"THE ECOLOGY OF BILHARZIA AND AGRICULTURAL DEVELOPMENT IN PUERTO RICO DURING THE TWENTIETH CENTURY" by William R. Jobin. CENTER FOR ENERGY AND ENVIRONMENT RESEARCH, UNIVERSITY OF PUERTO RICO AND U.S. DEPARTMENT OF ENERGY.

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The history of tropical diseases in the Caribbean has been unusually dynamic, alternating disastrous epidemics with outstanding successes in disease control, often related to man's efforts at modifying his geographical or agricultural limitations. One thinks immediately of the yellow fever and malaria outbreaks during attempts by the French to dig an isthmian canal in 1880, followed in quick succession by elimination of yellow fever from Havana, Cuba after the Spanish-American War and then from the Panama Canal Zone. These dramatic upheavals were accompanied by other, less noticed changes such as the slow recession of hookworm infections, and the stealthy spread and collapse of endemic zones of schistosomiasis in various Caribbean Islands, notably Puerto Rico (Figure 1). Schistosomiasis in Puerto Rico is of exceptional interest because it appears to be nearing extinction. A wealth of epidemiological information was available on schistosomiasis in Puerto Rico since 1906. Various surveys showed geographical distribution of the infection, apparently influenced by several major programs related to development of the island such as irrigation projects, water supply program, and rural community development schemes (Figure 1). The purpose of this report is to link the various epidemiological surveys with other historical trends, and thus ascertain the interplay of these forces on the rise and fall of this parasitic infection in Puerto Rico.

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The geographical distribution of schistosomiasis infection apparently existed as several small foci at the turn of the century. In 1904, the disease was first described in Puerto Rico by Dr. Isaac Gonzalez Martinez.

"We discovered, not long ago, the typical and spiculated eggs of Bilharzia (mansoni) in the stools of two young subjects, born and raised in this country, from which they never emigrated, and who had been suffering from dysenteric enteritis for months. It was clearly proven that the terrible worm of bilharz, crossing the Atlantic barrier, extended its odious domain to the islands surrounding the American Continent.

Perhaps further investigations will also show that the continent itself does not escape its fatal influence, given its multiple and easy communications with the Antillean Archipelago. But until now, we have seen nothing published in this sense, and we believe that no one has had the fortune to verify it. Be that as it may, the first authentic observations of Bilharziosis in Puerto Rico are ours."

The data available since 1904 are not adequate to develop a rigorous statistical analysis of the changes in prevalence of the infection through time and throughout the island. Fortunately, however, the changes seemed to occur in rather obvious and drastic ways, thus detailed information was not required to detect these changes. Nonetheless, this epidemiological analysis had to be kept fairly simple, dealing only with the large-scale changes, and the results should be regarded as largely qualitative.

HOOKWORMS AND SCHISTOSOMES

The development of a hookworm control program in Puerto Rico at the beginning of the century provided a great deal of information on the distribution of schistosome infections as well. This ran parallel with public health efforts of U.S. Army medical personnel in Cuba and

In Panama, a massive program for hookworm control began in 1903 under the guidance of Dr. Bailey K. Ashford. This program included diagnostic surveys by fecal smears in most population centers on the island. Dr. Isaac Gonzalez Martinez, who first identified the schistosome eggs in fecal smears, trained the microscopists working with Dr. Ashford, and they were searching for the eggs of the schistosome as well as those of the hookworm.

In the first decade of the twentieth century, low prevalences of schistosome infection were found in the towns of Mayaguez, Utuado, Aibonito, and a higher level on Vieques Island. Although the fecal examinations were not conducted as part of a randomized sampling program, they did cover most of the island. The complete absence of schistosome infections in Guayama and many other towns indicated that the parasite was quite limited in its distribution at that time.

In 1906, fecal samples from 600 people were examined for parasite eggs at the Guayama Substation of the Anemia Commission. In these samples, eggs of many common parasites were found, but no schistosome eggs. By 1909, over 2600 persons had been examined at this substation, and no schistosome eggs had been found in their feces.

In contrast, fecal examinations in Vieques showed a 13% prevalence of schistosome infections during the same years, the highest value found anywhere in Puerto Rico at that time.

To provide some historical context, yellow fever had been eliminated by this time from Havana, and was controlled in the Canal Zone in 1905, mainly due to the efforts of Finlay, Reed, and Gorgas. Malaria had been sharply reduced in cities where larviciding and drainage works were implemented, under the direction of Le Prince and others of the U.S. Army and the Rockefeller International Health Foundation.

