed picture on the recent trend of the infection.

The incidence of the disease in the various counties of these states is shown in the following tabulations:

Alagôas

Municipalities (counties)	1950	1951	1952	1953	1954-56	1957	1958	1959	1960	1961	1962	1963
Agua Branca	-	-	7	-	-	-	-	-	-	-	-	-
Anadia	-	-	-	2	-	-	-	-	-	-	-	-
Arapiraca	2	-	-	-	-	-	-	-	-	-	-	-
Belém de Alagôas*												1
Feira Grande	-	-	-	-	-	-	-	-	-	1	-	-
Limoneiro de Anadia	1	-	-	-	-	-	-	-	-	-	-	-
Mata Grande	8	-	-	-	-	-	-	-	-	6	1	1
Major Isodoro	-	-	-	-	-	-	-	-	1	-	-	-
Pão de Açucar	2	-	-	-	-	-	-	-	-	-	-	-
Palmeiro dos Indios	2	-	3	-	-	1	-	-	-	4	-	1
Paulo Jacinto	-	-	-	-	-	1	-	-	-	-	-	-
Quebrangulo	2	-	-	-	-	3	-	-	-	1	-	-
Santana de Ipanema	2	-	2	-	-	-	-	-	-	-	-	-
São Braz	-	-	-	-	-	-	-	-	5	-	-	-
Traipu	-	-	-	-	-	-	-	-	7	-	-	-
Viçosa	-	-	1	-	-	-	-	-	-	-	-	-
Not located	-	-	28	-	-	-	-	-	-	-	-	-
Totals	19	-	41	2	-	5	-	-	13	12	1	3

* In Brazil some new municipalities have recently been created.

Bahia

Municipalities	1950	1951	1952	1953	1954	1955	1957	1958	1959	1960	1961	1963
Andarai	-	-	-	-	-	-	-	-	-	5	-	-
Baixa Grande	-	-	-	-	-	-	3	-	-	-	-	-
Barrada Estiva	-	-	-	2	-	2	-	-	-	-	-	-
Campo Formoso	-	-	-	-	-	-	-	5	-	-	-	9
Castro Alves	4	-	-	-	-	-	-	-	-	-	-	-
Cícero Dantas	2	-	-	-	-	-	-	-	-	-	-	-
Conc. do Coité	-	-	-	-	-	-	1	5	-	-	-	-
Feira de Santana	-	-	-	-	1	-	1	-	-	-	-	-
Ibiquera	-	-	-	-	-	-	-	-	-	-	1	-
Ibitiara	-	-	-	-	-	-	-	-	-	4	-	-
Inhambupe	4	-	-	1	-	-	-	-	-	-	-	-
Ipira	1	-	-	-	-	-	-	3	-	-	-	-
Itaberaba	-	-	-	-	-	1	-	1	-	-	1	-
Jaraguari	-	-	-	-	-	-	1	-	-	-	-	-
Jiquié	-	4	-	-	-	-	-	-	-	-	-	-
Macajuba	-	-	-	-	-	-	7	-	-	-	-	-
Macaúbas	-	-	-	-	-	-	-	-	16	-	9	-
Maracas	-	-	-	-	-	1	-	-	-	-	-	-
Piata	-	-	-	-	-	-	-	-	-	2	-	-
Pocoes	-	-	-	-	-	4	-	-	-	-	-	-
Riachão do Jaculpe	-	-	-	-	-	-	2	6	-	-	-	1
Ribeiro do Pombal	1	-	-	-	-	-	-	-	-	-	-	-
Rui Barbosa	-	-	-	-	2	2	2	1	-	-	-	-
Sta. Terezinha	-	-	-	-	1	1	-	-	-	1	-	-
Santo Estevão												4
Seabra	-	-	-	-	-	-	-	-	-	1	-	-
Senhor do Bonfim	-	-	-	-	-	-	1	4	-	-	1	-
Serra Preta	-	-	-	-	-	-	2	-	-	-	3	-
Vitoria da Conquista	-	-	-	-	-	9	-	-	-	-	-	-
Serrinha	3	-	1	-	-	-	-	-	-	-	-	-
Totals	15	4	1	3	4	20	20	25	16	13	15	14

Note: 1956 and 1962 each with no cases.

Ceará

Municipalities	1950	1951	1952-54	1955	1956	1957	1958	1959	1960	1961	1962	1963
Araripe	-	-	-	-	-	-	-	-	-	2	-	-
Baturité	-	-	-	-	-	-	-	-	-	-	3	-
Crato	-	-	-	-	-	-	-	-	-	1	-	1
Ipu	-	2	-	1	-	-	-	-	-	-	-	-
Itapira	-	-	-	-	-	-	-	-	-	-	9	8
Ipueiras	-	-	-	3	-	-	-	-	-	-	-	-
Jardím	-	-	-	-	-	-	-	-	-	-	4	-
Pacoti	-	4	-	-	-	-	-	-	-	-	-	-
Palmácia	-	-	-	-	-	-	-	-	-	4	-	-
Milagres	2	-	-	-	-	-	-	-	-	-	-	-
Santana do Cariri												4
Totals	2	6	-	4	-	-	-	-	-	7	16	13

Paraíba

Municipalities	1950	1951	1952-54	1955	1956	1957	1958	1959	1960	1961	1962	1963
Aroeiras	-	-	-	-	-	-	-	-	-	10	1	-
Boqueirão	-	-	-	-	-	-	-	-	-	2	-	-
Campina Grande	-	-	-	-	-	-	-	-	-	16	1	-
Cuité	-	-	-	-	-	-	-	-	-	3	-	-
Princeza Izabel	5	-	-	-	-	-	-	-	-	-	-	-
Puxinana	-	-	-	-	-	-	-	-	-	-	1	-
Queimadas												2
Totals	5	-	-	-	-	-	-	-	-	31	3	2

Rio Grande do Norte

Municipality	1950	1951	1952-54	1955	1956	1957	1958	1959	1960	1961	1962	1963
Coronel Ezequiel	-	-	-	-	-	-	-	-	-	-	3	-
Totals	-	-	-	-	-	-	-	-	-	-	3	-

Pernambuco

Municipalities	1950	1951	1952	1953	1954	1955	1956	1957	1958-59	1960	1961	1962	1963
Aguas Belas	3	-	1	1	-	-	-	-	-	-	-	-	-
Angelim	-	-	-	-	-	2	-	-	-	-	2	1	-
Araripina	-	1	-	-	-	-	-	-	-	-	-	-	-
Arcoverde	-	-	-	-	2	-	-	-	-	-	-	-	-
Belo Jardím	-	-	-	-	-	-	-	-	-	-	-	7	-
Bezerros	-	-	-	-	-	-	-	-	-	-	1	-	-
Bodocó	-	3	1	2	-	-	-	-	-	-	2	-	-
Bom Conselho	-	-	3	1	-	-	-	1	-	-	3	1	-
Canhotinho	-	-	-	-	-	-	-	3	-	-	1	1	-
Caruarú	-	-	-	-	-	-	-	-	-	-	3	-	-
Correntes	-	-	-	1	-	-	-	-	-	-	3	1	-
Cupira	-	-	-	-	-	-	-	-	-	-	1	-	-
Exú	-	2	1	1	-	-	-	-	-	-	1	-	-
Garanhuns	1	-	-	-	-	-	1	-	-	-	2	2	-
Inajá	2	-	-	-	-	-	-	-	-	-	-	-	-
Lagôa de Ouro													2
Panelas	-	-	-	-	-	-	-	3	-	-	-	-	5
Pedra	-	-	-	-	-	-	-	-	-	-	1	-	-
Pesqueira	1	-	-	-	-	-	-	-	-	-	-	-	-
San Bento do Uno	-	-	-	-	-	-	3	-	-	-	13	-	-
São Caetano	-	-	-	-	-	-	-	-	-	-	6	-	-
Triunfo	-	-	-	-	-	1	-	5	-	-	-	-	-
Not located	-	-	10	-	-	-	-	-	-	-	-	-	-
Totals	7	6	16	6	2	3	4	12	-	-	39	13	7

Minas Gerais

Municipality	1950	1951	1952	1953	1954	1955	1956	1957	1958-59	1960	1961	1962	1963
Coronel Murta	-	-	-	-	-	-	-	-	-	-	2	-	-
Totals	-	-	-	-	-	-	-	-	-	-	2	-	-

Rio de Janeiro

Municipality	1950	1951	1952	1953	1954	1955	1956	1957	1958-59	1960	1961	1962	1963
Teresópolis	-	-	3	-	-	-	-	-	-	2	-	-	-
Not located	-	-	1	-	-	-	-	-	-	-	-	-	-
Totals	-	-	4	-	-	-	-	-	-	2	-	-	-

Cautious as one must be in evaluating merely statistical evidence, it is nevertheless safe to state the following:

1) Plague seems to have permanently disappeared only from two Brazilian states, namely São Paulo in the south and Piauí in the northeast, while it continues to occur in all other formerly infected states.

2) Whereas it occurs in a quite or fairly continuous manner in two of the latter (Bahia and Pernambuco), in the other affected states apparently clear periods seem to alternate recently with those during which an incidence of the disease becomes once more manifest.

3) It is a priori unlikely that, as was formerly believed, the long continued existence of plague in the States of Bahia and Pernambuco has been due solely to a persistence of the infection in the common rats and not to the presence of wild-rodent reservoirs. It is therefore most gratifying that, as will be discussed later, recent investigations of De la Barrera have adduced prima-facie evidence for the existence of sylvatic plague foci in Brazil.

The existence of such foci is also suggested by the statistical data for Pernambuco, where the disease was found to become repeatedly manifest in previously affected counties (e.g., Garanhuns, and especially Bom Conselho). The evidence for the existence of such foci of the infection in Bahia is not clear-cut.

4) Pending further investigations, it is impossible to say whether the recrudescence of plague in the apparently not permanently affected states is the result of a reimportation of the infection from adjacent permanent foci or of a continued latent existence of enzootics.

5) It is disquieting, but at the same time interesting to note that in the not permanently affected northeastern states, after more or less quiescent periods, the disease has become rather more frequent in 1961. It is tempting to assume that this increased frequency of human plague is the result of a high incidence of the infection in the rodent populations which, having been decimated by a past epizootic, had become numerous once more.

6) Of great interest also are (a) the reappearance of plague after a long absence in Minas Gerais; (b) the possible existence of a plague focus in the Teresópolis county of Rio de Janeiro State, manifested by the occurrence of a few human attacks in 1952 and again in 1960; and (c) the appearance for the first time (recorded) of plague in Rio Grande do Norte State.

There are thus ample opportunities for ecological studies in Brazil which, by proving the existence of circumscribed strongholds of the infection, might in their turn lead to a better control of the plague situation.

Summarizing past experiences, Pollitzer stated that, as was to be expected, the seasonal incidence of plague in São Paulo was different from that farther north. Most of the bubonic attacks in São Paulo occurred during the sultry days of summer, with the peak in January. In marked contrast to this, a pneumonic plague outbreak at São Paulo in 1936 took place during the winter in July, and the same held true of an earlier pneumonic plague epidemic at Santa Maria in the State of Rio Grande do Sul in 1912.

The period of maximal plague incidence in Rio de Janeiro was from September to January, having commenced earlier than in São Paulo.

Though the seasonal plague incidence in the northeast of Brazil was not as clear-cut as in the south, during the period 1935 to 1949 it was in general comparatively highest from July to October. However, according to Barreto (1940), the onset of the plague season in Ceará was already occurring in May-June. Both there and in Pernambuco the period of maximal plague incidence coincided with the harvest season.

The seasonal incidence of plague during the period 1950 to 1961 is shown in the following table:

Total Case Incidence from 1950-1961, by Months

Month	Alagôas	Bahia	Ceará	Paraíba	Pernambuco	Minas Gerais	Rio de Janeiro (State)	Total
I					1			1
II	5	4			8			17
III	2	17	4		3			26
IV	1	3			2			6
V	3		2		2	2		9
VI		1			2			3
VII		24			5			29
VIII	4	34	4		10		3	55
IX	17	20	5	6	11			59
X	27	13			25		1	66
XI	32	20		17	10		2	81
XII	6	4	4	13	18			45

Thus, although in the State of Pernambuco in particular human plague was recorded throughout the year, recently also the case incidence in the northeast of Brazil is highest from July-August to November or December.

While, as noted above, occasional pneumonic epidemics have occurred,* bubonic plague is largely preponderant in Brazil. The mortality from the disease is generally low and atypically mild attacks of the disease have been frequent.

Ecological Observations

Turning attention to the ecology of plague in Brazil, it is distressing to note that recent information is available only in regard to the affected areas in the northeast of the country. The latest publication dealing with Minas Gerais is the study by Macchiavello and Martins de Almeida (1947) and no record referring to the recent plague manifestations in the State of Rio de Janeiro could be found.

For the discussion of the ecological situation in northeast Brazil it is proposed to concentrate attention upon the recent article by De Freitas (1957) and the ample report rendered in 1960 by De la Barrera. The voluminous studies on these areas by Macchiavello must be considered as out-dated not only because they were published more than 20 years ago (1941), but also because they led that author to the no longer tenable conclusion that:

"The domestic black rat, R. rattus, was proved to be the most important factor in rural plague in northeast Brazil, both human plague and plague among other rodents being accidental and secondary to plague in this rat." (1941, Public Health Reports).

Observations on the Common Rats and House Mice

Briefly summarizing the results of the early observations on the incidence of the various species and subspecies of the common rats in Brazil, Pollitzer (1954) stated:

"While R. rattus was preponderant in the rural areas of the northeast, Norway rats were most common in some of the ports and in São Paulo State. In Rio de Janeiro this species and M. musculus were more frequent than R. rattus and rattus alexandrinus."

The results of trappings made during the period 1952 to 1955 in urban centers as well as in the rural plague foci of the States of Alagôas and Pernambuco, taken from the article by De Freitas, are set forth in the

* In addition to the earlier-mentioned manifestations of this type, De la Barrera referred, without giving details, to a pneumonic plague focus observed in 1957 at Macajuba, while De Freitas quoted a report on "Peste pneumônica em Pesqueira," rendered in 1950 by him and Valença Junior at the VIII Congresso Brasileiro de Higiene. Unfortunately the transactions of this congress were not available to the present reporters.

following table, in which for the convenience of record data on the incidence of the marsupialia are also entered.*

State and district	R.r. rattus	R.r. alex.	R.r. frugiv.	Mus musculus	Monodelphis domestica	Didelphis paraguayensis
Alagôas						
Viçosa	-	50	221	-	86	28
Palmeira dos Indios	1	27	136	-	546	181
Pernambuco						
Bodocó	-	-	-	-	281	24
Caruaru	-	44	7	2	127	35
Pesqueira	-	354	24	1	345	25
Triunfo	-	158	10	20	1,128	85
Garanhuns	-	90	15	61	150	98

As far as these figures go, R. r. rattus seemed to be practically absent in both states, R. alexandrinus more frequent in Pernambuco than R.r. frugivorus, while the reverse held true in Alagôas. The absence or rarity of M. musculus trapped in most of the districts was probably but accidental. The general frequency of the marsupialia, which are apt to maintain liaison between the wild and the peridomestic or intradomestic rodents, is significant.

In the material collected by De la Barrera in the rural houses and the fields of various stations in the States of Pernambuco and Ceará, the common rats and house mice figured as follows:

Species	Pernambuco		Ceará	
	No.	Per cent	No.	Per cent
R. r. rattus (houses)	5	1.7	6	4.7
R. r. alex. (houses)	231	81.3	91	71.6
R. r. frugiv. (houses)	48	16.9	30	23.6
	Number		Number	
R. r. alexandrinus (fields)	5		1	
R. r. frugivorus (fields)	7		14	
Mus musculus (houses)	173		92	
Dto. (fields)	27		32	

* The corresponding statistics furnished by De Freitas for the State of Ceará are not ample enough to deserve attention.

Thus, while R.r. alexandrinus was found to be the most prevalent rodent, Norway rats appeared to be absent from the rural localities studied by De la Barrera. However, that this species continues to be present or even prevalent in some of the ports of northeast Brazil, is proved by the following 1956 statistics quoted by that author:

	Recife (Pernambuco)		Fortaleza (Ceará)	
	No.	Per cent	No.	Per cent
R. norvegicus	846	62.1	-	-
R.r. rattus	19	1.3	360	14.8
R.r. alexandrinus	77	5.6	1,172	48.3
R.r. frugivorus	419	30.7	896	36.8
Totals	1,361	99.7	2,428	99.9

Discussing the ecology of the common rats in the localities studied by him, De la Barrera pointed out that the rattus subspecies, not being impeded by the presence of the Norway rats, were able to occupy the ground-floor of the rural habitations. In his opinion, the rats inhabiting the houses and those of the fields had little contact, each group thus leading an independent existence. Concerning the relation between the common rats and the wild rodents, he maintained that:

"The sylvatic fauna comes sufficiently near to the human habitation so that the Rattus, in its nocturnal excursions and without moving far, enters in contact with the wild rodents or their nests and, consequently, with their fleas."

According to the observations made in Minas Gerais at the time of the 1946-1947 outbreak, R.r. alexandrinus and R.r. frugivorus seem to have been the prevalent species both in the towns and in the rural habitations, but Macchiavello and Martins de Almeida referred also to some trappings of R.r. rattus, apparently in the rural areas. The conclusions the two authors reached in regard to the role of these rodents in the outbreak were that:

(a) an extensive migration of R. alexandrinus had taken place, and bore a connection with the cultivation of maize;

(b) these rats invaded the human habitations immediately before the appearance of plague and

(c) died in the barns and maize plantations;

(d) the fleas of these rats were X. cheopis and the human cases occurred in sites with epizootics among R. alexandrinus, having been caused by fleas that left the dead rats;

(e) the infection probably had its origin in the county of Salinas (in northeastern Minas Gerais) and neighboring locations in the north--an endemic plague focus--and was conveyed by some commercial product, possibly jute bags, in a manner that has not been established.

Observations on Wild Rodents

The comparative frequency with which the wild rodents and lagomorpha of Brazil known to suffer from spontaneous plague have been caught in Alagôas (according to Freitas) and in the States of Ceará and Pernambuco (by De la Barrera) is shown in the following table:

Species	Alagôas		Ceará		Pernambuco	
	No.	Per cent	No.	Per cent	No.	Per cent
Cavia aperea	-	-	-	-	-	-
Cercomys cunicularius laurentius	18	0.18	82	23.29	106	5.35
Cercomys inermis	976	9.81				
Galea spixii	518	5.21	34	9.66	50	2.52
Hesperomys tener	34	0.34				
Hesperomys sp.	-	-	-	-	2	0.10
Holochilus sciureus	609	6.12	14	3.98	23	1.16
Kerodon rupestris	14	0.14	-	-	8	0.40
Oryzomys laticeps intermedius	2	0.02	-	-	-	-
Oryzomys subflavus	2,064	20.75	25	7.10	434	21.94
Thomasomys pyrrhorhinus	176	1.76	-	-	19	0.91
Zygodontomys pixuna	5,489	55.19	197	55.11	1,336	67.54
Lepus sp.	-	-	-	-	-	-
Sylvilagus brasiliensis	14	0.14	-	-	-	-
Totals	9,914	99.66	352	99.14	1,978	99.92

As will be gathered from this table, Zygodontomys pixuna was by far the most common wild rodent in all three states, followed in frequency in Alagôas and Pernambuco by Oryzomys subflavus. In Ceará Cercomys cunicularius laurentius was caught more frequently than the latter rodent, but the total number of captures in this state was too small to render this observation significant.

The information furnished by De la Barrera in regard to some of the above-enumerated species may be summarized as follows:

Galea spixii (preá)--Various species of both genera of the subfamily of Caviinae, all known under the common name of preá, are encountered in Brazil; the genus Cavia is represented by the domesticated-type species Cavia porcellus, by C. aperea and C. fulgida, and the genus Galea by G. spixii, among others. It is important to note that this animal, like the other free-living species of preás, is much hunted by the inhabitants of Ceará and Pernambuco for the sake of its meat.

Contrary to what occurs in Argentina, the Galea species of northeast Brazil do not live in subterranean burrows but shelter by preference in sites covered by a low and dense vegetation. They are often encountered in localities frequented by other naturally plague-infected wild rodents and thus are apt to become involved in the epizootics. The mortality among them sometimes becomes so considerable as to lead to a stoppage of their hunting. However, as deplored by De la Barrera, such occurrences have never been made the subject of bacteriological studies. Still, no doubt exists that the preás (G. spixii, and also C. aperea) suffer from spontaneous plague and instances are on record in which the handling of their carcasses led to the appearance of the disease in man.

The flea index, determined by De la Barrera on 31 G. spixii, averaged 2.7, practically all the fleas being Polygenis bohlsi jordani. Tiamastus cavicola, though common on the Caviinae elsewhere in South America, appeared to be absent in Pernambuco.

Kerodon rupestris (mocó)--This species, which as described in detail by De la Barrera, lives in chinks and crevices of rocks, is also much hunted for the sake of its meat and sometimes even bred in captivity. It freely approaches human habitations without, however, entering them.

As noted by several observers, the flea index of this species is rather low. Thus, De la Barrera, examining eight specimens which had been killed by shooting, could collect only two fleas, both P. bohlsi jordani.

According to this author, considerable uncertainty exists regarding the occurrence of natural plague in the mocó. It has been found susceptible to experimental infection and Macchiavello and his associates observed deaths from plague among animals of this species kept in captivity at the time of an outbreak in rats and man.

De la Barrera, while admitting that K. rupestris was potentially dangerous because it was hunted, pointed out that this rodent did not enter human habitations, had only limited contact with other sylvatic species, had few ectoparasites, and was neither frequent nor widely spread.

Cercomys cunicularius laurentius (punaré)--This animal, which is also used for food in northeast Brazil, though apt to live under rocks, is likewise found in other locations. It was repeatedly caught in the vicinity of Kerodon rupestris--a fact which, in De la Barrera's opinion, was deserving of some attention, because in contrast to the mocó it is regularly flea-infested.

Zygodontomys pixuna--Although adaptable to various environments, this rodent has some predilection for humid locations. It is by far the most frequent among the sylvatic rodent species in northeast Brazil.

Oryzomys subflavus--Known as rato de cana or under other common names, this rodent is next in frequency after Z. pixuna. It builds its nests in various locations, including heaps of stones, spaces between dry boughs, in hollows of trees, etc.

Thomasomys pyrrhorhinus--This small animal is also known under different names, like rato de fava or de palmatorio. It lives in small colonies in nests inside the hollow of trees. On one occasion it was caught inside a house.

Discussing in a general manner the problem of a penetration of the wild rodents into the habitations of Pernambuco and Ceará, De la Barrera stated that (a) he practically never caught animals of these species inside the rural houses; and (b) apparently there existed no local rodent species, like the Graomys of Argentina, standing according to its habits between the wild and the "domestic" rodents. He admitted, however, that--as had been claimed by Macchiavello--Monodelphis domestica, which was apt to frequent the houses, might play the role of a liaison animal between the wild and the intradomestic rodent fauna. That this species, which has been found naturally plague-infected (see Pollitzer, 1954), was potentially dangerous, was proved by its infestation with Polygenis bohlsi jordani, no doubt the principal, if not the sole, vector of sylvatic plague in the northeast of Brazil.

Observations on Fleas

(a) Fleas of the Common Rats

Summarizing the results of his observations in northeast Brazil, Macchiavello (1941) stated:

> "Xenopsylla cheopis and X. brasiliensis were the most common fleas in R. rattus and R. alexandrinus (which generally lives in the fields); Rhopalopsyllus and possibly Parapsyllus were found on field rats, preas (Galea spixii) and mocós (Kerodon rupestris), although these rodents were rarely flea-infested. X. cheopis and a Chiastopsylla sp. were discovered on Monodelphis caught in rat nests. Some Pulex irritans and, rarely, Echidnophaga gallinacea were found on rattus and alexandrinus. However, X. cheopis was the only ectoparasite found plague-infected. Even when X. brasiliensis were taken from a rat on which infected cheopis had been found, they failed to produce plague."

In Macchiavello's opinion a survival of infected fleas in the rat nests was responsible for the continuance of subterranean epizootics, which gained new impetus through "the arrival of new susceptible animals, whether as the result of breeding or through migration."

