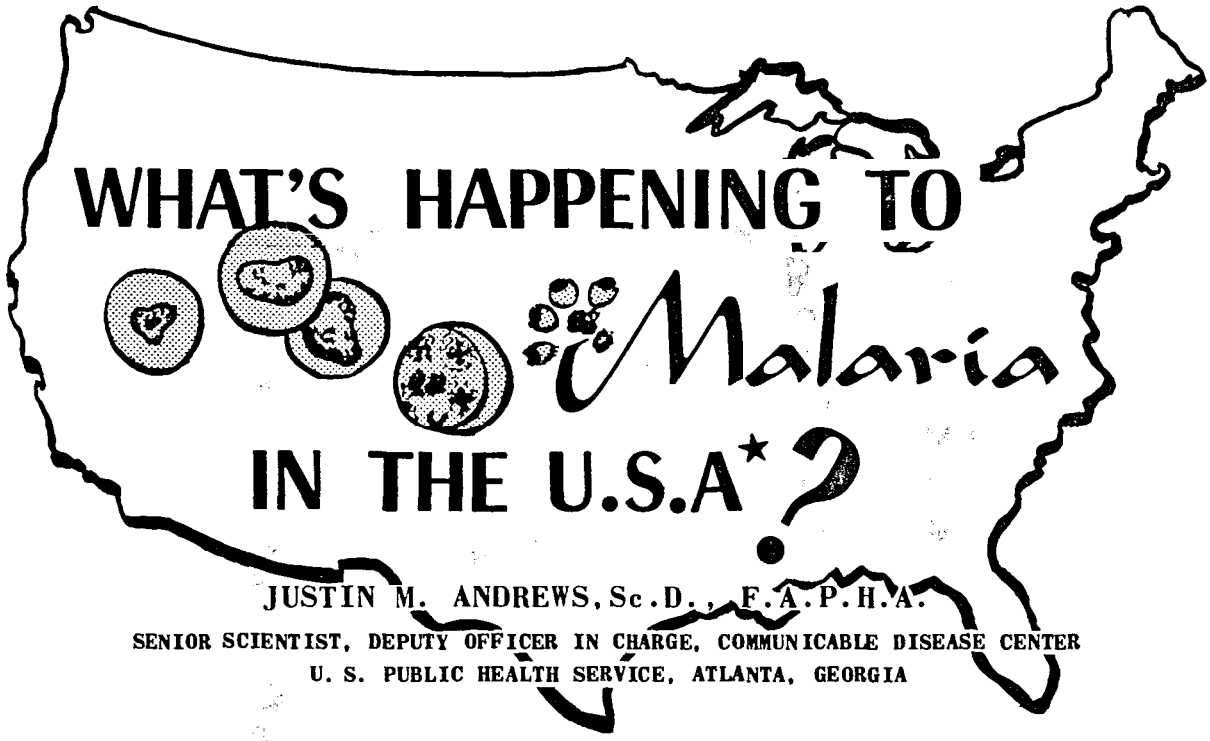

WHAT'S HAPPENING TO Malaria IN THE U.S.A.*?

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The general decline of malaria in this country is believed to have begun during the last quarter of the 19th century,[1,2,3] some years before it was known how the disease is transmitted. At that time, malaria virtually blanketed the eastern two-thirds of the nation, except for the Appalachian highlands, and extended up the Central Valley of California.[4] Its retreat has been interrupted, at least during the latter half of the intervening period, by resurgences in prevalence at such regular intervals that a five-to seven-year cyclicity in epidemic manifestations has been postulated.[4,5] The last of these periods of enhanced transmission took place during the mid-thirties of this century. By that time, the principal areas of endemicity had contracted to the coastal plains and lime-sink sections of the southeastern states and the flood-plain areas of the lower Mississippi and its main tributaries. Since this last upswing, 12 to 14 years ago, reported malaria prevalence in the U.S.A. has decreased steadily as shown in the accompanying graphs (Fig. 1). Making generous allowance for the traditional errors of ommission and commission in malaria reporting, it is evident that consistent declines in recorded morbidity and mortality, unprecedented in their magnitude and duration, have been in effect for the last decade or more. This downward trend is verified by the general testimony of residents and by special field studies[6,7] in areas where malaria has been highly endemic in the past.

What is the significance of this latest recession? Since 1935 there has been no reported increase in indigenous malaria cases or death rates in the country as a whole. This indicates that the regular wave-like pattern of malaria epidemicity throughout the nation is not an immutable phenomenon. If the negative slope of the last 12 years' experience can be continued or accelerated, it can mean nothing more or less than the ultimate extinction of

