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THE ECOLOGY OF BILHARZIA AND
AGRICULTURAL DEVELOPMENT IN PUERTO RICO
DURING THE TWENTIETH CENTURY

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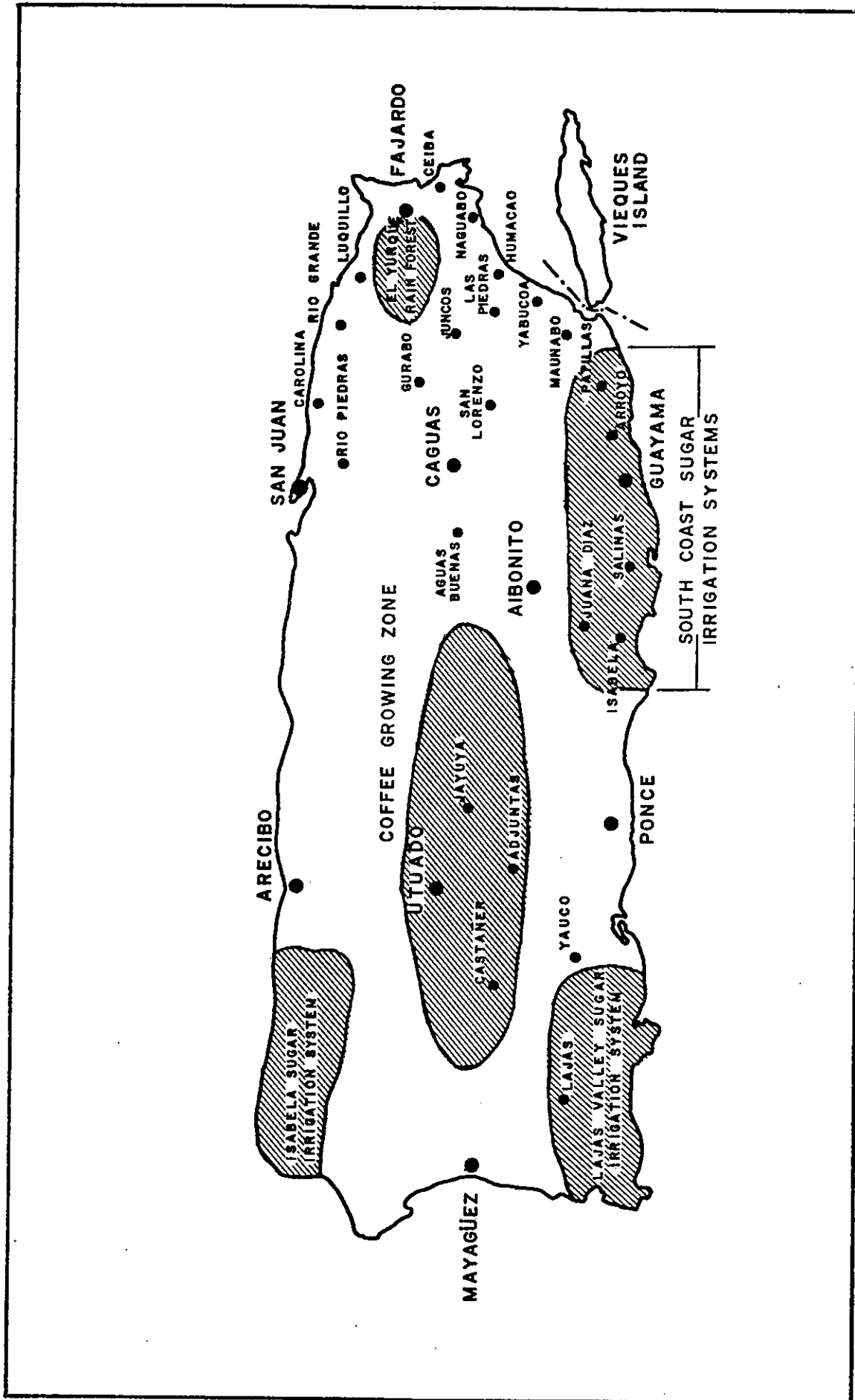
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The history of tropical diseases in the Caribbean has been unusually dynamic, alternating disastrous epidemics with outstanding successes in disease control, often related to man's efforts at modifying his geographical or agricultural limitations. 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 programs, and rural community development schemes (Figure 1). It was the purpose of this report to link the various epidemiological surveys with the other historical trends, and thus ascertain the interplay of these forces on the rise and fall of this parasitic infection in Puerto Rico.