There was a major agricultural shift in Puerto Rico around 1905 from coffee to sugar, due to changes in the world market.

Conditions changed due to American intervention in the island's economy following the American military invasion of 1898. The shift in agriculture was made permanent by the construction of the South Coast Irrigation Systems, which provided the necessary water to increase cane field yields to highly profitable levels. In 1895, the income from coffee had been $7.5 million, three times the income from sugar. However, by 1910, even before the irrigation systems were completely operational, the income ratio had reversed with a sugar crop worth $23.5 million and a coffee crop worth less than $6 million. This agricultural shift caused a general migration of the labor force from the coffee haciendas of the central mountains to the coastal sugar plantations. This subsequent agricultural and social upheaval was vividly portrayed in the novel "La Vispera del Hombre," which described the growth of a boy to manhood during these early decades of American occupation. The decrease in coffee cultivation seemed to assist the efforts of the Anemia Control Commission to control hookworm, as transmission required the moist, shaded hillsides of the coffee plantation. The Commission treated over 300,000 of the 9 million people living on the island in the first decade of the century. This campaign, as well as the increased use of shoes and boots, eventually resulted in the disappearance of hookworm anemia and disease, although light infections persist even today. In 1966, about 12% of the children in first grade were infected with hookworm. Twenty years after the hookworm campaign was completed, a thorough study of the distribution of schistosomiasis was conducted by Drs. Hoffman, Faust, and others involved in the establishment of the School of Medicine and Public Health. Their surveys confirmed earlier findings and additionally discovered a new, major endemic zone, the South Coast Irrigation System between Guayama and Patillas. Detailed investigations within this area showed that the disease was more prevalent.

EPIDEMIC IN GUAYAMA

In order to clarify the changes in prevalence of schistosome infections in the south coast irrigation district of Guayama over the past 70 years, it was necessary to analyze results from several diagnostic tests on various age groups. Because the

The most common test prior to 1963 was the demonstration of the presence of eggs from a single stool of six-year-old children. All of the surveys were interpreted according to this standard. The approximate prevalence to be expected if a single stool had been examined from six-year-olds, using the formol ether concentration technique (9). This interpretation required estimation of the ratio of prevalence among various age groups and the prevalence among six-year-olds. Although several laboratory procedures had been used to locate schistosome eggs in feces, they all have been calibrated and it was fairly easy to reduce the data to the common standard (Table 1).

Using the age equivalence factor and the diagnostic test equivalence factor, the results from 21 fecal surveys showed a marked rise and fall of infection, reaching a fairly stable plateau at 252 between 1930 and 1950. This high prevalence then declined to zero 12 years after the initiation of control measures (Figure 3).

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The decline of prevalence was confirmed from skin-test data on older children, decreasing to 5% skin test reactors in fifth graders by 1976, the rate of false positives expected in a non-infected population. In composite, the various prevalence surveys made between 1906 and 1976 indicated that in Guayana, the disease, which was originally almost non-existent, was spread by the introduction of irrigation. Consequently, by combining snail control with other methods, the infection rate was brought back to near zero and the disease disappeared as a public health problem. Although outbreaks of Schistosoma haenatobius have been reported in Africa, this information is probably the first documentation of an epidemic of S mansoni in a water resource development scheme.

POST-WAR TRENDS

In a survey of over 19,000 military recruits during the Second World War, the previous island-wide distribution of infection was confirmed with some additional information obtained on outlying areas such as Lajas, Fajardo, and Naguabo (Figure 2, adapted from reference 6). Several surveys in 1953 and 1954 presaged the beginning of a control program in the endemic zone along the South Coast. The combined results of these surveys indicated two changes from 1944. The Utuado and Mayaguez foci had definitely diminished and new endemic areas were appearing in the eastern lowlands, probably due to the construction of rural communities known as Parcelas, (Figure 2). As in previous surveys, the zone of highest prevalence was the irrigated coastal strip between Patill and Guayana. The causes of the reduced prevalence of disease in the western portion of the island cannot be precisely defined but urban growth after the war probably caused a reduction in snail populations, and the government

The sponsored water supply program was also probably important. No control measures had been instituted in these areas except individual chemotherapy. The endemic foci in Aibonito and Caguas were not related to sugar cane or coffee. Rather, the specific transmission sites were small, extremely poor settlements along streams on the fringes of the cities.

