STUDIES ON SCHISTOSOMIASIS MANSONI IN PUERTO RICO *

II. THE EPIDEMIOLOGY AND GEOGRAPHICAL DISTRIBUTION OF SCHISTOSOMIASIS MANSONI IN PUERTO RICO

1. EPIDEMIOLOGY OF THE INFECTION ON THE ISLAND.

By WILLIAM A. HOFFMAN and ERNEST CARROLL FAUST
From the School of Tropical Medicine of the University of Puerto Rico under the auspices of Columbia Uinversity and from the Department of Tropical Medicine, Tulane University of Louisiana, New Orleans, La.

CONTENTS

INTRODUCTION

GEOGRAPHY, CLIMATE AND CHIEF AGRICULTURAL PRODUCTS OF PUERTO RICO

Puerto Rico, the smallest and most easterly island of the Greater Antilles, lies in latitude 18.29° N. and longitude 66.7° W. It is rectangular in form, with an area of about

* Contribution from the School of Tropical Medicine, San Juan, P. R., and from the Department of Tropical Medicine, Tulane University of Louisiana, New Orleans, La. Supported by grants from the Bailey K. Ashford Scholarship Fund and the National Research Council.
This is the second article of a series dealing with schistosomiasis in Puerto Rico.
Received for publication, December 10, 1933.

3,600 square miles. The climate is subtropical and equable, with an average annual mean temperature of 76° F [1]. Greater fluctuations of temperature occur in the high, irregular interior than in the coastal zones.

The principal range of mountains runs from east to west through the center of the Island, with the result that the moisture-laden Trade-winds precipitate their rain on the northern slope and leave the southern coastal area so dry that, in some districts, a xerophytic vegetation has developed. Such rain as may fall is carefully conserved, where feasible, in reservoirs. The aridity is combated by diverting the abundant water supply of the north coast for the use of extensive irrigation for the south coast, thus equalizing the distribution of water for the flourishing sugar industries of the Island. These sugar plantations and mills of the southern coast give employment to thousands of Puerto Rico's dense population. Conditions relating to the cultivation of the crop play an appreciable part in the maintenance of Manson's schistosomiasis.

METHODS OF OBTAINING EPIDEMIOLOGICAL DATA ON SCHISTOSOMIASIS

One of the most dependable and interesting methods of collecting data concerning the presence, distribution and incidence of schistosomiasis is by perusal of publications of previous investigators, outstanding among whom is González Martínez [2a & 2b], discoverer of rectal schistosomiasis in Puerto Rico and pioneer research worker in this phase of parasitology. Dr. Buitrago first informed us of the presence of the disease in the Guayama district. First-hand experience recounted by various contemporary physicians on the Island has also largely contributed to our fund of knowledge.

Several districts have been revealed to us as endemic foci through the examination of the excreta of all patients brought to the University Hospital, which operates in conjunction with the School of Tropical Medicine, clinical data also helping to furnish the clue in some of these cases. Ability to recognize initial symptoms may also provide information of value [5].

Examination of large series of fecal samples, preferably from individuals of school age, constitutes one of the best methods of determining presence as well as incidence of the

disease. Smear examinations do not always reveal the presence of schistosome ova. A method of concentrating ova through sieving and sedimentation usually markedly increases the percentage of positives among a group [3]. One of us (E. C. F.) employs a method of concentrating ova, utilizing the principles of sieving and centrifugation, and finds it particularly useful in studies where time is the limiting factor.

Piquiña, or intense itching, a symptom which often follows the penetration of the skin by cercariae, may be used as a means of determining the presence of schistosomiasis and the locality where it has been contracted. An isolated instance of schistosomiasis, however, does not necessarily brand the district from whence the patient comes as infective. We have seen two positive cases among an otherwise negative series examined at the town of Adjuntas, who upon questioning were found to have contracted the disease at the endemic focus of Utuado. Definite proof of the presence of schistosomiasis in a district is offered by the demonstration of the cercariae of *S. mansoni* in the intermediate host, *Helisoma (Planorbina) guadeloupense* [4]. This proof is difficult and tedious to obtain—snails must be collected, tested over a period of time to be certain of infection, development, and shedding of cercariae, and careful discrimination must be made between the cercaria of *S. mansoni* and that of another fork-tailed variety occasionally seen.

KNOWN ENDEMIC FOCI

Thus far, investigations have shown schistosomiasis to be endemic in the following localities: (1) Guayama, Arroyo, Patillas, (2) Humacao, (3) Caguas, (4) Río Piedras, (5) Aibonito, Barranquitas, Comerío, (6) Utuado, (7) Mayagüez, Añasco, (8) Lajas, (9) the Island of Vieques. In addition to these, other apparently isolated districts have come to light, which may be included in this list *.

(1) *The Guayama–Arroyo–Patillas area.*

As regards incidence and comparative frequency of severe cases, the area comprising Guayama, Arroyo and Patillas must be considered the most important of the endemic foci. This is largely due to the conditions attendant upon the

* See map showing endemic districts of Puerto Rico.

◓ = POSITIVE CASES AND POSITIVE SNAILS

● = POSITIVE CASES

○ = NEGATIVE SNAILS

MAP SHOWING PRESENT KNOWN ENDEMIC AREAS.

extensive irrigation system there, of which we will give a short explanation:

Large reservoirs in the hills supply irrigation for the extensive cane lands on the coastal plain. These plantations are divided into units, each one being called a *colonia* or *hacienda.* The term, *central,* may refer either to the extensive holdings of a sugar-producing organization possessing grinding-equipment, or to the mill itself and the immediately adjoining land. Here the term will be restricted to the first definition. Many of the *colonias* have their individual reservoirs supplied from large hill reservoirs, from wells, or water from the small rivers of the region. Irrigation ditches, the largest with control gates, ramify the section they supply, branching, re-branching, and gradually dwindling in size to the point of disappearance among the cane.

In Guayama, series of fecal samples from residents—principally school children—have given infestation rates of from 20 to 30 per cent by means of gross smear technique.

Colonia Vives (Esperanza), of this district, showed a high incidence, 56 per cent of the feces of those examined there containing ova of *Schistosoma mansoni.* This may be due to the fact that the conditions under which water is obtained help to make Colonia Vives the most schistosomiasis-ridden district visited. The reservoir itself receives its water from the infected Guamaní River through a broad, deep ditch of slowly flowing water, and is of earth, so thickly beset with aquatic vegetation that it may be taken for a natural pond. We have found numerous snails of all sizes there, with an infection rate varying from 8 to 28 per cent.

It was interesting to compare the low infestation rate of millworkers generally with that of the fieldworkers of Colonia Vives. This may be accounted for by the different working conditions of the former, whose water supply originates in a deep well nearby, and whose occupational activities are restricted to the mill and immediate vicinity. Though residing in a highly endemic area, this group and the families belonging to it can readily avoid exposure.

Piquiña is frequently experienced by people who have bathed, waded, and washed clothes, or cars, in the Guamaní River, such sensation being felt more frequently at periods

of drought when very low water prevails than at times of high water when the swiftness of the current makes the assembling or permanency of snail colonies extremely difficult.

The rough and rapid course of the Guamaní from its source near Carite reservoir to Charco Pérez, a pool about 2 kilometers north of Guayama, seems to offer little opportunity of existence to snails. This pool, a favored bathing place, must be given serious consideration, since several residents of Guayama claimed it as the source of their illness (schistosomiasis). When this site was visited (August, 1933), the stream resembled a mountain torrent, under which conditions neither snails nor cercariae could survive. Near the Municipal Hospital the stream is dammed, and most of the water diverted into a lateral channel supplying Vives. No snails were taken in the quiet area above the dam at this time, nor in the pool below, a bathing place frequented chiefly by small boys. About 3 kilometers west of the city the Ponce–Guayama road crosses the stream as a ford. Here automobiles are frequently washed, and statements were made to the effect that *piquiña* is noticeable during periods of low water. Another pool, Charco Dajao, between the road and sea, also attracts bathers.