MAJOR TOWNS AND GEOGRAPHICAL FEATURES OF PUERTO RICO

FIGURE 1

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 González Martínez:

"Al descubrir nosotros, no hace mucho tiempo los huevos típicos y espiculados de la Bilharzia (mansoni) en las deposiciones de dos sujetos jóvenes, nacidos y criados en este país, del cual jamás emigraron, y que desde hacía meses venían padeciendo de enteritis disenteriforme, quedó provado claramente que el terrible verme de bilharz, salvando la barrera del Atlántico, extendía su odioso dominio por las islas que rodean el Continente Americano."

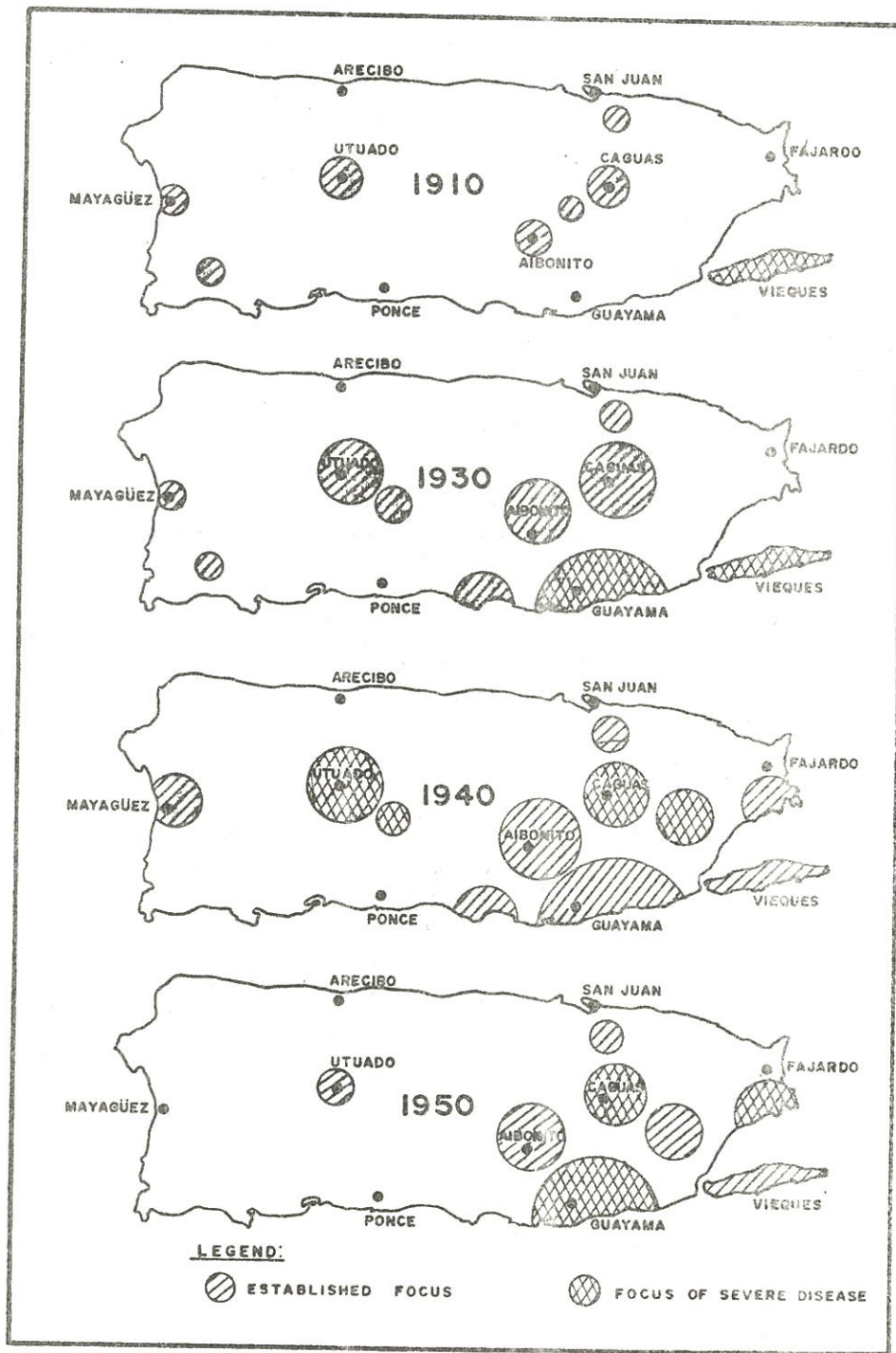
"Tal vez investigaciones posteriores demuestren también que el mismo Continente no escapa a su fatal influencia, dadas sus múltiples y fáciles comunicaciones con el Archipiélago Antillano. Pero hasta la fecha, nosotros nada hemos visto publicado en tal sentido, y creemos que nadie ha tenido la fortuna de comprobarlo. Sea de esto último lo que quiera, es lo cierto que las primeras observaciones auténticas de Bilharziosis en Puerto Rico son las nuestras."

