Urban Malaria in Puerto Rico[1]

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THAT SEVERAL of the commoner diseases in Puerto Rico are more prevalent here than in the forty-eight states is neither an original observation, nor enlightening to the average reader. It is also generally known that, in spite of a mortality reduction of 35 percent—from 138 to 89 per hundred thousand for the ten-year period ending in 1939—and displacement from fifth to seventh place among the leading causes of death, malaria mortality in Puerto Rico in 1939 was exceeded by the mortality of only two other diseases commonly recognized as preventable, diarrhea and enteritis, and tuberculosis. There is some reason to believe that the rank of malaria may be even higher in terms of economic loss.

The prevalence of urban malaria in relation to rural and total occurrence of the disease in Puerto Rico is, however, not so commonly recognized, and it is the purpose of this paper to present some information on that phase of the problem.

For the five-year period 1934–38, the average urban malaria mortality rate in Puerto Rico was 131.5 per hundred thousand, or 3 percent greater than the average rural death rate of 127.2. The urban rate was higher than the rural in four of the five years under study. In all population classifications up to 100,000 or more, urban malaria mortality rates were substantially higher in major than in minor cities. For the same five-year period, the average rate for urban populations of 10,000 to 25,000 was 72 percent greater than the insular-wide rural rate, while that for cities of 25,000 to 100,000 was 69 percent higher than the rural rate, compared with a superiority of only 3 percent for all urban areas. As there is only one city (San Juan) in the population classification of 100,000 or more, the rate for this group was determined solely by the experience of one city, and declined sharply in view of the relative absence of Anopheles albimanus breeding places within flight range of central residential areas in San Juan.

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The statistics used in this article are largely drawn from the following:
Annual Reports of the Commissioner of Health of Puerto Rico, 1929–40.
Mortality Statistics, 1934, 1935, and 1936 (U. S. Census Bureau).
Vital Statistics of the United States, 1937 and 1938 (U. S. Census Bureau).

Five-year average mortality rates for these three urban classifications above 10,000 population were 218, 215, and 41 per hundred thousand respectively. For comparison, malaria mortality rates for the same urban population classifications in the thirteen ranking malaria states in the United States in 1937 (an average year) were 8.2, 3.6, and 1.4 per hundred thousand respectively. Puerto Rican rates were accordingly 27, 60, and 29 times greater. These thirteen states had 20 percent of the national population, but reported 94 percent of all mainland malaria deaths. Total malaria deaths reported in mainland United States for the five-year period were 18,005, as compared with 11,075 reported in Puerto Rico, or 61.5 percent of mainland United States deaths.

In the latest year (1938) for which comparative figures are at hand, the number of malaria deaths reported from one highly urbanized Puerto Rican municipality of approximately 100,000 population was exceeded by only one of the forty-eight states. Malaria deaths reported for the urban area proper of this municipality with a population of 60,000 were exceeded by only seven of the forty-eight states. In another urban area of 16,000 population, the five-year average malaria mortality rate was 710 per hundred thousand.

This comparison between Puerto Rican and mainland malaria mortality carries no adverse implication with regard to efforts of insular health authorities to control malaria. Mortality has declined substantially from earlier levels. The yardstick of public health accomplishment is improvement, not comparison with the vital statistics of other areas.

The apparent superiority of urban over rural malaria mortality in Puerto Rico at first glance has the appearance of an epidemiological phenomenon, in view of normal contrary experience. Upon closer examination the normal pattern is revealed. With one exception, mortality rates in the local rural areas immediately adjoining each city are higher than in the urban area. The exception occurs in one of the more malaria-free sections of the Island. A relatively small number of deaths are involved, and the urban rate is only 12 per hundred thousand higher than the rural.

The insular-wide superiority of urban over rural malaria mortality is due to the fact that the principal urban cities are predominantly coastal, where malaria is most prevalent. Malaria mortality rates in the population classifications of 10,000-25,000 and 25,000-100,000 are also heavily weighted by the large number of deaths occurring on the even more highly malarious south shore of the Island.

While elimination of the urban malaria problem in Puerto Rico from the phenomenon class might discourage further inquiry by some investigators with special interests, significance of the problem is not lessened from the standpoint of malaria control. In planning an insular-wide attack on malaria, the interest of the control worker is still attracted to the fact that malaria mortality rates in cities between 10,000 and 100,000 population are greatly superior to rural and small city rates, as well as to that of the single city above 100,000 population.