On the subject of rat fleas, De la Barrera quoted Simon (1954), who trapped on the floors of 30 houses in the counties of Viçosa and Quebrangulo (Alagôas State) 6,583 fleas of the following species:

Pulex irritans	5,506	Xenopsylla brasiliensis	15
Ctenocephalides felis	1,017	Polygenis bohlsi jordani	13
Xenopsylla cheopis	32	Total	6,583

The results of De la Barrera's own flea collections in various localities of Pernambuco and Ceará may be tabulated as follows:

		X. cheopis	X. brasiliensis	Ct. felis	P.bohlsi jordani	P. irritans
(a)	Pernambuco					
	R. alexandrinus (fields)	-	-	-	2	-
	" (houses)	60	2	-	2	-
	" (nests)	204	-	-	20	-
	R. frugivorus (fields)	-	-	-	2	-
	" (houses)	4	-	-	1	-
	In the houses	12	-	-	19	300
(b)	Ceará					
	R. alexandrinus (houses)	31	-	1	19	-
	R. frugivorus (fields)	3	-	-	8	-
	" (houses)	30	-	-	9	-
	In the houses	77	-	2	62	985

The ubiquity of the wild-rodent flea P.bohlsi jordani forms a striking feature of these observations.

In his report De la Barrera stated that the cheopis index on the common rats varied within wide limits. The rarity or even absence of this flea on the animals living in the fields was in accordance with previous observations; Macchiavello, for instance, found in the county of Bom Conselho (Pernambuco) a cheopis index of 4 or 4.3 inside the houses, and of 0.75 outside them.

(b) Wild-Rodent Fleas

The data furnished by De la Barrera regarding the flea-infestation of wild rodents known to suffer from spontaneous plague and of the marsupialia may be tabulated as follows:

	P. bohlsi jordani	P. tripus	Adoratopsylla antiquorum	P. irritans	Ct. felis
(a) Pernambuco					
Cercomys cunic. laurentius	63	-	-	-	-
Galea spixii	35	-	-	-	1
Holochilus sciureus	4	-	-	-	-
Kerodon rupestris	2	-	-	-	-
Oryzomys subflavus	189	5	-	-	-
Zygodontomys pixuna	565	3	-	-	-
Nests of wild rodents	174	2	-	-	-
Didelphis marsupialis	60	1	-	-	7
Monodelphis domestica	42	-	1	-	-
(b) Ceará					
Cercomys cunic. laurentius	86	1	-	-	-
Galea spixii	8	-	-	1	-
Holochilus sciureus	2	-	-	-	-
Oryzomys subflavus	25	-	-	-	-
Zygodontomys pixuna	13	24	2	-	-
Nests of wild rodents	-	54	-	-	-
Didelphis marsupialis	24	-	-	-	3
Monodelphis domestica	5	-	-	-	-

As stated by De la Barrera, Polygenis bohlsi jordani, the overwhelmingly most frequent flea of the wild rodents in northeast Brazil, was first identified by Costa Lima in 1937 in collections made from Cavia aperea and a rato de cano. Its vector capacity, preliminarily established by Simon (1954), was confirmed by experiments made in 1958 by De la Barrera. There can be no doubt that this flea is practically alone responsible for the spread of plague among the wild rodents and presumably it is also instrumental in conveying the infection from these to the common rats.

Discussing the problem of the occurrence of X. cheopis on the Brazilian wild rodents, De la Barrera stated that, according to systematic studies by Moojen and Paracampos, this flea was sometimes encountered in collections made in the field by the lower staff (guardas) of the Plague Prevention Service, but never in significant numbers. More noteworthy still: (a) Macchiavello and Martins de Almeida never found X. cheopis

on wild rodents during the 1946-1947 outbreak in Minas Gerais; and (b) Silva (1945), after an exhaustive investigation, came to the conclusion that "the fauna of the sylvatic rodents was not found infested by known vector species." In his own material of about 3,500 fleas collected outside, but partly quite near human habitations, De la Barrera never encountered X. cheopis. Considering the numerical disproportion between the common rats and the wild rodents, he came to the conclusion that a transition of fleas from the latter to the former was easier than the reverse. The above-recorded observations certainly support this contention.

Epizootiological and Epidemiological Observations

As already alluded to, De la Barrera was fortunate to detect in 1957 a sylvatic plague focus at Brejinho in the district of Triunfo, Pernambuco State. This region had been affected by plague with a varying intensity since the major epidemic of 1926, but more recently human manifestations of the disease had remained isolated and since 1952 no bacteriological confirmation of the continued existence of the infection had been obtained.

Undoubtedly, in 1957 plague had assumed epizootic proportions in the wild rodents of this locality, for in marked contrast to what had been observed in the working station of Periperi, only about 15 km distant, the wild-rodent population was scanty in the Brejinho area and 23 wild-rodent nests were found there containing carcasses of Oryzomys, Zygodontomys or Thomasomys. One of these nests contained the carcasses of three adult Oryzomys subflavus which, evidently having succumbed at least two months previously, were no longer fit for laboratory examination.

As shown by careful investigations, most (17 out of 23) houses in this rural locality were rat-infested, to a large extent by R.r. alexandrinus and to a lesser degree by R.r. frugivorus. Besides X. cheopis, abundant on the rats and in their nests and also present in the dust swept from the floors, X. brasiliensis was found on R.r. alexandrinus. Pulex irritans was comparatively abundant in the houses; Polygenis bohlsi jordani was found in small numbers on the rats as well as in the sweepings from the floor. No evidence of plague infection was found in any of these ectoparasites.

The first plague-affected rodent, an Oryzomys subflavus evidently dead for only a few hours, was found in the open near the stone wall surrounding a house. Two days later two more carcasses were detected, one of a Zygodontomys pixuna, the other of a Hesperomys sp. Although these two carcasses were already decomposed, it was possible to demonstrate the presence of plague in them through smear examination and cultivations from the bone marrow.

The complete examination possible in the case of the O. subflavus showed evidence of a fulminant infection manifested macroscopically only by a diffuse congestion of the inside of the skin flaps in the region of

the thorax and the abdomen, some subcutaneous hemorrhages, and hemorrhagic lesions of the lungs. However, P. pestis was abundant in all organs and, as proved by animal experiments, highly virulent. The cultures isolated from the other two carcasses also showed a high virulence.

After De la Barrera had left the locality, the finding of dead rats and the appearance of suspicious manifestations in man were reported in Brejinho but no bacteriological proof for the presence of plague could be obtained. It is deserving of attention in this connection that, evidently ever since the detection of the plague-affected wild rodents, energetic measures had been instituted by the local staff to prevent an intradomestic spread of the infection.

Making in a later part of his report an unfortunately brief reference to the 1957 plague manifestations in the State of Bahia, De la Barrera stated that:

"1. After a quiescent period of 22 months, plague appeared in Bahia and caused, from 15 August to 31 December, 18 cases in 13 separate foci (the focus of pneumonic plague in Macajuba is not included).

"2. The cases occurred in rural environments.

"3. An intensive epizootic among wild rodents was detected.

"4. There was no apparent relation between the foci. Within a brief time plague covered a large territory (see map)."

As De la Barrera concluded, there was no doubt that this was a sylvatic plague outbreak.

It is important to add that the following details can be gathered from De la Barrera's map:

Localities affected	Date of appearance of plague	Number of cases	Remarks
1) Baixa Grande	August	3	-
2) Macajuba	August	7	Pneumonic focus!
3) Serra Preta	September	2	-
4) Feira de Santana	October	1	-
5) Riachão do Jacuipe	October	2	-
6) Jacaraci	November	1	Situated far to the southwest of the other foci near Minas Gerais
7) Conceição do Coité	December	4	-
8) Campo Formoso	December	2	-
Total		22	

Commenting on a graph illustrating the possible routes by which in northeastern Brazil plague might reach man, De la Barrera stated:

"1. One encounters in the field numerous species of wild rodents, some marsupialia and a few rats, all infested by Polygenis bohlsi jordani. Xenopsylla cheopis is little abundant on Rattus and not met with on the other animals.

"2. The same fauna is met with in the subdomestic environment, but Rattus and cheopis are more abundant.

"3. Inside the houses there cohabit with man in a permanent manner Rattus, Mus musculus, dogs, and cats. Found in the habitations are Pulex irritans, Xenopsylla cheopis, Polygenis bohlsi jordani and some Ctenocephalides felis.

"4. The displacements of Rattus are limited and it is possible that the specimens caught in the houses and the field have independent fixed abodes. It is probable that the species maintains contact with the subdomestic milieu.

"5. Cheopis is more abundant on the rats caught in the houses than on those gathered in the fields. As this flea was not encountered on other animals, one has to deal apparently with a species particular to the rat and one must consider as confirmed the opinion of some authors that its passage to other animals would be difficult.

"6. The houses are visited by Monodelphis and, sometimes, by Didelphis, which on certain occasions nest there. These marsupialia are always infested by Polygenis bohlsi jordani, while X. cheopis was not found on the captured specimens.

"7. Only very rarely were wild rodents found in the houses.

"An infection of the domestic fauna is possible by the following routes:

i. The rats of the houses (could) become infected in the peridomestic milieu by picking up infected fleas;
ii. The marsupialia visiting the houses could be vehicles of infected fleas (P. bohlsi jordani) which they had picked up in extradomestic environments;
iii. The direct transport of plague or of infected fleas into the houses by wild rodents, usual in other regions, appears to be exceptional in northeast Brazil;
iv. It is not impossible that dogs and cats, which often carry P. bohlsi jordani, bring plague to the houses by means of this flea;
v. There is no evidence that M. musculus plays a significant role in the transport of the infection or of fleas;

vi. Man could become infected directly in the fields or bring infected fleas into the houses in his clothes;

vii. An intradomestic infection of man through P. bohlsi jordani, transported from extrinsic environments, is possible but must occur more frequently through cheopis coming from infected rats;

viii. The role of P. irritans is under discussion. In any case it could not be exclusive, since there is never a lack of cheopis with a much higher vector capacity."

Expressing his general views on plague in Brazil at the end of his report, De la Barrera stated:

"1. The incidence of plague in man and the common rats in Brazil has much decreased within the last years.

"2. The ports and cities remain free, the recorded outbreaks taking place in rural localities.

"3. The foci are generally isolated and show a tendency to disappear spontaneously. The focal incidence is low.

"4. Human plague attacks occur almost always simultaneously with the infection of the common rats and, sometimes, of wild rodents.

"5. An analysis of the epidemiological facts leads to the conclusion that the domestic rat (Rattus) does not play a role in the maintenance of plague and that, similarly as in the other American countries, the disease has now become limited to the sylvatic fauna of Rodentia and Lagomorpha.

"6. This concept was confirmed in August 1957 at Triunfo through the detection of plague in field rodents without a simultaneous infection of Rattus in the houses.

"7. The constant presence in the houses of rats densely infested with X. cheopis produces an epidemiological situation different from that of purely sylvatic plague, the rat being the intermediary between the wild-rodent (agreste) infection and man.

"8. The transmission (of plague) between the wild rodents and from them to man is effected through P. bohlsi jordani, a flea with a major vector capacity according to preliminary investigations and the experiences of the Brazilian observers.

"9. The conveyance of plague from the wild (agreste) or subdomestic environments is effected by Rattus, directly or by infected fleas, or by the marsupialia, often by fleas.

"10. Man can contract the infection in the fields, through direct contact with infected rodents or through their fleas. As a rule, this eventuality is less frequent than an intradomestic infection through Rattus."

The Known and the Unknown of Plague in Brazil

When an attempt is made to determine what is already known and what is still unknown regarding the ecology and epidemiology of plague in Brazil,* one must first of all fully agree with De la Barrera's contention that an entrenchment of the infection in the wild rodents and lagomorpha has become the fons et origo mali. As has been alluded to already, there can be hardly any doubt that in Brazil as well as elsewhere plague acts in the herds of these animals as a population regulator, becoming active and widespread whenever the periodically occurring increases of their numbers have furnished ample fuel for the spread of the infection and being reduced to a mere flicker after the resulting epizootics have decimated the herds. For such a sequence of events alone can explain the recrudescences of the disease after intervals not rarely so long as to suggest the disappearance of the infection.

Whether during these quiescent periods a territorial as well as a numerical reduction of the plague incidence takes place, is still not definitely known. However, as noted before, there is some statistical evidence for the existence of pockets of the infection where, owing to suitable ecological conditions, an equilibrium permitting the survival of both has been reached between the causative microorganisms and the reservoirs of the disease. As will be discussed later, the recognition of such strongholds of the infection would be of great practical importance as well as of theoretical interest.

Discussing the ecology of plague in Brazil, De la Barrera maintained:

"Generally speaking all the small rodents of the northeast can be caught in the same localities, without, however, being symbiotic in the strict sense. Some species have somewhat individual habitats (mocó) but never attain isolation."

"Therefore," De la Barrera continued, "it does not appear that in Brazil one or a few species play an exclusive role in the maintenance of plague. The mass of the Rodentia and Lagomorpha is homogeneous in respect to their sensitivity, habits, and flea infestation, it being thus natural that the infection makes no distinction."

* It should be noted that the statements following above refer solely to northeast Brazil. The ecology of plague in the States of Minas Gerais and Rio de Janeiro is still practically a terra incognita.

Noteworthy though this postulation is, based on observations in loco, the present reporters cannot help but point out that (a) the question of whether the various species concerned are in reality equally sensitive to infection with P. pestis seems not to have been studied sufficiently; and (b) marked ecological differences exist between these species which are bound to influence their comparative importance in the causation, spread, and maintenance of the disease. Thus, as shown by the table on page 55, in the three states for which data are available, Zygodontomys pixuna was by far the most numerous species, followed in frequency in Alagôas and Pernambuco by Oryzomys subflavus, and in Ceará possibly by Cercomys cunicularius laurentius, while most other species were markedly less frequent and some, particularly Kerodon rupestris, apparently rare. Statistical evidence has also been adduced to show that the degree to which the various rodents and lagomorpha are infested with the common plague vector P. bohlsi jordani varies within wide limits, Kerodon rupestris for instance being poorly flea-infested. On the other hand, as De la Barrera stated, this species was one of the few with gregarious habits, whereas many of the other rodents lived isolated or in pairs.

These brief notes suffice to show that the ecology of sylvatic plague in Brazil is influenced by many variable factors, at least some of which seem not to have been sufficiently evaluated. Under these circumstances it would seem rash to accept the above-quoted dictum of De la Barrera. Quite possibly further investigations will show that in Brazil as well as in other plague areas a distinction will have to be made between (a) wild rodent and/or lagomorpha species of prime importance as reservoirs of the infection; (b) species mainly or solely serving as fuel for the spread of the epizootics; and (c) a third group of species, the natural plague infection of which is merely of an accidental nature.

There is no reason not to agree with De la Barrera's assertion that the transitions of the infection from the now primarily and permanently plague-affected sylvatic species to the common rats lead only to short-lasting intradomestic manifestations of the disease which become rapidly extinguished, even though X. cheopis continues to be present and apparently often abundant not only on the surviving rats but in the houses. Pending further investigations it is not possible, however, to accept the tentative explanation he offers for this rather puzzling phenomenon, namely, that a state of resistance to plague has evolved in the domestic rat populations which is of a degree sufficient to impede the continued spread of the infection from rat to rat but not high enough to bar the initial transition of the highly virulent P. pestis strains harbored by the wild rodents to the domestic fauna. For, even if one could admit at all the possibility of the development of such a relative resistance in rural rat populations with little plague experience, as far as the present observers are aware no proof for the existence of such resistance in the rats of northeast Brazil has so far been brought forward. Thorough studies of this factor, as well as of the peculiarities of the intradomestic plague manifestations there, in general would be necessary to explain their unusual course and termination.

Suggestions for Further Plague Investigations in Brazil

One must fully agree with De la Barrera that until recently Brazil had an excellent national plague prevention service covering not only the plague-affected states of the northeast but also those of Minas Gerais, Rio de Janeiro, and São Paulo. The service was organized in three "circumscriptions" with bases in Recife, Salvador, and Rio. According to that author's description, the circumscriptions were:

> "divided into districts and these into sectors (totaling 28). Each sector had a medical officer and had a laboratory, an office, and annexed service installations for the personnel. A variable number of "guards" had the following functions: (a) deratization; (b) disinsectization; (c) capture of rodents and fleas; (d) house-improvement. The laboratory made bacteriological diagnoses and prepared skins and skulls of the captured animals for classification in the National Museum of Rio. The fleas were sent to Dr. Lindolfo Guimarães in São Paulo."

Unfortunately, however, De la Barrera had to add:

> "The decline of the plague incidence recorded during the last years rendered unnecessary, in the opinion of the health authorities, such a complete organization and for this reason it was incorporated into the Department of Rural Endemics, losing its former importance and "hierarchical" position. Nevertheless, the installations of the old service were preserved while its much competent personnel fulfills other functions."

If nothing else, the marked deterioration of the plague situation in Brazil in 1961 renders the re-establishment of an independent national antiplague service in that country most desirable, if not indispensable. This service should not only energetically resume the above-outlined functions but ought to devote also full attention to the problems of sylvatic plague, especially by (a) keeping in the enzootic areas a constant watch on the population trends of the wild rodents and lagomorpha so as to become aware of tendencies for an increase of these populations, which in their turn presage the appearance of epizootics; and (b) making systematic examinations of the pooled organs and/or the pooled fleas of these animals so as to detect at the earliest possible moment the presence or recrudescense of plague in them. As has been noted above, large-scale investigations of this kind, combined with studies on the comparative susceptibility of the various animals concerned to infection with *P. pestis*, may reveal the existence of species of prime importance for the maintenance of plague and possibly even that of limited foci where the infection persists and from which it is apt to break out whenever an increase of the rodent and lagomorpha populations provides adequate fuel for a spread of the disease. Though admittedly requiring great initial efforts, such investigations will in the long run greatly facilitate a watch over the trend of sylvatic plague.

It is hardly necessary to add that (a) the above-discussed investigations as well as those on the common rats outlined below ought to be undertaken not only in the northeast of Brazil but also in Minas Gerais and in the small focus persisting in Rio de Janeiro State; the latter, though suffering little from manifest outbreaks, is of great importance on account of its geographic situation; and (b) hand-in-hand with these investigations, all possible attention ought to be paid to the early detection, thorough study, and effective management of human plague attacks.

In order to gain an insight into the problem of the now peculiarly limited manifestations of rat plague, it would be of particular importance (a) to study the distribution and frequency of the common rats throughout the areas invaded or threatened by the infection; (b) to watch for signs of an appearance of the disease among these animals through large-scale and systematic examinations of their pooled organs and/or their pooled fleas; (c) to make large-scale tests to assess their susceptibility for or resistance to plague; and (d) to study the frequency and seasonal incidence of the rat fleas, especially those of X. cheopis.

Inasmuch as the enlarged activities suggested above would seem to be beyond the capacity of the existing services in Brazil, consideration ought to be given to the reinstitution of the national plague service as it once existed or to a similar establishment, and to the training of an adequate number of specialists for this work. International services, such as PASB/WHO, should assist by stimulating a greater interest in the plague problem, in the investigations and services needed to contend with it, and in the training of personnel.

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SECTION F

REVIEW AND EVALUATION OF THE PRESENT STATUS OF PLAGUE IN ECUADOR

History and Recent Incidence of Plague

In marked contrast to what could be recorded in the case of Venezuela, the history of plague in Ecuador is rather involved. Dealing with this problem, Jervis Alarcón (1958) distinguished three phases, namely: (1) invasion of the seaports and other settlements in the coastal provinces; (2) spread of the infection by the railway system to the mountainous provinces of the interior, which took place during the period 1909 to 1939 and led successively to the appearance of the disease in the Provinces of Chimborazo, Tungurahua, and Cañar, and finally in the small settlement of Guaytacama in the Province of Cotopaxi (north of Tungurahua Province), the northernmost locality reached by plague in Ecuador; (3) penetration of the infection into the rural areas, and also in the southern Province of Loja, in which plague, spreading by continuity from adjacent Peruvian areas, became entrenched during the period 1918-1926.

The first of these three phases commenced in 1908, when the importation of plague by the sea route led to an entrenchment of the infection among the rats of Guayaquil, followed soon by the appearance of manifestations of the disease in man. As a consequence of this fateful event, during the period 1908 to 1913 almost all coastal towns of Guayas and Manabí Provinces became plague-infected and the disease also appeared in the settlements of the coastal Province of El Oro and the inland areas of Los Ríos Province.

Generally speaking, plague in the coastal areas of Ecuador began to abate in 1924 and disappeared in 1930. However, owing to an importation from Chimborazo Province, the infection again flared up in Guayaquil in 1935 and persisted there until 1939, when the last human case in that port was recorded. Guayaquil has since then remained free of plague even though its rat population continues to be conspicuous. However, up to the present there has been a repeated reappearance of plague in other coastal localities, most frequently in El Oro Province where, according to Jervis Alarcón, 16 cases were recorded in 1939, 3 in 1940, 4 in 1950, and one in 1954 (community of La Libertad). These manifestations seemed to be due to an importation of infected fleas in bags of merchandise from Loja Province (Jervis Alarcón).

In 1954 the island of Puná, situated in the Gulf of Guayaquil, became the scene of a most noteworthy outbreak which, according to the just-mentioned observer, appeared to be due to an importation of the infection in goods from the seriously affected Loja Province, rather than from El Oro. Notwithstanding this mode of the infection, the common rats (R. norvegicus) of Puná town did not become involved, whereas a violent

epizootic broke out among the wild rodents of the island, the plague nature of which was proved through positive findings in the three species Sigmodon puna, Oryzomys xanthaeolus, and an unidentified species of Graomys (De la Barrera). The purely sylvatic nature of the outbreak is also proved by the fact that all eight persons involved in it had contracted the disease when staying in the fields to collect wool from the silk-cotton tree (the seeds of which form an attractive pabulum for the rodents). Drastic efforts to control the situation through a campaign against the wild rodents were crowned with success, and these animals were shown to be practically absent when De la Barrera visited the island in 1957. However, an exportation of the wool led to two plague cases recorded in 1955 at San Lorenzo, Canton of Guayaquil, in Guayas Province.

The information on recent plague manifestations in the coastal areas of Ecuador may be summarized as follows:

Year	Locality	Nature of outbreak
1956	Jipijapa Manabí Province	The occurrence of 7 plague cases in this important inland trading center stood apparently in causal connection with the importation of material for the manufacture of gunny-bags from Chimborazo Province.
1957	Vinces, Los Ríos Province	In the Daule-Guaya Rivers area not far from the port of Guayaquil, the infection of this important center of the cacao trade, leading to 11 human attacks, undoubtedly also originated in Chimborazo Province.
1961	Piñas and Zaruma, El Oro Province	For these two localities 9 and 8 cases, respectively, were reported in this coastal province. However, they are closer to the Loja focus (and may be part of it) than they are to the coast.
1961-63	Manabí Province	Recrudescence of rat-source plague has taken place in this coastal area and neighboring towns connected by railroad; Manta was the original focus.

From summaries published in the WHO Weekly Epidemiological Record (Vol. 36, 1961, 8:84, and Vol. 37, 1962, 29:355) and from data furnished

in the PASB Weekly Epidemiological Report (Vol. 34, Nos. 1-52, and Vol. 35, Nos. 1-52, 1963), it can be gathered that the plague incidence recorded in the coastal Provinces of El Oro and Manabí in 1960 through 1963 was as follows:

Province	Canton	1960	1961	1962	1963	Remarks
El Oro	Piñas	5	9	2	18	Localities closer to Loja focus than to the coast.
	Zaruma	-/5	8/17	-/2	-	
Manabí	Chone	-	-	13	4	All places on or connected with the coast.
	Jipijapa	-	-	1	-	
	Junín	-	-	1	-	
	Manta	-	36	86	14	
	Montecristi	-	-	9	7	
	Portoviejo	-	23	26	56	
	Rocafuerte	-	10	16	14	
	Santa Ana	-	-	12	7	
	Sucre	-	-	74	22	
	24 de Mayo	-	-/69	3/241	18/142	

Note: Two imported plague cases were recorded in 1961 in the city of Quito (Pichincha Province); they were believed to have been infected in Manabí.

Unfortunately, these statistics show that (a) human plague continued to be manifest in 1963 at Manta, where a rat-caused outbreak began in 1961, thus indicating that the infection continued to exist in the rodent population of that seaport; and (b) the infection has spread to the immediate hinterland of Manta, being manifest in the important centers of Portoviejo, Santa Ana, and Montecristi, which are connected by rail with Manta, and as far north as Chone and as far south as Jipijapa. There can be hardly any doubt that plague has once more become entrenched among the rats of at least some of these places, particularly in Manta, Portoviejo, and Rocafuerte.