Schistosomiasis is by no means lacking in other parts of the Guayama district. Field workers who are active round the various irrigation systems give histories of irritation of exposed external parts of the body, and some show advanced symptoms, as indicated by ascites. Large numbers of small *Helisoma* shells were found round the reservoir Machete (located near the Central Machete), but no living specimens.

In 1927 [4] the western limit of the infected area was tentatively placed at Colonia Reunión, an isolated Aguirre holding, which lies a short distance beyond the town. In 1933 the information given by majordomos (field superintendents) and fieldworkers of Central Guamaní, between Guayama and Central Aguirre, indicated that schistosomiasis is well established there. The usual testimony of *piquiña* was given and the presence of ascites noted. In addition to irrigation ditches, the wet weather stream, Río Seco (Dry River), running parallel to the Río Guamaní, is also a source of infestation; part of the year its stream is reduced to a series of pools in which some of the residents bathe. The

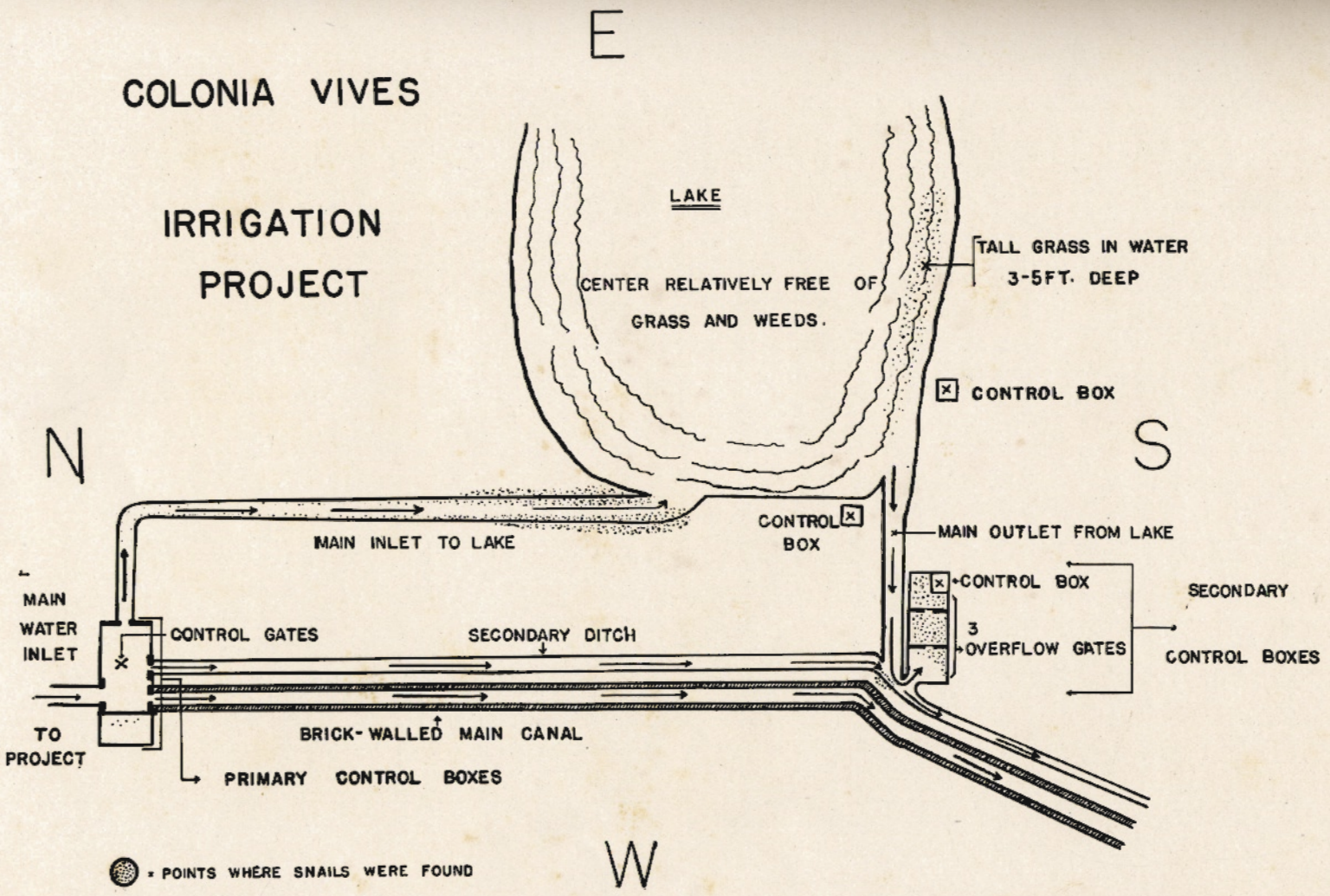


DIAGRAM ILLUSTRATES THE RELATIONSHIP OF THE RESERVOIR OF COLONIA VIVES TO PRINCIPAL IRRIGATION DITCHES, AND DENOTES PRESENCE AND RELATIVE ABUNDANCE OF SNAILS.

affected belt extends from the sea to the foothills, a distance of approximately 2 kilometers.

East of Guayama schistosomiasis is well known. Through the courtesy of Dr. Muñoz McCormick we were able to investigate conditions at Central Lafayette, just beyond the town of Arroyo. We found there a large, brick and concrete reservoir, about 100 feet square, in which empty shells only of small *H. guadeloupense* were found. The individual upon whom devolved the task of regulating the control gates and cleaning the reservoirs had attended to these duties for twelve years, during which time he had been exposed almost daily to the water and had frequently bathed in the reservoir. He stated emphatically that he had never experienced *piquiña,* and his excellent physical condition lent support to his statement. This apparently contradictory information was substantiated when the majordomo of the *colonia* said the water supply of the reservoir was pumped from a local well. The chances of schistosomiasis being contracted through the agency of a deep well are practically negligible.

On a neighboring *hacienda* a reservoir about $60 \times 80 \times 16$ feet, supplied with water from the Patillas Canal, was then examined. Though only about one third full at the time, a large number of living *H. guadeloupense* were visible along the sides. An employee stated that he had seen small snails being carried into the reservoir, near which there is a small ditch flanked by a group of houses. Residents of the vicinity were quite insistent regarding the *piquiña*-producing potentialities of the stream. 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 Arroyo River and other streams seem to be sources of infestation during periods of little precipitation, as *piquiña* has been experienced after bathing in them. Of six fecal samples from Arroyo recently submitted by Dr. Muñoz McCormick, ova of *S. mansoni* were found in three.

Patillas is also said to have a high incidence, statements of persons residing near the Patillas River lending additional evidence to the belief. Five hundred snails, from three of which cercariae of *S. mansoni* emerged, were taken

from a concrete irrigation ditch paralleling the road between Patillas and the Patillas River.

(2) *Humacao and vicinity.*

Humacao, a town of considerable size, lies on the east coastal plain of the Island beyond the irrigated region of Patillas. Here the annual rainfall makes the irrigation systems unnecessary. In 1927 [4] one positive case, that of an itinerant peddler, was found; in 1932, 30 fifth-grade pupils from this immediate locality submitted fecal samples, all negative by routine smear examinations, but four positive for *S. mansoni* by sedimentation-concentration. Dr. Charis Gould of the Ryder Memorial Hospital has encountered an occasional case from the vicinity of Central Pasto Viejo. At present, schistosomiasis is but of minor importance in Humacao, though further investigation may indicate a higher degree of incidence than we have so far found.

The Loíza and Humacao watersheds both drain the municipality of Las Piedras, from which several cases of schistosomiasis have been sent to us. Infestation of one of these was definitely traced to bathing in the Humacao River.