Probably the combination of large population centers and the locally flat topography were enough to provide the adequate mixture of snails and people to support transmission, especially around homes with poor sanitation.

Page 16: MALARIA TO BILHARZIA

Places such as Aibonito or Utuado.

Page 18: With this background, it is hardly surprising that the first director of the bilharzia control program was not a malacologist but an entomologist, Don Manuel Pérez Torres. The multi-faceted campaign for bilharzia control was gradually widened to Vieques, Naguabo, Aibonito, and the Lajas

Valley by 1956. Because of the experimental nature of these pilot projects, they were evaluated annually in the first decade of operation. The decrease in prevalence among first graders following the initiation of control in Guayama was dramatic evidence of the success achieved by these simple methods.

Page 19: APPROACHING ERADICATION

An island-wide sampling program, using adult worm antigen in a skin test on fifth graders in 1963, showed that the control program on the south coast had dramatically reduced the importance of this area. General decreases around the urban centers of Rio Piedras and Caguas were probably due to the elimination of lowlands and channelization of natural streams as part of the urbanization process.

The general rise in relative importance of eastern Puerto Rico was apparently due to the large number of rural communities constructed in lowlands under the Land Reform program initiated in 1941. The adjusted mean proportion of positive skin test reactors for the island was 24% in 1963, with only

"One small watershed near Castafier had a prevalence rate below 10%. The pilot control programs had been operating for 10 years, thus the geographic distribution of infection in 1963 was already affected. The 1963 survey showed that the eastern portion of the island had the highest positivity, especially in the Río Grande, Luquillo, Gurabo, Juncos, Las Piedras, Camuy, Aguas Buenas, San Lorenzo, and Naguabo municipalities. The next most infected areas were immediately east of the eastern focus (Fajardo) and on the western flank where the control program had reduced the prevalence.

20 PREVALENCE OF SCHISTOSOMIASIS IN PUERTO RICO FROM SKIN TEST SURVEYS,1963-1976

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FIGURE 4

An isolated focus of fairly high prevalence existed in the central mountains around Utuado, Adjuntas, and Jayuya. This was one of the first foci of schistosomiasis discovered on the island, noted in 1906 (1). By the second skin test survey of 1969, the overall proportion of positive reactors had dropped to half of the value observed in 1963 (13). One reason was the control efforts of the Health Department, but another factor was the extensive construction of water supply systems after the War (21). Of all the socio-economic changes occurring in this period, improved water supply correlated most strongly with a decrease in positivity (22).

By 1969, the island-wide proportion was 14%, with many watersheds below 10%, the lowest being the Barceloneta and Manatí area with 4% (Figure 4). All watersheds showed relatively large decreases except for Ponce which showed a slight increase, and the Upper Yauco-Castafier watershed which increased from 8% to 20%. Because of the small number of people involved in

this watershed, this increase was not too important.

In the principal focus on the eastern end of the island, the remaining municipalities with the highest positivity were Piedras, Juncos, reduced to a small pocket around Gurabo, Humacao, Maunabo, and Yabucoa."

Because of their high ranking in this survey, these areas were covered by an expanded snail control program in 1970.

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Positivity had decreased significantly in the original pilot projects, which were then placed on a maintenance program to deal with the occasional resurgences of snails. Meanwhile, the supplemented crews expanded to the new zones. For the first time, a mean proportion of positive less than 5% was found, occurring in two areas in north central Puerto Rico (Figure 4). This proportion of reactors was previously considered the level of false positives to be expected in a non-endemic area (11).

The final survey in 1976 indicated another large decrease in positive reactors, with an island-wide mean of 5.3% (14) The most striking result from this recent survey was the large number of watersheds where the mean proportion of reactors had dropped below 5% (Figure 4). This included two watersheds which had been covered by the Health Department Control Program (Patillas, Arroyo, and the watershed which included Aibonito).

In addition, this minimal proportion of reactors was found in the entire western tier of watersheds, in the Ponce watershed, and in a group of six watersheds in the central portion of the north coast. The only areas west of San Juan which had more than a minimal proportion of reactors were the Yauco watersheds which remained at 10%-13% despite means in the surrounding areas of less than 6%. This residual focus seemed related geographically to the six

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Reservoirs supplying water to the Lajas Valley Irrigation system. The positivity in watersheds covered by the expanded control program had decreased more rapidly than in the surrounding municipalities, except for Naguabo which showed only a slight decrease from 15% to 10%. Slight increases in two northeastern watersheds were due primarily to increases in several plots along the coastal highway between Carolina and Fajardo (Figure 4). Thus, the remaining center of positivity was a small portion of the

Eastern end of the island, covering about 15% of the population and about one fifth of the land area.

