

AN INTESTINAL PARASITE SURVEY ON RONGELAP ATOLL IN THE MARSHALL ISLANDS

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In March 1954, 84 Marshallese inhabiting the Atoll of Rongelap were accidentally irradiated with fallout following the experimental explosion of a large nuclear device. They were quickly evacuated to other atolls in the Marshall Islands due to radioactive contamination of their home atoll. In 1957 their island was considered safe for habitation and a new permanent village was constructed for them. They were returned there in July of that year. In addition, a group of Rongelap people who were not exposed to radiation because they were away from the island at the time of the accident, returned to live with their fellow islanders on Rongelap. This group has served as a comparison population for examinations conducted during the past two years.

Extensive medical examinations have been carried out on these people since their exposure. In order to attempt to explain the generally high incidence of eosinophilia in these people, and in view of the lack of reliable parasitological information for the area, an intestinal parasite survey was conducted as part of the examinations carried out in March 1958, four years after exposure to radiation. Sixty-nine exposed and 112 nonexposed individuals were examined in the intestinal parasite portion of this examination.

Because general information concerning the island is relatively sparse, we propose to present here, in addition to parasitological information, some background material so that the reader may have an idea of the environment in which the Marshall Islanders live. Most of this material has been abstracted from "Military Geography of the Northern Marshalls" and much of it was confirmed by personal observations of the authors.

* These surveys are carried out by the Brookhaven National Laboratory, with participants from other organizations, and are under the direction of Dr. Robert A. Conrad of Brookhaven National Laboratory. They are sponsored by the Atomic Energy Commission with the collaboration of the Department of Defense.

GENERAL BACKGROUND

The Marshall Islands constitute a group of low coral atolls in the Pacific Ocean about 2400 miles west-southwest of the Hawaiian Islands. They extend north of the equator from 4° to 15°, and in an east-west direction from 161° E. to 172° E. Rongelap Atoll is one of the most northern of the group with approximate coordinates of 11° N. by 166° E. The total area of this atoll is 426 sq. miles of which only 2.5 sq. miles are land. The population in 1954, when the fallout occurred, was about 100. At the time of this survey, the population was not known accurately but was probably over 200.

Climate

Rongelap Atoll has a tropical marine climate characterized by uniform temperature, high humidity, cloudiness and wind. The mean annual temperature is remarkably constant at about 80°F with mean monthly temperatures not varying more than 2°. The sunlight is intense and the heat is uncomfortable in sunny places sheltered from the trade wind. Mean relative humidity is about 80 per cent and is comparatively uniform throughout the year.

Most of the rain falls in moderate to heavy showers of short duration during late summer and early fall. If a hurricane develops in the area, several days of almost continuous rain may occur. Annual mean rainfall in Rongelap is about 65 inches but there may be great variation from year to year. Although this does not represent a dry climate as understood in continental regions, the special soil conditions on the atolls result in a condition of semiaridity with such levels of precipitation.

Terrain

The usual arrangement of an atoll is a reef of varying width, irregularly ring shaped, enclosing a basin of water called a lagoon. Most of the reef is at or just below water level, but at intervals, low vegetated islets of all sizes and shapes

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FIG. 1. Rongelap islet as seen from the lagoon

may occur. Rongelap Atoll is approximately 20 by 35 miles in its greatest dimensions, and Rongelap islet, where the survey was performed, is the largest in the atoll. The islet is several miles long but only a fraction of a mile wide. Its highest prominence is probably less than 15 feet above sea level (Fig. 1).

Drainage and Water Supply

The "soil" on the islet is composed basically of loose organic limestone debris accumulated on the reef surface. The material is coarse and porous so that drainage by percolation through the ground is almost instantaneous. The amount of humus from decaying vegetation varies from place to place but nowhere is it more than a thin layer. There is normally no running or standing surface water. The only naturally occurring fresh water is rainfall which is caught on the aluminum roofs of houses and drained into cisterns (Fig. 2). Ordinarily, there exist in these coral islets, bodies of subsurface fresh water known as Ghyben-Herzberg lenses, but, so far as we know, this source of water was not used for drinking on Rongelap islet. There did appear to be one well or pit where clothes were washed but, for the most part, cistern water was used for that purpose. Stored rain water is used without chemical or other treatment.