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. Parallel with public health efforts of U.S. Army medical personnel in Cuba and Panamá, a massive program for hookworm control began in 1903 in Puerto Rico under the guidance of Dr. Bailey K. Ashford, including diagnostic surveys by fecal smears in most population centers on the island (1). Because Dr. Isaac Gonzalez Martinez, who first identified the schistosome eggs in fecal smears, also trained the microscopists working with Dr. Ashford, 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 (Figure 2).

Although the fecal examinations were not conducted as part of a randomized sampling program, they did cover most of the island, and 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



SIMPLIFIED DISTRIBUTION OF SCHISTOSOMIASIS FOCI IN PUERTO RICO, 1910-1950

FIGURE 2

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 (2). 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 set the historical references, yellow fever had been eliminated by this time from Havana, and was controlled in the Canal Zone in 1905, mainly due to 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 (15).

COFFEE TO SUGAR

There was a major agricultural shift in Puerto Rico about 1905 from coffee to sugar, due to changes in the world market conditions and because of american intervention in the island's economy after the american military invasion of 1898. The shift in agriculture was made permanent by construction of the South Coast Irrigation Systems which provided the necessary water to increase canefield yields to highly profitable levels. In 1895 the income from coffee had been \$7.5 million, three times the income from sugar. 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 (2). This agricultural shift caused a general migration of the labor force from the coffee haciendas of the central mountains to the coastal sugar plantations (Figure 1). The subsequent agricultural and social upheaval was vividly portrayed in the novel "La Víspera del Hombre" which described the growth of a boy to manhood during these early decades of american occupation (17).

The decrease in coffee cultivation seemed to assist the efforts of the Anemia Control Commission to control hookworm, since transmission required the moist, shaded hillsides of the coffee plantation. The Commission treated over 300,000 of the

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 at present. In 1966 about 12% of the children in first grade were infected with hookworm (19).

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 but in addition they 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 severe than in other parts of the island, and it was closely linked to activities within the irrigation system which had been constructed in 1914 (5):

"It was interesting to compare the low infestation rate of millworkers generally with that of the fieldworkers of Colonia Vives (Guayama). This may be accounted for by the different working conditions of the former...Fieldworkers who are active round the various irrigation systems give histories of irritation in exposed external parts of the body, and some show advanced symptoms, as indicated by ascites...One showed lesions which he claimed followed irritation of this type; another, showing evidence of marked ascites, said he had been a laborer in irrigation ditches for a long time, and recalled skin reactions on many occasions after his daily work...."

The shift in crops had apparently caused a similar change in endemic disease patterns from the hookworm related to the coffee haciendas in the mountains, to the new problem, schistosomiasis, related to the irrigation and drainage systems of the coastal sugar plantations. Given the ecological link between sugar and snails, it was not surprising that shortly after 1952 when sugar production reached a maximum of 1.4 million tons, schistosomiasis became of such pressing importance to the Department of Health that the first control program was initiated in these same irrigated zones of Guayama and Patillas.

In addition to the discovery of the new endemic zone in the South, Hoffman and Faust found that several new foci bordered the urban centers of Río Piedras and Caguas. Also the classical focus in Utuado was shown to be a small zone but with high prevalence, reaching almost 100% in children living along the river.

EPIDEMIC IN GUAYAMA

In order to clarify the changes in prevalence of schistosome infections in the south coast irrigation district of Guayama during the past 70 years it was necessary to relate results from several diagnostic tests, on various age groups. Because the most common test previous to 1963 was 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 25% between 1930 and 1950. This high prevalence then declined to zero 12 years after the initiation of control measures (Figure 3). The continuing

