TABLE 1

*Chemotherapy of trophozoite induced infections of* Plasmodium vivax *(Achiote strain) in unaltered* Saimiri sciureus

| Experiment no. | Monkey no. | Treatment initiated: Patent day | Treatment initiated: Parasitemia per mm³ | Response: Days to clear | Response: Negative days examined* |
|---|---|---|---|---|---|
| | | Chloroquine (10, 10, 5 mg base/kg in 3 days) | | | |
| 1 | 5885 | 3 | 1,100 | 3 | 52 |
| | 6409 | 5 | 1,040 | 4 | 175 |
| | 5881 | 7 | 1,160 | 2 | 15 |
| | 5890 | 7 | 1,760 | 2 | 21 |
| | 5882 | 8 | 940 | 2 | 67 |
| | 5900 | 8 | 3,850 | 3 | 73 |
| | | Chloroquine (10 mg base/kg in 1 day) | | | |
| 2 | 5895 | 5 | 1,120 | 2 | 126 |
| | 5896 | 6 | 1,160 | 3 | 38 |
| | 5886 | 7 | 1,070 | 3 | 194 |
| | 6386 | 8 | 1,590 | 1 | 161 |
| | | Pyrimethamine (1 mg/kg in 1 day) | | | |
| 3 | 5203 | 6 | 1,190 | 6 | 176 |
| | 5879 | 6 | 2,610 | 6 | 24 |
| | 5986 | 6 | 3,060 | 5 | 17 |
| | 5988 | 7 | 4,210 | 5 | 72 |
| | 5982 | 13 | 5,150 | 4 | 11 |

| | | Untreated controls: Primary attack: Patent period (days) | Primary attack: Maximum parasitemia per mm³ | Relapse(s): Subpatent period(s) (days) | Negative days examined after final patent period |
|---|---|---|---|---|---|
| 1 | 5892 | 24 | 87,130 | 40 | 103 |
| | 5876 | 39† | 69,420 | – | – |
| 2 | 5897 | 24 | 40,280 | 12 ; 33 | 23 |
| | 5898 | 55 | 76,530 | – | 22 |
| 3 | 5921 | 33† | 37,540 | – | – |
| | 5889 | 45 | 93,210 | 17 ; 31 | 105 |

* No relapses occurred in treated monkeys.
† Died during patency after maximum parasitemia.

approximated 1,000 per mm³, usually during the 1st week of patency, although some of these infections were treated during the 2nd week at higher parasitemias. Drug therapy was initiated for sporozoite induced infections also during the ascending phase, at parasitemias of at least 1,000 per mm³, except in two *Aotus* (6252 and 6894); these infections were at lower levels (after peak parasitemia) when treated. All drugs were given orally via gastric tube. Chloroquine and primaquine were administered as the diphosphate salt. One or more months after treatment of the primary attack, splenectomy was done to provoke parasite relapse in sporozoite induced infections.

The test monkeys were of Panamanian origin and free of naturally acquired malaria, as shown by examination of preinoculation blood films. Aspects of the husbandry of *Saimiri* and *Aotus* have been discussed previously.[4, 5]

## RESULTS

No evidence of drug toxicity at the highest dosages used was seen in uninfected *Saimiri* and *Aotus* as measured by body weight change and overt host activity.