With respect to the provinces in the interior of Ecuador, for the convenience of record it is preferable to deal with the plague manifestations in the Provinces of Tungurahua and Cañar before devoting attention to the earlier affected Chimborazo Province.

As reported by Jervis Alarcon, plague appeared first in Tungurahua in 1926 in the city of Ambato, which again recorded an epidemic, involving about 100 persons, in 1929. The disease then seems to have been absent from the province until 1956, when, probably imported through goods or infected domesticated guinea pigs from an adjacent area of Chimborazo

Province, it appeared in a rural area situated some kilometers southeast of Ambato. All the 16 attacks in the first affected area, as well as two afterwards recorded in Ambato city, seem to have stood in causal relation to the infection of domesticated guinea pigs. There was only one death among the 18 cases in 1956. In 1961 there were 8 cases in the Ambato area. It should be noted in this connection that, according to a brief statement by Jervis Alarcón, the size of the endemic plague area in Tungurahua Province was 40 km^2.

The Province of Cañar, south of Chimborazo Province, first became plague-affected in 1933, when about 200 attacks with a high mortality were recorded in three localities. The disease reappeared there in 1945 (9 cases with 4 deaths). Afterwards, 10 cases with 6 deaths were notified in 1951 at Las Postes, and 8 with 3 fatalities at Tambo. While the earlier outbreaks were evidently due to an importation of the infection from Chimborazo, that of 1953 was supposed to stand in relation to the importation of goods from the severely affected Cariamanga area in Loja Province. According to Jervis Alarcón, the size of the affected areas in Cañar was 60 km^2.

Dealing with the plague situation in Chimborazo Province, Jervis Alarcón furnished the following valuable general information:

The province has an area of 5,784 km^2 and, according to the 1950 census, 218,130 inhabitants, 72.61 per cent of whom lived in the rural zones. The altitude of the various regions ranges from 1,000 to 3,000 meters above sea level, and the temperature from 7º to 18ºC. The weather is apt to be changeable even within one and the same day. The dry season lasts from June to December, the rainy period from December to May.

Plague, undoubtedly imported from the coastal areas, with which the Chimborazo Province is connected by rail, appeared there in 1909, first affecting the towns but becoming rural in character in 1940. The case incidence of the disease during the first phase (1909-1939) was 1,420, according to De la Barrera (1957), as compared with an occurrence of 269 cases from 1940-1960. Some details on the manifestations of the disease during the period 1946-1956 were set forth by Jervis Alarcón as follows:

Year	Districts affected	Foci	Cases	Year	Districts affected	Foci	Cases
1946	2	2	7	1952	2	7	18
1947	4	5	9	1953	1	1	4
1948	1	1	1	1954	7	14	27
1949	0	0	0	1955	3	4	10
1950	2	2	4	1956	3	6	10
1951	4	14	25	Totals:		56	115

According to Jervis Alarcón, the affected areas in the Chimborazo Province, now all situated in rural regions, have a total size of 400 km^2

The recent plague incidence in Chimborazo Province was reported as follows in the WHO Weekly Epidemiological Record and the PASB Weekly Epidemiological Report:

Year	Cantons affected	Case incidence per canton	Annual total
1957	Guano	12	12
1958	Guano	7	
	Riobamba	1	8
1959	Guano	11	
	Riobamba	10	21
1960	Guano	15	
	Riobamba	10	
	Alausí	10	35
1961	Guano	1	
	Riobamba	1	2
1962	Riobamba	6	
	Alausí	21	27
1963	Alausí	57	
	Guano	8	
	Riobamba	2	67

Characteristic of plague in the Chimborazo Province were

(1) A high mortality, amounting, according to Jervis Alarcón, to 85.7 per cent in 1946 and 20 per cent in 1956;

(2) A high incidence of pneumonic plague, due no doubt to the prevailing climatic conditions which induced the people to crowd together in their houses.

The Province of Loja, lying in the south of Ecuador adjacent to Peru, comprises (according to Jervis Alarcón) an area of 9,926 km^2 and in 1950 had a population of 216,802, almost 70 per cent of whom lived in the rural zones. The province consists of (a) a low region, 200-800 meters above sea level with temperatures of 18º-30ºC in the shade; and (b) a mountainous part, at altitudes of 1,500-2,500 meters, with temperatures from 8º to 19ºC. It is important to note that the dry season, lasting from May to December, is the period of the year favorable for the occurrence of plague in the province, in which an area of about 3,000 km^2, situated for the larger part in the low-lying zone, is affected by the disease.

As has been noted above, the infection infiltrated into Loja Province during the period 1918-1926, the stages of this process having been thus described by Macchiavello (1957):

1918-21 - Plague became manifest in the Cazaderos-Alamor area.
1923 - The presence of the disease in the Canton of Celica was suspected.
1925 - The occurrence of plague was noted in the cantons of Catacocha (Paltas), Gonzamaná, and Cariamanga (Calvas).
1926 - Loja city was reached by the infection.

Considering this evolution, Macchiavello entertained no doubt that the appearance of plague in Loja Province was due to an extension of the previously existing sylvatic focus in the Lancones district of Peru into Ecuador, resulting in the entrenchment of the infection among the wild rodents in a large area situated on both sides of the frontier between the two countries.

As stated by Macchiavello, during the period from 1925 to 1948, 1,617 plague cases with 864 deaths were noted in Loja Province, distributed as follows:

Canton	Cases	Deaths	Canton	Cases	Deaths
Alamor	305	135	Macara	67	33
Celica	230	125	Cariamanga	266	139
Catacocha	372	188	Gonzamaná	210	157
Loja	46	13	Amaluza	121	74
		Totals:		1,617	864

The incidence of the disease in Loja during the period from 1946 to 1956 was thus characterized by Jervis Alarcón:

Year	Districts affected	Foci of human plague	Foci of rodent plague	Cases	Deaths
1946	7	18	?	46	13
1947	4	7	?	17	1
1948	6	20	?	38	2
1949	7	17	?	20	3
1950	6	11	?	21	3
1951	5	9	?	10	1
1952	9	20	?	41	3
1953	6	28	11	64	15
1954	9	34	1	111	8
1955	2	2	?	3	1
1956	7	30	5	42	3
Totals:	68	196	?17	413	53

Dealing in his article with the distribution of plague in Loja during the five-year period 1952 to 1956, Jervis Alarcón stated:

"The spots (lugares) affected in these last five years are: in the eastern sector, 4 out of 9 lugares of the Loja district; 4 out of 8 in La Toma; 4 out of 6 in Gonzamaná; 19 out of 23 in Sozoranga; 18 out of 22 in Cariamanga; all 7 of Amaluza, all new; in the western sector, 5 of the 7 lugares of Chaguarpamba; 13 out of 26 in Celica; 9 out of 19 in Alamor; 7 out of 11 in Pindal; 7 out of 13, all new, in Zapitillo."

According to this observer, most severely affected were the districts of Cariamanga, Sozoranga, Catacocha, Celica, Alamor, and Amaluza, the persistence of the infection among the wild rodents in them being "the true cause of the rural endemicity" in Loja. This is certainly a clue deserving great attention.

As added by Jervis Alarcón, the plague mortality in the Province of Loja showed a marked decrease toward the end of the period considered by him, as shown by the following figures:

Period	Total cases	Recovered	Died	Mortality %
1926-1936	1,479	928	551	37.2
1936-1946	906	611	295	32.6
1946-1956	410	369	41	11.1

The comparative benignity of plague in Loja was also evidenced by the rarity of the pneumonic type, only one small outbreak of lung pest having been recorded in the Catacocha district in 1939 (7 victims).

Data on the recent incidence of plague in the Province of Loja taken from the WHO Weekly Epidemiological Record and (for 1963) from the PASB Weekly Epidemiological Report, may be set forth as follows:

Year	Plague cases	Districts involved
1957	62	No details.
1958	13	Calvas (2), Cariamanga (1) Celica (9), Macará (1).
1959	19	Catacocha (1), Celica (4), Loja (7), Macará (1), Paltas (6).
1960	36	Calvas (17), Celica (1), Macará (11), Paltas (7).
1961	7	Calvas (2), Celica (3), Paltas (2).
1962	56	Calvas (19), Celica (23), Macará (10), Puyango (3), Paltas (1).
1963	29	Calvas (9), Loja (5), Macará (2), Paltas (13).

Observations on Rodents and Other Ecologically Important Mammals

"Domestic" Species

As far as can be judged from the rather scanty information available in regard to the occurrence of the common rats in the plague-affected areas of Ecuador, these rodents, while abundant in the settlements of the coastal areas (where R. norvegicus appears to be the most frequent species), are irregularly distributed in the interior, especially in the mountainous districts. Macchiavello maintained in this connection, in his study on the Province of Loja, that the reason for this unequal distribution of the rats and their absence from still many settlements seemed to be that these rodents had begun to penetrate only since 1920 in the remote interior areas of Ecuador, especially those lying away from roads and railways. He illustrated the irregular distribution of the three rat species in the towns of Loja Province by the following table, based upon the results of captures made from 1938 to 1942:

Towns	R. rattus	R. norvegicus	R. alexandrinus
Loja	14	22	2
Guachanamá	0	0	2
Federico Páez	2	0	10
Zapotillo	0	0	0
Cazaderos	1	1	2
Zabiango	0	3	0
Sozoranga	0	5	4
Chaguarpamba	35	47	89
Cariamanga (Calvas)	24	53	109
Gonzamaná	17	56	260
Celica	66	72	173
Amaluza	22	329	696
Catacocha (Paltas)	6	335	439
Macará	5	281	293
Alamor	4	50	178
Totals:	196	1,254	2,257

To judge from these data, R. alexandrinus was most frequent among the urban rats in Loja, while R. rattus was rare. As stated recently by Jervis Alarcón, R. alexandrinus was also the prevalent rat in Chimborazo Province.

The irregular distribution of the common rats in Ecuador was confirmed by De la Barrera (1957), who, however, made almost all his observations in Loja Province and admitted, moreover, that he had devoted his main attention to the wild rodent species. As can be gathered from De la Barrera's report, he had met in Loja with all three subspecies of R.

rattus (rattus, alexandrinus, and frugivorus) as well as with R. norvegicus. While the latter was of rather domestic habits, never leaving the immediate vicinity of the houses, R. rattus was trapped not only in but also around the settlements within a radius of 1,200 meters.

Discussing the role played by the rats in the plague manifestations of the presently active Ecuadorian foci, De la Barrera (a) referred to a small 1956 outbreak which took place at Chinchil, in a region where the Rattus species were absent (domesticated guinea pigs serving as the means to convey the infection to man); and (b) stated in a general manner that he had not met with rats in the plague-infected houses. Maintaining in his final report (1961) that the common rats of Ecuador had become resistant to plague, De la Barrera came to the conclusion that "there was evidence that in the actual moment the importance of Rattus as reservoir and spreader of plague in Ecuador is secondary or nil." He was careful to add, however, that "the great murine communities parasitized by X. cheopis surrounded by sylvatic (plague) infection constitute a tangible risk."

Mus musculus

The frequency of the house mice in Loja Province is well illustrated by observations quoted by Macchiavello, according to which during the period from 1938 to 1942 not less than 49,393 out of a total of 68,566 captured rodents were M. musculus. In accordance with these data, De la Barrera stated that this species "was met with as usual, in the houses and in the open fields." However, Jervis Alarcón maintained that, though M. musculus was widely spread in Ecuador, existing also in the mountainous areas, still there were many communities which had not been invaded by these rodents or by Rattus, particularly in zones distant from roads and railways.

That the house mice in Ecuador occasionally may be involved in the transmission of plague from the wild rodents to the houses has been confirmed by an observation made in 1956 by De la Barrera: In a house at San Fernando, a locality around which wild-rodent plague was rampant, 12 plague-infected M. musculus were found. Since, however, before this discovery five people had contracted the disease, no doubt through the bites of wild-rodent fleas (Polygenis litargus) abounding in the house, it is possible that the infected mice were merely victims of the infection instead of playing a causative role in the human outbreak.

Domesticated Rodents

It has been proved on many occasions that domesticated guinea pigs, amply bred in the houses of the Ecuadorian plague foci and living in closest contact with the inhabitants, are apt to play an ominous role in the transmission of the infection from wild rodents to man. An observation in point, made by De la Barrera, has been quoted above. Owing to the Indians' habit of sending such animals as presents to their friends, the guinea pigs may also become responsible for a spread of the infection to a distance. Another most dangerous practice is the absconding of guinea pigs

from plague-affected houses of settlements, which is resorted to by the Indians whenever they fear that these animals might be taken away from them and destroyed as a control measure.

Besides guinea pigs, rabbits (Oryctolagus cuniculus) are also kept in the houses of the Ecuadorian plague foci, but this is done on a much more limited scale. Moreover, contact of man with them is less intimate than in the case of guinea pigs (De la Barrera, 1957).

Wild Rodents and Lagomorpha

Fairly ample information on the wild rodents of Loja Province can be derived from the reports of De la Barrera and Jervis Alarcón, while the latter also furnished some supplementary data in point for the Province of Chimborazo.

Most frequent among the wild rodents in both provinces are two species of Cricetinae, Akodon mollis and Oryzomys xanthaeolus (95 per cent of the captures of De la Barrera). Both are able to adapt themselves to a wide variety of habitations without predilection for any of them. Both are apt to invade the rural houses at nighttime. They differ in that O. xanthaeolus is more heavily infested with the fleas common to all the small rodents of Loja Province. Both species are highly susceptible to infection with P. pestis and are thus apt to be involved in widely spread acute plague epizootics. As observed by De la Barrera in 1956 at Santa Ana, plague-affected rodents of both species may be found even inside rural houses.

No ecological data could be found regarding some other Oryzomys species, including O. longicaudatus and O. flavescens, nor regarding Phyllotis fructicicolus which, like the two above-mentioned species of Cricetinae, have been found naturally plague-infected in Ecuador.

Sigmodon peruanus, also belonging to the subfamily of Cricetinae, though less frequent than A. mollis and O. xanthaeolus, is also widely spread in Loja Province. According to De la Barrera, it is moving about rather slowly, and therefore is but rarely encountered in the houses. Like its congener, Sigmodon puna, it has been found naturally plague-infected.

The squirrel Sciurus stramineus nebouxi, a tree-inhabiting species, though generally of sylvatic habits, not rarely enters the houses in daytime in search of morsels of food. This species deserves great attention insofar as, being considered to be comparatively resistant to plague, it survives and forms a reservoir in Loja Province, thus being responsible for the periodical appearance of acute epizootics in the highly susceptible Cricetinae A. mollis and O. xanthaeolus. It is important to note in this connection that S. stramineus, which has been found to be infested at a low rate with the flea Polygenis litargus, is met with in more restricted locations than

the small Ecuadorian rodent species. Hence, should the role of S. stramineus as the principal plague reservoir in Loja Province be proved, the localities inhabited by it might form strongholds of the infection.

As suggested by Jervis Alarcón, in Chimborazo Province Sylvilagus brasiliensis and allied species of lagomorpha, which are also comparatively resistant to plague, might play a role comparable to that of S. stramineus in Loja. It is noteworthy that Sylvilagus, a large animal hunted for the sake of its meat, also belongs to the species restricted in their habitat. Its specific flea is Hoplopsyllus manconis.

It deserves attention that, in strict contrast to the above-discussed postulations, De la Barrera insisted that the Ecuadorian wild rodents "constituted by species which live together or enter in contact, are equally sensitive (to plague), are parasitized by the same fleas, and constitute a homogeneous whole in regard to plague. The importance of each species in the transmission depends solely upon its abundance and its habits."

De la Barrera maintained also that the large rodent species (Cuniculus, Dasyprocta, Sylvilagus and Sciurus) apparently did not play an important role in the ecology of plague. It will be the object of further investigations to decide whether his contentions or, perhaps in a modified form, the more plausible suggestions of Macchiavello and Jervis Alarcón are valid.

Observations on Fleas

Rat Fleas

Dealing in a general manner with the occurrence of X. cheopis in Ecuador, Jervis Alarcón stated that in the coastal areas up to an altitude of 1,200 meters, this flea was practically alone met with on the common rats and was also solely responsible for the conveyance of the infection in the past epizootics and epidemics. In the mountainous areas of the interior, X. cheopis was considerably less abundant than on the coast, not occurring in numbers sufficient to cause widespread epizootics followed by epidemics. It was not found in localities above about 300 meters, and was replaced in the highly situated areas of Chimborazo Province by Nosopsyllus londinensis. As stated by Jervis Alarcón, this flea, frequent at altitudes above 1,400 meters, though a less efficient vector than X. cheopis, seemed at low temperatures more suited than the latter to serve as a reservoir of P. pestis and consequently was in Chimborazo Province the flea responsible (causante) for "the maintenance or endemicity of plague"--thus playing a role analogous to that of Polygenis litargus in Loja Province.

It is striking to note that De la Barrera, reporting on his investigations in Loja Province, listed among almost 12,000 fleas examined by him only four X. cheopis, apparently three in the nests of undetermined rodents

and one on a lot of 16 domesticated guinea pigs.* It must be noted, however, that (a) as already mentioned, this observer made his studies on wild rodents rather than on rats; and (b) to judge from Macchiavello's article, during the plague outbreaks observed by him in 1943 in the Cariamanga canton of Loja Province, X. cheopis was the prevalent flea on the rats (mainly R. alexandrinus) and thus evidently served as the vector of the infection. Further studies, showing the comparative frequency of X. cheopis in the various cantons of Loja Province, would therefore appear to be most necessary.

Mouse Fleas

As stated by Jervis Alarcón, the fleas encountered on the house mice of Ecuador belonged to the species Leptopsylla segnis, Tiamastus cavicola, Pulex irritans and (rarely) X. cheopis. Among 11 fleas collected by De la Barrera in Loja Province from M. musculus, 6 were L. segnis, 4 T. cavicola, and 1 N. londinensis.

Fleas of the Domesticated Guinea Pigs

Referring to the fleas of the domesticated guinea pigs, Jervis Alarcón recorded the following figures:

Loja Province		Chimborazo Province (Riobamba)	
P. irritans	67.7%	T. cavicola	69.5%
P. litargus	32.1%	Hectopsylla eskeyi**	29.4%

The flea incidence on Cavia cobaya observed in Loja Province by De la Barrera was as follows:

P. irritans	1,804	Polygenis sp.	2
T. cavicola	595	X. cheopis	1
H. eskeyi	45	L. segnis	1
P. litargus	44	Ct. felis	1
		Totals:	2,493

The occurrence of Polygenis litargus, the wild-rodent flea mainly responsible for the transmission of plague in Loja Province, on the domesticated guinea pigs is of great significance. Tiamastus cavicola, the specific flea of the guinea pig, has been found naturally plague-infected in both Ecuador and Peru but is not considered to be an efficient vector of P. pestis.

* Later in his report he also mentioned 2 cheopis fleas found on R. norvegicus.

** This species and also H. suarezi have been found naturally plague-infected in Ecuador. Both these fleas were also found on common rats.

Fleas of the Marsupialia

The fact that marsupialia (Monodelphis and Didelphis), because they have ample contact with the wild rodents but also frequent the houses, are apt to play a role in bringing infected fleas to the immediate vicinity of man, is confirmed by the following flea list furnished by De la Barrera for Didelphis marsupialia:

Polygenis litargus*	4	Rhopalopsyllus cacicus	32
P. bohlsi bohlsi*	2	Ctenocephalides felis felis*	3
Adoratopsylla intermedia copha*	3	Total:	44

Neotyphloceras rosenbergi, encountered by De la Barrera on Didelphis azarae, has also been found naturally plague-infected in Ecuador.

Wild Rodent Fleas

Amply dealing with the wild rodent fleas in the Province of Loja, De la Barrera furnished the general tabulation shown on page 82.

Commenting upon his findings, De la Barrera stated that Polygenis litargus was not only the flea most frequently met with on the wild rodents of Loja Province but was also found on the common rats of the rural areas and on the domesticated guinea pigs. Though considering this flea as a probable vector, conveying P. pestis not only from rodent to rodent but also to man, De la Barrera maintained that its role had not been definitely proved. It is, however, important to add that these doubts were soon set at rest; Macchiavello recorded, one year after the publication of De la Barrera's report, experimental findings confirming the capability of Polygenis litargus to convey the infection. Although with some restrictions, he considered that it is a "splendid" plague vector. One must, however, agree with De la Barrera that most probably this flea is not the only vector of the infection in Loja Province, and that thus there is an urgent need to test the capability of the other wild-rodent fleas encountered there, paying prime attention to the several species which, like P. litargus, have been found to harbor P. pestis under natural conditions.

It is disappointing to find that, in contrast to the quite ample prima facie evidence available in regard to the Loja fleas, information on the species probably concerned in the conveyance of plague in the Province of Chimborazo is not only quite scanty, but also contradictory. Jervis Alarcón is evidently of the opinion that in that plague area N. londinensis found on Oryzomys xanthaeolus and Akodon mollis, besides on the rats, plays

* Found naturally plague-infected.

Wild Rodent Fleas in the Province of Loja

(De la Barrera)

Flea species	Found on							
	O. xanthaeolus		Akodon mollis		Other wild rodents		Rodent nests	
	Nº	%	Nº	%	Nº	%	Nº	%
P. litargus*	439	76.4	757	45.7	343	71.7	4,878	71.4
P. bohlsi bohlsi*	43	7.4	248	20.4	78	16.3	1,557	22.6
P. brachimus*	63	10.9	23	1.8	1	0.2	350	5.0
Polygenis n. sp.	17	2.9	58	4.7	8	1.6	53	0.7
Plocopsylla n. sp.*	6	1.0	1	0.1	-	-	-	-
N. rosenbergi*	6	1.0	34	2.8	37	7.7	16	0.2
P. phobos	-	-	37	3.0	-	-	-	-
Pleochaetis dolens quitanus*	-	-	42	3.4	-	-	-	-
Tunga n. sp.	-	-	1	0.1	-	-	-	-
R. cacicus	-	-	1	0.1	-	-	-	-
Pulex irritans n. s. sp.	-	-	1	0.1	1	0.2	-	-
P. irritans*	-	-	2	0.2	-	-	4	0.05
C. felis felis*	-	-	5	0.4	1	0.2	1	0.01
Craneopsylla minerva	-	-	1	0.1	-	-	-	-
A. intermedia copha	-	-	1	0.1	7	1.4	1	0.01
Cleopsylla monticola	-	-	-	-	2	0.4	-	-
Ctenidiosomus spillmanni	-	-	-	-	-	-	2	0.02
Dasypsyllus lasius	-	-	-	-	-	-	23	3.3
X. cheopis	-	-	-	-	-	-	3	0.04
Totals:	574		1,212		478		6,888	

* Found naturally plague-infected.

a role analogous to that of P. litargus in Loja. However, in his 1961 report, De la Barrera made the following statement:

> "Though our information on the Siphonaptera of the northern zone (Chimborazo) seems incomplete, there can be no doubt that the flea species are not the same as in the southern zone. The principal difference is that Polygenis litargus, the predominant and probably the vector species in the Province of Loja, is not met with above 2,200 meters altitude, being replaced in Chimborazo by Pleochaetis dolens quitanus."

It is clear, therefore, that further studies on the occurrence and comparative importance of these two fleas are urgently called for. Great attention must also be paid to Hoplopsyllus manconis, the specific flea of Sylvilagus brasiliensis which, as has been noted above, is in the opinion of Jervis Alarcón possibly the fons et origo mali in Chimborazo.

It has to be added that the present reporters have not been able to find any information on the rodents and fleas implicated in the plague manifestations in the Provinces of Tungurahua and Cañar.