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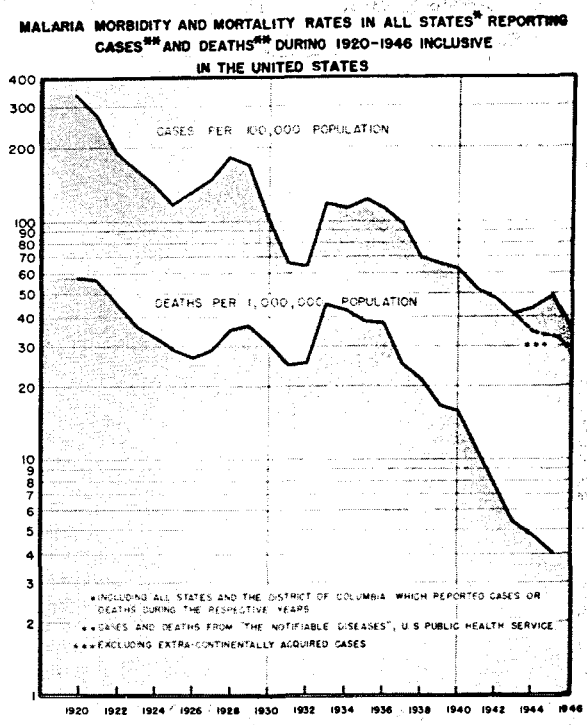


FIGURE 1.

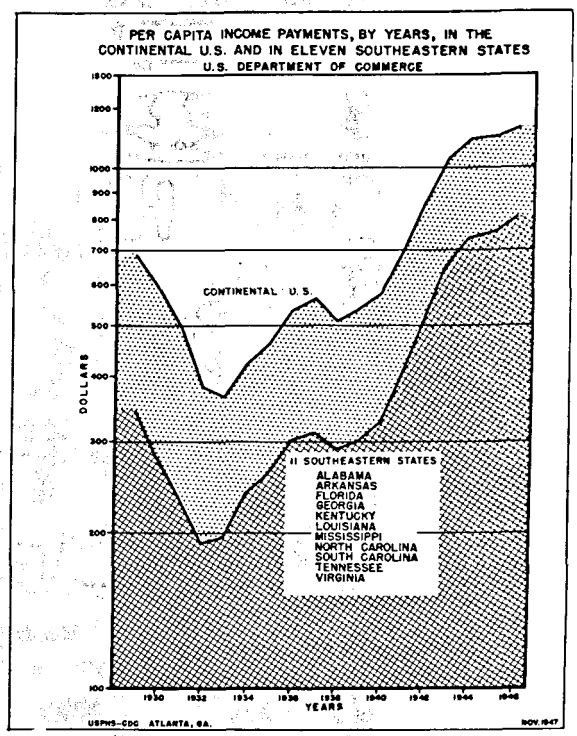


FIGURE 2.

malaria in the United States. To exploit this trend, it is important to determine its causes, if possible, while they are still in effect.

Is malaria being treated out of existence? Has it stopped relapsing or has man become generally refractory to infection? Have infectible anophelines become so few that transmission is not possible? Have these species lost their susceptibility to plasmodial parasitism — or their taste for human blood? Have all rural homes in the South been made secure against insects—and do their occupants remain indoors after dark so punctiliously that they are no longer accessible to mosquitoes? A brief review of these and other possible nullifying influences seems desirable: 1) to assess the evidence for or against their causal participation in the current malaria regression, 2) to judge the extent, if any, that these phenomena are due to purposeful control efforts, and 3) whether it would be wiser, in view of the present low level of malaria incidence, to stop all organized attempts at further malaria prevention as unjustified expenditures or to continue them with the hope and expectation that, within the foreseeable future, they will result in the total eradication of the disease.

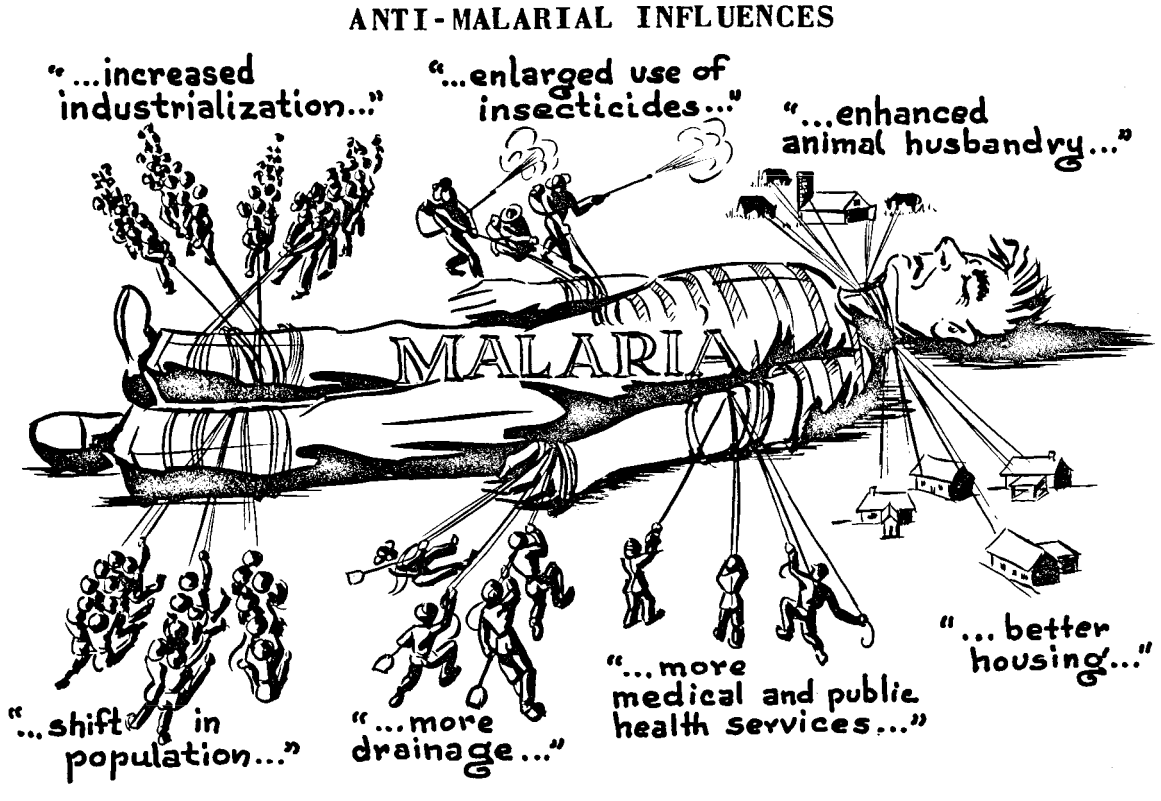
Economic improvement in the South — The South shared in the nation's present wave of prosperity which started its upward swing (see Fig. 2) at about the time malaria rates commenced their latest descent. In connection with this circumstance, it is pertinent to note that socio-economic progress was believed by various authorities[1,2,3,4,5] to be the prime determinant in the extinction of malaria in the Upper Mississippi Valley though they disagreed as to the most probable means by which it was achieved. Malaria is more firmly entrenched by environmental conditions in the South than it was in the North, nevertheless it seems probable that economic improvement is the basis for various pressures to which it is now yielding. Those which may be presumed to exert antimalarial influence include better housing, more medical and public health services, more drainage for agricultural and suburban development, enlarged use of insecticides in homes, enhanced animal