It is generally recognized that, in the absence of special impeding local factors, malaria can be more permanently controlled, and more economically controlled, in terms of per capita cost, in the larger urban areas than in small cities and rural territory. In planning the control of rural malaria, differences of opinion as to the method of attack are encountered among public health workers as well as between them and vested interests. These complicating factors are either absent or reduced to minimal level in planning and promoting the malaria protection of a principal urban area. Permanent measures of control are almost invariably indicated for correction of species breeding areas. Where these permanent measures are practiced, the quantity of malaria per unit of land area becomes a primary consideration in selecting places for maximum control economy. For this reason, the principal urban areas may frequently possess priority even where malaria rates may be a small fraction of those in small towns and rural territory. The situation rarely occurs when, as in Puerto Rico, justification for the focalization of malaria control effort on such areas is further augmented by superiority of mortality or morbidity rate over the averages of rural and small city areas.

In considering special impeding factors responsible for the high level of principal urban malaria in Puerto Rico, or for discouraging the prosecution of anti-malaria measures, or both, recognition must first be given to the greater flight range of Anopheles albimanus (the Puerto Rican vector) as compared with Anopheles quadrimaculatus (the principal mainland vector). As reported by Watson in his discussion of Earle's work at Salinas,[2] it was found necessary to extend the territory of the control area two miles beyond the town, and effective malaria reduction was not achieved until albimanus breeding was suppressed in the peripheral margin of the control area.

2. W. C. Earle, "The Relation between Breeding Area, Anopheles Albimanus Density, and Malaria in Salinas, Puerto Rico," *South. Med. J.*, XXX:946–50.

The maximum effective flight most commonly accepted by malaria control workers for quadrimaculatus is one mile. This does not imply that the average flight range of albimanus is twice that of quadrimaculatus, since the ratio of effective to average flight range for albimanus is probably increased by the commonly observed greater density of albimanus breeding. For a city having an urban diameter of one mile, the extra-urban flight range area is 6π square miles for albimanus, and 2π for quadrimaculatus breeding, a difference of 200 percent. For an urban area two miles in diameter, the respective extra-urban areas become 8π and 3π respectively, a difference of 167 percent. This difference continues to diminish with increase in urban area. At least partial compensation is realized, however, in the greater density of urban population in Puerto Rico. The same land area occupied by a mainland city of 10,000 population may accommodate 30,000 to 60,000 persons in a Puerto Rican city, thus reducing flight range area per capita. It is the author's belief that, in relation to the mainland, per capita flight range area is substantially greater for the smaller Puerto Rican towns and cities, but no greater for the principal city group.

Types of breeding areas favored by the two vectors are an important factor in the cost of urban malaria control. The elimination of quadrimaculatus breeding is a selective operation, generally involving the correction of relatively permanent watered areas in a restricted biological association range. These generally occur in the form of fresh still-water ponds, marshes, or waterways of known location; and corrective measures may be confined to specific locations.

Although inhibited by shade, a striking characteristic of albimanus is its apparent lack of selectivity in breeding place. Dense larval production may be observed in brackish wash areas in company with salt marsh mosquito species, in water with a high degree of organic pollution, in what appear to be temporary ground pools, and in hoof prints and cart tracks, in addition to the more permanent well-defined bodies of water. Drainage measures for albimanus control in the presence of a high ground water table in flat land require lowering of the ground water table over the land area as a whole, generally by subdrainage networks. Drainage practices are comparable to so-called "agricultural drainage operations," as performed for the purpose of converting poorly drained into well-drained crop land.

With reference to this factor of water table control, it appears that the practices of man to raise the water table, particularly in flat-relief topography, would be far more adverse to malaria control interests in albimanus areas than where quadrimaculatus is the primary vector. It is also a corollary that in albimanus areas, the malaria control worker may be even more concerned in preventing the artificial raising of the water table than with costly corrective measures made necessary by this act.