Ecology and Epidemiology of Plague

As has already been noted on several occasions and will be further discussed below, there are still many gaps in existing knowledge, but it may nevertheless be claimed that the general features of the ecology of plague in Ecuador have become clear. There can be no doubt that in the presently affected areas of that country plague is basically of a sylvatic nature, the persistence of the infection in wild rodents being responsible for the occasional appearance of the disease in the "domestic" rodent fauna and in man. Although to judge from the information available only for the two worst affected areas, the Provinces of Loja and Chimborazo, several species of wild rodents and lagomorpha have been found involved in the plague manifestations, Akodon mollis and Oryzomys xanthaeolus being at first glance the most seriously affected. There can be no doubt that, in these two most numerous and widely spread species, infection by P. pestis plays the role of a population regulator, the disease becoming periodically rampant among them when, for reasons too lengthy to discuss here, the tides of widespread acute epizootics are followed by periods during which, owing to the decimation of the herds, the infection finds little if any fuel for its spread or even persistence. It is under these circumstances a plausible idea that the above-mentioned Cricetinae species do but periodically suffer from plague, the infection being permanently harbored by other rodents. As has been stated, this has been actually postulated, Sciurus stramineus being incriminated as the permanent plague reservoir in Loja, while an analogous role has been ascribed in Chimborazo Province to Sylvilagus brasiliensis. As will be discussed in the following part of this report, observations made in Peru lend some support to the view that S. stramineus might be capable of serving as a permanent plague reservoir. However, as far as the present reporters are aware, no proof whatsoever has been obtained that an identical role might be played by S. brasiliensis. Nevertheless, one may accept it

as a working hypothesis that, not the Cricetinae, but other species of rodents or lagomorpha constitute the permanent plague reservoirs in the Ecuadorian plague foci. To confirm or to establish which species are actually involved, is one of the urgent tasks of further investigations, because only after their discovery will it be possible to determine whether and where within the affected areas strongholds of plague exist. The recognition of such "elementary foci," the existence of which seems to have been hinted at by Macchiavello and Jervis Alarcón, would be of great importance for the adequate prevention and control of plague.

In contrast to the above-discussed problem, for the attempted solution of which in part hypotheses rather than established facts had to be adduced, the manner in which plague finds its way from the wild rodents to man has in the main been elucidated.

As can be gathered from De la Barrera's reports, human infection has been sometimes contracted by persons working or staying in the foci of wild-rodent plague. No doubt, however, an intradomestic infection of man is the rule in the presently affected areas of Ecuador. This may be effected in various ways. Thus, as confirmed by an observation of De la Barrera, plague-infected rodents may occasionally carry their fleas into the houses and become capable of conveying the disease to man. Infected wild-rodent fleas may also be brought into the houses in other ways, especially by the marsupialia frequenting the human habitations as well as their vicinity, and may then directly attack man. It may be noted in this connection that De la Barrera was able to cultivate P. pestis from 2 out of 10 Polygenis litargus fleas collected in a plague-infected house.

Ample experiences have shown, however, that often the manifestation of plague in man is preceded by the infection of the common rats, the domesticated guinea pigs, or occasionally the mice living most or all of the time in the human habitations. While there can be no doubt that wild-rodent fleas are instrumental in conveying the infection to these animals, pending further investigations it is difficult to decide which fleas function as the vectors of P. pestis from the latter to man. It should be noted in this connection that (a) X. cheopis, a notoriously efficient vector, appears to be scanty in the presently plague-affected areas of Ecuador and altogether absent in their higher parts; (b) N. londinensis, found on the rats in Chimborazo Province, is not a highly efficient vector; and (c) it seems to be unknown to what extent the common rats are infested with wild-rodent fleas. It can be pointed out, however, that according to the above-quoted observations of Jervis Alarcón, the domestic guinea pigs of Loja Province were to a remarkable degree infested with Polygenis litargus and it seems likely, therefore, that this flea was instrumental in conveying the infection from guinea pig to guinea pig and from them to man. That P. irritans, according to Jervis Alarcón the predominant flea of the guinea pigs in Loja, played an important role in this respect, seems less likely at the present state of knowledge on this species.* Whether Hectopsylla eskeyi, found besides the rather inefficient

* This point will be further discussed in the report on Peru.

vector Tiamastus cavicola on the guinea pigs of Chimborazo Province, is of importance in the conveyance of plague, remains to be seen.

Although instances of the appearance of two or more cases in one and the same house seem to be frequent (occurring, according to De la Barrera, in 1956 in 42 per cent of the affected habitations), a spread of the disease from man to man through the agency of infected fleas seems not at all likely.

That fundamental differences in the ecology of plague exist between the Loja and Chimborazo Provinces, is confirmed by the fact that the seasons of the appearance of human plague in the two areas are not identical. Jervis Alarcón stated, in this respect:

> "In Chimborazo, between 1946 and 1956, the majority of the cases appeared in the hottest months with a high relative humidity, from February to May, and the rare cases appeared in the summer months of no excessive heat, between August and December; whereas in Loja (plague) became intensified after the rainy season, during the harvest period, i.e., from May to December."

Recommendations for Further Investigations

As already repeatedly stated in the foregoing pages, in many respects the information available in regard to the ecology and epidemiology of plague in Ecuador is still incomplete. There exists, therefore, an urgent need for further investigations, the most essential among which seem to be the following:

Coastal Provinces

Although since the final disappearance of plague from Guayaquil in 1939 it seems that the disease no longer has a permanent foothold in the coastal provinces of Ecuador, it must be noted that within recent years repeatedly long-distance sprints of the infection from the endemic foci in the interior have led to the appearance of the disease at or near the seacoast. To judge from the perhaps not complete available information, these outbursts could become quite serious, as in Manta for instance, where a considerable rat-epizootic preceded and accompanied the manifestation of the disease in man. The fact that such an epizootic could evolve shows clearly that the resistance of the Ecuadorian rats to plague is not as universal or not as permanent as has been postulated. An appraisal or reappraisal of the plague-receptivity of the rat population in the various communities of the coastal provinces (in the first line in the ports and other traffic centers), and as far as possible also in representative rural areas, would therefore be most desirable. As shown by large-scale investigations in point made in India, it would be possible to make the susceptibility tests in a central laboratory to which batches of rats from the various locations are forwarded. An exact knowledge of the plague history in each of these would be of great importance for the evaluation of the results.

Advantage ought to be taken of the trapping of these rats to assess:

(a) the comparative density of the rat populations in communities of different size and in the rural areas;

(b) the relative frequency of the two rat species and (though this is of lesser importance) of the subspecies of R. rattus;

(c) the occurrence and frequency of the various species of rat fleas, especially of X. cheopis, in the various locations studied.

(Since, however, the frequency of the rat fleas may be subject to marked seasonal changes, it would be highly desirable to continue such studies, at least in selected communities, for a period of not less than a whole year).

Detailed instructions for the trapping of rats, the collection of fleas, and the transport of both to the central laboratory, suitable under the local conditions, will have to be framed and issued.

Endemic Areas of the Interior

1) Ecological and Epidemiological Investigation

To judge from the available information, the endemic foci in the Provinces of Loja, Chimborazo, Tungurahua, and Cañar have been found to be well delimited. Since, however, the observations in point were made some years ago, it will be important to determine, in close cooperation with the workers of the National Plague Prevention Service, whether the boundaries of the endemic areas are still the same at present or whether the foci have shown a tendency to increase or to decrease in size. If possible, large-scale maps showing the present boundaries of the endemic foci should be prepared.

As has been mentioned above, it appears that within the endemic area of Loja Province there exist districts with a particularly serious plague situation, in which evidently the infection shows a marked or even permanent tendency to become recrudescent. Every possible effort should be made to confirm the continued existence of such centers of the infection, and the observations on the incidence of human plague (upon which the information presently available in this respect seems to be mainly based) should be correlated with particularly intensive studies on the rodents and fleas. Efforts should also be made to determine whether such centers of the infection exist also in the other three affected provinces, especially Chimborazo Province.

All human manifestations encountered by the study group ought to be made the subject of thorough investigations. In the first line, efforts should be made to establish which rodents and which fleas were responsible

for the infection of the patients. The presence of plague in them ought to be confirmed invariably through adequate laboratory tests, and the strains of P. pestis isolated from the sufferers ought to be kept in a lyophilized state for further study.* Moreover, efforts should be made to detect the occurrence of subclinical forms of the disease through clinical and serological surveys of groups of the population actually or potentially under the risk of infection.

2) Investigations on Rats, House Mice, and Their Fleas

As has been discussed, the information on the occurrence of the two species of rats, and also on the frequency of the house mice, in the endemic areas is rather incomplete. It is therefore most important to study the present distribution of these rodent species in the endemic areas or, if possible, in the four affected provinces as a whole. The zones inhabited by these animals might with advantage be indicated in the maps of the endemic areas.

All rats and house mice found dead or trapped within the endemic areas ought to be dissected and examined for the presence of plague or of past infection with P. pestis. Advantage ought to be taken for this purpose not only of macroscopic and microscopic observations, cultivations, and pooling tests, but also of serological tests. The latter as well as the pooling tests and perhaps even the cultivations might be made in base laboratories, to which the adequately preserved organs and the blood or serum of the dissected animals are forwarded.

It would be further essential to ascertain whether or to what extent the rats within the endemic areas are resistant to infection with P. pestis. If, as will probably be inevitable, the animals have to be sent for this purpose to a base laboratory, they would have to be carefully de-flead before they are dispatched.

The rather scanty information on the flea fauna of the rats in the endemic areas must be supplemented by further large-scale surveys. It is particularly important (a) to establish to what extent the rats of Loja Province are infested with X. cheopis and which fleas parasitize the rats in its absence; (b) to confirm that in Chimborazo Province N. londinensis is the specific rat-flea; and (c) to determine which species infest the rats in the endemic areas of Tungurahua and Cañar Provinces.

While the vector efficiency of X. cheopis may be taken for granted, it would be important to study the vector capacity of the fleas that replace it, particularly N. londinensis. Analogous studies ought to be made also with P. irritans, frequent on the domesticated guinea pigs of Loja Province, and with Tiamastus cavicola and especially Hectopsylla suarezi, which infest these animals in Chimborazo Province.

* This naturally also holds true of the strains isolated from rodents and fleas.

3) Investigations on Wild Rodents and Lagomorpha

As will be gathered from the statements made earlier in this report concerning the observations on wild-rodent plague in the Ecuadorian endemic areas, the most important problem yet to be solved is to ascertain which of the several species found to suffer from natural plague form the permanent reservoir of the infection. Thus far it has been assumed that in Loja Province the squirrel Sciurus stramineus nebouxi is the fountainhead of the infection, while in Chimborazo an analogous role of Sylvilagus brasiliensis has been suspected.* Apparently the main argument in favor of these species was that they were supposed to be less susceptible to plague than the Cricetinae. It would seem, however, that this claim is not supported by convincing evidence. Moreover, the present reporters must point out that the supposed resistance of a rodent species to plague should not be considered as the sole criterion of its capability to permanently harbor the infection. Experiences in other plague-affected countries have shown that a more or less refractory state to infection with P. pestis may be of a racial or seasonal nature instead of being inherent in the species in question as a whole all the time. Hence, while it is certainly important to make exact comparative studies of the degree to which the various species of the Ecuadorian wild rodents are amenable to P. pestis infection, a decision as to whether or not the above-mentioned or other species are the permanent reservoir of the disease should also be based upon careful considerations of their ecology and the constancy of the occurrence of natural plague in them. As suggested with much reason by Macchiavello, the best times for observations of the latter kind are the periods or seasons during which wild rodent plague in general is at an ebb. Findings of the continued existence of plague in a rodent species at such times would go a long way to incriminate it as a permanent reservoir of the infection. While paying due attention to these investigations, a careful watch must be kept also on the trend of the disease in the Cricetinae in which epizootics become periodically rampant. Since, as has been discussed above, there is every reason to assume that these high tides of the infection and subsequent ebbs are correlated with fluctuations of the population density of the animals, constant or at least periodical surveys ought to be made to assess their frequency. Well-organized observations of this kind would form an easy means to forecast the appearance of epizootics, during which the risk of human infection is highest.

In order to ascertain the presence of plague in the wild rodents it is necessary (a) carefully to examine all animals found dead, with the aid of macroscopic and microscopic observations, cultivation and, if indicated, animal experiments; (b) to watch for the occurrence of incipient

* No statements in point have been made in the case of Tungurahua and Cañar Provinces, which in this as well as in many other respects still represent a terra incognita.

or latent infection with P. pestis by trapping* adequate numbers of the rodents and, perhaps after a period of observation in the live state, sacrificing them and subjecting them to the above-mentioned laboratory tests (substituting pooling tests with their organs by individual animal experiments). Another promising method would be to make tests with the sera of apparently healthy animals. As far as possible, the above-outlined tests should be made in a base laboratory, to which the adequately preserved organs and the blood serum of the animals are forwarded. It is obvious that, whenever necessary, their skulls and skins should be preserved for identification tests.

A part of the trapped animals ought to be used for testing their susceptibility or resistance to infection with P. pestis. Since tests of this nature presuppose the availability of adequate laboratory facilities, consideration must be given to the possibility of forwarding batches of the animals to a base laboratory after they have been de-flead and kept for some time in quarantine; one must fear, however, that the high mortality frequent in wild rodents kept in captivity will militate against the implementation of these procedures. As soon as the importance of a species of rodents or lagomorpha for the permanent harborage of P. pestis has been established, a close study of its ecology, especially of the limits of its habitat, must be made and the trend of the infection in the animals in question must be taken under constant observation. If the ecological conditions so warrant, a pilot study might be made to assess the possibility of eradication campaigns.

4) Investigations on Wild-Rodent Fleas

To obtain ample material of the Ecuadorian wild-rodent fleas for study is of the utmost importance in order (a) to arrive at a better understanding of the comparative frequency of the various species on the different wild rodents or lagomorpha and in their nests, as well as on liaison animals like the marsupialia and on the rodent species living in or near the houses; (b) to study at the same time the seasonal incidence of the various fleas; and (c) to assess the comparative importance of the different wild rodent fleas in the transmission and the inter-seasonal carry-over of plague. Constant efforts should be made, therefore, not only to collect fleas from all rodents coming under observation but also to make systematic searches for these parasites in the rodent nests and harborages as well as in the houses where the guinea pigs, veritable flea-traps, are apt to furnish adequate material.

It is clear that the above-outlined investigations would yield valid results only when the various flea species encountered can be properly identified--a task which unfortunately could by no means always

* In the case of species which are difficult to trap, killing the animals by an adequate method may become necessary.

be properly performed by the field workers. They should take care, therefore, to submit representative specimens of their collections to an expert for identification. It would certainly be best if, for this purpose, advantage could be taken of the unique knowledge on the South American flea species possessed by the custodian of the Rothschild flea collection in Tring (England);since, however, the results of his identifications would become available only with delay, it would be essential to attach a flea expert to the study group operating in South America.

To arrange for adequate tests on the vector capacity of the fleas is also difficult. No doubt this task could be performed most satisfactorily in one of the United States laboratories possessing special experience in this field. Nevertheless, it would seem well to make preliminary tests of this nature in a base laboratory in Ecuador and to attempt at the same time to raise colonies of the various fleas, lots of which could then be sent to the United States for final vector studies.

When investigating the role of the wild-rodent fleas in the individual endemic areas of Ecuador, prime attention ought to be paid to the following problems:

(a) Loja Province. Further studies on the distribution and seasonal incidence of Polygenis litargus ought to be made and its vector efficiency should be confirmed through further tests. At the same time it should be determined through ecological investigations, laboratory tests, and vector studies to what extent other species of wild-rodent fleas participate in the transmission of plague. Prime attention should be paid in this respect to the species already found naturally infected.

(b) Chimborazo Province. The distribution and seasonal incidence of Nosopsyllus londinensis, Pleochaetis dolens quitanus and Hoplopsyllus manconis should be thoroughly investigated and large-scale tests ought to be made to determine to what extent they are naturally plague-infected. It would also be essential to compare the vector capacity of these species.

(c) Tungurahua and Cañar Provinces. Since no information on the flea fauna in the endemic areas of these two provinces could be elicited, it would be important to establish by what species the rodents met with are infested, to study the seasonal incidence of the fleas, and to determine through ample laboratory tests which of them are naturally plague-infected. The vector capacity of the species incriminated in this or other ways should then be studied.

It is hoped that, for the drafting of a definitive plan for plague studies in other parts of Ecuador, it will be possible to take advantage

of the experiences gathered in the course of the investigations in point now envisaged for the Peru-Ecuador border area.

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SECTION G

REVIEW AND EVALUATION OF THE PRESENT STATUS OF PLAGUE IN PERU

History and Recent Incidence of Plague

As summarized by Pollitzer (1954), following its importation by the sea route into the port of Callao in 1903, the disease spread along the coast of Peru, most of the principal ports having become infected within two years, and eventually invaded 10 of the 20 departments of the country, as well as the three special provinces of Tumbes, Callao, and Moquegua. The situation became worst in the coastal departments of Lambayeque, Libertad, and Lima, as well as inland in Cajamarca. The total incidence of the disease may be summarized as follows:

Period	Cases	Annual average
1903-1912	8,865	886
1913-1922	6,922	692
1923-1932	4,642	464
1933-1942	1,087	109
1943-1952	738	74
1954-1960	353	50
1903-1960	22,607	2,275

More detailed figures for the period 1956 to 1963 may be set forth as follows:

	Areas affected		Incidence		
Year	Department	Province	Per province	Per department	Annual total
1956	Piura	Ayabaca	8		
		Huancabamba	16	24	24
1957	Piura	Ayabaca	9		
		Huancabamba	14	23	
	Ancash	Huaraz	11		
		Recuay	3	14	37

Year	Areas affected: Department	Areas affected: Province	Incidence: Per province	Incidence: Per department	Annual total
1958	Tumbes	C. Villar	3	3	
	Piura	Sullana	6		
		Paita	1		
		Ayabaca	24	31	
	Lambayeque	Lambayeque	7	7	
	Cajamarca	Hualgayoc	3	3	
	Ancash	Huaraz	5	5	49
1959	Piura	Ayabaca	10		
		Huancabamba	4		
		Paita	1	15	
	Cajamarca	Hualgayoc	18	18	33

As can be gathered from the PASB Weekly Epidemiological Report (1960 through 1963), the case incidence of plague in Peru was:

1960	Piura	Ayabaca	15		
		Huancabamba	117	132	
	Cajamarca	Hualgayoc	7	7	139
1961	Piura	Ayabaca	3		
		Huancabamba	65	68	68
1962	Amazonas	Bagua	25	25	
	Piura	Ayabaca	48		
		Huancabamba	44	92	
	Cajamarca	Jaén	47	47	164
1963	Amazonas	Bagua	34	34	
	Ancash	Casma	6	6	
	Piura	Ayabaca	23		
		Huancabamba	9	32	72

It is impossible to decide how far this increase of the case incidence since 1960, at first glance a rather disquieting one, is merely the result of an improved reporting system.

In his classical study of the plague situation in Peru, Eskey (1932) stated that the central part of the country, situated between the 7th and 13th degree of latitude, and especially the areas between the 7th and 9th degree with average annual mean temperatures between 69ºF (20.5ºC) and 71ºF (21.7ºC), suffered most from the disease. There the infection spread rapidly to rural as well as urban communities, produced more cases than elsewhere in the country, and showed little tendency to disappear spontaneously. However, the degree of rat infestation of the houses was also of importance. Thus the ports of Paita in the north and of Mollendo in the south of Peru, though situated well away from the zone where the climate favored the spread of plague, suffered heavily because their wooden buildings were attractive to the rats. Lima, on the contrary, though open to inroads of the infection as far as the climatic conditions were concerned, had a lesser morbidity than these two ports because of having better-class houses.

Generally speaking, the annual plague epidemics in Peru tended to reach their peak during the summer months. However, there as elsewhere the plague seasons fell into an earlier period in areas where the winter months were warm, than in localities with a colder climate.

Human plague in Peru was mostly bubonic, but one pneumonic outbreak, claiming 21 victims in the Department of Junín, is on record.

As described by Eskey, R. norvegicus, R. rattus, and R. r. alexandrinus were common in the towns of northern Peru, while in the central and southern coastal areas as a rule Norway rats greatly exceeded the other two species. X. cheopis was the most common rat flea and, according to Eskey, the only important plague vector.

Recent Manifestations of Rat-Caused Plague

Information on further rat-caused plague outbreaks in Peru is rather scanty. Ramos Díaz (1938) referred to a manifestation of this kind, observed in 1938 in a small village of the Lambayeque Department, situated in a mountainous area 1,300 meters above sea level. There an epizootic among R. rattus led to the appearance of the disease in guinea pigs kept in the house of the first victim. Two children in a neighboring house to which some garments of this woman had been brought also contracted the infection but recovered under serum treatment. In the opinion of Ramos Díaz, X. cheopis, the principal flea of the rats in the locality, had been responsible for the infection of the domesticated guinea pigs, but P. irritans had been instrumental in conveying P. pestis from the latter to the first victim. He claimed to have proved the presence of this organism in a lot of P. irritans collected from a garment used by the second affected family, but the technique he used for this purpose cannot be considered to be fully reliable. Be this as it may, it is not easy to believe that in a locality where rats infested with X. cheopis had become plague-affected, this vector had not been responsible for the human infections.

As has been noted above, the presence of plague in the Lambayeque Department was again recorded in 1958, but it would seem that on this occasion a coastal and not a mountainous area was affected.

Describing a successful antiplague campaign with DDT and "1080" (sodium fluoro-acetate) in 1945 in Tumbes, capital of the department of the same name, Macchiavello (1945) stated that before the outbreak fought by him this town had suffered from the disease in 1909, 1915, 1922, and 1940. In his opinion the cause of the 1945 outbreak had been the importation of fleas in bags of merchandise from Lambayeque Department; 95 per cent of the rats then present in Tumbes were R. r. alexandrinus, and 5 per cent were R. rattus, all of which were almost exclusively infested with X. cheopis.

As noted above, the presence of plague in Tumbes Department was again recorded in 1958.

Manifestations of Wild Rodent Plague

Trujillo Area

With reference to the situation in the area of Trujillo, capital of the Department of La Libertad, Macchiavello (1958) made the following statement:

> "During the plague control campaign in Trujillo we could repeatedly confirm a reinfection derived from the surrounding rural area where an epizootic is maintained in the Sigmodons (S. peruanus). Suddenly, during a season unfavorable for the activity of X. cheopis, plague attains epizootic proportions in the rural area, where every day hundreds of Sigmodons succumbed to the infection are found. R. r. frugivorus, which lives together with Sigmodon in the fields and breeds particularly around the small hamlets, was practically not touched by the epizootic during the cold season, in which X. cheopis remains inactive and in which the transmissions from one species to the other depend upon P. litargus... The epizootic becomes first manifest in R. frugivorus and afterwards passes to R. rattus and R. alexandrinus of the settlements only when the season becomes favorable for X. cheopis and the infection originally acquired by a few rats in the fields can spread among these rodents. During the summer the epizootics in these two rat species follow an independent course, and the number of X. cheopis on the Sigmodons was not more important than that of P. litargus recovered from the rats."

It would thus seem that, while S. peruanus had become the reservoir of plague, common rats and X. cheopis were responsible for its spread in the settlements.

Lancones District

In his article on plague in the Lancones district (Sullana Province, Department of Piura), to which further reference will be made below, Macchiavello (1957) furnished the following data on the early rat-caused and cheopis-borne bubonic outbreaks in the Provinces of Paita and Piura.

	Paita		Piura		Sullana		
Year	City	Province	City	Province	City	Province	Lancones district
1904	174	174	0	0	0	0	0
1905	80	80	0	0	0	0	0
1906	59	59	0	26	0	0	0
1907	177	177	27	90	0	0	0
1908	29	39	19	140	1	1	0
1909	46	46	6	23	0	0	0
1910	0	0	12	49	0	0	0
1911	1	1	13	92	0	0	0
1912	29	29	8	176	1	1	0
1913	15	15	7	9	0	0	0
1914	0	0	40	94	0	0	0
1915	0	0	25	52	0	0	0
1916	50	54	0	21	3	3	0
1917	0	0	1	14	0	0	0
1918	17	17	55	93	61	61	0
1919	101	102	9	22	4	4	0?
1920	63	63	24	52	33	33	0
1921	68	84	8	104	17	17	0?
1922	39	42	20	25	9	9	0
1923	31	31	32	47	1	1	0
1924	12	12	0	0	2	2	0
1925-27	0	0	0	0	0	0	0
1928	3	3	0	0	0	0	0
1929	13	13	0	0	0	0	0
1930	0	0	0	0	0	0	0

As indicated by this table, plague showed little tendency in the Province of Paita to spread to the hinterland, having remained practically restricted to the port of Paita, while in Piura Province the incidence of the disease in the capital was often considerably below that in other localities of the province. As far as can be judged from the available data, plague ceased to be manifest in the latter province in 1925, in Paita Province in the year of 1930.