TABLE I

ANIMALS SURVEYED FOR ENTEROBACTERIAL PATHOGENS ALONG ROUTE 17, DARIEN PROVINCE, PANAMÁ
SEPTEMBER–DECEMBER 1967

| Host Species | Common Name | No. Specimens Collected | | | Total |
|---|---|---|---|---|---|
| | | Area 1 Santa Fé | Area 3 Morti Hydro | Area 5 Sasardi | |
| Rats | | | | | |
| *Oryzomys caliginosus* | dusky rice rat | 7 | 7 | 27 | 41 |
| *Oryzomys fulvescens* | pigmy rice rat | 6 | 8 | 24 | 38 |
| *Oryzomys talamancae* | rice rat | 7 | 1 | 23 | 31 |
| *Proechimys semispinosus* | spiny rat | 62 | 64 | 62 | 188 |
| *Rattus rattus* | common rat | 5 | 1 | 10 | 16 |
| *Tylomys panamensis* | climbing rat | 2 | 2 | 0 | 4 |
| Opossums | | | | | |
| *Didelphis marsupialis* | common opossum | 11 | 7 | 13 | 31 |
| *Marmosa robinsoni* | murine opossum | 3 | 4 | 52 | 59 |
| *Metachirus nudicaudatus* | brown-masked opossum | 1 | 8 | 8 | 17 |
| *Caluromys derbianus* | wooly opossum | 2 | 0 | 0 | 2 |
| Bats (diff. spp.) | bats | 62 | 11 | 14 | 87 |
| Rabbits | | | | | |
| *Sylvilagus brasiliensis* | forest rabbit | 1 | 1 | 3 | 5 |
| Others | | | | | |
| *Sciurus granatensis* | red squirrel | 2 | 0 | 0 | 2 |
| Birds spp. | | 3 | 0 | 2 | 5 |
| Codorniz sp. | partridge | 2 | 0 | 0 | 2 |
| Total | | 176 | 114 | 238 | 528 |

dence of infection observed in *Oryzomys talamancae* (rice rat). In the marsupials, it varied between zero and 13 per cent, and the infection rate was highest (13.0 per cent) in *Didelphis marsupialis*, the common opossum.

In Table III, the incidence of enterobacterial pathogens among rodents and marsupials are compared by collection sites. The highest recovery rate for rats was obtained at Area 5 (Sasardi) collection sites while that for opossums was obtained at Area 1 (Santa Fé).

The frequency and distribution by collection area, and by animal host, for all serotypes of *Salmonella* and *Arizona* that were isolated are given in Tables IV and V, respectively. Of the 18 enteric bacterial pathogens recovered, 15 were *Salmonella*, two were *Arizona* and one was *Edwardsiella*, a newly recognized species apparently associated with diarrhea in human beings.[13] The predominant pathogen was *Salmonella enteritidis* ser Sandiego; it was the only serotype recovered from rodents as well as from marsupials.

## Discussion

The results of the present study not only demonstrated for the first time the isolation of *Salmonella*, *Edwardsiella* and *Arizona* from wild Panamánian rodents and marsupials, but revealed a variety of bacterial serotypes present among some of the more common wild mammals in this remote area of Panamá.

Although this investigation was undertaken over a short period of time (four months), we feel that the resulting information contributes to our general knowledge of the enteric pathogens for this region of Panamá.

*Salmonella* and *Arizona* infections in wild animal populations may contribute to the hazards of health in villages and communities in the Darién Province of Panamá. Such animals may be important symptomless carriers of diarrhea producing organisms and probably form a reservoir of infection for man and for other wild animals. This may prove important with the opening of the Darién region to agriculture and to settling of the human population who are beginning to migrate from other areas of Panamá. Furthermore, should a sea-level canal be constructed along Route 17, adequate measures for the prevention and control of diarrheal diseases among the work force and inhabitants of the region must be implemented in order to reduce the opportunities for exposure to enteric pathogens.

The presence of diarrhea-producing agents such as *Salmonellae* in rodents and marsupials may be of public health importance in Darién, through fecal contamination of food and water or direct contact of rodents with man and other animals. The chronically inadequate sanitation that prevails in the villages and communities of this region is an important contributing factor that may favor the transmission of diarrheal disease.