The practice of augmenting rainfall for agricultural benefit, with resultant influence on the ground water table, is known as irrigation. When performed in low-lying, impermeable soil types for improving the yield of such crops as sugar cane and rice, there is a world-wide association with increased breeding of local still-water anopheline vectors. The increase appears particularly pronounced where albimanus is the vector. This experience has been summarized by Williams, who states in his review of the anti-malaria program in North America: "Agriculture in the tropics, in developing irrigation, has added greatly to the malarial burden, for control has been confined to the larger cities and to a few of the industrial settlements and to a very few of the larger agricultural projects."[3] Note the inference that irrigation has not only caused more malaria, but has discouraged control by raising its cost to an unreasonable level.

Since irrigation of sugar cane land is extensively practiced in some sections of Puerto Rico, comparison is indicated between principal urban areas in proximity to (*a*) irrigated sugar cane land, (*b*) non-irrigated sugar cane lowland, and (*c*) little or no low-lying sugar cane land. The first classification comprises principal cities located on the south shore of the Island, in what is termed "the dry southern coastal plain," by Tulloch.[4] As reported by Earle,[5] annual precipitation in this area is often only 25 to 30 inches per year, mostly distributed over three or four months. Irrigation is practiced in sugar cane lands to increase the supply of water to 75 inches, well distributed throughout the year.

The second classification, "nonirrigated sugar cane lowland," comprises principal cities located in what Tulloch[6] terms "the wet coastal plains of the north, east, and west"; while the third is comprised of foothill cities, plus San Juan, around which the acreage of low sugar cane lands is negligible.

3. "Symposium on Human Malaria," *A.A.A.A.*, 1941.

4. G. S. Tulloch, "The Mosquitoes of Puerto Rico" and "The Brackish Water Mosquitoes of Puerto Rico," *J. Agric. of the U.P.R.*, XXI: 137–59 and XXI: 581–83.

5. W. C. Earle, "Malaria in Puerto Rico in Its Relation to the Cultivation of Sugar Cane," *South. Med. J.*, XXIII (1930), 449–53.

W. C. Earle, "Malaria in Puerto Rico," *Am. J. Trop. Med.*, X (1930), 207–30.

6. Tulloch, *op. cit.*

In Group (*a*), composed of the urban areas of Guayama and Ponce, both bordered by arid, irrigated, coastal plain, the five-year average malaria mortality rate was 387 per hundred thousand. In Group (*b*), composed of the urban areas of Mayaguez, Aguadilla, and Arecibo, bordered by "wet coastal plain" low sugar cane lands, the average rate was 136; while in Group (*c*), consisting of the urban areas of Bayamón, Caguas, and Río Piedras, bordered by some upland sugar cane, the average rate was 77. Adding San Juan, this average is reduced to 51 per hundred thousand. The differential between (*a*) and (*b*), attributable in whole or in part to irrigation, was 251 per hundred thousand.

Earle, in 1929,[7] pointed out that the cultivation of sugar cane *per se* did not increase the malaria hazard. The vital statistics in this paper support that position.

It was also demonstrated, at least fifteen to twenty years ago, that production of albimanus could be effectively suppressed in irrigated sugar cane fields and in systems of irrigation aqueducts and reservoirs by the subdrainage of cane fields and careful agricultural management. These malaria control practices have been subsequently promoted for many years by health authorities, and ample time has elapsed for their adoption by the various interests involved. Although these compensatory measures involve substantial financial outlay, they are economical and practical in relation to land and crop values.

In spite of this knowledge and promotion, application of compensatory measures by landowners to correct man-made malaria hazards has not progressed to the stage where public agencies can correct residual albimanus production in natural breeding areas around the two largest south shore cities. Earle's experience in Salinas[8] has demonstrated that the partial suppression of albimanus production (from only natural breeding areas around these cities), will accomplish little or no malaria reduction under the conditions of heavy albimanus production occurring on the irrigated south shore of the Island.

As a result, 2,572 malaria deaths were reported over the five-year period for the municipalities of Guayama and Ponce alone, with

7. W. C. Earle, *op. cit.*

8. *Ibid.*

morbidity in proportion, and 1,489 deaths were reported for the urban areas proper, among a total population of 76,942, in the latter.

Until recently the possible influence of irrigation in impeding progress in urban malaria control has been only of academic interest to the public health worker. No effective machinery has existed for solution of the problem, which involves government as well as private landowners, since irrigation systems on the south shore are largely publicly owned.

Lately, consideration has been given by governmental representatives to a systematic review of the large question of land utilization. Legislation has been passed toward the realization of improved practices in land tenure and usage. A Land Authority has been created as a principal governmental instrumentality for accomplishment of these objectives.