Chapter 24: RURAL COMMUNITIES

Since the early 1960s, increases in schistosomiasis were noted in many parts of eastern Puerto

Rico where rural communities, called "parcelas", had been created by a government program to improve rural housing (11). This program originated in the Land Reform Act of 1941 and provides free land for housing and limited farming to persons who are otherwise unable to obtain it. In most of the 400 parcelas constructed since 1950, there were no schistosomiasis problems, but in those constructed on alluvial plains in eastern Puerto Rico where drainage was poor and rainfall was high, definite foci of schistosomiasis transmission were created (23). The results of the 1976 survey indicated that the parcelas along the northeastern coast were the most important remaining foci of the disease, especially the parcelas of Monte Bello, Malpica, Fortuna, Casa Blanca, Pitahaya, Mata de Platano, Dolores and others in the municipalities of Carolina, Rio Grande and Luquillo (Figure 1). In addition to the endemic disease caused by the infections in people living in these parcelas, recent cases of acute schistosomiasis have been documented in residents of metropolitan San Juan who use this northeastern coastal area for fresh water recreation (24). There are undoubtedly many more individual

cases which go unreported, since an improved highway along the coast has made this area easily accessible to almost a million people. The present situation in Puerto Rico has changed significantly from the classic picture of endemic schistosomiasis described by Faust in 1934. In only a few small communities is there stable transmission, the majority of cases apparently coming from random sporadic exposures, thus the parasite population may be gradually decreasing in number due to geographical discontinuities in the transmission cycle (25). When a resident of San Juan becomes infected

By a dozen or 20 cercariae during a shrimp-hunting expedition along the northeast coast, those schistosomes return with him to the city and are taken out of the endemic, transmitting population. Hopefully, the drug oxamniquine will soon be approved for use in Puerto Rico, making it possible to treat the infected persons in the endemic areas. This final blow to the worm population will probably be sufficient to completely disrupt the cycle, leading to parasite eradication. The malaria parasite was eradicated from Puerto Rico after the War, and it is quite likely that the schistosome can also be eradicated. However, a word of caution is necessary, as Puerto Rico is not typical of the endemic areas of Brazil and the Nile Valley. Control or eradication is much easier in Puerto Rico since it is on the northern fringe of the tropical zone of transmission, thus temperature conditions barely allow the snail to survive.

26 The neighboring island, Hispaniola, is the last habitat of the snail as one proceeds northward, and Cuba has neither the snail nor the parasite. Furthermore, it is clear from this historical review that most of the severe disease in Puerto Rico occurred in areas of artificial environmental modifications. Before the introduction of the irrigation systems, the parasite infection seemed spotty and minor in extent.

27 SUMMARY A wealth of epidemiological information available on schistosomiasis in Puerto Rico made it possible to trace historical trends in the distribution of the disease. Using a variety of diagnostic methods, many island-wide surveys had been made on the prevalence of the infection, including a final series of 3 identical skin-test surveys terminating in 1976. The various surveys

were analyzed chronologically and the geographical distribution of the parasite was discussed in light of several major programs related to the development of the island. From a few scattered foci present in the early twentieth century, the extent and intensity of the disease.

"Increased on the south coast after the construction of sugar irrigation systems in 1914. After 1953, this major endemic area was brought under control. However, a new endemic area was developing in the eastern portion of the island, due to the creation of rural communities known as "parcelas". This increased transmission, caused by the parcelas, had been counteracted in other parts of the island after the Second World War by the widespread construction of water supply systems, and by the filling of wetlands and channelization of streams on the growing suburban fringes of the major cities. Finally, an expanded snail control program of the 1970s covered most of the newer foci created by the parcelas, except for a small area on the north coast, east of San Juan.

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By 1976, only about 100,000 people carried the parasite, mostly children with asymptomatic infections. They lived primarily in the northeastern municipalities of Rio Grande and Luquillo, with isolated groups in the Naguabo and Yauco areas, as well as scattered remnants throughout the classical endemic areas. Complete control of the disease should be accomplished in a few years if the newer drugs become available for wide-scale use in Puerto Rico.

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