(3) *The Caguas area.*

Caguas, about 15 miles west of Humacao, can be considered one of the most important foci of schistosomiasis on the Island, both from the extent of territory involved and frequency of advanced cases found. One group of samples, supplied as usual by school children, gave a schistosome incidence rate of 30 per cent; another group, more than 60 per cent. The Caguas valley is devoted in the main to the cultivation of sugar and tobacco, though some land serves as pasture. The most heavily infested area lies in a district known as Barrio Bairoa in which the mill of Central Defensa, just north of Caguas, is situated. In contrast to the cane fields south of the Cordillera Central, irrigation is not practiced, so there is no relationship between the production of sugar cane and the disease. The employment roll of the mill, however, has brought many people to a site favorable for the contraction and dissemination of schistosomiasis. On two occasions when snails were collected near Central Defensa, an average of 2.5 to 3 per cent gave off cercariae of *S. mansoni,* but they were found in scanty numbers. The Cagüitas River, a tributary of the Loíza River, passes to the

south of Central Defensa and just beyond flows beneath the main road between Ponce and San Juan. Between this bridge and the Aguas Buenas road there is a number of pools frequented by bathers; one, for example, in the *barrio* of Cañabón is known to be endemic. Recent enquiries have elicited the information that the Bairoa endemic area extends at least a kilometer further north to the Bairoa River, in which, a short distance from the main road, there is a pool, Charco Grande, where *piquiña* has been felt after bathing.

The Río Cañas, a rapid and strong stream 6 kilometers north of Central Defensa, marks the northern limit of Barrio Bairoa and a topographical change from low to elevated land. No signs of *Helisoma* could be found there, nor could any history of autochtonous schistosomiasis be gathered from the inhabitants.

About 5 kilometers south of Caguas, the Las Quebradillas River runs parallel to the San Juan–Ponce road for a short distance. At this point there is a village and a demonstration school. Practically all residents interviewed stated that at times of low water itching was noted after exposure to this stream. At Trujillo Alto, in the same watershed, the examination of several hundred school children disclosed only one positive case. The Caguas area of infection may yet be found to have wider boundaries than those we have tentatively placed.

(4) *The Río Piedras district.*

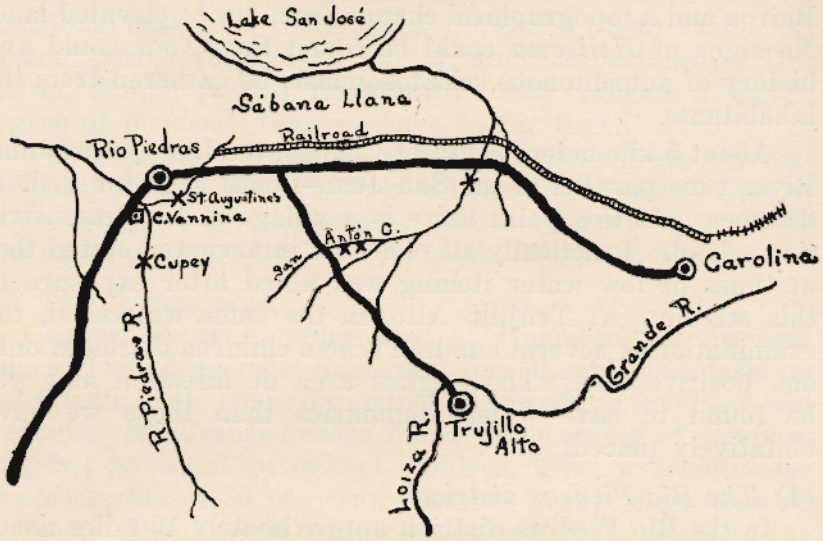
In the Río Piedras district, approximately 15 miles north of Caguas, there exists an important and extensive area in which schistosomiasis is contracted, but whose boundaries are not yet defined.

A rate somewhat in excess of 20 per cent prevailed recently among children of a small rural school within the southern limit of the locality.

The Río Piedras River, too deep to permit detailed examination, meanders along in a sluggish manner between banks thickly beset with smartweed and high grass, which would seem to be a most favorable environment for *Helisoma.* Few snails have been found near the surface, and those few were uninfected. We are, however, forced to consider this stream as an important factor in the spread of schistosomiasis, due to serious and fatal cases which have occurred in

the district from Barrio Cupey to San Agustín School, located near the Río Piedras–Carolina road, and from fecal examinations of school children who have bathed in the river.

San Antón Creek, a little more than 2 kilometers south of Río Piedras, crosses the Trujillo Alto road, roughly parallels the Carolina road, later crosses this highway, and finally discharges itself into the salty lake of San José. Apparently its course west of the Trujillo Alto road is of little importance, while the "dangerous stretch" undoubtedly includes



RIO PIEDRAS DISTRICT

Sites where schistosomiasis is known to have been contracted are marked with an X

that part from a half kilometer east of the Trujillo Alto road to a point where the stream crosses the Carolina road.

Eight cases recorded by Pons and Hoffman [5] traced their infestation to a pool about 3 kilometers southeast of Río Piedras, as did three other cases who also had bathed in it. Residents along or near the stream state that irritation frequently follows bathing or exposure during periods of little flow. Some of these persons give histories of abdominal distress, diarrhea and bloody stools—in other words, typical symptoms of schistosomiasis. Fecal examinations of chil-

dren between the ages of 5 and 15 from several schools of the Sabana Llana district, situated on the Río Piedras–Carolina road, revealed infestation rates ranging from 16 to 60 per cent, the last figure representing the incidence at a school 7.5 kilometers east of Río Piedras. This, at present, marks the eastern limit of the Río Piedras–Sabana Llana area.

(5) *The Río Plata watershed.*

The Río Plata and its tributaries comprise the most extensive drainage system on the Island. The source of the main stream lies in the mountains southwest of Cayey; it discharges itself into the Atlantic Ocean near Dorado. The area including Aibonito, Barranquitas and Comerío is one in which apparently a high incidence of schistosomiasis is found. At Comerío during 1926–27 [4] routine smears disclosed a schistosome infestation rate of 12 per cent among a group consisting chiefly of young individuals. By improved methods of diagnosis this figure would probably have attained 20 per cent.

From Aibonito no similar data are available, but infestations of two boys [3], one a temporary, the other a permanent resident, were traced to a creek beyond the town. Adjoining an estate, the property of the temporary resident's family, there is a pool with a mud bottom, partially shaded by bamboo; the current is reduced on entering this pool, and adhering to the bamboo roots and other vegetation, specimens of *H. guadeloupense* were found in fair numbers, a few of which discharged cercariae of *S. mansoni.*

At Barranquitas a third of the fecal samples from 220 individuals, mostly children, contained ova of *S. mansoni.* This may have been caused by bathing in a pool formed by the River Barranquitas, where infected snails have been found, and where people have felt *piquiña* when emerging from the water.

(6) *The Utuado focus.*

Utuado, almost midway between Arecibo and Ponce, is one of the longest established centers of schistosomiasis in Puerto Rico. The first recorded autopsy case of González Martínez [2b] reported by him in April, 1904, was from this area. By the end of that year the Anemia Commission [6] had found ova of *S. mansoni* in stools of 21 patients at Utuado. The

investigators were inclined to think the affection more common than was then evident. The results of a short survey in 1927 [4] and the testimony of Dr. Carrasquillo seemed to bear this out. At Salto Arriba, a *barrio* above the town, smears of 23 per cent of the samples submitted by children contained schistosome ova. At Río Abajo, a district just below Utuado, 30 per cent of 47 children, and 50 per cent of 14 adults, were found positive. Concentration methods undoubtedly would have increased these figures. During the past summer, one of us (E. C. F.) found ova in 35 of 89 samples from Río Abajo, and in 10 of 24 samples submitted by persons living along the banks of the Viví River.

