MANAGING MALARIA: SELECTED MAPS OF THE TWENTIETH CENTURY

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Abstract

Understanding malaria's geographic occurrence throughout the world is amazingly complex. Jacques May wrote that "a whole atlas, comprising several dozens of maps, could justifiably be devoted to the cartographical representation of what we now know about malaria and its geographical significance." Three themes motivate this work: (1) renewed interest in the occurrence of malaria in Africa, (2) the popularity of work using a Geographic Information System (GIS) to estimate the economic burden of malaria, and (3) an appreciation for the challenges faced when mapping malaria. Selected malaria maps of the 20th century from the World Health Organization (WHO), the American Geographical Society (AGS), and others, are analyzed to identify the way maps are used to communicate information about malaria. Conclusions are drawn about the use of GIS for mapping malaria, and an argument for the importance of cartographically informed GIS users is made.

Table of Contents

Malaria Revealed **1**
Malaria's extent historically 1
Identifying and disrupting the transmission cycle 2
Malaria and the founding of post-WWII health organizations 3
Malaria Conceived **8**
Early examples 8
United States Army Medical Intelligence 8
Producing medical and sanitary surveys 11
A need for maps 12
WHO annual malaria updates and maps 14
Malaria Studied **17**
WHO 1946 18
WHO 1965 22
WHO 1994 27
Three other WHO global malaria maps 32
Some conclusions on the WHO maps 36
Malaria Homogenized **38**
Economist's Geography 38
Gallup and Sachs Risk Map 40
Interpreting this map 45
Malaria Cartography **47**
Atlas of Diseases: Malaria 47
Extensively distributed malaria vectors 50
Anopheles locally distributed in the African region 54
Malaria Parasites 56
Malaria Conceptualized **59**
Comparing the WHO and AGS maps 59
Reader response to the AGS map 60
Reader response to WHO global maps 61
Metadata deficiencies of the AGS and WHO maps 63
Malaria Reconsidered **65**
Needing modern malaria maps 65
Earlier economic assessments of malaria 67
The perils and pitfalls of GIS 70
Contesting the cartographers role 71
Limited map use 73
Conclusion 76
Notes **79**
Works Cited **80**

List of Tables and Figures

Table 1.1 A list of WHO Malaria maps 1955 to 1997 16

Figure 1.1 WHO Regional offices and the areas they serve 7
Figure 2.1 Geographical distribution of malaria throughout the world 9
Figure 2.2 La malaria dans le monde 10
Figure 2.3 Malaria, United States Army 13
Figure 3.1 WHO 1946 malaria map 19
Figure 3.2 WHO 1946 map's path of visual analysis 21
Figure 3.3 WHO 1965 malaria map 23
Figure 3.4 WHO 1965 map's path of visual analysis 25
Figure 3.5 WHO 1994 malaria map 28
Figure 3.6 WHO 1994 map's path of visual analysis 30
Figure 3.7 WHO 1956 malaria map 33
Figure 3.8 WHO 1959 malaria map 34
Figure 3.9 WHO 1989 malaria map 35
Figure 4.1 Gallup and Sachs data sources 40
Figure 4.2 Gallup and Sachs Risk Map 41
Figure 4.3 Gallup and Sachs digitization 42
Figure 4.4 Gallup and Sachs map design 44
Figure 5.1 *Atlas of Diseases*, Map of Malaria Vectors 49
Figure 5.2 Distribution of Malaria Vectors, *Atlas of Diseases* 51
Figure 5.3 Distribution of Malaria Vectors in Africa, *Atlas of Diseases* 55
Figure 5.4 Distribution of Malaria Parasites, *Atlas of Diseases* 57
Figure 7.1 The user-environment relationship model 74

Malaria Revealed

chapter one

Malaria's extent historically

The confrontation between humans and malaria has occurred in many locations on earth for millennia. Before the rise of ancient Greece, it is believed that malaria occurred throughout "parts of Mesopotamia, India, and south China" in addition to parts of Africa (Russell 1955). Historical information on these non-western locations is scarcely available to western scholars. The dominant ideas explaining malaria's occurrence largely originated in ancient Greece (Ross 1910, Russell 1955) and they are fundamental to our understanding of malaria today. It was the Greeks who identified "quartan, tertian, quotidian and semitertian" (Ross 1910) fevers' link to swampy areas, an idea attributed to Greek scholar Hippocrates (Russell 1955). The modern word *malaria* is a contraction of the Italian phrase *mala'aria*, meaning "bad air." By the time this phrase appeared in the Middle Ages, the etiology of these intermittent fevers had been refined from swamps to the *air* from swamps.