Flora and Fauna

In general, the species of plants making up the vegetation are few in number. Coconut plantations form the dominant plant life on Rongelap but, in addition, forests of other types of trees or tall shrubs exist. Grasses of various types are also found. The canopy in these forests is not thick but considerable shade is provided. An important physiological char-

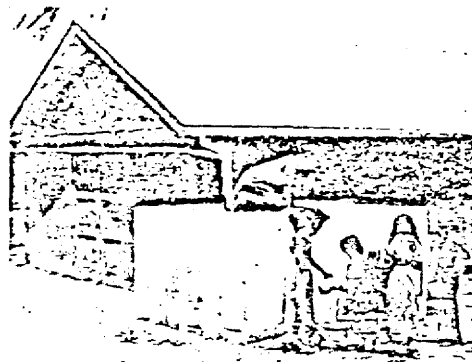


FIG. 2. Aluminum roof with downspouts leading into concrete cistern for catching rain water.

acteristic of the plants is a high salt tolerance. The windward sides of the islet are exposed to continual drenching with salt spray, and the size of Rongelap islet is such that probably all of the soil is exposed to salt washed down by rainwater from the canopy.

In keeping with the generally limited biological potential of the islets, the numbers and types of land animals are small. The only mammals (besides man) seen on Rongelap were pigs, dogs, cats and wild rats. The three domestic species are not numerous. The pigs forage in and away from the village, whereas the cats and dogs stay around the houses. The wild rat is a small species which lives in the brush away from human habitation. It invades houses in search of food but lives principally on coconuts. The only other domestic animals on Rongelap at the time of the survey were chickens. These ranged around the village.

The other obvious land animals on Rongelap are arthropods, of which the coconut crab is probably the largest. In general, insects, except for flies, were hardly noticed. One was much less conscious of them while he walked through the forests on Rongelap than in a wooded area practically anywhere in the United States. Houseflies, however, were common in the village. They were persistent in lighting on bare skin and were a distinct annoyance. Unlike houseflies in the States, which can be caught by flypaper hanging from the ceiling, these flies almost never flew above table level except to light on an individual.

In contrast to the condition on land, the sea and lagoon teemed with living things. Many varieties of fish, crustacea and mollusks were

to be found, and some of them were important food items for the islanders.

Culture and Living Conditions

The Marshallese are a Micronesian people (Figs. 3, 4 and 5). They are brown, less than medium American height, of unknown origin but speak a language with Indonesian relationships. Their hair is black and generally straight or curly but not kinky. They prefer to live in villages rather than in isolation. On Rongelap



FIG. 3. Rongelappese girls and a boy



FIG. 4. Rongelappese boys

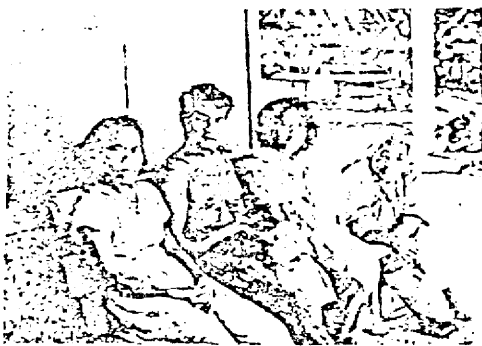


FIG. 5. Rongelappese adults

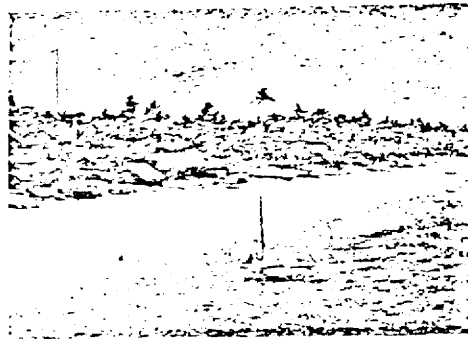


FIG. 6. Village on Rongelap islet, bordering the lagoon.

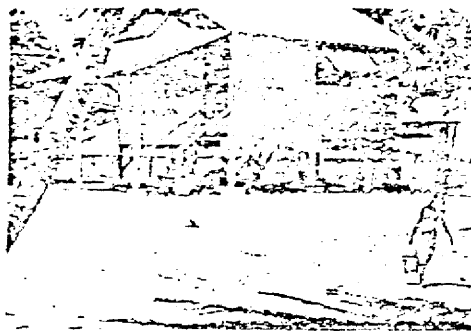


FIG. 7. Typical new house showing construction on stilts.

the village was situated on the lagoon side of the islet (Fig. 6). The houses were new, having been recently provided by the American government as the trust power. The houses are mostly raised on stilts, leaving a space about 3 feet high under the floor (Fig. 7). Much of the activity around the house takes place in this shaded, dry area, the house itself serves primarily for sleeping purposes. Sanitary facilities consist of pit privies similar to those in rural areas in the States. These are provided for each house or small group of houses.