The Viví River, which joins the Arecibo River at Utuado, is notorious for the relationship it bears to *piquiña*, although in 1927 a thorough search along its course failed to yield specimens of *H. guadeloupense*. Some were taken from various small branches of the main stream, and many from a drainage ditch along the Utuado–Adjuntas road. Only one specimen taken from one of the tributaries, was found to be infected. This area of infection seems to be limited, probably extending not more than 5 miles above and below Utuado. At Adjuntas rocky and rapid streams occur. Below Utuado a fair grade is evident, and the current of the Arecibo River for some distance is quite swift. Special conditions conducive to the spread of schistosomiasis seem to exist at Utuado, including, first, the location of this municipality in a valley, and second, the slow current of the Viví River at certain seasons, both of which are factors of importance.

(7) *The West Coast area.*

Along the west coast, Mayagüez seems to be the most important center. González Martínez [2b] first definitely demonstrated that schistosomiasis was by no means uncommon in this region, and reported 136 cases from Mayagüez. A series from this locality in 1926 showed a low rate. During the past summer an incidence of 10 per cent was obtained from 89 samples submitted by individuals living in the southern part of the town, near the slaughter-house (Río Coquí). A few cases with a heavy output of ova accompanied by intestinal symptoms have been seen, who have given a history of having bathed in the Yagüez River, north of the city. No snails collected near Mayagüez gave off cercariae of *S. man-*

soni. Schistosomiasis appears to be entirely absent at Maricao, located in the hills east of Mayagüez. A few positive cases from Añasco have been met with, and Dr. García de Quevedo states that occasional positives from the district have come to his attention. Situated in a plain well supplied with water, Añasco would seem to be a favorable site for the development of schistosomiasis, though snails have not been found there as yet.

(8) *The Southwest Coast area.*

Dr. Ruiz Nazario, who formerly practiced at Lajas, claims schistosomiasis is endemic there, his statement being based upon smear examinations of patients. A scattered case or two has been encountered at Barrio Candelaria near Laguna Cartagena, a large, swampy body of water not far distant from Lajas. One of these had always resided there. *Helisoma guadeloupense,* for the most part small specimens, abounds along the margin of the lake.

(9) *Vieques.*

Twelve per cent of fecal samples examined by the smear method at Vieques, a small island of about 20×5 miles off the east coast of Puerto Rico, contained ova of *S. mansoni.* Infected snails were also collected. Nearly all the streams on the island are brackish, but salinity, within certain limits, at least, does not seem to affect the molluscan host.

Additional isolated foci.

Jayuya, a small town 12 miles southeast of Utuado, on the basis of vague reports relating to the contraction of schistosomiasis had, in the past, been considered as an area possibly infected. Within the last few months, two individuals, a member of the staff of a sugar *central* and his wife, bathed on several occasions in the Caricaboa River, one of the branches of the Caonillas River, which latter flows into the Arecibo River some 10 kilometers below Utuado, and found that irritation of the skin followed such activities. Later, owing to abdominal distress they consulted a physician, who found by stool examination ova of *S. mansoni.*

A branch of the Bayamón River flows through Barrio Pueblito Viejo, just before it reaches the center of Bayamón. One severe case, that of a young girl who has always resided in the aforementioned *barrio,* has come to our attention. No

systematic study has been attempted here, but the affirmative accounts of *piquiña* experienced at this point seem sufficient to establish it as a focus. Citrus growers owning property in the upper portion of this stream have also given confirmatory though undetailed information as to the occurrence of schistosomiasis on their lands. People living near this stream use it for bathing.

Data has been furnished by Dr. Colmore, a member of the University Hospital Staff, concerning a woman who bathed or waded in a stream at Quebrada Limón, a *barrio* between Ponce and Peñuelas, a district heretofore unsuspected. The irritation that was felt after exposure was quite intense. Later, ova of *S. mansoni* were recovered from the stool. A similar instance has been recorded from Morovis.

From the Gurabo district two cases have been recorded, one quite seriously ill, both of whom had bathed in the Gurabo River, or its tributary, the Valenciano.

Information of such definite character may be considered sufficient to rate an area as infective, even though the evidence relates to but one case.

Suspected areas.

No cases of schistosomiasis were encountered at San Lorenzo during the survey of 1926–27. The same watershed involved at Caguas drains this municipality, and part of its course through the district apparently offers favorable conditions to snails which have been found there. An employee of the School of Tropical Medicine, a former resident of San Lorenzo, had suffered from schistosomiasis, although it could not be determined whether the ailment had been acquired actually there. On making inquiries among friends there, he has found that they have suffered from urticaria after bathing; thus, San Lorenzo, for the present, can only merit suspicion.

Though no evidence has accumulated as yet in regard to the occurrence of schistosomiasis in Aguas Buenas, its presence might be expected at least between that town and Caguas; the Cagüitas and Bairoa Rivers, both infective streams near Caguas, have their origins in the vicinity of Aguas Buenas.

Salinas, mentioned before, may be an endemic area. Reports of *piquiña* in the district, correlated with an abun-

dance of snails in a narrow aqueduct which runs along the Ponce road, give some ground for the belief that it will in time be included among the known positive localities.

The same holds true for the Colonias Florida and Alomar near Santa Isabel, and Hacienda Teresa near Salinas. The presence of thousands of shells along irrigation ditches in the cane fields east of Ponce provides at least justification for investigation in that section. Information has come to hand from various points within the area including Salinas and Santa Isabel giving accounts of *piquiña*. A limited number of fecal samples obtained from Central Mercedita and St. Luke's Hospital of Ponce yielded one positive case, that of an itinerant food pedler, Similarly, the abundance of snail shells in a stream adjacent to Central María Antonieta near the Cayey radio station should be considered sufficiently important to call for further study, even though the Cayey series of fecal samples in 1927 were entirely negative.

In the cane area between San Germán and Mayagüez, snail shells were encountered in abundance as were snails in the bottom lands between Lajas and Guánica. In the latter locality *S. mansoni* cercariae were not found.

Juncos, like its neighbor, Gurabo, is drained by the infective Loíza watershed. Several fecal samples forwarded from there by Dr. Mújica were found to be positive; however, Juncos can only be classified as suspected territory, until the epidemiological evidence is confirmatory, which at present it is not.

It must be borne in mind that the presence of *H. guadeloupense* does not necessarily signify that *S. mansoni* is present. Localities where this species is known to occur without the apparent co-existence of *S. mansoni* are: the Quebradillas–Lares region, Dorado (La Sardinera), Pueblo Viejo, Toa Baja, Cabo Rojo, Sunoco and San Juan.

THE HABITS OF THE INTERMEDIATE HOST

Partial control of schistosomiasis may be achieved by repressive measures against the intermediate host. To effect these measures we must first study the habits of the snail in relationship to its environment, which study has been begun, but is at present incomplete.

We present some of the known facts pertaining to this phase of the problem:

The molluscs appear to be partial to the roots of various plants, especially to those of the water hyacinth, among which they may obtain both food and protection.

All bodies of water in which snails seem to thrive have thus far been alkaline in reaction, the pH varying in the main from 7.2 to 7.8. The tap water of San Juan (pH 6.6) appears to exert a deleterious effect which may be due in part to the high chlorine or alum content, these substances being added to sterilize the water and to precipitate foreign matter. Open exposure of the water for several hundred feet seems to eliminate this unfavorable factor. In the Muñoz Rivera Park of San Juan there are series of pools formed after the chlorinated water has run some distance, which have become definitely alkaline in reaction. Aquatic vegetation may be partly responsible for this change [7]. Snails occur in considerable numbers here and seem to thrive.

Representatives of *H. guadeloupense* have also been taken from water so brackish that it has a salty taste, at Sunoco, a suburb of San Juan, and from the island of Vieques.