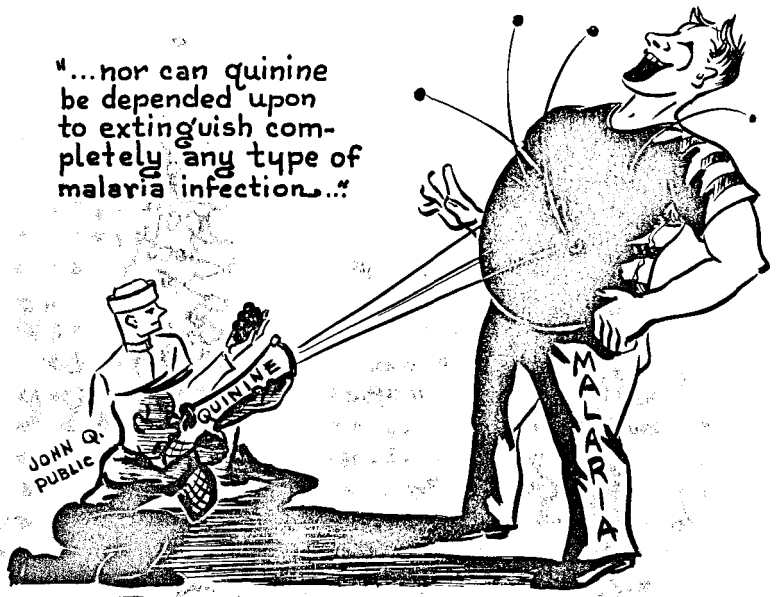
husbandry, and increased industrialization with its attendant shift in population residence from rural areas to or near metropolitan centers. Wartime and post-war shortages of materials and professional personnel have doubtless prevented the fullest elaboration of these forces against malaria.

Human susceptibility — Considering first the human factors which may have been involved in the present recession, there appears to be little reason for assuming that it is due to an American loss of susceptibility to initial infection or relapse. Well over a half million American soldiers and sailors,[8] including many from the South, acquired malaria overseas from 1942 to 1945, inclusive, evidencing no resistance to the numerous strains of plasmodia encountered. Some of the tertian infections imported subsequently are still relapsing after three years. Paretics and other recipients of induced malaria in this country appear to accept and react to blood- or mosquito-transmitted infections with old or new strains of parasites in recent years as their predecessors did before them according to observers whose investigations involve the extensive use of this procedure.[9,10,11,12] Furthermore, it was shown in 1947 that native cases of falciparum and quartan malaria in South Carolinian Negroes, with or without symptoms, were readily infective to insectary-reared and wild-caught *A. quadrimaculatus*, even though gametocyte densities were very low in some instances.[13]

Antimalarial medication — It is difficult to assess correctly the role of medication in the malaria decline. Since the days of "Sappington's Anti-Fever Pills", residents of endemic areas in the United States have consumed huge quantities of ethical and proprietary antimalarials with the object of treating or preventing malaria. It seems logical to expect that drugs which reduce parasite densities in man should diminish his infectiousness to mosquitoes at the same time but this effect has not always been sufficiently realized to be of significance in the prevention of malaria.