Macchiavello felt certain that the appearance of plague in the city of Sullana, where the disease was quite active from 1918 to 1924, was due to an invasion from the two above-mentioned provinces. There can be hardly any doubt that this entry of the disease eventually led to an entrenchment of plague in the wild-rodent population of the Lancones district

and also of an adjacent Ecuadorian area; although it became manifest only in 1946, it presumably had commenced considerably earlier, perhaps already during the period 1919 to 1921. Macchiavello noted in this connection that one plague case had been recorded in 1939 at Huasimal in the Lancones district and that possibly three human attacks occurred there in 1943. The reappearance of the disease in June 1946 in the Lancones district, and the simultaneous involvement of the adjacent Cazaderos-Alamor area in Ecuador, led to an investigation under Macchiavello, the main results of which were as follows:

a) Domestic rodents and their fleas. The common rats were entirely absent in the affected Peruvian area. Their existence in Bolasbamba, one of the affected localities on the Ecuadorian side, was reported but could not be confirmed. Mus musculus were present in most of the houses, but with the exception of one animal trapped in the house inhabited by the study group, on which one X. cheopis was found, the not numerous specimens seen were free of fleas. Macchiavello felt certain that the cheopis had been imported in the baggage of the detachment.

b) Wild rodents. The species of wild rodents met with and the occurrence of plague in them are shown in the following table:

Species encountered	Examined	Plague-infected
Sciuridae:		
Sciurus stramineus nebouxi	51	14
Cricetinae:		
Oryzomys xanthaeolus xanthaeolus	18	3
Oryzomys nitidus	5	0
O. stolzmanni stolzmanni (O. longicaudatus auctt.)	1	0
Rhipidomys equatoris	11	3
Akodon mollis mollis	3	1*
Akodon mollis orophilus	1	0
Sigmodon simonsi	1	0

* Found positive in Ecuador

Dealing with the findings in the squirrels, Macchiavello stated that (a) only two or three of his positive specimens showed macroscopic signs of rather subacute plague, associated with the presence of numerous P. pestis in their organs; (b) on the other hand, guinea pig experiments made with the organs of apparently healthy squirrels gave positive results; and (c) the plague strains isolated from some of the squirrels showed an attenuated virulence which, however, could be restored through guinea pig

passages. He concluded from these findings that, besides an active form of plague, a "residual" type of the infection was apt to occur in the squirrels.

It is important to add that in many of the examined squirrels organisms of the aspect of P. pestis were seen in smears but guinea pig tests made with material from such animals gave a negative result.

In marked contrast to the findings recorded above, most of the positive Cricetinae showed signs of acute plague with numerous P. pestis in the smears. Commenting on the rarity of positive results in these animals, Macchiavello stated:

> "The relatively low incidence of plague in the Cricetinae stands in contrast to the relatively high occurrence of inapparent or resolving plague met with in Sciurus. This may be due to the fact that the Cricetinae are more susceptible to the infection and succumb to it, being almost immediately devoured by birds of prey."

c) Wild-rodent fleas. The fleas met with on the wild rodents all belonged to the genus Polygenis, most of them being identified as P. litargus, while some, found on Akodon mollis mollis in the Ecuadorian part of the focus, were of another still unidentified species. The flea index of the Cricetinae was fairly high (2.4 in the case of O. xanthaeolus, 1.1 in that of Rh. equatoris, and 3 in A. mollis), even though most of the animals had been caught with the aid of cyanogas. The flea index of the squirrels, on the contrary, was only 0.22, solely 16 per cent of these rodents having been flea-infested. Commenting on this observation, Macchiavello stated: "in general the wild-rodent fleas are more sedentary than the rat-fleas and prefer the environment of the homogeneous temperature of the nests or of dark and cool places. The observation that in May (a month with moderate temperature in Lancones) the rodents harbor many fleas and the occurrence of comparatively many free fleas on the harvested maize fields... makes it probable that at a certain season of the year the flea index of the rodents is high and that, undoubtedly, these free fleas come from rodents succumbed at that time to plague. This holds true of the squirrels as well as of the Cricetinae in general."

The presence of plague was confirmed with the aid of pooling tests in (a) a batch of 3 P. litargus collected from squirrels, and (b) a lot of 14 fleas of this species, which had been kept under observation in a hollow tree for 6 months. Thus P. litargus, besides conveying the infection, was evidently also capable of maintaining it.

Referring to his successful vector studies with P. litargus Macchiavello stressed the willingness and capability of this flea to feed on man.

d) Epidemiological observations. As can be gathered from Macchiavello's article, during the 1946 outbreak observed by him, a total of 28 attacks of bubonic plague with 6 deaths were recorded, 20 in persons living in 10 different localities of the Lancones district and 8 in people inhabiting 4 localities of the Cazaderos-Alamor area in Ecuador. As he emphasized, "if not all, then the majority of the cases stood in relation to previous activities in the maize fields. Some persons fell ill also while staying on maize farms. With rare exceptions, all the individuals slept in places where some of them noted an abundance of fleas. At least 6 of the patients observed dead rodents in the maize fields or adjacent fields or found evidence of epizootics among them."

Evaluating these observations and the findings he had made in the rodents and their fleas, Macchiavello came to the conclusion that plague in the Lancones district and the adjacent areas of Ecuador was of a purely sylvatic type, a persistence of the infection in the squirrels having led periodically to epizootics among the Cricetinae, which in turn were mainly responsible for the appearance of human outbreaks. Polygenis fleas, in the first line P. litargus, served in all these manifestations as the vector of the infection.

Huancabamba and Ayabaca Provinces

Whereas no recent information on the Lancones district is available, the early studies on the plague situation in the Provinces of Huancabamba and Ayabaca by Macchiavello in 1946-1947 were followed by investigations made in 1955-1956 and again in 1960 by De la Barrera, who, however, mostly reported on observations in Huancabamba Province.

In his report, Macchiavello furnished the following general information on the two provinces:

	Huancabamba Province		Ayabaca Province
Area (km^2)	6,557		7,082
Population (1940 census)	51,613		75,068
Inhabitants (capital)	2,580		2,620
(districts)			
Huancabamba	21,605	Ayabaca	24,255
Canchaque	8,540	Cumbicus	13,350
Huamarca	13,242	Frías	18,122
Sondor	3,027	Montero	5,777
Sondorillo	2,462	Sicches	2,856
		Suyo	6,767

The population of these areas consisted almost exclusively of Indians or mestizos, whose standard of life was deplorably low. The climate, and accordingly the vegetation, varied in relation to the altitude of the different regions, with forests in the low-lying valleys (in some of which tobacco and cocoa were cultivated), scanty growth in the high regions, and cultivations of cereals and alfalfa in the prairie regions and on the slopes of the hills. The plague area of Huancabamba was mainly wheat-growing, groups of workers migrating from one cultivated locality to the others to perform the necessary labors and thus, while sojourning in the fields, being under the risk of infection if plague epizootics were present. Of great epidemiological importance was also the practice of the people to store the harvested wheat in their houses, especially in the attics with which many of the houses were provided. Thus, since the grain stores in the houses attracted the wild rodents, at the time of epizootics facilities were created for a transition of infected fleas to the intradomestic rodent fauna or directly to man, especially if wild rodents succumbed to plague in the storerooms.

The intradomestic rodent fauna consisted of M. musculus (which, however, sometimes lived in contact with the Cricetinae in the fields around the houses) and of the amply bred guinea pigs. However, Macchiavello insisted that, except in the regions at the foot of the mountains, Rattus was absent.

The prevalent domestic flea, P. irritans, occurred not only--often in almost incredible numbers--in the clothes, on earthen floors, etc., but also infested the domesticated guinea pigs, sometimes to a higher degree than their specific flea, Tiamastus cavicola. P. irritans was likewise found on the house mice on which, however, it was outnumbered by their specific flea, Leptopsylla segnis.

Macchiavello found in the course of his work only one specimen of X. cheopis in the Changra region, a zone situated at low altitude in the border district between Ayabaca and Morropón Provinces in which the plague incidence during the 1946-1947 epidemic was unusually high. Generally speaking he upheld that this flea might be present in the regions at the foot of the mountains. This seemed to hold true, for instance, of the low-lying Chalaco district in Morropón Province, the involvement of which in the 1946-1947 outbreak presumably stood in causal relation to the presence of R. rattus and X. cheopis.

Referring only to the wild rodents and lagomorpha involved in the 1946-1947 outbreak, Macchiavello enumerated the following species:

a) Akodon mollis orophilus, the most prevalent species, often and sometimes to a high degree infesting the houses, particularly at the time the grain supplies were stored in them,

and apt temporarily to occupy the nests of M. musculus (which thus could become infested with wild rodent fleas);*

b) An undetermined species of Oryzomys;

c) Oryzomys stolzmanni stolzmanni (O. longicaudatus stolzmanni auctt.), also a widely distributed species;

d) Cavia tschudii sp., a species distinct from the usually domesticated Cavia porcellus and, in contrast to the latter, apt to lead a peridomestic or even "sylvatic" existence;

e) Sylvilagus species, presumably S. andinus and S. ecaudatus.

The rather scanty data supplied in the study presently under review in regard to the wild-rodent fleas may be summarized as follows:

Number and species of rodents searched	Number of fleas found	Species of fleas
33 Akodon mollis orophilus	20	Besides 3 L. segnis, Pleochaetis dolens quitanus, P. equatoris, P. litargus, and Plocopsylla mars.
8 Oryzomys stolzmanni	8	1 P. litargus and 7 Pleochaetis, mostly Pl. dolens quitanus
16 Cavia tschudii	997	P. irritans, L. segnis, T. cavicola, Ct. felis, H. suarezi, Pl. dolens quitanus, and the specific Rhopalopsyllus cacicus
4 Sylvilagus sp.	118	Pl. dolens quitanus (4), P. litargus (3), Pol. brachinus (33), R. cacicus (27), Hoplopsyllus manconis (11), Cediopsylla spillmanni (40)

Note: It is also important to note that Sylvilagus and probably also O. stolzmanni were infested only with wild-rodent fleas.

* In localities where no cereals were cultivated, Akodon mollis oroph. was apt to live around the houses, particularly in the stone-walls separating the various properties.

Discussing the history of plague in the two provinces under review, Macchiavello maintained that the disease first appeared in 1920 in Huancabamba Province at Canchaque, situated halfway between Piura and Huancabamba city, a locality up to the present infested with R. rattus and X. cheopis. The involvement of the city of Huancabamba in 1923 led in turn to a spread of the infection to the rural areas. From 1928 plague in the capital became sporadic but continued to become manifest in more and more distant villages. In Ayabaca Province the disease was first recorded in 1922, as far as it is known initially in a hamlet near the capital, and also spread in the rural localities.

The affection of both provinces was presumably due to the importation of infected cheopis fleas from the coastal areas in goods or in the baggage of travellers, the presence of a numerous and susceptible wild-rodent population offering ample fuel for the spread of the disease. To judge from data furnished by Macchiavello, human plague in the foci of Huancabamba and Ayabaca, which eventually became confluent, showed a seasonal incidence, being manifest in spring and summer but absent in winter.

Dealing with the types of plague observed in Huancabamba Province, Macchiavello furnished the following global statistics:

	Number of patients						Total		
	1939-1945			1946-1947			1939-1947		
Type of plague	Men	Women	Total	Men	Women	Total	Men	Women	Total
Without data			23			7			30
Septicemic	2	1	3	5	11	16	7	12	19
Bubonic	57	44	101	123	157	280	180	201	381
Totals			127			303			430

As far as these data go, the overwhelming number of the patients whose histories were known suffered from bubonic attacks, and pneumonic plague was altogether absent. However, Macchiavello referred to vague reports speaking of whole families succumbing to the disease, which were suggestive of the latter type of the plague. It appeared that under such circumstances the neighbors were prone to burn down the affected huts without even making sure that all inmates had died.

Comparing the earlier epidemics with the 1946-1947 outbreak, Macchiavello stated:

> "Before 1946, plague appeared in isolated houses and the number of human cases did not stand in direct relation to the plague in the wild rodents, the intensity of which was not known. In 1946-1947, the intensity of the wild-

> rodent epizootic could be guessed, not only through the rapid and successive infection of 50 odd villages but also through the extension of the area in which it was observed. In each hamlet plague acquired a familial form and it is this appearance of the epidemic which favors the false supposition of an interhuman transmission,* which, moreover, is favored by the frequent observation that secondary foci appeared in new hamlets precisely in the houses inhabited by members of plague-affected families who had flown from the infection in their own villages."

It would also seem that the mortality in the 1946-1947 epidemic (52.8 per cent) was markedly higher than that during the period 1939-1946, when 23 out of the 80 patients, about whom details are known, seem to have succumbed to plague.

Referring to his observations on plague manifestations in the rodents, Macchiavello stated that he had proved the presence of the infection in 15 or 16 out of a total of 124 specimens, namely, in one of 63 house mice, in 6 out of 33 Akodon mollis, in one (or possibly in 2) out of 8 O. stolzmanni, in 4 out of 16 Cavia tschudii, and in 3 out of 4 Sylvilagus. In the opinion of that observer the appearance of the infection not only in Oryzomys and C. tschudii, but also in Sylvilagus, was of a secondary nature. In regard to the last-mentioned genus, he noted:

> "References to epizootics among the rabbits in the rural (agrestes) areas and at the foot of the mountains were frequent. The tardy appearance of these epizootics and the fact of finding on the rabbits Akodon fleas indicate that the epizootics were secondary, possibly originating in the deserted wheat fields, where an enormous infestation of Akodon fleas persisted in the empty nests and where, besides this, occasionally rabbit fleas were found. These, however, were not found on the Akodon captured in houses."

With regard to the role of the wild-rodent fleas, Macchiavello stated that, following up his earlier studies on P. litargus in the Trujillo area and the Lancones district, he (a) established the vector capacity of Pleochaetis dolens quitanus and, moreover, found the following fleas naturally plague-infected: Cediopsylla spillmanni, Hoplopsyllus andensis, H. manconis, Polygenis brachinus, and Sphinctopsylla (Plocopsylla) mars. Positive results were also obtained with a pooled sample containing, among other fleas, Rhopalopsyllus cacicus cacicus. The majority of the positive fleas had been collected from plague-affected rodents, but infected Pleochaetis were found also in deserted wild-rodent nests, P. brachinus once in a "domestic" nest.

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* Macchiavello referred in this connection to an unpublished article on the interhuman transmission of plague, and also said in the above-reviewed report that "if P. irritans were a plague vector, the human population would have disappeared from the Andean territory."

Commenting on these findings, Macchiavello stated:

> "The comparative importance of the 2 Pleochaetis species and the 3 Polygenis species met with in the transmission of plague among the Cricetinae, and from these to man, remains to be determined. Judging simply by their numerical frequency, one may infer the preponderant role of Pleochaetis dolens quitanus."

Exact studies were also required to delimit the habitat of the various flea species.

In Macchiavello's opinion Pl. dolens quitanus was responsible for the conveyance of plague to man in the houses as well as in the open, even though this flea by preference seemed to be a nest-dweller. Its mean extrinsic incubation period was about 25 days in the laboratory, but was probably much longer in the open at high altitudes, where from August to November the nights were rather cold.

Summarizing and evaluating his observations on the 1946-1947 outbreak, Macchiavello distinguished between (a) an initial phase in which the evolvement of a violent epizootic among the Cricetinae, especially Akodon mollis orophilus, led to occasional infections of field workers, conveyed by Pl. dolens quitanus and P. litargus, especially the first; (b) a main phase in which the wild rodents, attracted by the stores of the harvested cereals in the houses, brought the infection to the villages and an epidemic of a "familial domestic" character ensued; (c) a final phase in which Sylvilagus, leading by preference a sylvatic existence, and free-living guinea pigs (C. tschudii) became the victims of not properly studied epizootics, in which probably Hoplopsyllus and Polygenis fleas were the vectors of the infection.

Factors favoring the spread of infection at the acme of the outbreak were (1) panicky flight of the people; (2) removal of domesticated guinea pigs to other settlements so as to avoid their destruction by the plague prevention staff; and (3) involvement of the peridomestic wild rodent species, particularly Oryzomys sp. and O. stolzmanni, in the epizootics.

It is important to add that in Huancabamba Province the spread of plague in man was cut short by the ample use of DDT. However, wild-rodent plague continued in enzootic form, leading especially in the formerly infected localities to sporadic manifestations in man. In Ayabaca, where less systematic use of DDT had been made, plague showed some tendency for further progress, reaching in 1953 the districts of Montero, Suyo, and Sicches, adjacent to Ecuador

The statements of Macchiavello will be evaluated together with the more recent findings of De la Barrera (1957), which are summarized below:

In marked contrast to the above-recorded observations, De la Barrera stated in his 1957 report that R. rattus was found side by side with the ubiquitous house mice and, usually, domesticated guinea pigs, not only in the houses of Huancabamba city but also in the rural dwellings of that area, in which, however, it was rare. He found no evidence that the common rats were involved in the plague outbreak and explained the absence of the disease among them by the assumption that they were resistant to infection with P. pestis. According to De la Barrera's observations, the wild-rodent fauna of Huancabamba Province was identical with that generally encountered in the plague regions of Peru. Akodon mollis formed 85 per cent of the rodents trapped in the fields, Oryzomys xanthaeolus being accordingly less frequent. Four rodents of the former species and one of the latter were caught inside rural habitations. Plague was confirmed in 1956 in two specimens only, once in A. mollis and once in Oryzomys longicaudatus.

Discussing the wild rodents and lagomorpha of the plague-affected areas of Peru in general, De la Barrera especially referred to the following species:

a) A. mollis and O. xanthaeolus were the species most often met with and most often found plague-infected. Their relative frequency varied in different sites, but generally the first-mentioned was prevalent at higher altitudes.

b) Sigmodon peruanus was frequently found plague-infected but, as De la Barrera somewhat ambiguously stated, "on account of its much lesser abundance than that of Oryzomys and Akodon, does not appear to figure on the first level in the list of plague reservoirs." S. peruanus was a slow-moving animal, which left its dens during daytime. It constructed its nests on the level of the ground under various protective coverages, but if disturbed by man was apt to hide in cracks of the ground. As far as scanty observations went, it was almost exclusively infested with P. litargus.

c) Proechimys decumanus, a large rodent encountered only in the northwest of Peru near the Ecuadorian border, was always heavily infested with Polygenis klagesi, but was also found to harbor some P. litargus.

d) Sylvilagus brasiliensis inca, the rabbit (conejo) of Peru, was also found plague-infected. However, in De la Barrera's opinion, its affection was "an accident in the progress of the wild-rodent epizootics." The specific flea of this species of lagomorpha was apparently Hoplopsyllus manconis.

Dealing with the flea fauna of the rodents in Huancabamba city and its environs, De la Barrera furnished the following important data:

Species of fleas	City Nº	City %	Rural houses Nº	Rural houses %	Fields Nº	Fields %	Wild rodents Nº	Wild rodents %	Rodent nests Nº	Rodent nests %
Xenopsilla cheopis	52	43.6	31	20.9	18	43.9	-		-	
Pulex irritans	38	39.1	27	18.2	3	7.3	1	0.4	1	1.0
Leptopsylla segnis	4	4.1	60	40.5	-		1	0.4	-	
Ct. felis felis	2	2.2	5	3.3	-		2	0.8	-	
E. gallinacea	1	1.0	11	7.0	-		-		-	
Pleochaetis dolens quitanus	-		7	4.7	10	24.3	44	20.5	10	11.7
Craneopsylla minerva	-		7	4.7	6	14.6	42	19.2	-	
Polygenis brachinus	-		-		4	9.7	95	44.3	55	64.7

Note: Found only on wild rodents or in the rodent nests were: Neotyphloceras rosenbergi, Ctenidiosomus spillmanni, Plocopsylla hecto, Hoplopsyllus manconis, Plocopsylla n. sp. and Cleopsylla townsendi.

The most significant among these findings are (a) the infestation of the common rats in all locations with X. cheopis; (b) the comparatively frequent occurrence of P. irritans in this rodent species; and (c) the presence of not inconsiderable numbers of wild rodent fleas on the rural rats.

In the part of his report devoted to a discussion of the Peruvian rodent-fleas in general, De la Barrera made the following statements:

> a) X. cheopis. Generally speaking, this flea was more numerous on the settlement-rats than on those trapped in the fields. Its frequency decreased with the altitude, so that while still met with in the Huancabamba region (1,900-2,000 meters), it was absent in the higher parts of the province, e.g., at Silur (2,740 m) and Jacocha (2,840 m). Which flea replaced it there, is obviously an unsettled problem. The only fact known in this respect seems to be that De la Barrera found only one specimen of Nosopsyllus londinensis in his flea material.

In the opinion of that observer, X. cheopis took no part in the spread of the infection in the Peruvian sylvatic plague foci. He maintained, in this connection, that possibly in the Huancabamba area and other localities situated near the upper limits of its habitat the vector capacity of this flea was reduced, but he admitted that this assumption did not hold true for other localities like, for instance, Llampa* and Puná in Ecuador, where

* As recorded by De la Barrera, an epizootic involving mainly Oryzomys xanthaeolus in the region of Llampa in 1955 led to 6 plague attacks in man. R. norvegicus, though frequent in that locality in and around the houses, remained free of the infection.

conditions for this flea to play a role seemed to be excellent. De la Barrera evidently inclined to the belief that the failure of X. cheopis to convey the infection stood in relation to the resistance of its rat-hosts to plague.

b) Pulex irritans was found in great quantities in the garments and bedclothes of the inhabitants and, as noted above, was by no means rare on the common rats. Of course it was also frequent and sometimes prevalent on the domesticated guinea pigs.

Discussing the possible importance of this flea in the spread of plague, De la Barrera drew attention to the contention of Karl Jordan and F.G.A.M. Smit that P. irritans was not a homogeneous species but consisted of several forms. Referring to the two varieties encountered in the Peruvian material, Smit stated:

> "The new Pulex is different from the cosmopolitan human flea, Pulex irritans... it may well be that the rodent irritans could also act as a carrier of the wild-rodent plague."

Reverting to this problem in a later part of his report, De la Barrera cautiously noted:

> "The possibility that this flea could be a (plague) vector, especially in interhuman infection, has attracted attention since long ago, and in this part of America has been given as an explanation for the frequent infections among the participants in wakes--which, of course, is purely theoretical. Of different value are the experimental data of Burroughs, that P. irritans becomes blocked and can, as a consequence, transmit (plague). Mention has been made also of the observations made in the British Museum regarding the heterogeneity of Pulex irritans..."

There can be no doubt that the recent observations of Jordan and Smit necessitate a reconsideration of the possible role of P. irritans in the spread of plague--a problem which, to great advantage, could be studied in the course of the proposed plague investigations in South America.

c) Tiamastus cavicola was frequent and often prevalent in Peru on the domesticated guinea pigs and occasionally was also found on the domestic mice. De la Barrera thought that this flea, though not a good vector, might play a role in the intradomestic spread of plague.

d) Wild rodent fleas. According to De la Barrera's observations, Polygenis litargus was not only the most frequent flea on the wild rodent, but was also met with on R. rattus which lived under rural conditions, as well as on the domesticated guinea pigs and in small numbers in garments. Though not yet aware

of the studies on the vector capacity of this flea, De la Barrera admitted that it might play a role in the conveyance of plague even to man. He reiterated, however, that certainly it was not the only plague vector, as it was absent in the sylvatic plague areas situated above about 2,200 meters, where its place was apparently taken by Pleochaetis dolens quitanus.

Referring briefly to the 1956 plague outbreak that occurred in numerous foci lying at high altitudes in Huancabamba Province, De la Barrera stated that the epidemic, having been preceded by a wild-rodent epizootic, remained restricted to rural areas and neither the rats nor the human population of Huancabamba city become involved. Instances of an appearance of successive attacks in one and the same household were evidently frequent. De la Barrera considered it to be significant that (1) in all houses with multiple attacks, one or more of the first affected patients died, no doubt after they had developed a generalized infection; and (2) P. irritans abounded in all the dwellings.

According to De la Barrera's final report, the plague outbreak in the Province of Huancabamba in 1960* was also characterized by the frequent occurrence of several attacks in the affected houses, in which infection of the domesticated guinea pigs often preceded the appearance of human infection. It was not clear which species of fleas were responsible for the conveyance of the disease from these animals to man.

As summarized in the 1960 report, the salient features of this as well as of the previous recent outbreaks, were:

1) A sylvatic origin.
2) Absence of the infection from the centers of the population.
3) Seasonal incidence during the rainy period (i.e., usually from November to April or May).
4) Frequency of multiple attacks in one and the same house.
5) High mortality due to frequent lack of treatment.