This investigation, like the two previous ones,[7,14] confirm the endemicity of enterobacterial pathogens in the region under study. A low order of infection or of exposure of *Salmonella* was demonstrated among personnel engaged in canal studies along Route 17; *Shigella* and *Edwardsiella* also were isolated, but *Salmonella* was the commonest.[7] The serotypes of *S. enteritidis* represented in the isolations included ser Flint, ser Miami, and ser Sandiego. These same serotypes, as well as others, were isolated from rodents and marsupials

TABLE II

INCIDENCE OF ENTEROBACTERIAL PATHOGENS AMONG SMALL PANAMANIAN ANIMALS COLLECTED ALONG ROUTE 17

| Host Species | Number Examined | Number Positive | Per Cent Positive |
|---|---|---|---|
| Rats | | | |
| *Oryzomys caliginosus* | 41 | 1 | 2.4 |
| *Oryzomys fulvescens* | 38 | 0 | |
| *Oryzomys talamancae* | 31 | 2 | 6.5 |
| *Proechimys semispinosus* | 188 | 6 | 3.2 |
| *Rattus rattus* | 16 | 1 | 6.2 |
| *Tylomys panamensis* | 4 | 0 | |
| Total Rats | 318 | 10 | 3.1 |
| Opossums | | | |
| *Caluromys derbianus* | 2 | 0 | |
| *Didelphis marsupialis* | 31 | 4 | 13.0 |
| *Marmosa robinsoni* | 59 | 3 | 5.1 |
| *Metachirus nudicaudatus* | 17 | 1 | 5.9 |
| Total Opossums | 109 | 8 | 7.3 |
| Bats (diff. supp.) | 87 | 0 | |
| Others[1] | 14 | 18 | |
| Grand Total | 528 | 18 | 3.4 |

[1]Squirrels (1 sp.), Rabbits (1 sp.), Partridge (1 sp.), Birds (spp.)

in the present study (Table IV) provide additional evidence of the importance of enteric bacteria in the local inhabitants, who live in scattered communities throughout the jungle and in close proximity to the wild animal populations of the forest.

Because the distribution of *Salmonellae* in man is inextricably linked with that in the animal population of man's environment,[15] salmonellosis is more frequently transmitted from animals to man than from man to man.[16] In developed communities, poultry and other domestic animals appear to be the principal reservoir of most of the *Salmonella* infections in man, except those infections by *S. typhi*, *S.*

TABLE III

INCIDENCE OF ENTEROBACTERIAL PATHOGENS IN RODENTS AND MARSUPIALS BY LOCALITY

| Animal Host | Area | No. Exam. | No. Positive | Per Cent |
|---|---|---|---|---|
| Rats | | | | |
| | 1 (Santa Fé) | 89 | 1 | 1.2 |
| | 3 (Morti-hydro) | 83 | 1 | 2.0 |
| | 5 (Sasardi) | 146 | 8 | 5.5 |
| | Total | 318 | 10 | 3.1 |
| Opossums | | | | |
| | 1 (Santa Fé) | 17 | 2 | 11.7 |
| | 3 (Morti-hydro) | 19 | 1 | 5.3 |
| | 5 (Sasardi) | 73 | 5 | 6.8 |
| | Total | 109 | 8 | 7.3 |

*enteritidis* biosct Paratyphi—A and *S. enteritidis* ser Paratyphi-B. But in remote rural and jungle communities, where there are few domestic animals, the wild animal fauna may constitute the important reservoir for *Salmonella* and for *Arizona*, from which man and his domestic animals can be infected or from which his food can become contaminated. Several species of amphibians and reptiles widely distributed in Panamá have already been found infected by a variety of *Salmonella* serotypes, many of which have been implicated in salmonellosis and diarrheal diseases in man in rural Panamá.[5] The various species of rodents and opossums studied in the present investigation occur throughout Panamá in high population densities. The fact that they harbor enteric pathogens merits attention as potential important reservoir and carriers of these organisms.