Thus while the world thankfully accords





memorable prominence in medical history to quinine for the relief it has given to countless millions suffering from malaria, it is now well known that the drug possesses no prophylactic properties, except the ability to effect the temporary suppression of symptoms, nor can it be depended upon to extinguish completely any type of malaria infection. Therefore, it is doubtful if quinine interferes perceptibly with the transmission of the disease. Certainly there appears to be no reason for believing that it contributed any more to the control of malaria in the South since 1935 than before that date.*

Quinacrine hydrochloride (atabrine) was introduced into general use in the South during the middle and latter years of the decade when the present malaria recession was just getting under way. Its early experimental application as a mass therapeutic and prophylactic among predominantly Negro populations with almost exclusively falciparum malaria was associated with encouraging reductions in spleen, parasite, morbidity and mortality rates.[14,15,16] Later observations in Panama,[17] led to the conclusions that atabrine was no more dependable than quinine for malaria control purposes when used in treating parasite positives discovered at monthly blood surveys. Critical tests[18,19] and general experience in malarious areas during World War II concurred in establishing that this drug, while not much more effective than quinine against vivax and quartan malaria, is virtually a specific against falciparum infection, its use in therapeutic or suppressive dosages resulting in a high percentage of non-relapsing cures of this and no other types of malaria. This unique characteristic plus the temporal association of atabrine and the recent malaria decline qualifies atabrine medication as one of the possible causes of the recession, without defining its actual importance.**

Population migration out of rural areas— Since 1935, there has been a notable migration from rural to urban surroundings throughout the United States. This was most marked during the first half of the present decade due, presumably, to military induction and to the attractions of higher wages and better living conditions in and near the more populous centers where materials and equipment for Defense and War Indus-

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* According to Mr. Norman Taylor, Director, Cinchona Products Institute, Inc. (personal communication), this country, prior to 1939, used roughly four million ounces of quinine each year, the annual variation being within ten percent of this figure. Its consumption "over a period of years" did not increase with the population. There is no way of determining the actual proportion used as an antimalarial in the South but, on the basis of available distribution data, it was estimated at the Institute that about two million ounces were used for that purpose.

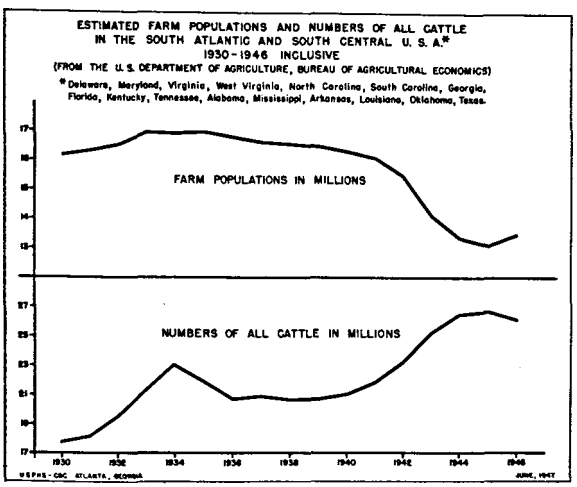
** Information regarding the distribution and consumption of atabrine in this country could not be obtained from its principal manufacturer as the output of this product for the last six years has been controlled largely by the Army, Navy, and Public Health Service and has been subject to use abroad as well as in the United States.

tries Programs were being fabricated.

From 1917 to 1940, there was a small but steadily increasing progress in the industrialization of the South as northern manufacturers shifted their factories to take advantage of more favorable labor conditions below the Mason-Dixon Line. From July 1940 to May 1944, the South received 24.4 percent of the $14,000,000,000 authorized by the War Production Board for manufacturing plants and equipment; this does not include the cost of plants whose post-war conversion to peacetime industry is doubtful.[20] During the same period, considerable numbers of Negroes travelled to the northern states to escape the effects of a waning cotton economy and with the hope of finding more productive and congenial surroundings.[21]

In many sections of the southeastern quadrant of this country, these events have resulted in transferring people OUT of rural areas where they might have had

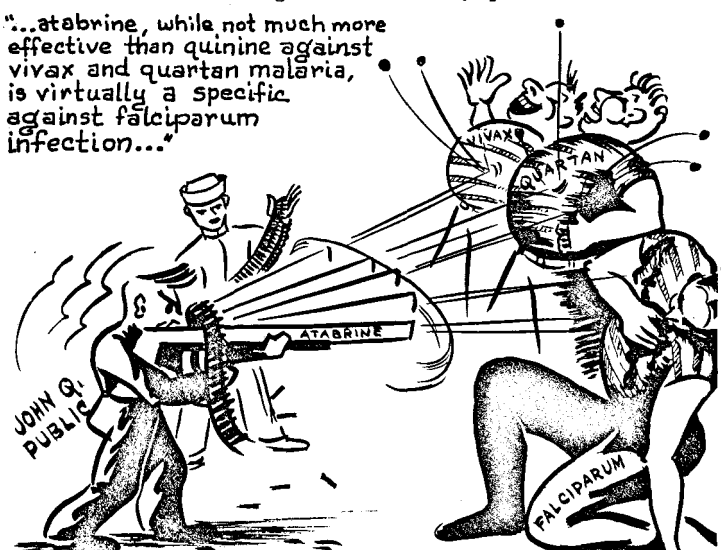
FIGURE 3.