Evaluation and Recommendations for Further Investigations

The task of evaluating the present plague situation in Peru is fraught with great difficulties insofar as fairly up-to-date information, comparable to that available for Venezuela and Ecuador, could be obtained only for the sylvatic plague focus in the Provinces of Huancabamba and Ayabaca. To what extent plague is still active in the Lancones

* As stated in this report, during the first 5-1/2 months of 1960 a total of 101 plague cases were recorded in Peru, distributed in the following provinces: Huancabamba (77), Ayabaca (15), Hualgayoc (7), and Canchaque (2). The total mortality was 36 per cent.

district, formerly studied by Macchiavello, could not be ascertained, while for the other recently affected parts of Peru really nothing is known other than the bare figures recording the appearance or recurrence of the disease. Hence, should it be considered advisable to make plans for plague investigations in Peru on a country-wide scale, it would be indispensable to establish through consultations with the Plague Prevention Service, and if necessary, through a preliminary survey, to what extent it would be advisable to undertake work in the last-mentioned areas. If work in the Lancones district were called for, it ought to be done according to the plan set forth in sufficient detail in the preceding section of this report for the adjacent areas in Ecuador. Indeed, since these and the Lancones district are but component parts of one common plague focus, work in these parts could profitably be done only by an international team having free access to the plague areas situated south and north of the border between the two countries.

In view of this fact, and since there can be hardly any doubt that, even if a country-wide plan for plague investigations in Peru were to be decided upon, priority would have to be given to the most seriously affected Huancabamba-Ayabaca focus, it seems logical to concentrate for the present attention upon this area.

While the earlier investigations made in this focus leave no room for doubt that it is one of sylvatic plague, the question as to which species of wild rodents is, or are, the reservoir of the infection does not yet seem to have been satisfactorily answered. As has been noted, in contrast to the conclusions reached on other South American sylvatic plague foci, Macchiavello maintained that in the Huancabamba-Ayabaca area the infection is permanently harbored by species of Cricetinae which, because apparently highly and uniformly susceptible to plague, are periodically decimated by widespread epizootics. Thus, in the opinion of this observer, the other species of wild rodents that were found plague-infected, including Sylvilagus, which has been incriminated as a reservoir of the infection in Ecuador, play only a secondary role or, as maintained by De la Barrera, become in part only accidentally involved. The present reporters do not wish categorically to refute these postulations. They must insist, however, that the scope of the observations upon which they were based is really insufficient for a final decision on the problem. Thus, in order to solve it, further large-scale and systematic observations, made not only at the rather unpropitious time of the plague seasons but continued throughout at least one year, preferably for a longer time, are indispensable to ascertain where and in what species plague persists during the interepizootic periods. A point deserving of great attention in this respect is that, as mentioned by Macchiavello, apparently these strongholds of the infection are limited in their number and their extent. To prove the existence of such "elementary" foci and thoroughly to study their ecology would be not only scientifically valuable but of great practical importance.

The question as to which fleas are responsible for the spread of sylvatic plague in the Huancabamba-Ayabaca focus is also by no means settled.

While several species have been found naturally infected, experimental studies to assess their vector capacity have been made only in the case of Polygenis litargus and Pleochaetis dolens quitanus. To confirm the results of these tests, to determine the vector capacity of at least the flea species which have been or will be found naturally infected, and thoroughly to study the distribution of the various species, would be a second task indispensable for a thorough knowledge of the ecology of the disease in the focus.

While in the past Macchiavello found the common rats to be present only in the low-lying valleys of the Huancabamba-Ayabaca area, De la Barrera's more recent experiences indicate the presence of these rodents in all parts of the focus, though rarely in the rural habitations. At the same time the latter observer insisted that the rats, because they were resistant to infection with P. pestis, were not involved in the plague manifestations. To judge from the published information, however, it would seem that the postulated resistance of these rodents has not been confirmed through laboratory tests. Efforts to fill this gap, hand-in-hand with systematic investigations on the distribution of the common rats in the focus, would be a third important object of the proposed studies.

A further unsettled problem is that of ascertaining which flea replaces X. cheopis on the rats in the highly situated parts of the focus. Besides adequate studies to settle this point, systematic investigations would be called for to study the frequency of X. cheopis in the rural areas as well as in the towns within the zone of its habitat. Due attention ought to be paid in the course of these investigations to the occurrence of this flea on hosts other than the common rats, especially the domesticated guinea pigs. If it is found to be rare or absent on the rodent species other than the rats, tests ought to be made to assess the capability of X. cheopis to subsist and feed upon the domesticated guinea pigs and on other rodents which it might have an opportunity to attack. The assumption of De la Barrera that X. cheopis is a less efficient plague vector in localities near the upper limits of its habitat, is an interesting one. However, it would be rather difficult to test the validity of this postulation.

To judge from the hitherto available information, the mechanism by which the infection originating in the wild rodents of the Huancabamba-Ayabaca plague focus ultimately finds its way to man, has not been fully elucidated. This transition of the infection could satisfactorily be explained in the past when, following the pattern of "purely" sylvatic plague, the sporadic human affections were mainly if not solely contracted in the fields. However, attention had to be drawn to the fact that from 1946-1947 onwards an intradomestic type of infection was the rule, often resulting in the appearance of not one but some successive attacks in one and the same house. There can be little doubt that an affection of domesticated guinea pigs, due to the bites of infected wild-rodent fleas, was often a link in the chain of factors leading to the appearance of

plague in man. However, it is still quite uncertain which flea species are responsible for the human infections. Attention has been drawn, in this connection, to the possibility that the appearance of successive plague attacks in one and the same household might be the result of an intrahuman spread of the infection conveyed by P. irritans. As mentioned earlier in this report, the recent discovery that this species is not homogeneous has led to the suspicion that some of the subspecies composing it might be efficient plague vectors. It would be essential, therefore, to make a thorough comparative study of the vector efficiency of the subspecies of this flea encountered in the Huancàbamba-Ayabaca focus. At the same time, however, systematic studies of the intradomestic and peridomestic flea-fauna in general are called for, and special attention should be paid to the houses and settlements recently or presently attacked by plague.

A close study of the manifestations of plague in man would have to form an integral part of the proposed investigations. The records on the incidence of the disease during recent years would have to be carefully examined so as to detect localities in which plague has appeared repeatedly or even perennially, and every possible effort would have to be made to elucidate the reasons for such a persistence of the infection. As proposed already in the report on Ecuador, all human plague manifestations met with by the study group ought to be made the subject of thorough investigations. In the first line, effort should be made to establish which rodents and which fleas were responsible for the infection of the patients. The presence of plague in the latter ought to be confirmed invariably through adequate laboratory tests, and the strains of P. pestis isolated from the sufferers should be kept in a lyophilized condition for further study. Moreover, efforts ought to be made to detect the occurrence of subclinical forms of the disease through clinical and serological surveys of groups of the population actually or potentially under the risk of infection.

In his reports, De la Barrera justly and laudably stresses the necessity of improving the case-finding system so as to reduce the deplorably high mortality from plague in patients who, because they were detected too late or not at all, could not be given the benefits of treatment. While thoroughly concurring in this plea, the present reporters wish to emphasize the necessity of going one step further by trying to detect not the early incidence but the imminence of human plague through a constant watch over the fluctuations of the density of the rodent populations and the frequency of plague manifestations in them. Therefore, in the course of the proposed studies every possible effort ought to be made to work out such a system of gauging the plague situation in the Huancabamba-Ayabaca focus. In this way, the contemplated work would not only contribute materially to a knowledge of the ecology and epidemiology of plague in South America and possibly pave the way for future attempts to control the situation, but would be of immediate benefit to the people exposed to the risk of infection.

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SECTION H

BRIEF OBSERVATIONS ON THE INCIDENCE AND ETIOLOGY OF PLAGUE IN THE UNITED STATES OF AMERICA

The incidence of human plague in the United States from the first recorded appearance of the disease in the Hawaiian Islands in 1899, and in the port of San Francisco in 1900, up to 1963 is summarized in the following tabulation. As for all countries, the figures for the first two decades may not be complete and differ in various reports. An attempt has been made to equate the differences.

Rat-Caused Human Epidemics of Plague in the USA

Continental USA	Year	Cases	Deaths
San Francisco, California	1900-1904	121	118
	1907-1908	167	89
Oakland, California	1907-1911	21	11
Seattle, Washington	1907	6	6
New Orleans, Louisiana	1914-1915	31	10
	1919-1923	25	11
Oakland, California	1919	14	13
Pensacola, Florida	1920	10	4
Galveston, Texas	1920	18	12
Beaumont, Texas	1920	14	6
Los Angeles, California	1924	41	34
Hawaii			
Island of Oahu	1899-1910	228	204
Island of Maui	1900	9	9
	1930-1938	7	6
Island of Kauai	1901-1906	15	11
Island of Hawaii - Hilo	1900-1918	43	34
- Hamabua	1910-1949	112	111
Puerto Rico	1912	55	36
	1921	33	11
Totals		970	736

Human Cases of Plague Reported in the USA, 1925 - 1949

Year	State	Cases	Deaths
1925	California	2	1
1927	"	1	1
1928	"	3	2
1933	"	1	1
1934	"	1	1
	Oregon	1	1
1936	California	4	0
	Utah	1	0
1937	California	1	1
	Nevada	1	0
1939	Utah	1	0
1940	Idaho	1	1
1941	California	2	2
1942	"	1	0
1943	"	1	1
1944	"	1*	0
1947	"	1	1
1949	New Mexico	3	1
	Totals	27	14

* Laboratory infection in San Francisco

The incidence of plague in the United States for the period 1950-1963, as reported by the U.S. Public Health Service, may be summarized as follows:

Year	Reported from	Human cases	Rodent plague	Report and findings
1950	Pecos, New Mexico	1 fatal		Bubonic plague reported by New Mexico Health Department; patient died 4 July, Pecos, N. M.
	Lea County, New Mexico	1		Bubonic plague of Maljamar, N. M., onset 8 January.
	Arizona	1		Case in Ganado, Arizona, onset 23 July.

Year	Reported from	Human cases	Rodent plague	Report and findings
1951	Lea County, New Mexico	1 fatal		Onset 6 January. In the week ended 21 February 1951 it was stated that the patient saw the physician on 9 January 1951 and died the same day.
	Santa Fe, New Mexico		Sylvatic	Fleas from 2 white mice found infected. Trapped 14 miles southeast of Santa Fe city on 14 April.
1952	Tacoma, Washington		Sylvatic	Positive specimens found in Grant, Yakima, and in Lincoln and Douglas Counties, May and June.
1952-1955				No cases of human plague reported.
1953	Douglas County, Nevada	2 suspect cases		The Nevada Department of Health reported on 20 October 1953: "The two men made rapid recovery from their infection following the use of two antibiotics. The men were entirely recovered before we received the report that all tests were negative for plague. The nature of their infection was never determined." Dr. Link's report of 12 May 1953 stated: "Both patients had inguinal buboes presumably resulting from exposure to wild rodent fleas... both patients had received penicillin at first and streptomycin subsequently..." On evidence, it was impossible to distinguish what might be plague or tularemia.
1954	Tacoma, Washington		Sylvatic	Fleas from 3 rats trapped in Tacoma were positive for Pasteurella pestis on 24 October 1954. Area declared free of infection 20 January 1955.

Year	Reported from	Human cases	Rodent plague	Report and findings
1956	Oxnard, California	1		Confirmed 25 May in Oxnard. Man had been fishing in Sespe Creek, Ventura, on 16 June 1956. From NOVS, Communicable Disease Summary, week ended 23 June 1956: "This is the first case of human plague reported in the United States since January 1951, when a case occurred in New Mexico. The last previous case in California was reported in 1947. In 1948 there were no cases in the United States, but 3 cases were reported in 1949 and the same number in 1950. Of these, 5 were in New Mexico. The 6th occurred in Arizona in 1950."
1957	Hamakua District, Hawaii		Sylvatic	District was reported as infected with plague in June 1957. It was declared free of infection 19 July 1960.
	Wichita Falls, Texas	1 fatal		Case of bubonic plague reported in Wichita Falls on 11 September 1957. Infection said to have been contracted on camping trip near Boulder, Colorado. Investigations that followed in Colorado were negative for plague. This was not carried as confirmed case of plague in the annual report because the attending physician did not report it as such. Following an inquiry from NOVS, in February 1960 the Health Officer of Texas advised NOVS that this was a confirmed case of plague and should be charged to Colorado. As Colorado refused to accept the responsibility, the case was to be reported as a case of plague for Texas.

Year	Reported from	Human cases	Rodent plague	Report and findings
1958	Klamath County, Oregon		Sylvatic	Specimens collected from ground squirrels, marmots, etc., for the period December 1957 through May 1958 were positive for plague. Area not put on infected local area list of WHO.
1959	Contra Costa County, California	1		Confirmed case in Boy Scout reported on 30 June. He had been camping in the area of Tiogia Pass, Yosemite National Park, Mono County. Mono County was declared the infected local area. WHO Weekly Epidemiological Record No. 28, 10 July 1959, carried the infected local area as Contra Costa County and as Mono County the following week. The area was removed from the infected local area list the week of 24 July 1959.
	Sonora, Toulomne County, California	1		Case of bubonic plague reported in a veterinarian residing in Sonora, July 1959. Onset of symptoms 8 July 1958. Sonora was declared the infected local area and was removed from the infected local area list 7 August 1959.
	Sandia Park, New Mexico	1 fatal		Confirmed case reported on 24 July in a 12-year old white female, in Sandia Park, N.M. Date of onset 7 July, date of death 13 July 1959; probable source of infection jack rabbit. Daughter of an Air Force pilot stationed at Kirkland Air Force Base, Albuquerque. Bernalillo County, excluding the city of Albuquerque, was declared free of infection 15 October 1959.
	Maryland	1		Pneumonic plague reported in a laboratory worker.

Year	Reported from	Human cases	Rodent plague	Report and findings
1959 (cont.)	Northeast Fresno County, California		Sylvatic	Plague in chipmunk fleas reported in mountainous area of Northeast Fresno County. Area of infection declared as Fresno County, exclusive of all towns. Area not listed in the infected local area list of WHO.
1960	Roswell, Chaves County, New Mexico	2		2 cases reported in Air Force personnel, 5 March. 1st case, male, age 24, date of onset 23 February, confirmed by blood culture and a variety of other tests. 2nd case, not confirmed by laboratory. Symptoms were milder than 1st case and clinical picture the same. Both had hunted rabbits on 19 February 1960 on the base and again the next day some 30 miles north of Roswell, N.M. Chaves city, excluding Roswell, declared area of infection. Area declared free of infection 25 November 1960.
1961	Santa Fe, New Mexico	1 fatal		1st case, septicemic form, entered hospital in Santa Fe on 27 June and died 28 June 1961. Patient was a 38-year-old lumberman who lived in a remote area of Pecos.
		1		2nd case in a 23-year-old telephone lineman who became ill 4 August 1961. Clinical diagnosis. Treated before cultures were taken. Serology (convalescent serum about one week later) was positive dilution of 1:80. Reported 8 August to Foreign Quarantine. The infected local area for these 2 cases was the Northwest Corner of San Miguel County. Declared free of infection 15 September 1961.

Year	Reported from	Human cases	Rodent plague	Report and findings
1961 (cont.)	Cambridge Massachusetts and New Mexico	1 fatal		1 confirmed case of plague reported in Cambridge, Mass., on 1 August 1961, had died 29 July 1961. Diagnosis of plague made at time of autopsy. The case was originally diagnosed as streptococcal septicemia. Not carried as a case of plague officially. Male patient, a 38-year-old associate professor of Harvard University, had been in New Mexico until 20 July with a group from the Geological Survey. WHO notified that the area was not significant to international traffic on 9 August 1961. The WHO Weekly Epidemiological Record of 4 August 1961 listed Santa Fe with a note that the case had occurred in an isolated area; it was not carried on the infected local area list.
1962	No cases			
1963	Apache County Arizona, and Gallup, New Mexico	1 fatal		Bubonic case, 28-year-old sheep herder in Houk, Arizona. Entered Gallup Indian Hospital on 7 December and died the same day. Blood cultures were positive.
	San Francisco, California		1 rodent	Plague identified in a dead rat in San Francisco on 12 March. Intensive studies of the area found no other positive rodents.
	Park County, Colorado		Sylvatic	The Communicable Disease Center (CDC), the U.S. Public Health Service, and State health authorities reported plague in prairie dogs wherein widespread epizootics wiped out large numbers in an extensive area surrounding Denver.

A tabulation showing the annual incidence of plague in California (1900-1963) is contained in Table I appended to this Section.

At first glance these data seem to indicate that the evolution of plague in the United States was in accordance with the pattern typical for several other countries invaded by the sea-route during the present pandemic, an initial "murine" phase of the infection eventually leading to a spread of the disease to the wild-rodent populations. However, in the opinion of some observers the appearance of plague in North America was due not to its recent introduction by sea, but to an early importation through wild rodents which, coming overland across the land bridge later replaced by the Bering Strait from Central Asia, brought P. pestis with them as a population regulator. This fascinating hypothesis was rejected by other authors, mainly on the ground that, in contrast to the plague strains isolated from the Central Asiatic wild rodents, those from both the rats and the wild rodents in America failed to produce an acid reaction in glycerol-containing media. At the same time some of the opponents to the above-mentioned hypothesis considered it likely that plague existed in California before its appearance was officially recorded in 1900, the infection having been imported from the China coast (affected since 1867) at an earlier date. The same apparently holds true of the sylvatic manifestations, since wild-rodent plague, though definitely detected in California in 1908, had evidently existed in the Contra Costa county of that state from 1903 at least.

While, as shown by the table in the first part of this Section, rat-caused epidemics ceased to occur after 1924, the infection among the wild rodents persisted and spread so that besides California, where sylvatic plague was first discovered, 14 other states had become involved.

Dates When Sylvatic Plague Was First Proven by Isolation of P. pestis from Wild Rodents or Their Ectoparasites

State	Year of detection	State	Year of detection
California*	1903**	Washington	1937
Hawaii*	1920***	Arizona*	1938
Idaho*	1930	New Mexico*	1938
Montana	1935	Colorado*	1941
Oregon*	1935	North Dakota	1941
Nevada*	1936	Oklahoma	1944
Utah*	1936	Kansas	1945
Wyoming	1936		

* Human plague also.

** Original proven case in 1908, but in 1903 and 1904 cases occurred in areas where there was a high mortality among ground squirrels, although no laboratory testing was done at that time.

*** It is difficult to determine when sylvatic plague first existed in Hawaii, if it ever did; Meyer and Pollitzer claim not. Eskey pointed out that from 1920 on, positive rodents were collected in the cane fields and valleys of the Hamakua district in areas where buildings did not exist.

Fortunately, as indicated in the above table and in that appearing in the first portion of this Section, the presence of wild-rodent plague rarely led to human infections, and did so in only nine of these states.

As shown in Tables II and III attached to this Section, large numbers of wild-rodent and flea species have been found infected in the various foci of the United States. Attempting a classification of the former, Eskey and Hass (1940), in their classical study on plague in the western part of the United States, came to the conclusion that at least three groups of rodents constituted the great primary reservoirs of the infection: the ground squirrels (Citellus), which were widely involved in the coastal regions and in the northern part of the Intermountain Plateau; the wood-rats (Neotoma), which formed the plague reservoir in the southern deserts; and finally, the prairie dogs (Cynomys), which harbored the infection in the plateau region of Arizona and New Mexico. It deserves, however, great attention that Kartman and his associates (1958), confirming findings recorded by Meyer in 1943, came to the conclusion that:

> "Historically, emphasis has shifted from the large colonial rodents such as ground squirrels to the small, inconspicuous native field voles and mice such as Microtus and Peromyscus."

It is of great importance to note that wild-rodent fleas have been found upon several occasions on the common rats and that isolated instances of rat plague conveyed by such fleas have been detected. Thus Meyer and Holdenried (1949), working on a Californian ranch where wild-rodent plague was present, found the infection also in R. rattus and R. norvegicus which were in part infested with ground-squirrel fleas. Observations in point were also recently made by Kartman and associates, who were able experimentally to confirm the transition of wild-rodent fleas to rats with radioactively tagged Malaraeus telchinus. It is, however, reassuring to find that so far the recent strictly sporadic human infections with P. pestis were invariably of the pattern of purely sylvatic plague, having been contracted away from the settlements in the wild-rodent foci. Thus, the only distressing feature of the situation is that, owing to the paucity of the human attacks, quite often the occurrence of human plague is not recognized early enough to save the patients or a diagnosis is even arrived at only after the death of the victims. To alert the medical profession and the public in this respect is therefore an important task.

TABLE I

HUMAN CASES OF PLAGUE BY RODENT SOURCE

CALIFORNIA, 1900-1963

	Years	Human cases	Source		
			Rats	Wild rodents	Unknown
Total	1900-1963	412	343	56	12
	1900	22	22		
	1901	32	32		
	1902	42	39		3
	1903	20	17	3*	
	1904	10	10		
	1907	180	178	1*	1
	1908	9	4	4	1
	1909	4		3	1
	1910	2		2	
	1911	5		3	2
	1913	2		2	
	1914	1		1	
	1915	1		1	
	1919	14		14	
	1920	1		1	
	1921	2		2	
	1922	2		2	
	1923	1			1
	1924	39	38		1
	1925	2	2		
	1927	1		1	
	1928	3		3	
	1933	1		1	
	1934	1		1	
	1936	4		2	2
	1937	1		1	
	1941	2		2	
	1942	1		1	
	1943	1		1	
	1944**	1			
	1947	1		1	
	1956	1		1	
	1959	2		2	
	1963	1	1		

Years in which no cases were reported are omitted.

* Wild-rodent source not proven by laboratory testing, but a high mortality among the ground squirrels in the area indicates this as a possible source.

** One laboratory infection in San Francisco.

TABLE II

LIST OF WILD RODENTS AND LAGOMORPHA FOUND NATURALLY PLAGUE INFECTED IN THE WESTERN UNITED STATES

FAMILY AND SUBFAMILY	SPECIES	STATE
Rodents:		
Geomydae	Thomomys bottae	California, ? Colorado
(Gophers)	Th. fossor	Colorado*
	Kangaroo rats:	
Heteromyidae	Dipodomys sp.	Texas
Dipodomyinae	Dipodomys ordi	Washington
	Perognathus parvus	Washington*
	Wood rats:	
Muridae	Neotoma algibula	Arizona, New Mexico
Cricetinae	N. cinerea occidentalis	California
	N. desertorum	Nevada, Utah
	N. fuscipes	California, Oregon*
	N.F. mohavensis	Nevada
	N. intermedia	California
	N. lepida	? Utah
	N. micropus	Texas
	Grasshoper mice:	
	Onychomys sp.	Texas*
	O. leucogaster	New Mexico* and other Western areas*
	O. torridus	New Mexico*
	Peromyscus boylii	Arizona*
	P. leucopus	New Mexico, California*
	P. maniculatus	New Mexico, California* Washington*
	P. truei gilberti	California
	P. truei truei	California, New Mexico
	P. truei nevadensis	Utah
	Reithrodontomys megalotis	California*, Kansas* New Mexico*
	Sigmodon hispidus	New Mexico*
	Voles:	
Muridae	Lagurus crutatus	Washington*
Microtinae	Microtus californicus	California
	M. montanus	Oregon, Washington*
	M. manus	Washington*
	M. townsendi	Washington
	Squirrels:	
Sciuridae	Citellus armatus	Western part of USA
	C. beecheyi beecheyi	California
	C.B. douglasi	California, Oregon
	C.B. fisheri	California
	C.B. nudipes	California*
	C. beldingi beldingi	California
	C.B. oregonus	California, Nevada, Oregon
	C. columbianus columbianus	Washington

TABLE II (cont.)