Though the snails evidence a decided preference for quiet water, they can maintain themselves, at least for a time, in fairly rapid currents. At Aibonito numerous specimens were found in a quiet pool, below which point the stream flowed rapidly over stones, and here also numbers of snails were discovered, flourishing despite adverse conditions. On various occasions they have been observed holding their own against a rather noticeable current, although aquatic vegetation then served as an aid. At another time snails were seen actually proceeding against a current of moderate velocity. This happened between the Vives reservoir and the principal control gate, the snails moving toward the latter point. It would seem, then, that the species is capable of adapting itself in part to unfavorable factors.

Though usually found in streams, *H. guadeloupense* occurs in another type of water deposit, namely in the limestone sinks so common between Quebradillas and Lares. These pools, some of which attain a length of 100 feet, come into being through the gradual dissolution of the limestone until a lower impermeable layer is reached, or until sufficient débris is deposited on the bottom of the depression to permit the retention of water. Despite the relatively low rainfall prevailing in this region, many of the limestone sinks con-

tain water throughout the year, and a permanent water supply plus abundant vegetation creates stable conditions of a favorable nature for the existence of the snails, which thrive in many of these ponds, a large proportion of them reaching the maximum dimensions for the species, a diameter of 1.25 inches. Owing to the abundance of lime for shell formation, the shells are strong, not fragile, as is the case with snails from many other districts, at Río Piedras and the vicinity which produce the most delicate types, and the molluscs themselves are hardy, as are those from Guayama and Patillas. No example of an infected snail has so far been found in a limestone sink.

Though the biology of *H. guadeloupense* is at best but imperfectly known, a few facts relating to its development have been ascertained. The egg masses consist of various numbers of yellow, broadly oval eggs, about 1 mm. long, embedded in a translucent albuminoid material. These masses often contain 30 eggs and are laid on stones, vegetation, soil beneath the water, or on other snails. In the laboratory, emergence of the snail body from the egg capsule usually takes place 7 to 8 days after oviposition. As mentioned above, the snail may attain a maximum diameter of about 1.25 inches, though only in situations most favorable to its development. After a year's growth, the diameter is approximately 1 inch.

Occasional observations during several years have indicated that certain conditions are detrimental to the existence of snails. One of these is the drying of the stream or body of water in which snails live. While it cannot be claimed that total destruction results from removal of water in the irrigation ditches and reservoirs, yet the procedure seems partially effective at least in reducing the molluscan population. During the past summer heavy rainfall gave sufficient water at Colonia Vives and the supply of irrigation water was cut off. About 10 days after this the reservoirs and ditches were practically empty except for small pools here and there, and for a short channel in the reservoir leading to the outlet (control gate), in which a number of living snails were found. Shells of many snails (*Helisoma*) of all sizes were observed in the branch leading to the reservoir. Some, quite obviously were dead; others, doubtless, had receded more deeply into their shells, so that their

bodies were not visible from the shell orifice. Since tests were not made to ascertain what percentage of these shells contained living snails, no definite statement can be made regarding the effects of the drying. Furthermore, the snails, during this period of approximately three weeks in which irrigation water was withheld, received water from frequent showers, some of which persisted for hours. Barlow [8] has shown that a large proportion of *Planorbula* in the Nile region survived a drought period of from 40 to 50 days, the majority having saved themselves by burrowing into the mud. At Colonia Vives there was little evidence of such adaptation to circumstances.

A detrimental effect appears to be exerted upon the snails by the daily emptying and filling of reservoirs, with the exception of that of Vives, which more closely resembles a pond of natural origin than the others. All such structures invariably contained, in so far as conditions permitted examination, examples of numerous small shells of *H. guadeloupense*. It would seem that the small snails are continually brought to these reservoirs, but that the daily fluctuations of the water level prevent development, though possibly mature snails might be present on the bottom. Difficulty of access, however, due to the soft muddy depths and possibility of contracting infestation, have combined to prevent detailed examination of such sites. In spite of the failure to demonstrate large snails in these reservoirs, the testimony of laborers concerning irritation following exposure inclines one to the belief that those that exist may be instrumental, in part at least, in conveying the infestation to man.

A reservoir which supplies the mill of Central Lafayette near Arroyo is not included in the group of reservoirs considered above, as it does not seem to be emptied and filled with the same regularity that the others are; hence its condition is more or less stable and favorable to the propagation of snails, and we found quite large specimens of *H. guadeloupense* in it, on the day we visited it. Occasionally the water of this reservoir is allowed to overflow (it has its base at ground level), and at such times the floating shells of all sizes are carried to the earth below.

Heavy rainfall may also adversely affect snails. After protracted rains these molluscs are often absent, or present in greatly diminished numbers, whereas previously they were

quite abundant. Heavy rains give rise to strong river currents which may carry the snails to unfavorable situations or even to the sea. Rainfall, if sufficiently heavy to cause flooding, may form residual pools, which in the muddy stage of evaporation may hold infected snails, endangering any one treading in them with bare feet. Instances of this nature have been noted in the Caguas area. However, this factor may also act in such a manner as to disseminate infected snails and schistosomiasis.

Great meteorological disturbances also wreak havoc on the intermediate host. After the hurricanes of San Felipe and San Ciprián in 1928 and 1932, respectively, *H. guadeloupense,* which had previously abounded in the branch leading to the Colonia Vives reservoir, had entirely disappeared. A similar condition was observed near San Juan.

H. guadeloupense is more widespread than *S. mansoni,* the parasite it harbors. Yet, careful search, even in a very highly infected area often fails to reveal snails, or at best, but few. At Utuado where numerous cases, many of them serious, have been known for years, the intermediate host could not be found in the Río Viví along which most infestations of the district occur. Relatively few were taken elsewhere in the area. From the *barrio* Río Coquí of Mayagüez in which the disease is known to occur, only one shell was recovered. Large numbers of the snails were collected in a swampy area north of the city; none, however, infected with *S. mansoni.* There were few found at Barranquitas and Comerío, both endemic centers, and only fair numbers at Aibonito. The Río Piedras River ranks as very dangerously infective; few snails, all non-infected, have been collected there. From the San Antón Creek of the same district, the efforts of two collectors were required to obtain 65 snails. As regards the abundance of the intermediate host species, conditions in the Cagüitas River, flowing near Caguas, are similar to those of San Antón Creek.

It appears that the molluscan host flourishes most abundantly in water artificially impounded. The large numbers obtained from the irrigation ditches near Guayama and Patillas have already been mentioned. Another favorite site seems to be municipal reservoirs, as those of Río Piedras, Río Grande, Central Lafayette and Camp Buchanan (this last near the Bayamón road, a short distance from San Juan).

The Río Piedras River supplies the town of Río Piedras, and in time of water-shortage, San Juan. Snails are unknown in a series of reservoirs adjacent to the river, although their sides are covered with algae and aquatic vegetation grows in the water. This water is pumped into a reservoir on a hill several hundred feet above the city. Here, thousands of *H. guadeloupense* may be seen. Snails of this species have been taken from water deposits on the island which comprises old San Juan, which deposits are supplied through the municipal water system. Possibly small snails or eggs have been carried to these points from the Río Piedras reservoir. The molluscs attain their greatest abundance in the reservoir in July, August and September, similar seasonal abundance having been noticed by residents of the Cayey district. Failure to find the snails in considerable numbers in any particular locality may be attributed in part to seasonal fluctuations.