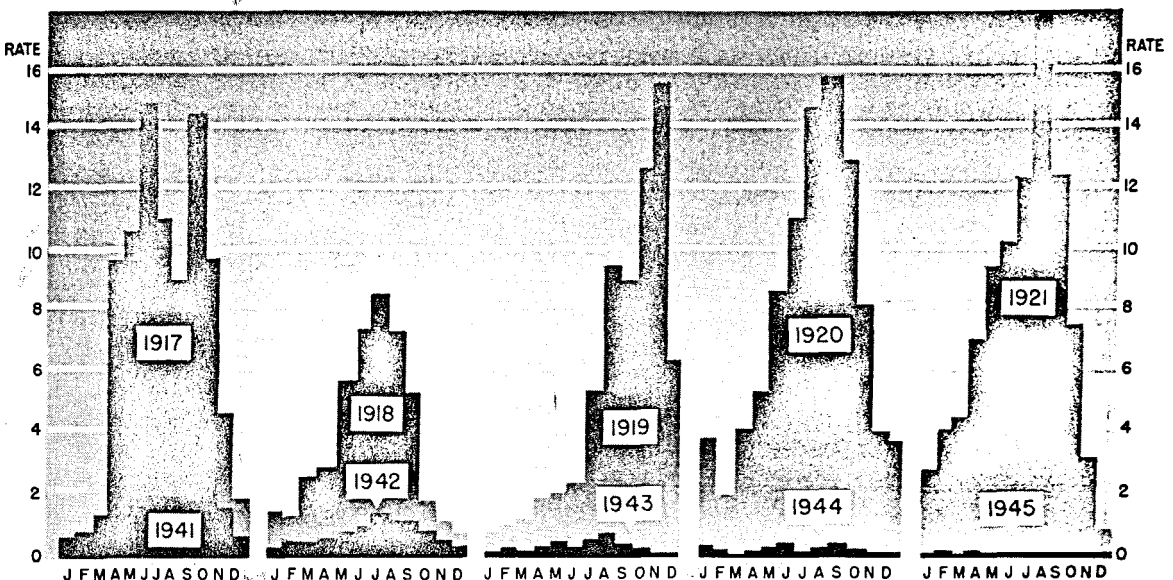


malaria and INTO urban situations where the chances of acquiring it were negligible. The total extent to which this phenomenon has taken place is not known at present but some idea of its trend is conveyed by the upper curve in Fig. 3, which indicates the progressive reduction in farm populations in the South Central and South Atlantic States from 1935 to 1945, inclusive. Thus it seems probable that a considerable depletion in rural population has occurred. This may have assisted materially in malaria reduction in the last five or six years.

Anopheline susceptibility — Consideration must also be given to the possibility that changes in anopheline populations may have interfered with the transmission of malaria. Among such hypothetical factors, reduction in mosquito susceptibility to plasmodial parasitism due, perhaps, to environmental or cosmic influences would be of paramount significance if demonstrable. Such a phenomenon might be reasonably expected to manifest itself in insectary-reared as well as wild strains of mosquitoes. There is no published evidence to that effect with reference to the principal transmitting species in this country. Induced malaria for therapeutic and experimental purposes appears to have been transferred from one person to another by means of mosquitoes with comparable degrees of regularity throughout and prior to the period under consideration.[9,10,11,12] While most of the naturally induced malaria has been transmitted with the Boyd strain of *A. quadrimaculatus*, established in 1932,[22] other insectary stocks have been used and wild strains of this species have been brought into laboratories and their infectibility proved.[12,23,24]

Antilarval measures — Has the abundance of this transmitter diminished sufficiently during the last twelve years to account for the malaria reduction observed? During this period, efforts of considerable magnitude have been made by Federal, state and local health agencies and by private





MALARIA ADMISSIONS PER THOUSAND MEN PER YEAR FOR THE ARMY IN THE CONTINENTAL UNITED STATES WORLD WAR I — WORLD WAR II
(NOTE THE REDUCED MILITARY MALARIA EXPERIENCE IN THIS COUNTRY DURING THE LAST WORLD WAR)

FIGURE 4.

interests aimed at reducing anopheline densities both on a community-wide basis and within homes. Entomological evidence of success as a result of these endeavors is limited; their probable effectiveness must be inferred largely from the nature and scope of their physical accomplishments.

The U. S. Army's continental experience with malaria during World War I was severe enough (see Fig. 4) to require environmental control measures around southern cantonments. These activities had to be financed jointly from Federal and local resources, thus directing attention to the fact that local governments were unable to bear the costs of malaria control operations which, as then conceived, were mainly antilarval.

Thus, during the depression years which followed, Federal relief organizations (Civil Works Administration and Federal Emergency Relief Administration established in 1933, and the Works Progress Administration in 1935) were called upon to supply manpower for malaria control purposes. They completed a tremendous amount of drainage in 16 southeastern states. The exact total is uncertain as existing reports of accomplishment[4,25] are not in agreement, but from them it appears probable that something in the neighborhood of 32,000 miles of "average-size" ditches were constructed, draining 623,000 watered acres. Most of them were dug by hand labor—machine and dynamite excavation accounting for only a minor percentage — and a few hundred miles of the ditches were paved with concrete.