Family relationships are difficult to define by the American system. Most inhabitants of the islet are related to each other and families frequently visit and eat with one another. It was common to distribute 6 or 7 cartons for stool collections to a single household. There were many children and young people on Rongelap. During the period of the survey, school was not in session and the children generally played in large groups. Older children commonly



FIG. 8. Children at play; note very young child in the group.

took care of the younger ones, including the toddlers (Fig. 8).

The Rongelapese dress as the Americans do in the same climate, with the exception that a higher percentage of them go barefoot. They eat flour, rice and canned foods in addition to fish, clams and other mollusks. Local vegetable foods are limited to coconuts, taro tubers, breadfruit and pandanus fruit. The islanders appear to be well fed and generally are in good health. The normal pattern of activity of these people, which is concerned with coconut cultivation and fishing, had been disrupted by the events of the past few years. At the time of the survey they had not yet entirely gone back to their usual activities.

Although, as mentioned above, privies are available around the houses in the village, it is probable that defecation is common in the brush by both children and adults. The practice of morning defecation on the beaches below the high-tide line appears to have disappeared among the Rongelapese.

MATERIALS AND METHODS

The procedures used for stool examinations were direct examinations of saline mounts, using

the Beaver¹ method for standardizing the preparations, and formalin-ether concentrations.² One stool specimen was examined per person. Cartons were distributed in the evening with the request that specimens be brought in the next day at any time. As a result, most specimens were examined within an hour after being passed. Egg counts were made on the Beaver preparations.

RESULTS

Infections found in the two main groups examined are tabulated in Table 1. For most parasites the incidence in exposed and non-exposed populations was close enough to be considered the same. There were more infections with small race *Entamoeba histolytica* and with hookworm in the nonexposed group, and more infections with *Trichomonas hominis* in the exposed group. For the three major pathogens found the over-all infection rates were: *E. histolytica*, 18.2%; hookworm, 5.5%; *Trichuris trichiura*, 34.3%.

Of the 69 exposed individuals, 40 had eosinophile counts of 5% or more, and 29 had counts of less than 5%. Among the nonexposed individuals, there were 60 cases on whom both stool examinations and eosinophile counts were avail-

TABLE 1
Relationship of radiation exposure to infection with intestinal parasites

Organism	Exposed (69 cases)	Nonexposed (112 cases)	Totals (181)
<i>Entamoeba histolytica</i>	14 (20.3)*	19 (16.9)	33 (18.2)
<i>Entamoeba histolytica</i> (small race).....	2 (2.9)	10 (8.9)	12 (6.6)
<i>Entamoeba coli</i>	25 (36.2)	35 (31.3)	60 (33.1)
<i>Endolimax nana</i>	14 (20.3)	35 (31.3)	49 (27.1)
<i>Iodamoeba butschlii</i>	—	3 (2.7)	3 (1.7)
<i>Giardia lamblia</i>	5 (7.2)	9 (8.0)	14 (7.7)
<i>Chilomastix mesnili</i>	4 (5.8)	4 (3.6)	8 (4.4)
<i>Trichomonas hominis</i>	24 (34.8)	30 (26.8)	54 (29.9)
Hookworm.....	2 (2.9)	8 (7.1)	10 (5.5)
<i>Trichuris trichiura</i>	21 (30.4)	41 (36.7)	62 (34.3)
No parasites.....	11 (15.9)	30 (26.8)	41 (22.7)

* The figures in parentheses are per cent.

TABLE 2
Relationship of eosinophilia to infection with intestinal helminths

Organism	Exposed population		Nonexposed population		Combined population	
	Eosinophilia (40 cases)	No eosinophilia (29 cases)	Eosinophilia (34 cases)	No eosinophilia (26 cases)	Eosinophilia (74 cases)	No eosinophilia (55 cases)
<i>T. trichiura</i>	14 (35.0)*	7 (24.1)	17 (50.0)	7 (26.9)	31 (41.9)	14 (25.5)
Hookworm	1 (2.5)	1 (3.4)	5 (14.7)	2 (7.7)	6 (8.1)	3 (5.5)
No helminths	26 (65.0)	21 (72.4)	13 (38.2)	19 (73.1)	39 (52.7)	40 (72.7)

* The figures in parentheses are per cent.