Occasionally snail-colonies are encountered. Though few snails have been taken in the Río Piedras River, yet, in a small brook less than 50 feet from where it joins the main stream, several hundred snails were collected among water plants and grass in an area of a few square feet. Similar collections have been made near Utuado, Cayey, and from a few other localities. Such findings suggest that the small tributaries supply the larger streams in great part with their snail population. Occasionally, concentrations of *H. guadeloupense* are encountered in the most unexpected situations such as in a swampy area of La Sardinera near Dorado, in a ditch bordering the bay of San Juan, and in very brackish water at Sunoco, an outlying *barrio* of San Juan. The dissemination of the snail in many cases cannot be satisfactorily accounted for, and long and careful studies will be required to answer some of the difficult questions that have arisen concerning its spread. Thus far, no evidence of the presence of snails has been found in the Guajataca and Patillas reservoirs, although the profusion of vegetation along the margins of the latter would seem to provide a most favorable environment; the former furnishes irrigation to land between Arecibo and Aguadilla, the latter to the cane fields between Patillas and Salinas. The principal canals of both systems contain large numbers of snails whose presence can usually be disclosed at the further end of the

inverted siphons through which the canals are enabled to cross beneath the roads. At such a site near Guayama, hundreds of snails, some living, most dead, nearly all rather small, can be seen among the débris that accumulates there. The current in the main canal is very swift, the sides quite bare, and in so far as we are aware, receives its water only from the reservoir. Where do these snails breed? We believe that they must come from the reservoir though none as yet have been found there. These observations tend to indicate that the distribution of *H. guadeloupense* is very "spotted" and irregular.

HABITS OF THE POPULATION FAVORING EXPOSURE AND INFECTION

The habits of the people play no small part in the contraction and spread of schistosomiasis; in fact, could these be modified in certain respects, schistosomiasis as well as other intestinal helminthiases would cease to be a public health problem in Puerto Rico. However, when it is considered that hookworm has been combated in Puerto Rico for thirty years and is still widely distributed, though to be sure, individual infestations have decreased, it cannot be presumed that any great change in the habits of the people will be effected in the near future or that schistosomiasis may be controlled through such means.

Promiscuous defecation is probably the most important factor in the spread of schistosomiasis, in so far as man is concerned. Fecal samples were found along the banks of the Cagüitas River, which would be carried into the stream itself at the first heavy rain or rise of the river above its normal level. The same conditions are noticed at Colonia Vives. The field laborer, far from his dwelling and latrines, relieves himself at the most convenient place, which is sometimes a partially dry irrigation ditch. Near Guánica a latrine was seen built directly over a drainage ditch.

The tendency of children to defecate promiscuously is well known. Cort [9] and others have stressed this point in relation to ascaris, as have Faust and Meleney [10] in connection with their studies of schistosomiasis japonica in China. We have observed the same tendency in Puerto Rico on occasions even in propinquity to latrines. This habit in children is of

her condition improved considerably, and she was warned not to expose herself again to the waters of this stream. Later, however, she resumed the practice of laundering clothes there, probably because the river provided the only available place to do so.

Some pools located below waterfalls may offer comparative safety. Thus far snails have not been encountered in such sites. In one highly endemic area (Barranquitas), the residents are advised to use a pool of this type which happens to be accessible.

The later stage of schistosomiasis, evidenced by cirrhosis and ascites, occurs among laborers in the cane fields, especially among those to whom the care of the irrigation ditches has been delegated. Their activities include cleaning the ditches and diverting the water of a large artery into one of two smaller ones by raising a dam of earth across that one which is to remain unfilled. These cases are frequently met with in the Guayama and Arroyo cane lands, where the men, through almost daily exposure to cercariae, develop infestations comparable to those of the fellaheen of Egypt. Interrogation of such individuals almost invariably elicits the information that they have been working in irrigation ditches for a long time. The highest mortality due to schistosomiasis may be found among this group.

The first director of the irrigation service had *piquiña* twenty-five years ago, and technical workers of the Insular Irrigation Service, as well as employees of a lower grade, are subject to schistosomiasis through the very nature of their professional activities. The death of one of the former group is attributed directly to this.

The youngest individuals we found harboring eggs of *S. mansoni* were a girl under two years and a boy of three and a half, both from Colonia Vives. Several other cases only four years old have been recorded. Infestation at such an early age is usually connected with residence in close proximity to cercariae-containing waters, though the age at which infestation begins may vary with the locality. The most frequented bathing site of Barranquitas is more than a mile distant from the town. School children, questioned in regard to this point, stated that they usually bathed there about the

time they were in the fifth-grade age group. Positive cases were not consistently found until the tenth year, although one was discovered at 5 years old. In the Sabana Llana district fecal samples of pupils from four schools were examined. At one of these the rate of infestation reached 60 per cent. The homes of these children in the main were close to San Antón Creek—in fact, it flowed along their back yards. Here an appreciable percentage of children already passed schistosome ova in their seventh year. Among these children more males than females harbored schistosomes, for although the girls often bring water to the home, and while so engaged may be exposed, the boys bathe more frequently, and thus have more ready access to infective waters. Where pupils live a considerable distance from streams containing infected snails, the proportion of girls passing ova is lower, and such a group is less prone to infestation; moreover, boys show in increasing rate after the tenth year. The available data pertaining to the age of first exposures in regard to the distance of homes from infective waters are not sufficiently extensive to present in tabular form; nevertheless, the trends expressed above are quite definite.

Members of the lowest classes, from an economic viewpoint, are naturally affected to a greater extent than those in more fortunate circumstances. In an endemic area they will probably live in greater proximity to infective waters, upon the supply of which they are often entirely dependent. This holds good especially for rural and semi-rural districts. The towns as a rule have some type of piped water system and their inhabitants need not expose themselves to schistosome cercariae in obtaining the household's supply.

A better economic status, however, does not necessarily bar schistosomiasis. Children of well-to-do parents desire to go swimming as much as other children, and often do so in cercariae-infested waters, thereby contracting schistosomiasis. Also, many temporary residents spend the warmer months at Aibonito and Barranquitas, either living in hotels or on estates. Several such cases have been brought to the attention of the writers. Recently, aquariums have become fashionable in Puerto Rico, and an instance has been known where the owner of the fish, anxious to include local snails and pond vegetation in his collection, has dabbled in infested

waters to his own undoing. Picnics or excursions in a rural locality are also a source of danger when bathing activities form part of the programme. On one occasion in which business and pleasure were combined, eight individuals became ill [5]. Foreign residents as well as islanders fall victims to the disease, though less frequently.

On the whole, there are many foci on the Island where the necessary factors combine to propagate the infestation. Evidence points to the conclusion that the disease is gradually spreading, not only in regard to endemic areas, but to new areas, heretofore unsuspected as infective.

These epidemiological observations recorded here have been made over a period of several years, and although incomplete, the data justify certain conclusions which we present:

CONCLUSIONS

1. Schistosomiasis is an important public health problem in Puerto Rico. As far as available data indicate, it is widely but irregularly distributed. The most important foci are the Guayama area, including Arroyo and Patillas, Humacao, Utuado, Caguas, Río Piedras, Sabana Llana and Barranquitas. Our knowledge of the distribution is still being added to.

2. Two principal types of environment are responsible: (1) streams, especially the pools where individuals prefer to bathe, and (2) the irrigation system south of the principal mountain range. The second is derived from the first. Both co-exist in the irrigated regions of the south, while only the first is known to other areas. In the interior, the disease tends to be more prevalent where the water systems go into the valley.

3. The intermediate host, *Helisoma guadeloupense,* prefers a quiet environment such as that provided by pools formed in periods of low water which generally develop during the first four months of the year, and which are frequented by individuals for bathing purposes. These mutual preferences tend to bring the definitive and intermediate host in close proximity, and thereby favor the spread of the disease. *H. guadeloupense* as a rule is not found in great numbers in natural bodies of water, with the exception of

limestone sinks. It can be found in great abundance in water courses and deposits of an artificial nature, municipal reservoirs, and in parts of irrigation systems. Hydrogen-ion readings of water from various situations where snails were found were uniformly alkaline. Removal of water, frequent fluctuations of water level, heavy rains and hurricanes, affect the snails unfavorably. The methods by which the snails are spread, are still imperfectly known.

4. The habits of the people play an important role in the spread of the disease. Evidence of pollution of water courses can be observed frequently and instances of diversion of sewage into streams are also known.