The development of technology for preventing and treating malaria is also fundamental to the contemporary western understanding of malaria. During the late 17th century, the draining of swamps was identified as an effective means for preventing the seasonal malarial fevers common in Italy (Ross 1910). The first effective medicinal treatment of malaria came from a substance extracted from the bark of the Peruvian cinchona tree. European explorers to South America found that indigenous people drank a bitter tea made from the cinchona bark to treat fevers. Later (in the early nineteenth century), European scientists would isolate the curative substance in the bark as the alkaline *quinine*, and the harvesting of the tree bark would be an important item of colonial export and trade from South America (Rocco 2003).

A theme of the colonial period was the exploration by Europeans into often inhospitable environments, where disease was one of the main sources of personal discomfort. While little is known about how various indigenous civilizations dealt with malaria endemic to their regions prior to European colonization, the incidence of yellow-fever and malaria in European visitors was frequent, and was widely incorporated into stereotypes of life in the tropical colonies. As European governments expanded their interests into foreign territories during the colonial period, the colonialists were increasingly confronted with malaria (Watts 1997). Malaria was not simply a problem in the colonies of Africa and India but continued to occur epidemically in parts of Eastern and Western Europe (Russell 1955, Rocco 2003) and endemically in the United States as well (Ackerknecht 1945, Russell 1955).

Identifying and disrupting the transmission cycle

Sir Ronald Ross identified definitive links between mosquitoes, man, and malaria parasites while working for the British Government in India during the late nineteenth century. In 1902, he was awarded the Nobel Prize in Medicine for this discovery (Ross 1902). On the other side of the world, the American William Gorgas had been trying since 1898 to rid the city of Havana, Cuba, of malaria and yellow fever using a variety of sanitation techniques. In 1899-1900, Dr. Walter Reed of the U.S. Army Medical Corps led a team of U.S. doctors sent to Havana to study yellow fever. Reed's investigation brought conclusive evidence that mosquitoes were not only the vector of malaria, but of yellow fever as well. Gorgas went on to refine techniques and establish sanitary standards for screening buildings and eliminating unnecessary water-holding receptacles working in Cuba, and later in the Panama Canal Zone (Russell 1955, p138-142).

In 1945, DDT became widely available in the United States (Perkins 1978), as did the drug chloroquine (Humphreys 2001). These technological advances in the prevention and treatment of malaria provided the United States Public Health Service (USPHS) and other well-funded national public health systems the necessary weapons to finish off malaria in most of these mid-latitude countries. The epidemiological achievements prior to this time period are well documented (Ross 1910, Russell 1955), as is the role of malaria in the Southeastern United States and the coevolving national public health system in the early twentieth century (Humphreys 2001).

The military importance of malaria and other diseases is well established in history (Smallman-Raynor and Cliff 2004). In the U.S. Army the incidence of malaria mortality domestically decreased steadily through the early twentieth century due largely to the measures implemented by the USPHS (Simmons 1942). For troops abroad, the risk of dying from disease was often higher than death from enemy fire. In 1942, the U.S. military fighting in the Pacific lost eight times more men to malaria than to Japanese action (Hart 1946). Nearly two years before its use would be approved at home, the U.S. military was already using DDT abroad to try to moderate the debilitating effects of disease. The effectiveness of combining DDT (for prevention) and chloroquine (for treatment), developed during the wartime period heavily influenced post-WWII malaria control attitudes and practices (Hays 2000).

Malaria and the founding of post-WWII health organizations

Interest in combating malaria was stronger than ever at the end of WWII. Politically savvy USPHS officials secured ever larger budgets by playing upon domestic concerns about malaria reintroduction by returning GIs to areas where malaria was now controlled or eradicated (Humphreys 2001). Prolonged military occupation and rebuilding efforts in former European and Pacific theaters of wars meant that the

United States military maintained a strong interest in malaria abroad. As the political, social, and economic relationships throughout the world were restructured, large multilateral organizations such as the United Nations, the Breton Woods organizations, and others were founded to manage and direct the process of reorganization.