TABLE 1
 ANALYSIS OF PREVALENCE DATA FOR
 SCHISTOSOMIASIS IN GUAYAMA, PUERTO RICO
 1906-1976

YEAR	DIAGNOSTIC METHOD	AGES TESTED	NUMBER TESTED	NUMBER POSITIVE	REPORTED PREVALENCE	EQUIVALENT PREVALENCE BY ETHER CONCENTRATION METHOD	EQUIVALENT PREVALENCE FOR SIX YEAR OLDS
1906	1* fecal smear (1)	all	623	0	0%	0%	0%
1909	2 fecal smear	all	2,612	0	0%	0%	0%
1927	3 fecal smear	students(2)	83**	32	39%	78%	50%
1930	4 fecal smear	all	916	121	13%	26%	26%
1933	5 fecal smears	students			20-30%	40-60%	13-40%
1944	6 acid ether conc.	18-38 yrs.(3)	393	114	29%	29%	20%
1953	7 sodium sulfate						
1954	8 triton-ether	first grade	748	150	20%	20%	20%
1953-66	9 formol ether	all	4,000		19%	19%	6%
1960	10 formol ether	first grade	250-700		20%-	20-0%	20-0%
1963	11 fecal smear	students	1,127	56	5%	10%	6%
1965	12 skin test	fifth grade			33%	N. A.	N. A.
1969	13 fecal smear	students	1,693	17	1%	2%	1%
1976	14 skin test	fifth grade			26%	N. A.	N. A.
					5%	N. A.	N. A.

- (1) simple smear prevalence=1/2 prevalence by ether concentration method
- (2) age conversion for students (6-18 yrs)=1.5 x 6 year olds.
- (3) age conversion for inductees (18-38 yrs)=1.5 x 6 year olds.