## Summary

Enteric bacteria pathogenic to man were sought in a total of 528 animals representing various genera of rats, opossums, bats, birds, and other small animals. Animals

TABLE IV

FREQUENCY AND DISTRIBUTION OF BACTERIAL PATHOGENS ISOLATED

| Species and Serotype | Salmonella Serogroup | Area | | | Total Strains Isolated |
|---|---|---|---|---|---|
| | | 1 (Santa Fé) | 3 (Morti Hydro) | 5 (Sasardi) | |
| *Salmonella enteritidis* | | | | | |
| Ser Anatum | E | | | 3 | 3 |
| Ser Bonaire | Z | | | 2 | 2 |
| Ser Flint | Z | | | 1 | 1 |
| Ser Javiana | D | | | 1 | 1 |
| Ser Miami | D | | | 1 | 1 |
| Ser Muenster | E | | 1 | | 1 |
| Ser Sandiego | B | 1 | | 4 | 5 |
| Ser Wassenar | Z | 1 | | | 1 |
| *Arizona hinshawii* | | | | | |
| Ser 24:24:28 | | | 1 | | 1 |
| Ser unidifferentiated | | | | 1 | 1 |
| *Edwardsiella tarda* | | 1 | | | 1 |
| Total | | 3 | 2 | 13 | 18 |

TABLE V

FREQUENCY AND HOST DISTRIBUTION OF BACTERIAL PATHOGENS IN ANIMALS CAUGHT ALONG ROUTE 17

| Species and Serotype | No. Times Strains Isolated from Host Species | | | | | | | Total Strains Isolated |
|---|---|---|---|---|---|---|---|---|
| | * | ** | † | ‡ | § | ¶ | Δ | |
| *Salmonella enteritidis* | | | | | | | | |
| Ser Anatum | | 2 | | 1 | | | | 3 |
| Ser Bonaire | | | | | 2 | | | 2 |
| Ser Flint | | | | | | 1 | | 1 |
| Ser Javiana | | | 1 | | | | | 1 |
| Ser Miami | 1 | | | | | | | 1 |
| Ser Muenster | | | 1 | | | | | 1 |
| Ser Sandiego | | | 3 | | 1 | 1 | | 5 |
| Ser Wassenar | | | | | | 1 | | 1 |
| *Arizona hinshawii* | | | | | | | | |
| Ser 24:24:28 | | | | | | | 1 | 1 |
| Ser undifferentiated | | | 1 | | | | | 1 |
| *Edwardsiella tarda* | | | | | | 1 | | 1 |
| Total | 1 | 2 | 6 | 1 | 3 | 4 | 1 | 18 |

*Oryzomys caliginosus
**Oryzomys talamancae
†Proechimys semispinosus
‡Rattus rattus
§Marmosa robinsoni
¶Didelphis marsupialis
ΔMetachirus nudicaudatus

were collected in various habitats along proposed sea-level canal route in eastern Panamá.

Ten (3.1 per cent) of 318 rats yielded *Salmonella* or *Arizona* organisms and, of the 109 opossums collected in various localities, eight (7.3 per cent) were positive for *Salmonella*, *Arizona*, or *Edwardsiella*. In contrast, none of 87 bats nor of 14 other birds and mammals sampled yielded enteric pathogens.

The incidence varied from zero to 6.5 per cent in rodents, with the highest incidence of infection (6.5 per cent) observed in *Oryzomys talamanca* (rice rat). In the marsupials, it varied between zero and 13 per cent, and the infection rate was highest (13.0 per cent) in *Didelphis marsupialis* (common opossum). Eight *Salmonella* serotypes, two *Arizona* serotypes, and one *Edwardsiella* were recovered. The predominant pathogen was *Salmonella enteritidis* ser Sandiego and was isolated from rodents as well as from marsupials. Three of the serotypes of *S. enteritidis* (ser Flint, ser Miami, and ser Sandiego) and *Edwardsiella*, isolated from the rodents and marsupials, have been implicated in human salmonellosis among personnel engaged in the feasibility studies for the proposed canal.

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