From the standpoint of good malaria control practice, these projects had serious faults. In the fulfillment of relief objectives, operations could be carried out 1) where and only for as long as the numbers of locally unemployed were large enough so that crews could be manned for malaria control drainage as well as for other relief labor projects desired by the community, and 2) where locally provided materials and equipment were available for matching against Federal funds.

These conditions tended to concentrate malaria control drainage projects in the more populous and wealthy counties, not necessarily the more malarious ones. Justification for locating work units was frequently based on nothing more than lay testimony of past malariousness. Drainage construction was restricted to new works, which meant that existing drainage-ways could not be maintained or improved with relief labor nor could it be used to keep in serviceable condition the ditches which it dug originally. In many, though not all instances, local governments have provided for the maintenance of the drainage facilities.

As the Defense Program gathered momentum in 1941, national unemployment declined and many of the WPA Malaria Control Drainage Projects were discontinued except in the neighborhood of military training camps. During 1942, these were taken over by the U. S. Public Health Service and, together with other environmental malaria control operations around areas of military or war industries significance, were continued during the war years as a cooperative works program of the Federal and various state health services concerned. Their efforts were coordinated by the Office of Malaria Control in War Areas, headquartered in Atlanta, Georgia.

During the period of maximal military training and industrial production, malaria control drainage, filling, and larviciding were accomplished by this organization around approximately 2,200 localities of military concern in 19 different states. Through 1945, these activities included clearing and cleaning, incidental to larviciding, of 37,000 watered acres and 96,700,000 linear feet of ditches; 5,700,000 gallons of oil and 73,000 pounds of paris green were used in larviciding 660,486 acres; approximately 10,900,000 linear feet of drainage ditch of varying cross-section were dug (90 percent of them by hand labor, 5 percent with dynamite, 3 percent by heavy machinery, and the other 2 percent were lined or tiled ditches); mechanical and hydraulic fill amounted 315,000 cubic yards.

This program was a great improvement over the preceding one from the standpoint of malariologic principle. Maintenance operations could be undertaken as readily as new construction. Local contributions were required only when adjuncts to drainage works such as concrete ditch-lining or culverts, tile, dynamite, etc. were desired. Early in the development of the War Areas Program, the policy was adopted of basing operations on potential malariousness, i.e., presence of infectible species of anophelines, rather than lay testimony of previous malariousness. Entomologic evaluations were made throughout the progress of the program to check operational accomplishments. These have been summarized in Fig. 5 and show 1) that malaria-carrying types of mosquitoes were less numerous within the zones where mosquito control activities, exclusively antilarval until calendar year 1945, were carried on than in adjacent unprotected areas, and 2) that anopheline abundance in uncontrolled areas

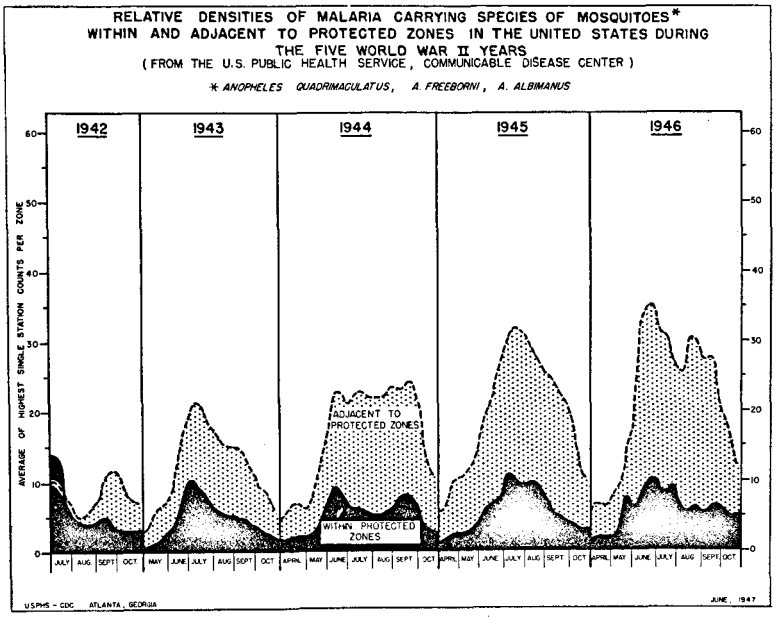


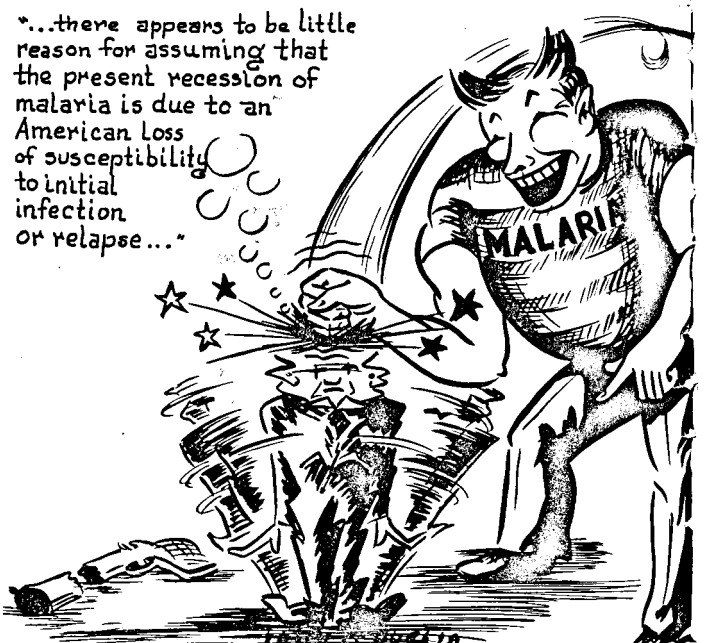
FIGURE 5.