5. Infestation is usually contracted through bathing or wading in infected waters. The dependence of inhabitants of an endemic area upon the water of an infected stream for household purposes exposes individuals to cercariae. The most advanced cases occur with greatest frequency among laborers connected with the irrigation system of cane fields in the south. Women washing clothes in the streams may develop schistosomiasis.

6. Schistosomiasis is not restricted to the poorer classes, although infestations occur most frequently in this group, since the well-to-do individuals usually have less opportunity of exposure. Many of them, however, especially children, contract the disease through bathing.

7. The age at which schistosomiasis is first contracted depends in part upon the distance of a source of infestation from the homes of individuals or of a community. Among one group who resided near an infective stream, infestation was already common in the seventh year; in another, where the source was distant, infestations were not numerous until the tenth year. One child, at two years of age passed ova, another, at three and a half years; one case did not become exposed until after his forty-fifth year.

8. We believe that schistosomiasis is spreading and its incidence increasing, though slowly. The north western part of the Island, at present not an endemic area, may, unless certain unknown inhibiting factors be present, become so. Snails abound in the limestone sinks there, one of which is known to be surrounded by dwellings and is grossly pol-

luted. Snails have established themselves in the recently developed irrigation system of this area and have increased enormously. The spread of schistosomiasis to these regions seems inevitable.

ACKNOWLEDGMENTS

Acknowledgments are due to those many individuals from whom we have requested aid during the preparation of this study. Members of the Insular Departments of Health and Education have rendered valuable service in obtaining fecal samples, thus enabling us to ascertain the presence and incidence of schistosomiasis in many areas. Private individuals and practitioners have also supplied information of value. Dr. P. Bonelli has for several years been indefatigable on our behalf in Guayama. His fellow physicians in that city have also aided us. The help given by the organizations of Central Aguirre and Central Guánica has been much appreciated. The labors of Mr. J. Janer, assistant in the School of Tropical Medicine, and of his predecessors, Dr. R. A. Marín and Mr. Oliver González, have played no small part in the preparation of this work. It is a matter of great regret that we are unable to acknowledge in detail the many favors rendered.

REFERENCES

1. Fassig, O. L. The Climate of Puerto Rico. P. R. Rev. of Pub. Health & Trop. Med. **4**: 201. 1928.

2a. González Martínez, I. La Bilharziosis en Puerto Rico. Tip. Bol. Merc. San Juan. 32 pp. 1904.

2b. Investigations on the Prevalence and Clinical Features of Intestinal Bilharziosis (Schistosomiasis mansoni) in Porto Rico. New Orleans Med. & Surg. Jour. **69**: 352. 1916.

3. Hoffman, W. A., Pons, J. A. and Janer, J. C. The Sedimentation-Concentration Method in Schistosomiasis mansoni. The Puerto Rico Jour. of Pub. Health & Trop. Med. **9**: 283. 1934.

4. Hoffman, W. A. Studies on Schistosomiasis (*S. mansoni*) in Porto Rico. Preliminary Report on the Distribution of *S. mansoni*. P. R. Rev. of Pub. Health & Trop. Med. **3**: 223. 1927.

5. Pons, J. A. and Hoffman, W. A. Febrile Phenomena in Schistosomiasis mansoni with Illustrative Cases. P. R. Jour. of Pub. Health & Trop. Med. **9**: 1. 1933.

6. Ashford, B. K., King, W. W. and Igaravídez, P. G. The First Anemia Commission. San Juan, P. R. pp. 92. 1904.

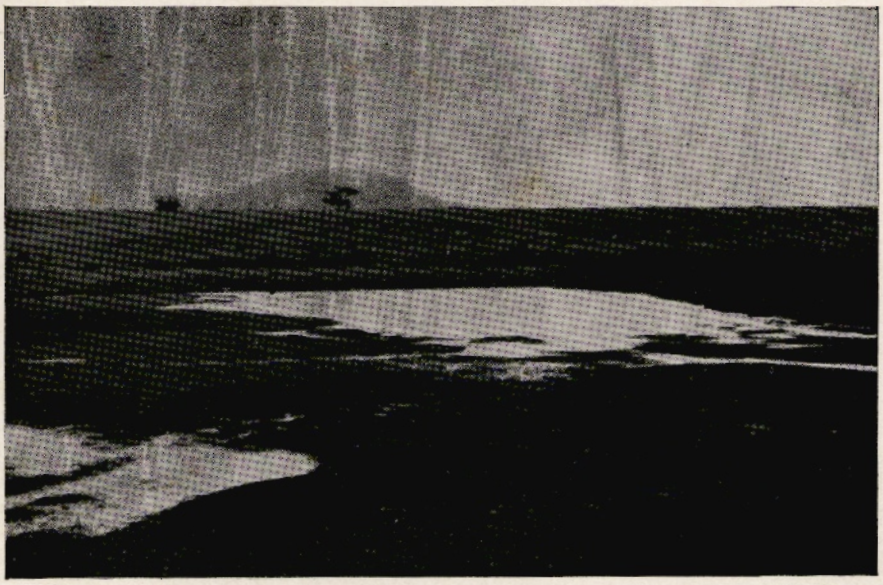
7. MATHESON, R. and HINMAN, E. H. A Seasonal Study of the Plancton of a Spring-fed Chara Pool versus that of a Temporary to Semi-Permanent Woodland Pool in Relation to Mosquito Breeding. Am. Jour. Hyg. 11: 174. 1930.

8. BARLOW, C. H. The Effect of the "Winter Rotation" of Water upon Snails involved in the Spread of Schistosomiasis in Egypt. Am. Jour. Hyg. 17: 724. 1933.

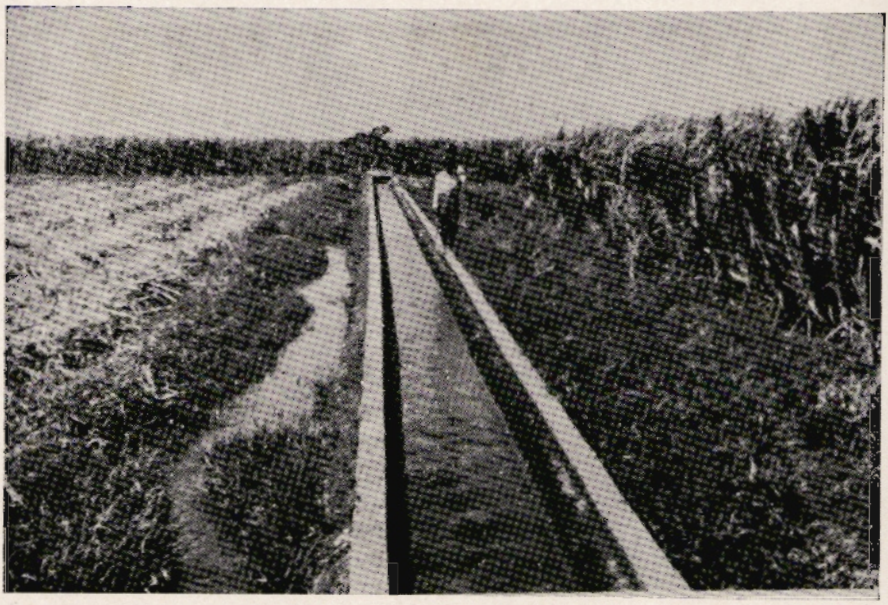
9. CORT, W. W. Recent Investigations on the Epidemiology of Human Ascariasis. Jour. Parasit. 17: 121. 1931.

10. FAUST, E. C. and MELENEY, H. E. Studies on Schistosomiasis Japonica. Am. Jour. Hyg. Monogr. Ser. No. 3: 339 pp. 1924.