The World Health Organization (WHO) was one of the new multilateral organizations founded in the postwar era. In order to understand and appreciate it, aspects of its unique history needs to be traced. Like the other postwar multilateral organizations, the WHO was not an entirely new organization nor were the principles it was founded upon. However, the way in which it facilitated broader political and financial support for its policies and programs was unique.

The Pan American Sanitary Bureau (PASB) founded in 1902, and headquartered in Washington D.C., was the first international health organization (Siddiqi 1995). Economic interests were closely tied to health interests, and the PASB had emerged from the commercially oriented Organization of American States founded approximately ten years earlier. This stands out in the PASB list of duties, which required each country to (Russell 1955):

> (1) report current sanitary data of ports and territories to the Bureau, (2) aid the Bureau in investigating outbreaks within its borders, (3) develop the most comprehensive public health protection plan possible to facilitate international commerce by eliminating preventable diseases, (4) contribute to an annual budget for the Bureau activities.

Additionally, the bureau was to enforce and maintain established sanitary standards for seaports to control, and when possible, eliminate communicable diseases.

The Health Organization born of the League of Nations prior to WWII is commonly thought of as the origin for the WHO. It is notable, though, that PASB existed earlier than the League of Nations Health Organization, and only after several productive decades did it choose to join the WHO with practically no change to its existing structure or operation.

Equally important, though, to the history of malaria is the Health Organization of the League of Nations, which decided to establish a malaria committee of scientific experts in 1924. Significantly the committee's instructions were to study the incidence of malaria, create an agenda for further epidemiological study, and consider world quinine requirements. The committee's creation brought together malariologists from different countries to assess malaria problems using their collective knowledge and expertise (Russell 1955).

While the activities of the League of Nations and its malaria committee were largely suspended during WWII, the function of the committee was revived after the war in 1947, a year before the WHO came into existence. Thus, at the inception of the WHO, malaria occurrence worldwide was already a primary agenda item. Malaria eradication through environmental sanitation (by draining lowland swamps and eliminating or treating small catch basins) paired with treatment by quinine (later by chloroquine) had proven extremely effective in numerous locations. At the same time the application of DDT through household spraying had been shown to be a more cost effective way of preventing malaria. In comparison, drainage and screening were much more labor intensive.

According to Packard (1998), the idea of eradication was so persuasive, because it embodied the postwar belief in "scientifically based technology as the key to human advancement." It appealed to the sensibilities of politicians from a majority of the countries, because it supported the economic advancement of both developed and developing countries. Developed nations could use their manufacturing prowess to produce the chemicals and applications necessary to kill mosquitoes, and developing countries would become economically advantaged by a healthier labor force.

A significant date for malaria throughout the world was 1955, when the eighth World Health Assembly meeting in Mexico City, passed a resolution to commence the WHO Global Malaria Eradication program. The members of the WHO consented (World Health Organization 1956b):

> …to intensify plans of nation-wide malaria control so that malaria eradication may be achieved and the regular insecticide spraying campaigns safely terminated before the potential danger of a development of resistance to insecticides in anopheline vector species materializes.

For the next 14 years, the malaria eradication program was managed by the Division of Malaria Eradication based at WHO Headquarters in Geneva, Switzerland, and still informed by the Malaria Expert Committee. The anti-malarial activities of the WHO were more directly administered by the WHO Regional offices (Figure 1.1) in Africa, the Americas (PASB), Eastern Mediterranean, Europe, and the Western Pacific (World Health Organization 1958).