was certainly no less, probably more, in 1946 than in 1942 when enumerative observations were commenced. Spleen and parasite surveys were also made for evaluative purposes but were not very meaningful because of their lack of sensitivity in the face of decreasing malaria prevalence. Community health education and information programs were developed to teach the lay public simple facts about the cause, nature, transmission, and prevention of malaria thus securing cooperation in effecting the objectives of the program.

The main malariologic shortcoming of this War Areas Program was that it was aimed only at the protection of military trainees and war workers. Thus it did not nullify foci of primary malaria endemicity unless they were near military training camps, maneuver areas, airports, shipyards, or the sites of war industrial or recreational facilities.

A third federally-sponsored program which may have exercised some effect on anopheline prevalence over a considerable portion of the South is that of the Tennessee Valley Authority. This organization was created in 1933. Since then it has constructed or acquired 26 artificial impoundments along the Tennessee River and its tributaries. At maximum normal operating level, these lakes cover nearly 600,000 acres and their total shore line extends well over 10,000 miles.[26] Much of the marginal area is within the limits of traditional malariousness where conditions favor the propagation of *A. quadrimaculatus*, a notorious impoundment breeder. The threat of enhanced malaria incidence was recognized early in the planning phase and, as an important element of the Health and Safety Department, a Malaria Control Division was activated. Its functions, at first investigational and operational, now consist of the development of the TVA malaria control program and the planning and appraisal of its execution in the field. The antilarval measures utilized include reservoir preparation and improvement, water-level management, larviciding, drift removal and herbiciding — all prosecuted on very large scales. The studies of the TVA Malaria Control Division and the operations performed by it or under its technical supervision appear not only to have kept malaria from becoming a major cause of morbidity in the Tennessee Valley but to have reduced to the point of public health insignificance the malaria prevalence which existed when construction was begun. It is interesting to note that, due to a combination of uncontrollable circumstances in the early spring of 1945, anophelism in the lower two-thirds of the Valley reached the highest level recorded in twelve years but without evidence of an accompanying increase in malaria prevalence.[7]

This incomplete catalog of federally-stimulated efforts at reducing anopheline production is impressive but the effect of these endeavors on malaria prevalence is hard to appraise. Their application extends over the period of malaria decline, a fact which should neither hastily be dismissed as fortuitous nor taken for granted to have causal significance. That malaria reduction occurred near many of these operation sites as a result of breeding-place destruction and antilarval measures is indisputable, but that these areas were sufficiently numerous, extensive, or malariogenically important to form a coalescent malaria depression throughout the South is hardly credible. Furthermore, malaria has diminished to a greater or lesser degree in



areas beyond the influence of the TVA and untouched by WPA or MCWA. Thus it is evident that other factors in addition to interference with anopheline production have been concerned in this phenomenon.

Measures against adult anophelines — In spite of active educational efforts, demonstration projects [27, 28, 29] and higher incomes, the amount and quality of domestic insect-proofing has increased significantly in only a few of the rural sections of the South where it would have its greatest effect as a malaria reductive measure.[30, 31] Doubtless, this is due to the excessively high ratio of insect-proofing construction and maintenance costs to the value of poorer type houses.[32, 33]

On the other hand, the use of domestic insecticides has increased prodigiously during the period under consideration. Data concerning the actual amounts packaged and sold are difficult to obtain as these are viewed by dealers as competitive information; however, certain regional distributors (serving the southeastern states) and national manufacturers were willing to disclose production trends in terms of annual percentage increase. According to the estimates of the former, the distribution of these products, commencing with 1931, increased each year by amounts which varied with different concerns from 20 to 40 percent until 1943, when output was crippled by lack of metal for containers and hand-sprayers. Compounded at the annual rate of 20 percent, this would represent an over-all increase of nearly seven and one-half times for this period.

One national producer wrote that the volume of his company's household insecticide distribution in the southeastern states increased 140.4 percent from 1935 to 1945 but he believes that this was due to the energetic advertising of his concern and that competitive business did not advance to that extent. However, one of his principal competitors supplies the following indices expressing in terms of percentage relationships, based on business done in 1939, the amounts of domestic insecticides distributed by his dealers in 13 southeastern states (figure for 1939 being taken as 100%).

Year	Percent	Year	Percent
1931	20.25	1939	100.00
1932	27.14	1940	85.07
1933	32.23	1941	89.23
1934	41.63	1942	147.08
1935	51.83	1943	159.59
1936	63.80	1944	139.50
1937	75.16	1945	140.36
1938	78.85	1946	55.84

This manufacturer is of the opinion that the sharp decrease in sales volume during 1946 was due to the large amount of "free" spraying which was done by local and Federal government agencies during that year.