TABLE 3
Relationship of age of individuals to infection with intestinal parasites*

Organism	Age of individuals (yrs)				
	1-5 (43 cases)	6-12 (30 cases)	13-20 (15 cases)	21-50 (56 cases)	51 and older (29 cases)
<i>E. histolytica</i>	2 (4.6)†	7 (23.3)	2 (13.3)	15 (26.8)	5 (17.2)
<i>E. coli</i>	10 (23.3)	10 (33.3)	5 (33.3)	20 (35.7)	14 (48.3)
<i>E. nana</i>	8 (18.6)	4 (13.3)	7 (46.7)	18 (32.1)	9 (31.0)
<i>G. lamblia</i>	8 (18.6)	2 (6.7)	0	1 (1.8)	1 (3.4)
<i>T. hominis</i>	13 (30.2)	11 (36.6)	3 (20.0)	17 (30.4)	8 (27.6)
Hookworm	1 (2.3)	1 (3.3)	1 (6.7)	7 (12.5)	0
<i>T. trichiura</i>	13 (30.2)	19 (63.3)	11 (73.3)	9 (16.1)	9 (31.0)
No parasites	17 (39.5)	3 (10.0)	2 (13.3)	11 (19.6)	5 (17.2)

* Eight individuals whose ages were unknown are omitted from this table.

† Figures in parentheses are per cent.

able. Of these, 34 showed eosinophilia, 26 did not. When the incidence of *Trichuris* was determined in these groups, it was found that in both exposed and nonexposed populations more of the eosinophilia cases had *Trichuris* infections than those with no eosinophilia (Table 2). However, about half of the cases with eosinophilia showed no helminth infections at all.

In 11 of 17 *Trichuris* infections only one egg was found in the Beaver preparation. The number of eggs in the remaining 6 ranged from 2 to 6. Similarly, the hookworm burden was low.

Because infection rates for both exposed and nonexposed groups were similar, the following analyses are based on pooled results for both groups.

Table 3 presents the age distribution of infections found. *E. histolytica* was found in 4.6% of 43 children 5 years old or younger. In the 6 to 12 year group, detected infections went up to 23.3%. The highest incidence, 26.8%, was found among adults in the 21 to 50 age group.

The other two intestinal amebas, *Entamoeba coli* and *Endolimax nana*, occurred much more frequently in the youngest age group, 23.3 and 18.6%, respectively, and both showed increases among the older individuals. Among flagellates, the *Giardia lamblia* incidence was highest in the young children and almost nonexistent after the age of 12. *T. hominis* showed a high, relatively unchanged incidence in all age groups.

Of the two helminths found, hookworm showed a steady rise in incidence with age up to 50, from 2.3 to 12.5%. No infections were found after 50. *T. trichiura* occurred in 30.2% of very young children, 5 years or less, and in 66.7% of the 6 to 20 year group. In the older age group, 21 to 50, the incidence dropped to 16.1%, rising again, after 50, to 31%.

Table 4 shows a breakdown of infections according to sex, with a further division into two groups, less or more than 13 years of age. Division into the two age groups was made on the basis that both sexes probably engaged in similar

TABLE 4
*Relationship of sex of individuals to infection with intestinal parasites**

Organism	Male		Female	
	Under 13 years (41 cases)	13 and over (49 cases)	Under 13 years (32 cases)	13 and over (51 cases)
<i>E. histolytica</i>	5 (12.2)†	10 (20.4)	6 (18.7)	12 (23.5)
<i>E. coli</i>	14 (34.1)	22 (44.9)	6 (18.7)	17 (33.3)
<i>E. nana</i>	6 (14.6)	20 (40.8)	6 (18.7)	14 (27.5)
<i>G. lamblia</i>	5 (12.2)	1 (2.0)	5 (15.6)	1 (2.0)
<i>T. hominis</i>	14 (34.1)	11 (22.4)	10 (31.3)	18 (35.3)
Hookworm	0	6 (12.2)	2 (6.3)	2 (3.9)
<i>T. trichiura</i>	18 (43.9)	10 (20.4)	14 (43.8)	19 (37.3)
No parasites	9 (22.0)	8 (16.3)	11 (34.4)	10 (19.6)

* Eight individuals whose sex was unknown are omitted from this table.