FAMILY AND SUBFAMILY	SPECIES	STATE
Sciuridae (cont.)	Squirrels:	
	C. c. ruficaudus	Oregon
	C. idahoensis	Idaho*
	C. lateralis chrysodeirus	California
	C. lateralis	Wyoming*
	C. leucurus	Arizona*, California*
	C. mexicanus	New Mexico*
	C. richardsoni elegans	Wyoming
	C. r. nevadensis	Nevada
	C. r. richardsoni	Montana* (a)
	C. spilosoma major	New Mexico*
	C. townsendi	Idaho*
	C. tridecemlineatus	New Mexico*, Texas*
	C. variegatus grammurus	Utah, Arizona*, Colorado* New Mexico*
	C.V. utah	Utah
	C. washingtoni loringi	Washington
	C.w. washingtoni	Washington
	Prairie dogs:	
	Cynomys sp.	Colorado*, Texas*
	Cynomys gunnisoni gunnisoni	New Mexico
	C. G. zuniensis	Arizona, New Mexico
	C. leucurus	Wyoming*
	C. ludovicianus	Colorado, Kansas, Montana, New Mexico, Texas, Wyoming
	C. parvidens	Utah (b)
	Flying squirrel:	
	Glaucomys sabrinus lasivus	California
	Marmots:	
	Marmota flaviventris subsp.	Colorado, Oregon New Mexico* (c)
	M. fl. avara	Oregon*
	M. fl. engelhardti	Montana, Utah, Wyoming
	M. fl. nosophora	Montana
	Chipmunks:	
	Tamias minimus	Washington*
	T. quadrivittatus frater	California, Nevada
	Tamiasciurus douglasi	California
Lagomorpha: Leporidae	Rabbits:	
	Lepus californicus	California
	Sylvilagus audobonii	New Mexico
	S. bachmani	California*
	S. nuttalli	Washington

* The presence of natural plague infection was detected only in the fleas infesting these rodents.
(a) Also found naturally plague-infected in Alberta and Saskatchewan, Canada.
(b) A prairie dog, Cynomys mexicanus, was also found naturally plague-infected in North Mexico.
(c) Naturally plague-infected fleas were found on this subspecies in British Columbia, Canada.

TABLE III

LIST OF WILD-RODENT AND LAGOMORPHA FLEAS FOUND NATURALLY PLAGUE-INFECTED IN THE UNITED STATES

SPECIES	LOCALITY	USUAL HOSTS
Anomiopsyllus sp.	New Mexico	Neotoma
A. hiemalis	Texas	Neotoma
Atyphloceras sp.	Western part of USA	Lagurus, Peromyscus
A. multidentatus	Western part of USA	Peromyscus
Catallagia decipiens	Washington	Lagurus, Peromyscus
C. wymani	California	Microtus, Peromyscus
Diamanus montanus	Western part of USA	Citellus
Foxella ignota	Colorado	Thomomys
Hoplopsyllus anomalus	Western part of USA	Citellus
H. glacialis affinis	New Mexico	Sylvilagus
Hystrichopsylla linsdalei	California	Microtus
Malaraeus telchinus	Western part of USA	Microtus, Peromyscus
Megabothris clantoni	Washington	Lagurus, Peromyscus
Meringis shannoni	Washington	Lagurus and other wild rodents
Monopsyllus eumolpi	Western part of USA	Tamias
M. exilis	Texas	Onychomys
M. wagneri	Western part of USA	Lagurus, Peromyscus and other wild rodents
Opisocrostis hirsutus	Western part of USA	Cynomys
Opisodasis keeni nesiotus	California	Microtus, Peromyscus Reithrodontomys
Orchopeas leucopus	New Mexico	Peromyscus
O. neotomae	New Mexico	Neotoma
O. sexdentatus	Western part of USA	Neotoma, Peromyscus
Peromyscopsylla hesperomys adelpha	New Mexico	Peromyscus
Stenistomera macrodactyla	New Mexico	Peromyscus
Rhrassis bacchi bacchi (-Thr. gladiolis)	Western part of USA	Citellus
Thr. bacchi johnsoni	Western part of USA	Lagurus, Peromyscus
Thr. focus	Western part of USA	Onychomys
Thr. stanfordi	Western part of USA	Marmota

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SECTION I

REVIEW AND EVALUATION OF THE PRESENT STATUS OF PLAGUE IN VENEZUELA

History and Recent Incidence of Plague

As can be gathered from the article by Díaz (1948) and the statements that were summarized and supplemented by Pollitzer (1954) and recently confirmed by De la Barrera (1960), plague appeared in 1908 in the port of La Guaira and soon spread from there to Caracas, where it continued to occur until 1919, leading to a total of 204 cases with 99 deaths.

Even before this "urban" phase of the disease had come to an end, the infection had spread in 1910 to rural areas of Miranda State, in parts of which it continued to become manifest from time to time until 1951. An adjacent part of Aragua State, reached by the infection in 1939, has remained involved to date. As can be seen from a table inserted in Pollitzer's book, the total case incidence in Miranda State from 1910 to 1933 was 206. The recently available information of the plague manifestations in that state as well as in Aragua may be summarized as follows:

Miranda State

Year	Locality	Case incidence	Remarks
1950	La Palma	5	No details known.
1951	Mostaza (Munic. of San Pedro)	8	According to De la Barrera, 5 persons were attacked in Puerto Escondido during the last week of July in one house, where one month before dead rats had been found. In the nearby community of Puesto Topo de la Mina, 3 plague cases were recorded in one and the same house on 31 July, 15 August, and 30 August.

Aragua State

Year	Locality	Cases	Deaths	Remarks
1939	Ricaurte district, La Florida	11	8	As stated by Díaz, this outbreak took place in the Hacienda La Florida, where 4 plague-affected rats had been found and *X. cheopis* and *X. brasiliensis* were encountered in most of the houses.

Aragua State (cont.)

Year	Locality	Cases	Deaths	Remarks
1943	Ricaurte district, a) Guayita Tejerías Munic.	10	3	According to Díaz, the first 3 attacks occurred in a house where 20 domesticated guinea pigs had died, and the next 2 in a neighboring house. The other 5 sufferers were obviously infected during a wake held in the latter house, which appeared to have been much infested by rats and fleas.
	b) Trapiche de Medio, El Consejo Munic.	7	2	These attacks took place one month after the just-mentioned outbreak and appeared to be epidemiologically related to it.
1948	La Horqueta	7	3	As related by De la Barrera, 4 persons fell ill with plague in one house between 23-24 May, and 3 more from 27 to 30 May.
1949	Las Palomas, La Pepeña	2	1	No details known.
1953	Ricaurte district, Capachal Tejerías Munic.	1	?	No details known.
1960	Ricaurte district, Tejerías Munic.			According to the WHO Weekly Epidemiological Record 35 (1960) 7:80, evidence of plague was found on 26 January within the confines of Tejerías Municipality in a Sigmodon hispidus hirsutus. This is undoubtedly the animal that succumbed to "super-acute" plague, as referred to by De la Barrera.
1961	Ricaurte district	3	?	As summarized in the WHO Weekly Epidemiological Record 36(1961) 28:305, two bubonic cases were reported in April in Tejerías Municipality and one in June in El Consejo Municipality, a dead rat having been found in the house of one of the sufferers.

Aragua State (cont.)

Year	Locality	Cases	Deaths	Remarks
1961 (cont.)	Marino district	3	?	According to the same source, 3 bubonic cases were detected in June in Tumero Municipality of Marino district.
1962	Ricaurte district	1	?	As reported in the WHO Weekly Epidemiological Record 37 (1962) 8:93, one patient suffering from "bubonic sylvatic plague" was found in La Victoria Municipality in February of the present year."
1963	-	-	-	-

As far as reliance can be placed upon these partly and not yet confirmed data, it would appear that within recent years the plague manifestations in Venezuela were restricted mostly to the Ricaurte district of Aragua State, where the area of Tejerías Municipality seems to form a particularly persistent focus of the infection. Certainly one should be most cautious in using the absence of manifestations of the disease in man as a means to assert the absence of plague in an area, since--as was actually the case in Venezuela--the infection may remain latent in the wild rodents for prolonged periods. Nevertheless, one might reasonably ask if (a) the now involved area in that country is less extended than was stated by Díaz, who estimated that the territories affected in Miranda and Aragua States measured about 1,000 km^2 (386 sq. miles); or whether (b) within this area strongholds of the infection (called "elementary" plague foci by some recent Soviet authors) do exist, where the infection is particularly apt to persist during the interepizootic periods and which, therefore, may form the starting point of epizootic waves. As will be discussed later in this report, the detection of plague foci that are so territorially limited and particularly active within an affected area is a matter of the utmost importance.

Observations on Rodents and Other Ecologically Important Animals

"Domestic" Species

As stated by De la Barrera (1960), whose carefully checked observations deserve most credence, Rattus norvegicus occurs within the presently affected Venezuelan plague areas only in scanty numbers inside the houses of Las Tejerías town, while R. rattus is amply met with throughout the involved territories. According to that observer, the habitat of R. rattus rattus seems to be confined to the houses and their immediate vicinity, but he admits that owing to the small number of these rodents among the trapped

animals it was impossible to come to valid conclusions regarding their ecology.

To judge from the large number of their captures, R. r. alexandrinus and R. r. frugivorus are frequent in both the urban and the rural houses, the former appearing to be more common in the Venezuelan plague area than the latter. Both were also caught within a radius of at least 500 meters around the houses, having thus had opportunities to come in contact with wild rodents that approached the houses.

Mus musculus appears to be frequent in both the urban and the rural habitations of the plague area, as well as in their vicinity. As asserted by Díaz, this species has never been found plague-infected in Venezuela. It is noteworthy, however, that although according to De la Barrera these rodents are scantily flea-infested, besides Ctenocephalides felis wild rodent fleas (Polygenis bohlsi bohlsi) have been found on them.

Guinea pigs are kept in the rural houses of the Venezuelan plague areas, but to a lesser extent than is the case in Ecuador and Peru. Nevertheless, the above-recorded observations on the 1943 outbreak in Guayita suggest that in Venezuela, as well as in those two countries, the domesticated guinea pigs may be instrumental in conveying plague from the rodents to man.

Wild Rodents

Referring in his reports to the wild rodents encountered in the Venezuelan plague areas, De la Barrera furnishes the following data:

Species	Number of captures	Percentage
Sigmodon hispidus	1,950	62.08
Proechimys g. quairae	337	10.72
Akodon urichi venezuelensis	324	10.31
Heteromys an. anomalus	233	7.41
Neacomys spinosus	96	3.05
Oryzomys (Oecomys) bicolor	62	1.97
Rhipidomys venezuelae	46	1.46
Sciurus granatensis	31	.98
Zygodontomys p. thomasi	26	.82
Sigmomys alstoni	22	.70
Dasyprocta rubratta rubratta	10	.31
Cuniculus paca (=Agouti paca)	4	.12

To judge from the short notes added by De la Barrera, Sigmodon hispidus, Akodon venezuelensis, Neacomys spinosus Sciurus granatensis, and particularly often Heteromys anomalus were found to enter the houses. It is important to note that this list includes the only two wild-rodent

species thus far found plague-infected in Venezuela: Sigmodon hispidus and Heteromys anomalus.

It is possibly also significant that, in contrast to the other species enumerated in the list, Sigmomys alstoni, suspected to be a plague reservoir, was not found throughout the affected area, restricted to the vicinity of Las Tejerías. However, this species was also met with outside the plague areas in lower locations with a higher temperature, i.e., an environment different from that in most parts of the affected region.

Dasyprocta rubratta seems to be the only one of the above-mentioned rodents which is hunted. Although it has been found slightly infested with the common wild-rodent fleas Polygenis bohlsi bohlsi and P. klagesi samuelis, so far it has been neither plague-infected nor implicated in the causation of human affections.

Lagomorpha

De la Barrera listed Sylvilagus brasiliensis (12 captures), which are hunted. Because it is known to have been plague-infected elsewhere in South America, and was found in Venezuela to harbor P. bohlsi bohlsi, this lagomorph deserves attention as a possible plague reservoir.

Marsupialia

Didelphis marsupialis marsupialis (26 captures), an animal of nocturnal habits, is frequently in contact with rodents and, on the other hand, is apt to stay around the houses or even to enter them. It therefore seems rather suspect as a liaison animal, capable of bringing infected fleas to the environments of the domestic or domesticated rodents and of man. Actually, De la Barrera noted the presence of Polygenis species, including P. bohlsi bohlsi and P. klagesi samuelis, on these animals. It further deserves attention that allied species have been found plague-infected in other parts of South America.

Observations on Fleas

Rat Fleas

The findings on rat fleas recently made by De la Barrera (1960) in the Venezuelan plague area stand in a most remarkable contrast to those recorded by earlier observers. Díaz (1948) stated in this connection that "the rats which frequent the houses, especially in the urban centers, were mainly infested with X. cheopis and X. brasiliensis. The rats of the sylvatic type (i.e., apparently the wild rodents) are mainly infested with Polygenis bohlsi, on rare occasions with X. brasiliensis. The flea index is generally low in the rural zone, in contrast to the high indices in the towns and settlements. Among the sylvatic rodents, the "Arditta comun" (Gerlinguetus auestuans) has been found infested with X. cheopis."

Dealing with the most common fleas in Venezuela, Cova García and Tallaferro (1959) recorded, unfortunately without indicating where they had made their investigations, that they had found X. cheopis not only on the common rats but also on Sigmodon hispidus hirsutus and Didelphis marsupialis marsupialis. On the other hand, they found Polygenis bohlsi bohlsi on both R. norvegicus and R. rattus, and recorded the presence of several species of wild-rodent fleas, including P. klagesi samuelis and P. roberti beebei, on the latter rat.

De la Barrera recorded the following data on the fleas he had found to infest R. r. alexandrinus and R. r. frugivorus:

	Percentages found on:			
	R. r. alexandrinus		R. r. frugivorus	
Flea species	In the houses	On the fields	In the houses	On the fields
P. klagesi samuelis	5.5	7.6	9.4	-
P. bohlsi bohlsi	38.8	38.4	32.0	46.6
P. roberti beebei	18.5	38.4	26.6	26.6
P. dunni	16.6	7.6	19.0	26.6
P. peronis	3.7	-	1.9	-
P. occidentalis steganus	3.7	-	3.8	-
Ct. felis felis	12.9	7.6	7.6	-
Totals:	99.7	99.6	100.3	99.8
Total fleas examined:	54	13	53	15

Although the number of fleas examined, especially those on the rats trapped in the open, was too small to give an exact idea of the frequency of the different species, De la Barrera's findings leave no room for doubt that X. cheopis was absent, the common rats in the Venezuelan plague area thus being presently infested almost exclusively by wild-rodent fleas; among them, P. bohlsi bohlsi, P. roberti beebei, and, to a somewhat lesser extent, P. dunni, appeared to be the most frequent.

Commenting upon these findings, De la Barrera stated that since X. cheopis "existed previously and the local climatic conditions have not become modified, it is logical to attribute the fact (of the disappearance of this flea) to the treatment with insecticides effected by the Plague Prevention Service. During the whole time of our work there were but very few fleas (Pulex irritans, Ct. felis, wild-rodent fleas, etc.) in the houses. However, the action of the insecticides does not seem to have been so efficacious against these fleas as against X. cheopis. Besides the possibility of a higher sensitivity of the latter, it is necessary to record that this species is essentially domestic and probably breeds only in this environment...If so, it is natural that the desinsectization can better reach it."

Wild Rodent Fleas

Referring to the fleas of wild rodents and evidently also of lagomorpha collected under his direction, De la Barrera furnished the following figures:

Species	Number collected	Percentage
P. bohlsi bohlsi	3,099	50.4
P. klagesi samuelis	1,672	27.2
P. roberti beebei	491	8.0
P. dunni	207	3.3
P. occidentalis steganus	65	1.0
P. peronis	48	0.7
Rhopalopsyllus australis australis	475	7.7
Rh. cacicus	80	1.3
Rh. lugubris cryctogenes	2	0.03
Totals:	6,139	99.63

As will be gathered from the Table I, the number of fleas collected from the specimens of the individual wild-rodent species varied considerably, data of statistical significance having been obtained only in the case of some of the species. It appears to be certain, however, that species belonging to the genus Polygenis which, as has been shown above, also preponderate most markedly on the common rats, form the overwhelming majority of the wild-rodent fleas in the Venezuelan plague area. Also, there can be hardly any doubt that the vectors of the infection there will be found among the Polygenis fleas, allied species of which have been found definitely capable of conveying plague in Argentina, Ecuador, and Brazil. It remains to be seen, however, which species are implicated in Venezuela.

Observations on Human Plague

Discussing the epidemiology of plague in the presently affected Venezuelan areas, De la Barrera emphasized that (1) though instances of infections in the fields had been observed, as a rule man contracted the disease within the houses; and (2) contrary to what was usually observed in bubonic plague outbreaks, multiple infections in one and the same house were frequent. Although he postulated that in Venezuela, as well as in South America in general, the common rats had become resistant to plague, he was inclined nevertheless to the belief that as a rule their temporary involvement, due to a transition of the infection from the wild rodents, was responsible for the intradomestically acquired human attacks. He further maintained that the appearance of multiple plague attacks in one and the same house could take place only if a highly efficient vector-flea was available there. Since in his opinion the wild-

TABLE I

NUMBERS AND PERCENTAGES OF FLEAS ON MAMMALIAN SPECIES

(Venezuela)

Fleas	Sigmodon hispidus	Heteromys anomalus	Akodon venezuel.	Dasyprocta rubratta	Neacomys spinosus
P. bohlsi	2518/87.4	14/8.4	372/90.7	2/0.5	3/8.3
P. klagesi samuelis	121/4.1	9/5.4	7/1.7	16/4.7	2/5.5
P. roberti beebei	127/4.4	11/6.6	12/2.9	-	31/86.1
P. dunni	79/2.7	84/50.9	12/2.9	-	-
P. peronis	3/0.1	42/25.4	-	-	-
P. occidentallis steganus	3/0.1	-	2/0.4	1/0.2	-
Rhopalopsyllus australis	1/0.03	-	-	313/92.0	-
Rh. cacicus	1/0.03	5/3.0	-	6/1.7	-
Rh. lugubris cryptoctenes	-	-	-	2/0.5	-
Adoratopsylla antiquorum	3/0.1	-	-	-	-
A. intermedia oxyura	2/0.06	-	-	-	-
Ctenocephalides felis	23/0.8	-	5/1.2	-	-

TABLE I (cont.)

Proechimys quairae	Proechimys cayennensis	Rhipidomys venezuelae	Sciurus granat.	Sigmomys alstoni	Zygodont. thomasi	Sylvil. brasil.	Didelphia marsupialis
118/6.5	32/50.0	5/9.4	-	7/33.3	11/91.6	4/26.6	24/2.1
1493/84.2	11/17.1	15/28.3	-	-	-	-	29/2.5
106/5.9	-	32/60.3	1/10.0	4/19.0	1/8.3	-	152/13.4
18/1.0	-	-	1/10.0	10/47.6	-	-	3/0.2
-	-	-	-	-	-	-	1/0.08
9/0.5	-	-	8/80.0	-	-	-	28/2.4
2/0.1	-	1/0.9	-	-	-	10/66.6	5/0.4
7/0.3	-	-	-	-	-	-	59/5.2
-	-	-	-	-	-	-	-
-	21/32.8	-	-	-	-	-	1/0.08
10/0.5	-	-	-	-	-	-	804/70.8
9/0.5	-	-	-	-	-	1/6.6	26/2.2

rodent fleas did not fall into this category, he came to the conclusion that in the plague outbreaks in Venezuela recorded by him, X. cheopis was still responsible for the intradomiciliary conveyance of the infection.

When evaluating these postulations, one must state that at first glance the apparently lessened incidence of plague observed in Venezuela within recent years, when X. cheopis seemed to be absent from the affected areas, seems to speak in favor of De la Barrera's views. However, since in the past this flea was no doubt considerably more numerous in the house than the present vectors of the infection (wild-rodent fleas) are now, the lessened incidence of plague and the absence of multiple attacks may be due merely to a scarcity of the vectors and not to their lessened capacity to convey the infection. It would not seem wise, therefore, to consider the Venezuelan wild-rodent fleas as inadequate plague vectors, before proof for this contention has been obtained through appropriate tests.

Summary and Recommendations

The recent observations on plague in Venezuela, briefly dealt with in the foregoing pages, enable us to conclude:

(1) The infection has remained restricted for more than two decades to adjacent districts of Miranda and Aragua States, the focus evidently showing no tendency to expand.

(2) Possibly at present plague is active only in a limited part of Aragua State, which, as has been discussed above, may thus form a permanent stronghold of the infection.

(3) There can be no doubt that wild rodents, two species of which have been found definitely implicated, form the permanent plague reservoir.

(4) The "domestic" rodent fauna, including, besides the common rats and house mice, in part also domesticated guinea pigs, becomes only temporarily involved in the wild-rodent epizootics, an event apt to lead to the appearance of plague in man.

(5) The houses of the plague area having apparently been freed from X. cheopis, wild-rodent fleas now form the usual, if not the sole, vehicle of the infection not only from rodent to rodent but also from the rodents to man.

Valuable as this information is, it must be realized that it furnishes only a general picture of the present plague situation in Venezuela, leaving unanswered many essential questions concerning the ecology of the disease. The most important among the problems of the latter category are:

(a) The contention that plague is now restricted to a limited part of its original focus in Miranda and Aragua States rests only on deductions made from the known incidence of human plague, and must therefore be confirmed or disproved through wholesale and thorough examinations of the rodents and their fleas within the maximal limits of the affected area.

(b) The hitherto obtained knowledge on the presence of wild-rodent plague is rather scanty, as it rests only on the apparently rather occasional detection of the infection in two of the several wild-rodent species (and lagomorpha) encountered in the affected areas. It is to be expected that the wholesale examinations proposed above will yield further information in this respect, but in addition to ample field investigations of as many rodent species as possible, it is essential to test their susceptibility to plague in the laboratory. Standard methods must be used for the latter work so as to detect differences in the plague susceptibility of the various rodent species.

(c) To render the above-mentioned field investigations effective and to pave the way for measures to control the wild rodents, those investigations must be accompanied, or even preceded, by a thorough study of the ecology of the animals on which, however, presumably much local information is available.

(d) Hand-in-hand with these field and laboratory studies of the wild rodents, thorough parallel studies must be made on the common rats, in particular to determine their susceptibility to plague. It should be stressed in this connection that, although it has often been postulated that the rural rat populations, not only in Venezuela but in other wild-rodent plague foci of South America, have become resistant to the infection, the present reporters have so far failed to find any exact data proving this point.

(e) As has already been noted, it is still unknown which of the numerous wild-rodent flea (or, one might safely say, Polygenis) species are involved in the spread of plague in Venezuela. Again, it may be expected that the field investigations will furnish information on this point, provided that care is taken to use exclusively lots consisting of only one well-identified flea species for the cultivation of P. pestis and for pooling tests in guinea pigs. However, in addition to this, exact studies have to be made to determine the vector efficiency of the various species of wild-rodent fleas. It would be advisable not only to use X. cheopis as a standard of comparison in these tests but also to study the vector efficiency of the local P. irritans and Ct. felis strains.

(f) In the course of the above field investigations, it is also important to make thorough epidemiological and laboratory studies of all human plague cases observed at the time. If possible, the plague strains isolated from man as well as from naturally infected rodents and fleas ought to be kept in a lyophilized state for further studies.

(g) The question as to whether a campaign against the wild rodents would be a practical possiblity can be decided only after the above-outlined investigations are well advanced, and in particular, after the present plague-affected area has been adequately delimited.

(h) It ought to be clear that a detailed program for the above-proposed investigations and studies can be drawn up only after consultation with the medical officers of the Venezuelan Plague Prevention Service, and after a preliminary survey to establish the manner in which the contemplated work could be conducted.

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SECTION J

PLAGUE IN OTHER COUNTRIES

Mainly for the sake of the completeness of the information in this study, there are listed below the countries of the Western Hemisphere where plague has occurred. In most of these countries, it is believed that plague no longer exists; in two of them, evidence of infection is currently being found.

Countries with Past Experience of Plague

Country	Periods when plague existed
Canada*	1939 - ...
Chile	1903 - 1942
Cuba	1912 - 1915
Mexico	1902 - 1923, 1963-
Panama	1905
Paraguay	1899 - 1928
Trinidad/Grenada	1907 - 1912
Uruguay	1901 - 1931

* Sylvatic only.

SECTION K

A LISTING OF NEEDS IN RESEARCH

1. PERU/ECUADOR: Plague Ecological and Epidemiological Studies in the Huancabamba-Ayabaca-Loja Focus

1.1 Wild Rodents and Lagomorpha

1.1.1 Ecology Studies

It is proposed to study the ecology of the various species of rodents and lagomorpha involved in the plague manifestations, particularly in order to (a) delimit their habitat; (b) establish the possible existence of strongholds of the infection; and (c) to determine the aptitude of the animals to approach or to enter human habitations or settlements.

1.1.2 Occurrence of Natural Plague Infection

It is proposed to make systematic wholesale studies on the occurrence of natural plague in the various species of rodents and lagomorpha, particularly in order to arrive at a distinction between reservoir species constantly harboring the infection and those becoming periodically or occasionally involved.

1.1.3 Susceptibility to Plague Infection

As planned, batches of the species involved in the plague manifestations will be experimentally infected with P. pestis strains of standard virulence so as to determine their susceptibility for, or resistance against, plague.