These indications, while remarkable, do not tell the whole story because numerous small operators commenced domestic insecticide production during this period thus adding materially to the total made available to consumers. It is probably conservative to estimate that there were 10 to 20 times as much household insecticide used in the southeast during the early war years as in 1931 to kill mosquitoes as well as other domestic insects.

In 1945, the Office of Malaria Control in War Areas embarked on its Extended Program of Malaria Control. This consisted of the application of residual DDT to the interior surfaces of homes and privies in counties where substantial mortality from

malaria* had been reported during the period just before World War II. This was aimed at preventing the dissemination of malaria from home-coming veterans who had acquired infection overseas. From January 1, 1945 to September 27, 1947, nearly 3.2 million house-spraying applications were made in rural areas or small towns in 309 counties. The average number of sprayings per house varied from nearly two in 1945 to not quite one and one-half in 1947, when 875,534 different houses were treated.

Domestic insecticiding with residual chemicals such as DDT appears to be the most feasible single approach to malaria prevention now available in the South considering the special problems of house construction, the distance between homes in rural sections, and the economy of the inhabitants. Most anopheline mosquitoes bite only at night and as more people are within their homes than elsewhere during the hours of darkness, it follows that measures which prevent mosquitoes from entering houses or which destroy the insects after they are inside are of transcendent importance in preventing malaria transmission. It is probable that the insecticidal applications, both ephemeral and residual, made within the home in the last 12 years have accomplished more than any other one measure to reduce malaria transmission in the South.

Anopheline deviation — Another circumstance which may have been of considerable assistance in reducing the domestic density of anophelines is the expansion of cattle-raising in the southeastern states. The lower curve in Fig. 3 shows the estimated cattle population in the South Atlantic and South Central states from 1930 to 1946. Cattle husbandry has increased in the South as cotton cultivation has receded in importance and as rural labor has migrated out of the region. Longer grazing seasons than are available elsewhere in the country, less labor requirements, accessibility to eastern markets, and better protective techniques now available against cattle diseases spread by biting arthropods are said to be factors contributing to this development. The presence of more cattle is believed to be important, malariologically, because *A. quadrimaculatus* has a strong preference for cattle blood.[34] As these mosquitoes emerge from their breeding places and seek blood meals, they are less likely to enter human habitations in large numbers if they can satisfy their appetites more conveniently from cattle in the fields or in stables close to houses.

The trends of the two graphs in Fig. 3

*In calendar year 1946, counties were approved for Extended Program operation if the average annual malaria mortality rate during 1938 to 1942, inclusive, was 10 or more per 100,000 population. In 1947, the base was broadened to include rates down to 5 per 100,000. Counties with evidence of current malaria morbidity were included both years.

indicate that the decrease in the farm population of the South occurred while the cattle population was on the increase. This suggests that the antimalarial influence of these two circumstances may have been compounded by their contemporaneous development.

DISCUSSION AND SUMMARY

Until medical and public health practices in the reporting of malaria cases and deaths are improved to the point of being more dependable measures of the actual morbidity and mortality due to this disease, certain reservations must be entertained concerning its real status and shifts in prevalence. It does appear to be diminishing, however, and on the basis of the foregoing, the following tentative deductions seem to be justified. Certain of these, derived from information collected over broad regional expanses, deserve more searching and precise investigation in restricted study areas to determine the nature and extent of their local impact on the incidence of malaria.

It appears that there has been no essential deterioration in the potentialities of the parasite-host-vector system of malaria transmission in the United States during the last twelve years. The infectivity of the various species of Plasmodium capable of parasitizing man and transmitting mosquito remains unimpaired. It seems more likely, therefore, that the malaria recession can be explained in terms of quantitative rather than qualitative changes.

The widespread efforts at AREAL reduction of anophelism in the South by antilarval measures have depressed and possibly extinguished malaria endemicity in certain localities but it is doubtful that these programs were primarily responsible for the regional decrease. The reduction of DOMESTIC densities of anophelines by the use of insecticides, as a result of deviation by cattle, and to a lesser extent by insect-proofing of houses is held to be a more important and uniformly extensive causal factor.

Other circumstances contributing to the general decline are 1) population movements from rural areas in the South where malaria could be acquired to urban centers in the South or to other parts of the country where malaria does not occur, and 2) improved antimalaria medication.

Economic advance has undoubtedly stimulated the development of most of these factors. A depression might be expected to send people out of the cities back to the country where unimproved housing would quickly deteriorate in the absence of maintenance. Money would not be spent for household insecticides and the most effective antimalarials. Under such conditions, malaria could again become a public health hazard of great prominence.

If malaria can be eradicated in this country and its reintroduction prevented or controlled — and this possibility is viewed as reasonable — [8,35,36,37,38,39,40] economic depressions could have no malariogenic effect. Malaria prevalence and transmission have reached new lows. Control techniques are more effective today than ever before, though doubtless their efficiency can be still further improved. These considerations constitute compelling motives for taking advantage of our present strong position. They offer a challenge to national, state, and local health agencies to combine in effecting the complete annihilation of the "world's greatest scourge" [38] in the United States.

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