† Figures in parentheses are per cent.

pursuits up to puberty, but that afterwards their daily routines probably differed. Older males had higher or similar incidences than older females for all parasites except *T. trichiura*, of which incidence was about half as great in males. Among younger males incidences tended to be lower than among young females except for *E. coli* which was distinctly higher among the males.

The only recent information available to us on intestinal parasites in the Marshallese was from a survey performed by the Medical Department of the U.S.S. Whidbey in 1948-1950. This report is deposited at the Bishop Museum, Honolulu. Sugar flotation was used to examine the stools and this may account for the rather low incidence of protozoan infections found. In that survey individuals were examined from many atolls of the Marshall Islands, but the over-all picture for helminths was similar to our findings, namely: hookworm, 6.8%; *Trichuris*, 11.0%; and *Ascaris*, 0.3%.

DISCUSSION

Although differences in incidence of various parasites occurred in exposed and nonexposed groups, there is no convincing indication that radiation had anything to do with the variations. In most instances differences can be accounted for by sampling errors in the relatively small number of cases studied. In addition, the two groups are not precisely comparable. The non-exposed "control" group consisted of individuals who lived on different islands before joining the exposed population of Rongelap. Environmental

sanitation was not necessarily the same for the two groups.

The environment on the coral atolls and the customs of the inhabitants are such that it was not expected that any trematode or cestode infections would be found. However, the complete absence of *Ascaris* in the face of a 34.3% incidence of *Trichuris* was unexpected. Life cycles of both these nematodes in the external environment are such that they are frequently found together in other areas. The history of Marshallese association with other peoples—Europeans, Japanese and Americans, make it likely that they have been exposed to *Ascaris*. Thus, one is led to the possibility that the external environment on Rongelap Atoll may be unfavorable for *Ascaris* even though very suitable for *Trichuris*. We were not successful in obtaining stools from any of the few dogs on the island in order to check for dog ascarids. Several dried pig droppings were examined a one time and no *Ascaris* was found in them. However, in the absence of more epidemiological and experimental information, one can only guess as to the reasons for the lack of *Ascaris*. Soil moisture, salinity, pH, porosity, etc., may all play some part in this unusual picture.

The fact that half the cases with eosinophilia showed no helminthic infections at all suggests that there were other significant factors causing this blood picture besides parasitic infections. On the other hand, the greater incidence of *Trichuris* among patients with eosinophilia than among those without eosinophilia, indicate that infection with that helminth was probably

a contributing factor in the incidence of eosinophilia.

It is obvious from the high incidence of parasitism in all age groups that fecal contamination is widespread and that infections begin to be acquired early in life. Although individual Marshallese are generally neat and clean looking, their simple sanitary facilities and rural life make it likely that fecal contamination is a continuing affair. The concentration of *Giardia* in children conforms to the usual picture for the incidence of this parasite. It would be unwise to ascribe special reasons for differences in infections between the sexes. Not enough individuals were examined, differences show no simple pattern, and the unsettled living conditions of these people during the past few years undoubtedly has upset their usual daily routine.

The findings of the U.S.S. Whidbey are similar to ours in the almost complete absence of *Ascaris* and in the hookworm level. We found about 3 times as many *Trichuris*, but this may have been due to better examination facilities and opportunities. The low incidence of *Ascaris* on these Islands contrast with the high rates reported by the Whidbey for Saipan (44.2%) and Palau (16.8%). It would seem that a real biological phenomenon is indicated by the *Ascaris/Trichuris* ratio of the Marshalls versus the rest of the "nearby" islands.

SUMMARY

1. A survey is reported of intestinal parasitism occurring in 69 Marshall Islanders exposed to radioactive fall-out four years previously. This is compared with parasitic infections occurring in 112 nonexposed Marshall Islanders.

2. No significant difference was found be-

tween the two groups. The over-all rates for *Entamoeba histolytica*, *Trichuris trichiura* and hookworm were 18.2, 34.3 and 5.5 per cent, respectively. No other important parasitic pathogens were found. Infected individuals generally had low worm burdens and none of the amebiasis cases showed clinical symptoms attributable to this infection.

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