The relationship of malaria to agricultural practices in general and to irrigation in particular deserves important consideration under any adequate concept of planning in this field. This is especially true where the welfare of large, concentrated population groups is seriously involved. Consideration should be given to two alternative solutions. The first is the withdrawal of public irrigation services, and the prohibition of private irrigation, from areas within two miles of these two principal cities. This might be practical in conjunction with crop diversification in the two-mile areas, in accordance with the objective of providing Puerto Rico with a more self-sufficient food supply, and would necessitate growing nonirrigated crops in these zones.

The second is the continuation of agricultural irrigation in the two-mile flight range under controlled management. This would require compensatory capital and operating expenditures for effective prevention of man-made malaria. Subdrainage systems to remove water would be considered as essential as aqueduct systems bringing water. The malaria control supervisory worker would be considered as indispensable as the sugar chemist.

While choice between alternatives is largely for the agronomist and agricultural economist to decide, hydrographic factors should not be overlooked. The same published studies which have demonstrated the practicability of managing irrigation distribution systems to avoid malaria hazard, and of operating subdrainage systems in cane fields to overcome the malaria hazards of irrigation practices, have also stressed the importance of "seepage areas" in the total picture of albimanus production on the south shore. These, for the

most part, are uncultivated areas in the vicinity of irrigated cane fields. The influence on the general local water table resulting from increasing applied water from 25 to 30 inches per year to 75 inches per year by irrigation over a large acreage of sugar cane land, has not been adequately studied. There is some reason to believe that water applied by irrigation may replenish the water table more than does an equivalent amount of rainfall, since runoff is temporarily checked by gates and dams, and percolation should be increased proportionately. Direct seepage into the lowlands from inland mountains should be rather limited, as the runoff coefficient is unusually high, due to the steepness of slope.

With the exception of lowland fields located at the immediate base of the foothills, are the seepage areas observed a by-product of irrigation? Would the added cost of compensatory control of seepage areas tilt the economic scales toward nonirrigated crop production, at least in restricted areas around principal cities?

These and other questions point to the need for joint planning and study of the broad question of land utilization by qualified public health authorities and other professional interests in conjunction with the agriculturist.

SUMMARY AND CONCLUSION

1. Malaria mortality rates in Puerto Rico as reported to the United States Bureau of the Census are substantially higher in urban areas between 10,000 and 100,000 population than in rural and small urban areas. For the five-year period 1934–38, the average rate in these principal cities was 70 percent greater than the rural rate. This is in marked contrast to experience in mainland United States.

2. The total number of malaria deaths reported for Puerto Rico over the five-year period 1934–38 was 11,075, while that for mainland United States was 18,005. On this basis, justification exists for the expenditure of 61.5 cents for malaria control in Puerto Rico for each dollar spent by city, county, state, and Federal governments in mainland United States for the same purpose. The recent trend of malaria mortality in Puerto Rico has been one of relative increase. For the latest year in which comparative figures are available (1940), deaths from malaria in Puerto Rico exceeded those in continental United States (1,817 deaths vs. 1,443 deaths). The undue prevalence of fatal malaria reported for principal cities in Puerto Rico lends further emphasis to the justification for public investment in permanent remedial measures.

3. Malaria mortality rates in principal Puerto Rican cities within Anopheles albimanus flight range of irrigated coastal plain sugar cane lands were substantially greater than for those cities proximate to nonirrigated coastal plain sugar cane lands. These, in turn, experienced higher malaria mortality rates than did cities in foothill topography. The differential malaria mortality between the first and second groups was 251 per hundred thousand, and between the first and third was 310 per hundred thousand, for the five-year period 1934–38.

4. The influence of broad-area irrigation on the ground water table of the south shore coastal plain of Puerto Rico is not adequately known. Hydrographic studies should be made with particular reference to seepage area associations.

5. Although effective compensatory measures have been known for many years, their application by irrigation interests has not been sufficient, even about the two principal south shore cities, for effective malaria control. The practice of compensatory malaria control measures as a necessary expenditure in agricultural irrigation has not been generally observed.

6. Land planning and administrative agencies should give initial attention to the removal of man-made malaria hazards around principal cities, resulting from existing land utilization practices. This could be accomplished by the production of nonirrigated crops within two miles of principal cities, or by controlled farm management practices. Either procedure should be carried out in coöperation with health authorities, to insure the concurrent suppression of residual albimanus production in natural breeding areas and to obtain malaria control consulting service.