*Reference

**Omit, group was too few in numbers.

HISTORY OF SCHISTOSOMIASIS IN GUAYAMA, PUERTO RICO

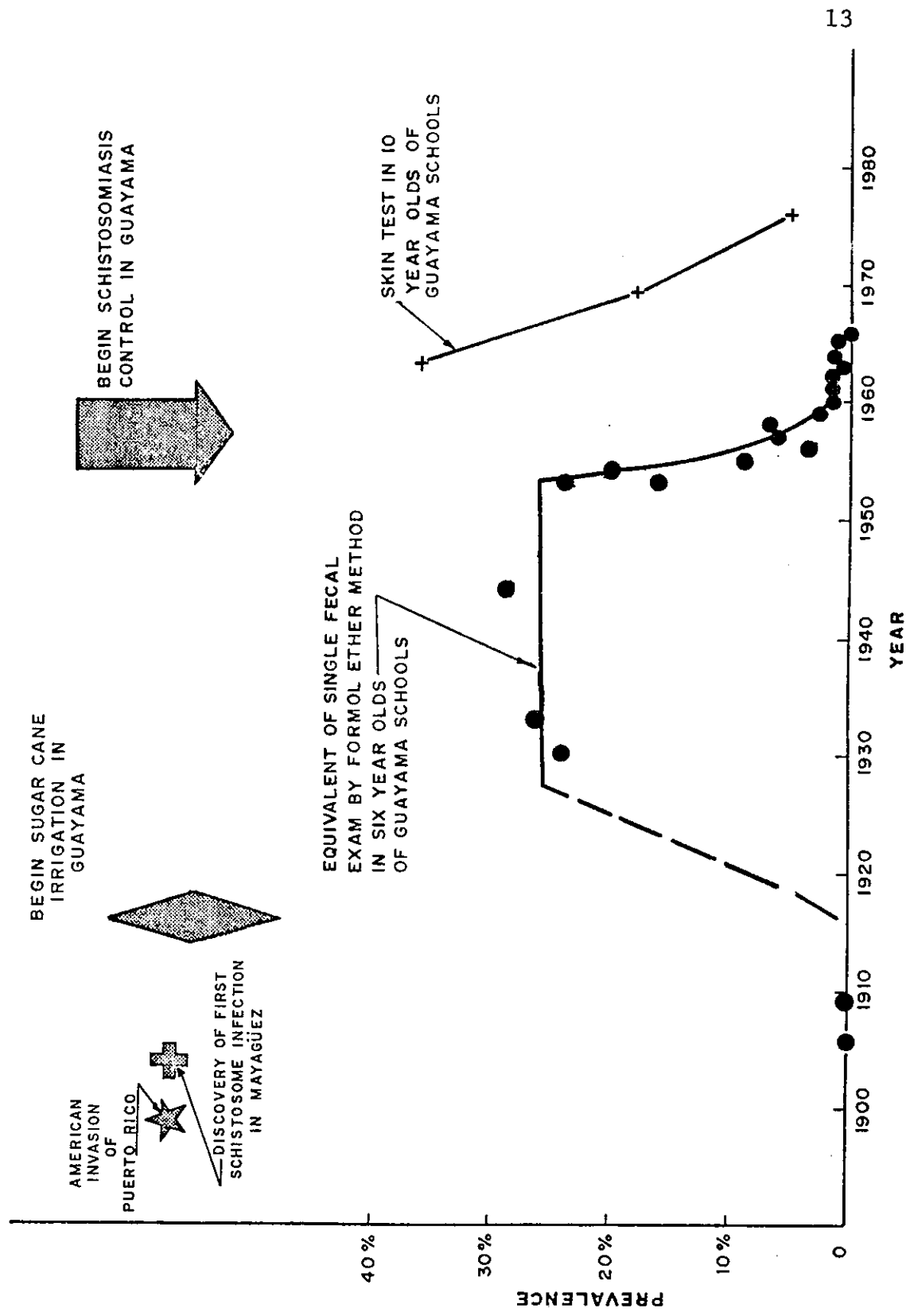


FIGURE 3

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 Guayama, the disease, which was originally almost non existent, was spread by the introduction of irrigation and that 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 haematobium 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 pre-saged 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 Patillas and Guayama.

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 reduction in snail populations, and the government 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.

MALARIA TO BILHARZIA

After the snail studies and parasitological surveys in the early 1950's the need for a schistosomiasis control program became clear and the Health Department gave the endemic zones of the south coast highest priority, establishing the first pilot projects in Patillas, Arroyo, and Guayama by 1954. In many respects, the program of bilharzia control began where the program of malaria control had finished. Malaria control began in Puerto Rico in 1925 and terminated in 1954 with eradication of the parasite from the island. The major drainage projects of the malaria program, constructed on the south coast from 1946 to 1948, undoubtedly reduced snail habitats somewhat, at least in the urban areas. In addition the ditching of swampy areas in Salinas, Santa Isabel, Juana Díaz, Patillas, Arroyo, and Guayama from 1949 to 1954 must have caused additional reductions in transmission foci in the south coast (20).

The preliminary work of the bilharzia control unit in Patillas, Arroyo, and Guayama was financed from 1951 to 1954 through the malaria control budget, and the malaria control personnel were then shifted to the bilharzia unit when malaria control operations were successfully terminated in 1954. Drainage projects for malaria control were limited to coastal areas, none being constructed in mountain towns such as Aibonito or Utuado.

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.