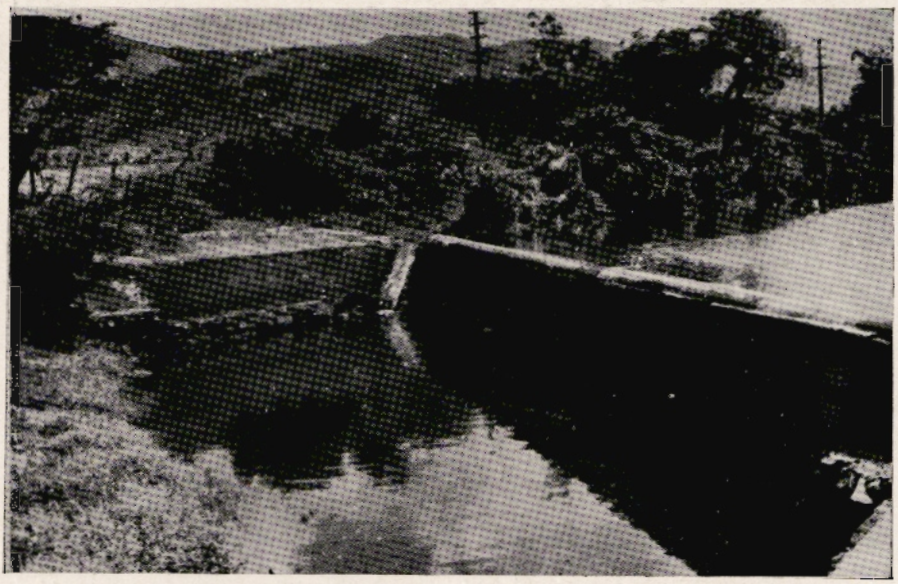
Reservoir at Colonia Vives. Note resemblance to a natural pond and thick marginal vegetation.



Reservoir at Colonia Vives. At this time, August 1933, owing to the heavy rainfall the reservoir was not needed to supply water, and was therefore permitted to remain empty.



Principal irrigation stream at Colonia Vives. Owing to the smooth sides and swift current few snails are able to gain a foothold. Many specimens of *Helisoma*, some infested, can be collected in the ditch at the left.

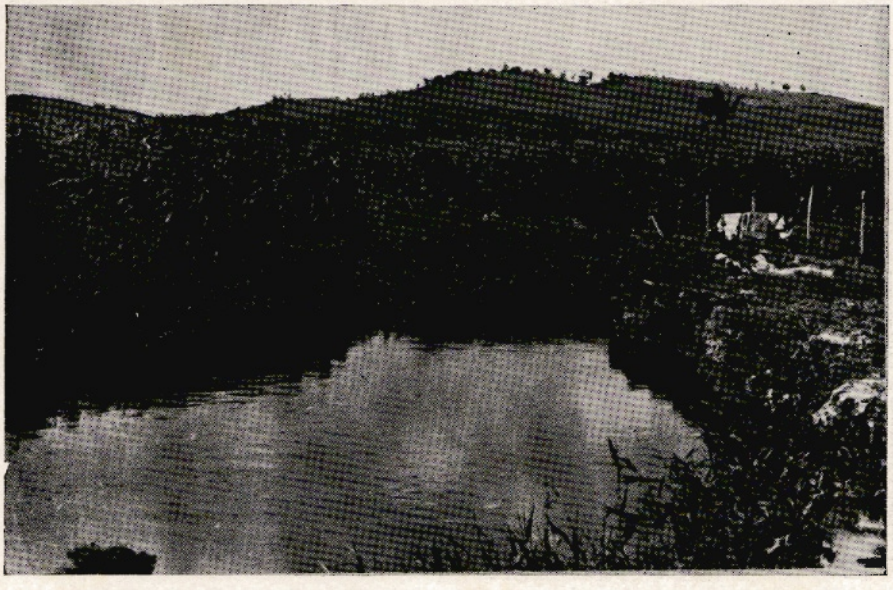


Dam, Río Guamaní, Guayama. Above and below this obstruction schistosomiasis is said to be acquired.

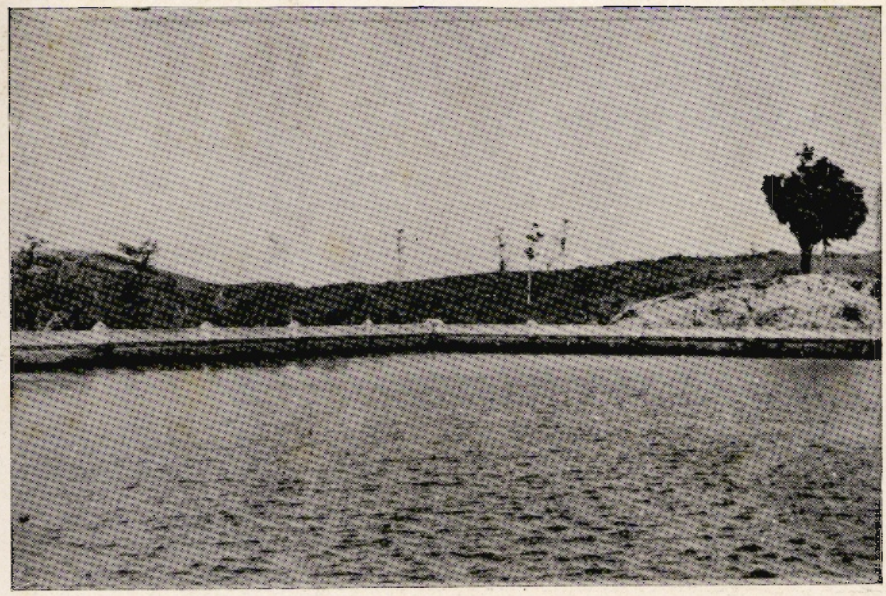
Dam, Río Guamaní, Guayama. Sluice gate by means of which water is diverted to Colonia Vives.

Charco Pérez, in the upper reaches of the Río Guamaní. Residents of Guayama have attributed their infections to bathing in this pool. When visited, August 1933, the current was too rapid to permit the existence of snails.

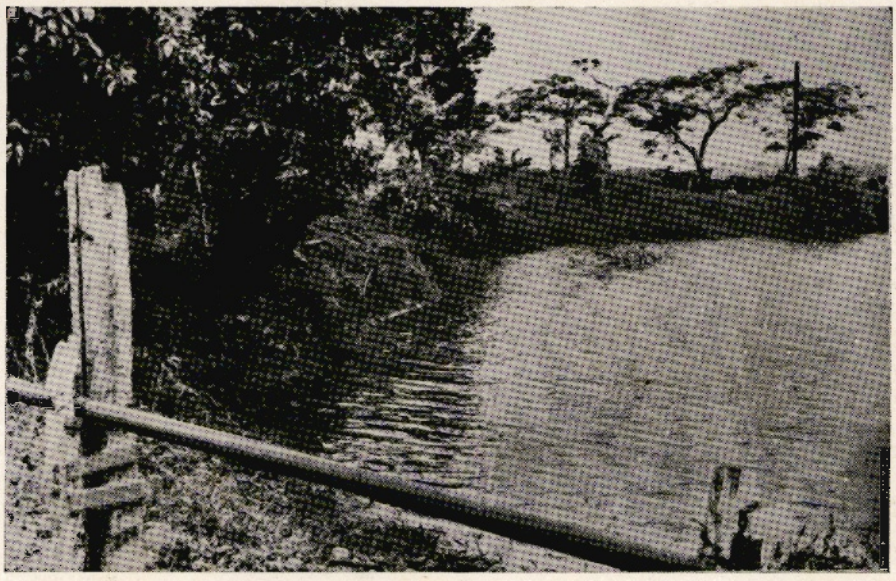
San Antón Creek, Sabana Llana. A schistosomiasis infected site.



San Antón Creek. Another pool where, apparently, numerous individuals have contracted schistosomiasis.



Municipal Reservoir, Río Piedras. Here, at times, *Helisoma guadeloupensis* is abundant.



A limesink near Quebradillas. Here numerous uninfected specimens of *Helisoma guadeloupensis* have been collected.