TABLE 1

Malaria Deaths (Puerto Rico) by Place of Occurrence

Municipality	*1935*	*Number of Malaria Deaths*					*Average Deaths*	*Average Rate*
	Population	*1934*	*1935*	*1936*	*1937*	*1938*		
PUERTO RICO	1,723,534	2,437	2,083	2,356	2,262	1,937	2,215	128.5
GROUP TOTAL	559,360	973	937	1,073	893	770	929.2	166.1
TOTAL								
Rural	221,510	511	473	510	362	337	438.6	198.0
Urban	337,850	462	464	563	531	433	490.6	145.2
AGUADILLA								
Rural	20,121	39	126	96	37	45	68.6	341.0
Urban	11,133	16	32	47	21	27	28.6	257.0
Total	31,254	55	158	143	58	72	97.2	310.0
ARECIBO								
Rural	48,680	133	73	61	50	50	73.4	151.0
Urban	14,332	28	22	34	21	13	23.6	165.0
Total	63,012	161	95	95	71	63	97.0	154.0
BAYAMÓN								
Rural	18,278	14	11	15	32	25	19.4	106.0
Urban	13,873	10	5	12	20	18	13.0	94.0
Total	32,151	24	16	27	52	43	32.4	101.0
CAGUAS								
Rural	25,986	36	18	21	11	29	23.0	88.5
Urban	22,599	24	18	17	10	17	17.2	76.0
Total	48,585	60	36	38	21	46	40.2	83.0
GUAYAMA								
Rural	11,488	83	104	132	114	46	95.8	835.0
Urban	16,075	80	129	166	138	57	114.0	710.0
Total	27,563	163	233	298	252	103	209.8	762.0
MAYAGÜEZ								
Rural	24,748	42	21	35	13	21	26.4	107.0
Urban	44,907	40	47	49	34	47	43.4	97.0
Total	69,655	82	68	84	47	68	69.8	100.0
PONCE								
Rural	36,912	149	104	144	97	110	120.8	327.0
Urban	60,867	174	161	179	222	183	183.8	302.0
Total	97,779	323	265	323	319	293	304.6	312.0
SAN JUAN								
Urban	137,215	71	38	50	59	62	56.0	41.0
Total	137,215	71	38	50	59	62	56.0	41.0
RÍO PIEDRAS								
Rural	35,297	15	16	6	8	11	11.2	32.0
Urban	16,849	19	12	9	6	9	11.0	65.0
Total	52,146	34	28	15	14	20	22.2	43.0

Sources: Population, 1935 Census of Puerto Rico.
Malaria mortality, U. S. Census Bureau Reports.

TABLE 2

Urban Malaria Mortality Rates by Selected Groupings

	Population 1935 Census	*Average Deaths 1934–38*	*Average Rate 1934–38*
PUERTO RICO	1,723,534	2,215.0	128.5
Urban	512,020	673.4	131.5
Rural	1,211,514	1,541.6	127.2
10,000–25,000 POPULATION			
Aguadilla	11,133	28.6	
Arecibo	14,332	23.6	
Bayamón	13,873	13.0	
Caguas	22,599	17.2	
Guayama	16,075	114.0	
Río Piedras	16,849	11.0	
Total	94,861	207.4	218.6
25,000–100,000 POPULATION			
Mayagüez	44,907	43.4	
Ponce	60,867	183.8	
Total	105,774	227.2	214.8
100,000 OR OVER POPULATION			
San Juan	137,215	56.0	
Total	137,215	56.0	40.8
IRRIGATED DRY COASTAL PLAIN			
Guayama	16,075	114.0	
Ponce	60,867	183.8	
Total	76,942	297.8	387.0
WET COASTAL PLAIN SUGAR CANE AREAS			
Aguadilla	11,133	28.6	
Arecibo	14,332	23.6	
Mayagüez	44,907	43.4	
Total	70,372	95.6	135.8
UPLAND OR PROTECTED AREAS			
Bayamón	13,873	13.0	
Caguas	22,599	17.2	
Río Piedras	16,849	11.0	
Subtotal	53,321	41.2	77.3
San Juan	137,215	56.0	
Total	190,536	97.2	51.0