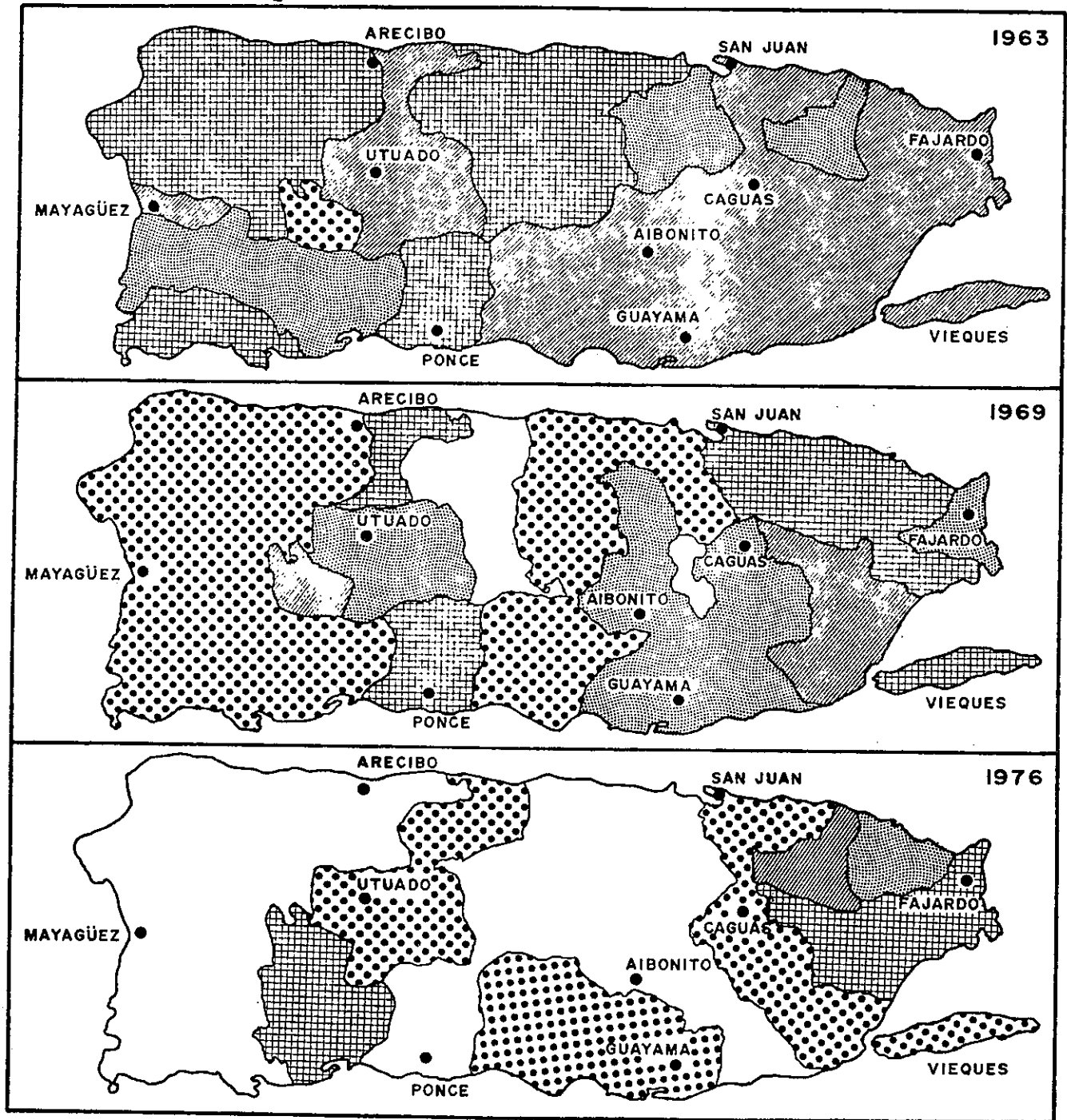
The multi-faceted campaign for bilharzia control was gradually widened to Vieques, Naguabo, Aibonito, and the Lajas Valley by 1956. Because of the experimental nature of these pilot projects, they were evaluated annually in the first decade of operation (9). The decrease in prevalence among first graders following the initiation of control in Guayama was dramatic evidence of the success achieved by these simple methods (Figure 3).

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 (Figure 4). General decreases around the urban centers of Río Piedras and Caguas were probably due to elimination of lowlands and channelization of natural streams as part of the urbanization process (11). 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 reactor for the island was 24% in 1963, with only one small watershed near Castañer 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 the Río Grande, Luquillo, Gurabo, Juncos, Las Piedras, Caguas, Aguas Buenas, San Lorenzo, and Naguabo municipalities. The next most important tier of infected areas were immediately East of the eastern focus (Fajardo) and on the western flank where the control program had brought the prevalence down.

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



LEGEND FOR PREVALENCE

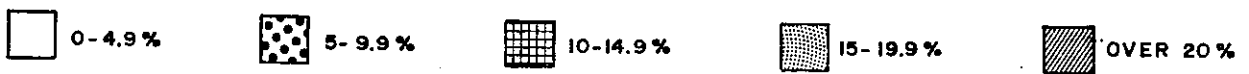


FIGURE 4

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 apparently another factor was the extensive construction of water supply systems after the War (21). Of all the socioeconomic changes occurring in this period, improved water supply correlated the most strongly with decreases 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-Castañer 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 reduced to a small pocket around Gurabo, Las Piedras, Juncos, Humacao, Maunabo, and Yabucoa. Because of their high rank in this survey, these areas were covered by an expanded snail

control program in 1970. 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, while 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

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 north eastern watersheds were due primarily to increases in several parcelas 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.

RURAL COMMUNITIES

Since the early 1960's 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 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 Plátano, Dolores and others in the municipalities of Carolina, Río 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 so 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. A word of caution is necessary however, since 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. 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. Previous to introduction of the irrigation systems, the parasite infection seemed spotty and minor in extent.

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 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 construction of sugar irrigation systems in 1914. After 1953 this major endemic area was brought under control while a new endemic area was developing in the eastern portion of the island, due to 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 filling of wetlands and channelization of streams on the growing suburban fringes of the major cities. Finally an expanded snail control program of the 1970's covered most of the newer foci created by the parcelas, except for a small area on the north coast, east of San Juan.

By 1976 only about 100,000 persons carried the parasite, mostly children with asymptomatic infections. They lived primarily in the northeastern municipalities of Río 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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