1.2 Fleas of the Wild Rodents and Lagomorpha

1.2.1 Distribution of the Various Flea Species

It is proposed to make systematic studies so as to determine the occurrence and frequency of the various flea species concerned on (a) the wild rodents and lagomorpha; (b) the common rats, the house mice, and the domesticated guinea pigs; and (c) in the various parts of the focus and at different seasons of the year.

1.2.2 Occurrence of Natural Plague in the Various Species

As projected, the occurrence of natural plague in the various fleas would be determined with the aid of pooling tests.

1.2.3 Vector Capacity

It is proposed to study the vector capacity of the various flea species found naturally plague-infected, using whenever possible laboratory-bred strains.

1.3 Common Rats and House Mice

1.3.1 Systematic studies are planned to determine the presence or absence of the two species of the common rats and of the house mice in both the settlements and in the rural areas of the focus.

1.3.2 Occurrence of Natural Plague

It is proposed to study the occurrence of natural plague in the common rats and the house mice by (a) examining all animals found dead; (b) making guinea-pig tests with the pooled organs of trapped rats and mice.

1.3.3 Susceptibility to Plague Infection

Since it has been claimed that the rats in the area have become resistant to plague, it is proposed to challenge batches of these animals, collected both in the settlements and in the rural areas of the focus, with P. pestis strains of standard virulence.

1.4 Domesticated Guinea Pigs

1.4.1 Frequency Studies

Observations would be made on the comparative frequency with which guinea pigs are kept in (a) the settlements and (b) the rural houses of the various parts of the focus.

1.4.2 Occurrence of Natural Plague

It is proposed to keep a watch for the occurrence of natural plague in the domesticated guinea pigs by (a) dissecting and examining all animals found dead; and (b) sacrificing and likewise examining those showing signs of illness.

The blood sera of all guinea pigs under test will be kept in a lyophilized condition so as to make them available for further exhaustive studies.

1.4.3 Susceptibility to Plague Infection

As planned, it will be determined whether differences in susceptibility to experimental infection with various P. pestis strains exist (a) between the guinea pigs kept, respectively, in recently plague-affected and in plague-free localities, and (b) at different seasons of the year.

1.5 Intradomestic Flea Fauna

1.5.1 Occurrence of the Various Flea Species

It is proposed to make studies on the occurrence and frequency of the various flea species infesting (a) the common rats, (b) the house mice, and (c) the domesticated guinea pigs; as well as (d) on the fleas found free-living in the houses, special attention being paid to the occurrence of (1) X. cheopis, (2) wild-rodent fleas, and (3) the various forms of P. irritans, the existence of which has recently been claimed.

1.5.2 Occurrence of Natural Plague

According to the plan, pooling tests would be made with batches of the various domestic fleas to determine the presence of plague in these parasites, especially in localities invaded or threatened by plague.

1.5.3 Vector Efficiency Studies

It is proposed to make vector efficiency studies with the intradomestic flea species, in particular with the various forms of P. irritans encountered.

1.5.4 Action of Insecticides

Comparative studies are also contemplated of the action exerted by DDT and other insecticides on the domestic flea fauna.

1.6 Epidemiological Observations

1.6.1 Observations on Manifest Plague Attacks

As planned, systematic studies would be made on all human manifestations of plague met with by the study group.

1.6.2 Subclinical Forms of Plague

It is proposed to study the occurrence of subclinical forms of plague with the aid of surveys in groups of the population exposed to the risk of infection.

1.6.3 Forecasting of Plague Manifestations

It is proposed to explore the possibility of forecasting the occurrence of human plague manifestations.

2. ECOLOGICAL AND EPIDEMIOLOGICAL STUDIES IN THE VENEZUELAN PLAGUE FOCUS

2.1 Studies analogous to those outlined above are also contemplated for the Venezuelan plague focus.

2.2 Pilot Study on the Control of Wild-Rodent Plague

Provided that strongholds of the infection are found in the Venezuelan plague focus, a pilot study is planned in order to explore the possibility of sufficiently thinning out the populations of the reservoir species in these localities so as to cut short the spread of plague. Consultations with wildlife experts would be indispensable in order to devise methods suitable for such a temporary reduction of the populations concerned; such measures, as proved by experiences in the Soviet Union, are an effective means of plague control.

3. ECOLOGICAL AND EPIDEMIOLOGICAL STUDIES IN THE ECUADORIAN PLAGUE FOCI

In view of the involved plague situation in Ecuador, it is proposed to postpone the framing of a program for studies in other parts of that country until experiences on the suitability of the plans contemplated for the Peru/Ecuador border area have been gathered.

4. STUDIES OF PLAGUE IN BRAZIL

On the basis of the knowledge gained in the plague studies outlined for the other countries, a study of plague in Brazil may be indicated. Also, the nature of such studies would be determined at that time.

5. PLAGUE CONTROL

Since the aim of the proposed investigations is, not to elicit facts of merely academic interest, but to serve practical ends, research would always be directed toward the ultimate goal of providing the knowledge and tools to enable the national plague prevention services to deal with imminent or actual manifestations of the disease in man. Attention would be paid in particular to studies on the possibilities of preventing human plague not only by the use of insecticides (see 1.5.4 above), but also with the aid of potent synergist vaccines in basic and booster doses and, whenever indicated by local emergencies, through administration of antibiotics or sulfonamides. The therapeutic use of these substances would likewise be studied as much as possible so as to arrive at a fully effective, yet simple and economical, scheme of treatment.

SECTION L

OUTLINE OF A RESEARCH PLAN FOR STUDIES ON THE ECOLOGY AND EPIDEMIOLOGY OF PLAGUE IN THE HUANCABAMBA-AYABACA-LOJA FOCUS, PERU/ECUADOR

1. General Organization of the Work

In order to cope with the involved problems to be investigated, the proposed study will be made on four levels:

(a) in the field;
(b) in a base laboratory at Lima, Peru;
(c) in one of the plague laboratories of the United States of America where the plague strains isolated in the field or at the base laboratory will be studied and tests with the sera of plague patients, contacts, and rodents requiring special techniques will be made;
(d) In three reference laboratories, namely: the Communicable Disease Center (CDC) Field Station at San Francisco, where the vector efficiency of the various species of fleas of the focus that play a role in the ecology of plague will be determined; the U.S. Natural History Museum in Washington, D.C., where final identifications of the different rodents and lagomorpha encountered in the course of the study will be made; and the branch of the British Museum in Tring (England), where the identifications of the fleas collected in the course of the work by the field and base laboratory staffs will be confirmed.

The division of duties between the field staff and the workers at the base laboratory will be made evident when the various parts of the research program are discussed.

2. Personnel Required

The personnel necessary for the proposed work is enumerated in the following roster:

International staff*	National staff	Collaborating laboratories
1 Ecologist/epidemiologist	1 Epidemiologist	It is expected that the collaboring laboratories will delegate members of their own staffs for the required work, but funds must be available to enable them to come for necessary consultations to Washington.
1 Bacteriologist	1 Bacteriologist	
1 Mammologist	2 Clinicians (part-time)	
1 Entomologist (flea expert)	1 Secretary	
2 Field supervisors	4 Qualified field workers	
1 Part-time consultant	6 Trappers*	
	2 Drivers*	
	Laborers	

* To be paid out of the research grant.

In order to assure adequate assistance for this study, key personnel of the Peruvian and Ecuadorian staff will be given some preliminary training abroad.

3. Length of the Study Period

In view of the large scope of the research program, and bearing in mind the seasonal changes of the ecological situation, the work of the team must be planned for a period of not less than two years, the first year to be used for obtaining an over-all picture of the situation, and the second for focusing attention upon the solutions of problems found to be of particular importance.

4. Investigations on Wild Rodents and Lagomorpha

In order (a) to investigate which species of wild rodents and lagomorpha suffer from natural plague, (b) to establish which of these species is or are the permanent reservoir of the infection, and (c) to ascertain the trend of the infection in the species involved, the following investigations are necessary:

4.1 To examine all animals found dead. These, after they have been preliminarily identified and after their fleas and other ectoparasites have been collected and put into individual vials, will be dissected by the field staff, who (a) will note and record all gross signs suggestive of plague; (b) will make impression films from the buboes (if present) and the spleen, liver, and lungs as well as smears from the heart blood; and (c) put the bubo, heart, and spleen (or a piece thereof) as well as pieces of the liver and lungs into a jar containing 2% saline solution or Broquet's fluid. In the case of decomposed or mutilated carcasses, one or a few marrow bones will be put into the preserving liquid. After the impression films and smears have become air-dry, the properly labelled slides will be put into a jar containing methylated alcohol. If the dissected animals are small, their carcasses will be put into a jar filled with methylated alcohol or 10% formol. In the case of larger animals, their skulls and skins will be forwarded to the base laboratory, together with the above-mentioned material. In the base laboratory the identity of the dissected animals will be confirmed or determined and all necessary bacteriological and serological tests will be made to detect the presence of plague in the dissected animals. All P. pestis strains isolated will be kept in a lyophilized state for further study in the United States.

4.2 In order (a) to watch for the occurrence of incipient or latent infections in the wild rodents and lagomorpha, and (b) to obtain specimens for a determination of the susceptibility of the various species to infection with P. pestis,

adequate numbers of all species present in the study areas will be trapped or obtained by other means.

4.3 The major part of the trapped animals--if possible after a period of observation in the live state--will be sacrificed, and material for tests for the presence of plague infection in the base laboratory will be obtained in the manner described in paragraph 4.1. When examining this material in the base laboratory, ample use will be made of animal experiments with the pooled organs of lots of animals belonging to one and the same species. The material from animals obtained by killing methods will be handled in an identical manner.

4.4 Lots of not less than 6 animals of the various trapped species will be dissected, serologically tested, and--if possible after a period of observation--will be challenged with adequate doses of a plague strain of standard virulence. It would be desirable to perform these tests in the base laboratory by forwarding to it, in flea-proof cages, animals trapped in localities free of epizootics at the time.

4.5 While it is impossible to predict the number of animals found dead, it will be attempted to examine a total of not less than 100 rodents and lagomorpha per week, or 5,000-6,000 animals per year.

4.6 In addition to the above-described work, ecological studies will be made to ascertain the distribution of the different species and the limits of their habitat.

4.7 A constant watch will be kept for fluctuations in the population density of the various species, with the aid of inquiries among the population and the plague prevention staff, periodic inspections, and systematic trapping operations in representative plots of standard size, repeated in the various localities at regular intervals.

4.8 The observations on the sporadic, periodic, or constant occurrence of positive findings in the various species, in combination with the ecological observations and the results of the resistance studies, will be used as a means to assess the importance of the different rodents and lagomorpha for the permanent harborage of the infection.

4.9 By correlating the results of laboratory observations with those on the population density of the essential species, the trend of plague in the focus will be gauged.

5. Investigations on the Fleas of the Wild Rodents and Lagomorpha

In order to ascertain the comparative importance of the various flea species of the wild rodents and lagomorpha in the Huancabamba-Ayabaca-Loja focus for the transmission of plague, the following investigations will be made:

5.1 Flea collections will be made from (a) all rodents and lagomorpha found dead as well as from those trapped or collected by other means; (b) rodent nests or burrows; and (c) other sites suitable for the harborage of fleas.

5.2 The collected fleas will be forwarded to the base laboratory and for this purpose use will be made of separate, adequately-labelled and well-closed vials for the flea lots collected from the individual rodents and lagomorpha, nests, etc. Should it be impossible to forward the fleas alive, they will be put in a preserving fluid like saline solution so as to permit their examination for the presence of P. pestis.

5.3 In the base laboratory the fleas will be subjected to preliminary identification tests and divided into lots consisting of only one species. Representative specimens, preserved in alcohol or glycerol alcohol, will be sent to Tring for final identification.

5.4 Pools of fleas belonging to one and the same species will be used for the experimental infection of guinea pigs so as to detect the presence or absence of P. pestis in the lots under test.

5.5 It will be attempted to handle about 200 fleas from wild rodents and lagomorpha per week, or 10,000-12,000 per year.

5.6 As far as possible, the species of fleas in which the occurrence of natural plague has been detected will be bred in the base laboratory, and lots of the bred fleas will be forwarded to the CDC Field Station in San Francisco for vector studies. In the case of species which cannot be bred in the laboratory, lots of the fleas in question collected in localities free from epizootics at the time will be sent to San Francisco.

5.7 Detailed accounts of the occurrence of the various flea species found on the different rodents and lagomorpha and in other sites will be kept so as to assess (a) the occurrence of the various flea species on the different species of rodents and lagomorpha; (b) the location and the limits of the habitat of the various fleas; and (c) the occurrence of seasonal fluctuations in their frequency.

5.8 The results of the examinations of the fleas for the presence of P. pestis, and the results of the vector capacity studies, correlated with the ecological observations (paragraph 5.7), will be used to determine the comparative importance of the species in question for the transmission of plague.

5.9 In order to ascertain the epidemiological importance of the fleas thus incriminated, their ability to attack the common rats, the domesticated guinea pigs, and man will be ascertained.

6. Investigations on the Common Rats and Domestic Mice

Since it has been maintained so far that the common rats (R. rattus) (a) are not uniformly distributed in the Huancabamba-Ayabaca-Loja focus, being rare in the rural areas, and (b) because they are resistant to infection with P. pestis, play no role in the transition of the infection from the wild rodents and lagomorpha to man, the following investigations will be made:

6.1 The comparative frequency of these animals throughout the focus will be studied through uniformly-conducted trapping operations in and around the houses.

6.2 Batches of at least 20 live specimens trapped in the various towns and rural areas of the focus will be used for uniformly-conducted susceptibility tests with P. pestis strains of standard virulence.

6.3 In localities where the occurrence of plague among the wild rodents and lagomorpha or in the human population has been recorded (a) a careful search will be instituted for rats and domestic mice found dead in or around the houses and any carcass found will be examined with the aid of the methods described in paragraph 4.1 of this plan; (b) ample trappings will be made and the trapped rats and mice will be examined for the presence of incipient or latent infection, particular stress being laid upon the performance of tests with their pooled organs. As will be stated below, the fleas collected from the rats and house mice will also be used for pooling tests.

6.4 It will be attempted to examine an average of 60-80 common rats and house mice per week, or about 3,000-4,000 per year.

7. Investigations on the Domesticated Guinea Pigs

7.1 Whenever the presence of plague in wild rodents and lagomorpha is detected, a careful watch will be instituted to detect a transition of the infection to the domesticated guinea pigs

by (a) dissecting and examining any of these animals found dead, and (b) sacrificing and likewise examining those showing signs of illness.

7.2 Comparative studies will be made to establish whether differences in the susceptibility to experimental infection with P. pestis exist between the guinea pigs kept in recently plague-affected settlements or houses (especially in places where these animals themselves have been involved in the manifestations of the disease) and those in localities recently freed from plague. Incidental to these investigations, studies will be made to ascertain whether seasonal changes of the susceptibility to plague exist in the domesticated guinea pigs.

8. Investigations on the Intradomestic Flea Fauna

8.1 A focus-wide study will be made of the fleas infesting the common rats, in particular (a) to delimit the areas in which X. cheopis infests these rodents; (b) to establish what species replace this vector in localities unsuitable for its existence; and (c) to note the infestation of the common rats with fleas not specific to them, and particularly with wild-rodent fleas and P. irritans.

8.2 In the course of the just-described work, analogous observations will be made on the flea fauna of the domesticated guinea pigs and on the fleas infesting the house mice. Particular attention will be paid to (a) the occurrence of wild rodent fleas and P. irritans on these rodents; and (b) the degree to which an interchange of fleas specific for the common rats and for the guinea pigs takes place.

8.3 When making the above-enumerated investigations, attention will be paid also to the occurrence and comparative frequency of the different forms of P. irritans on the rodents as well as in the houses in general.

8.4 Using separate, adequately-labelled vials for the lots of fleas from the individual rodents or locations, the flea material will be forwarded to the base laboratory for (a) identification and recording of the species met with; (b) pooling tests to detect the presence of plague-infected fleas; and (c) breeding of the flea species, the vector capacity of which it is indicated to study. In the case of species which cannot be bred in the laboratory (presumably in that of the various forms of P. irritans), lots of fleas collected in locations free of plague will be forwarded to the CDC San Francisco Field Station for vector efficiency tests.

8.5 Comparative studies will also be made of the action exerted by DDT and other insecticides on the domestic flea fauna.

9. Epidemiological Observations

9.1 A close study will be made of all human plague manifestations encountered by the research team, in particular to establish which rodents and which fleas were involved in the causation of the human infections. Houses in which several plague attacks have occurred will be given special attention in this respect.

9.2 The study group will stand ready to assist the plague prevention service of each country in obtaining in each instance of human plague a confirmation of the diagnosis through laboratory tests. The plague strains isolated in the course of this work will be kept in lyophilized form for further study in a reference laboratory.

9.3 In order to obtain complete and uniform records, an adequately-prepared record sheet will be used for each patient. The help of the plague prevention service will be enlisted to fill out such questionnaires also for patients seen by them in the recent past, and the future use of these record sheets will be recommended.

9.4 Efforts will be made to detect the occurrence of subclinical forms of plague through physical and serological surveys in groups of the population which have been or are under risk of infection.

9.5 As discussed at the conclusion of the report on Peru, attention will be given to forecasting the incidence of human plague through a correlation of all available data on the fluctuations of the population density of the rodent host of the infection and on the occurrence and frequency of manifestations of the disease in the herds of these animals.

SECTION M

OUTLINE FOR A RESEARCH PLAN FOR PLAGUE INVESTIGATION IN VENEZUELA

In accordance with the recommendations contained in Section I on Venezuela, a plan for the investigation of the ecology and epidemiology of plague in the presently affected areas of Venezuela may be itemized as follows:

1. Investigation on wild rodents and lagomorpha, comprising:

1.1 Examination for the presence of plague, of all animals found dead.

1.2 Collection of large numbers of apparently healthy animals by trapping or (as far as necessary) by other means so as to obtain material for:

1.2.1 Pooling tests with the organs of sacrificed trapped animals or animals obtained by killing methods, so as to detect the presence of plague infection.

1.2.2 Determination of the susceptibility of the various species to experimental infection with P. pestis strains of standard virulence.

1.3 Ecological studies to ascertain the distribution of the different species and the limits of their habitat.

1.4 Observations on fluctuations of the population density of the various species.

2. Investigations on the fleas of the wild rodents and lagomorpha, by:

2.1 Making flea collections from (a) all rodents and lagomorpha found dead, trapped, or collected by other means; (b) rodent nests or burrows; and (c) other flea harborages.

2.2 Utilization of pooled lots of fleas belonging to one and the same species of the various fleas encountered, for the purpose of experimental infection of guinea pigs so as to detect the presence of infected fleas. Cultures will also be made from the fleas to detect the presence of avirulent strains.

2.3 Breeding fleas of the species found to be plague-infected in the laboratory, and using the bred fleas for vector efficiency studies.

3. Investigations on the common rats and mice, including:

3.1 Studies on the occurrence and comparative frequency of R. norvegicus and R. rattus, together with observations on differences in the ecology of these two species.

3.2 Tests to detect the presence of plague in these species and in the house mice in localities where plague has become manifest (examination of all rats and mice found dead and of trapped or killed animals).

3.3 Uniformly-conducted susceptibility tests with P. pestis of standard virulence to determine to what extent the rats trapped in the various localities of the focus have become resistant to plague.

4. Investigations of the domesticated guinea pigs, comprising:

4.1 Observations on the frequency with which these animals are kept in the various localities of the focus.

4.2 Tests to detect the presence of plague in these animals in localities where plague has become manifest.

4.3 Comparative studies to establish whether differences in the susceptibility to experimental infection with P. pestis exist between guinea pigs kept in recently plague-affected settlements or houses and those in localities free of plague.

5. Investigations on the intradomestic flea fauna, consisting of:

5.1 Studies to determine the species of fleas habitually or accidentally infesting the common rats, the house mice, the domesticated guinea pigs, and also the marsupialia.

5.2 Pooling tests with the various species of the intradomestic fleas in localities where the occurrence of plague has been detected.

5.3 Vector efficiency studies with the species of the intradomestic fleas which seem to be of importance in the conveyance of plague.

5.4 Comparative studies of the action of DDT and other insecticides on the intradomestic flea fauna.

6. Epidemiological investigations, comprising:

6.1 Thorough clinical studies and laboratory examination of any human plague case met with. The efficacy of antibiotics and sulfonamides for the prevention and treatment of plague will also be studied.

6.2 Efforts to detect the occurrence of subclinical forms of plague through physical and serological surveys in groups of the population which have been or are under the risk of infection.

6.3 Attention to the possibility of forecasting the incidence of human plague through a correlation of the data on the fluctuations of the population density of the rodent hosts of the infection and the occurrence and frequency of manifestations of the disease in the herds of these animals.

7. Evaluation and utilization of the results of the investigations.

The results of the above-outlined investigations will be used:

7.1 To determine the present limits of the plague-affected areas.

7.2 To establish whether within the affected area strongholds of the infection exist.

8. Pilot study.

A decision will be made, on the basis of these data, as to whether or not a pilot study to assess the possibilities of a campaign against the wild rodents would be justfied.

ANNEX I

SEROLOGICAL TESTS FOR PLAGUE

Since the text for this monograph was prepared, there has appeared in the literature a number of important articles on serological procedures for use in plague surveys. The importance of this advent was considered sufficient to warrant the attachment of this annex in the final stages of publication of this study on plague in the Americas.

Attention is invited to the recent publications which are summarized below:

1. Meyer, K. F.: "Serological Tests for the Confirmation of Plague Infections." Bulletin of the World Health Organization (1964) 30:750.

Reports on serological tests of plague cases using procedures developed by Chen and others, at the George Williams Hooper Foundation in 1952, but refined by the use of a highly purified P. pestis Fraction I(F_1) antigen adapted to microtechnique developed by Cavanaugh. Details of the indirect hemagglutination test are to be found in Bull Wld Hlth Org (1956)14:478-479.

The author draws attention to the usefulness of serological tests by citing an outbreak in 1962-1963 wherein of 83 cases with 7 deaths officially reported, only 15, or 36 per cent, could be confirmed through bacteriological examinations, whereas retrospective serological tests were positive in 31 cases, or 78 per cent. HA and CF tests made two to three months after onset of the disease invariably confirmed the cultural findings. Especially in areas where, owing to isolation and high temperatures, the collection and transportation of specimens of bubo fluid or blood cultures make bacteriological tests impractical, non-hemolysed serum specimens should be sent to a laboratory capable of making HA and CF tests with standardized F_1 antigens.

2. Levi, M. I., et al.: "Results of Testing the Passive Hemagglutination Reaction and the Antibody Neutralization Test in the Practice of the Epizootiological Investigation of Wild Rodents for Plague." Zhurnal mikrobiologii, (1963)12:113-119.

During the period 1959 to 1962, more than 27,000 wild rodents were tested in some of the plague foci of the Soviet Union. As a rule, the number of the serologically positive animals exceeded considerably that of animals from which P. pestis could be isolated. In places where at the time of testing, or not long before, an acute plague epizootic had been present, the number of rodents showing antibodies reached 60-100 per cent.

To establish the presence of a plague epizootic with the aid of the bacteriological methods was considerably more difficult, and not rarely hundreds or thousands of rodents had to be examined to obtain one culture. (Ed. note: The semantics of passive and neutralization in this and the next paper are not clear.)

3. Suchkov, IU. G.: "Serological Examinations in Plague. XIV. Trial of some serological reactions in epizootiological investigations in natural plague foci." Zhurnal mikrobiologii, (1964) 1:135-141.

The report records the results of the use of the passive hemagglutination test for the retrospective diagnosis of wild-rodent plague and of the antibody neutralization test for the demonstration of the specific capsular antigen of P. pestis. The passive hemagglutination and the antibody neutralization test with formalized erythrocytes can be used under field conditions for epizootiological plague surveys of wild rodents. Wild rodents with antibodies against P. pestis are found in natural foci considerably more often than animals from which this organism can be isolated. According to the results obtained with the passive hemagglutination test, one can apparently judge the intensity and the approximate time of the plague epizootic (according to the findings in young animals). The antibody neutralization test is useful for examination of succumbed experimental animals, for testing putrified materials when isolation is difficult or impossible, and in cases when a rapid diagnosis of plague becomes indispensable.

In connection with rodent surveys, the author opines that serological tests may well supplant the time-consuming procedures involving autopsies, organ pools, and flea pools. Serological tests may be especially useful in determining if plague still exists in the rodent population of an area.

It would seem essential to include such serological work in plague surveys in the Americas.