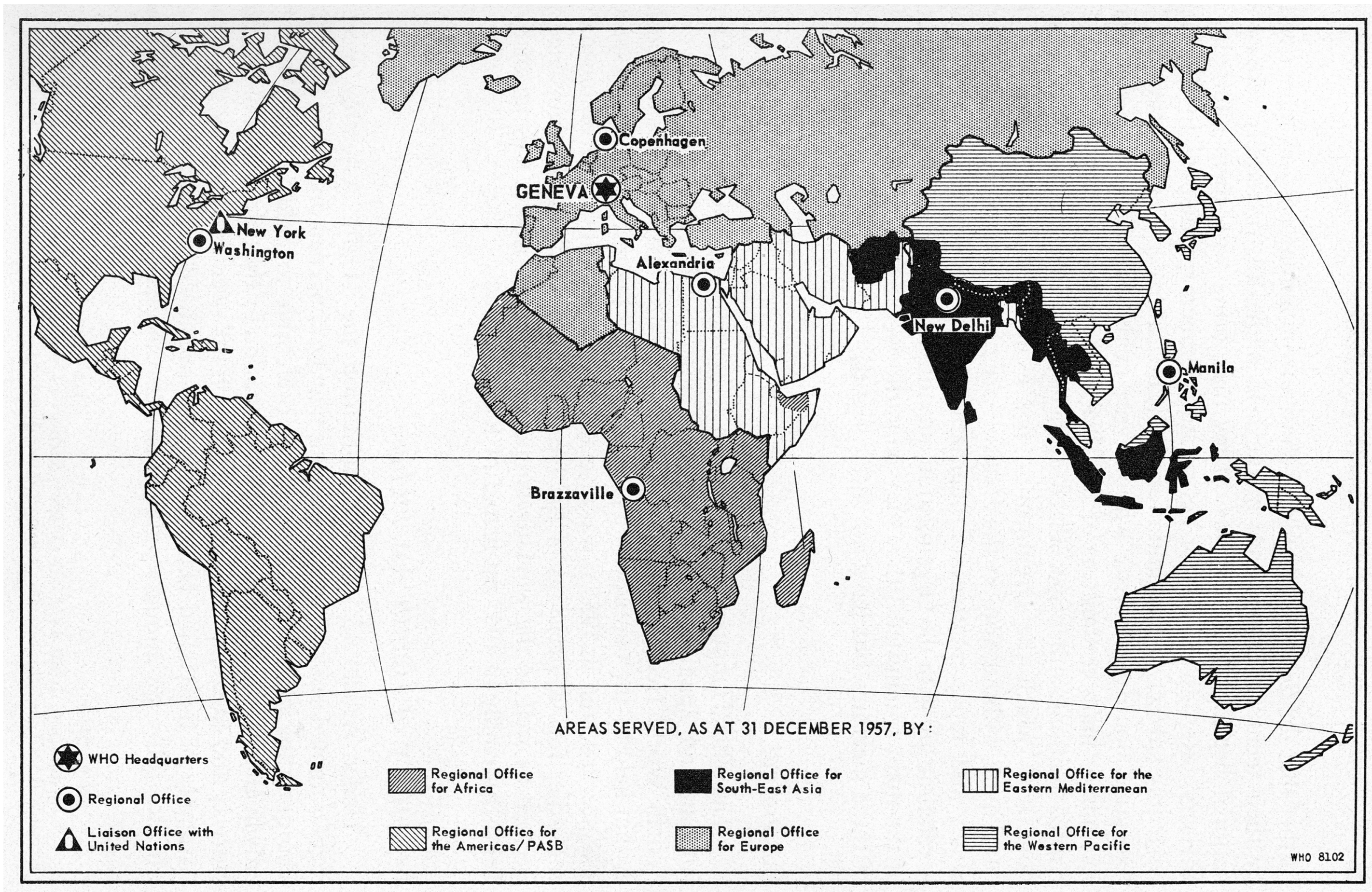


Figure 1.1 WHO Regional offices and the areas they serve (World Health Organization 1958). [original size 7.5" x 4.75", shown here at the original size].

Malaria Conceived

chapter two

Early examples

Throughout the history of malaria, maps have not been consistently used. However, several maps exist of malaria at a global extent before 1950. One appears in 1930 (Boyd, Figure 2.1) followed by a French map six years later (Le Lannou 1936 Figure 2.2). Both maps are general reference maps drawn at a very small scale. [1] The source of the malaria data for either map is not known, yet certain common patterns can be found in endemic malaria areas. Notably, both maps include isotherm data to shown the seasonal expansion of the malaria range in the northern and southern hemispheres. Later maps do not extract any data from these maps. However, as WWII broke out, the health risk posed by malaria would become an increasing concern in numerous countries.

United States Army Medical Intelligence

Within this historical development, World War II stands out as a unique period in history when significant innovation in science, technology, and political will were converging upon malaria. The US Army was one institution which found itself grappling with the questions: (1) what is the occurrence of malaria in man across the globe, and (2) how do you reduce or eliminate the detrimental effects of human malaria infection? To directly support the United States Military involvement in World War II, an office of Medical Intelligence was created by the Surgeon General In 1939, as it became more certain that the United States would be called upon to send troops to fight at the European front, the Surgeon General had begun preparing anti-malaria measures for areas of military importance. These included domestic training facilities

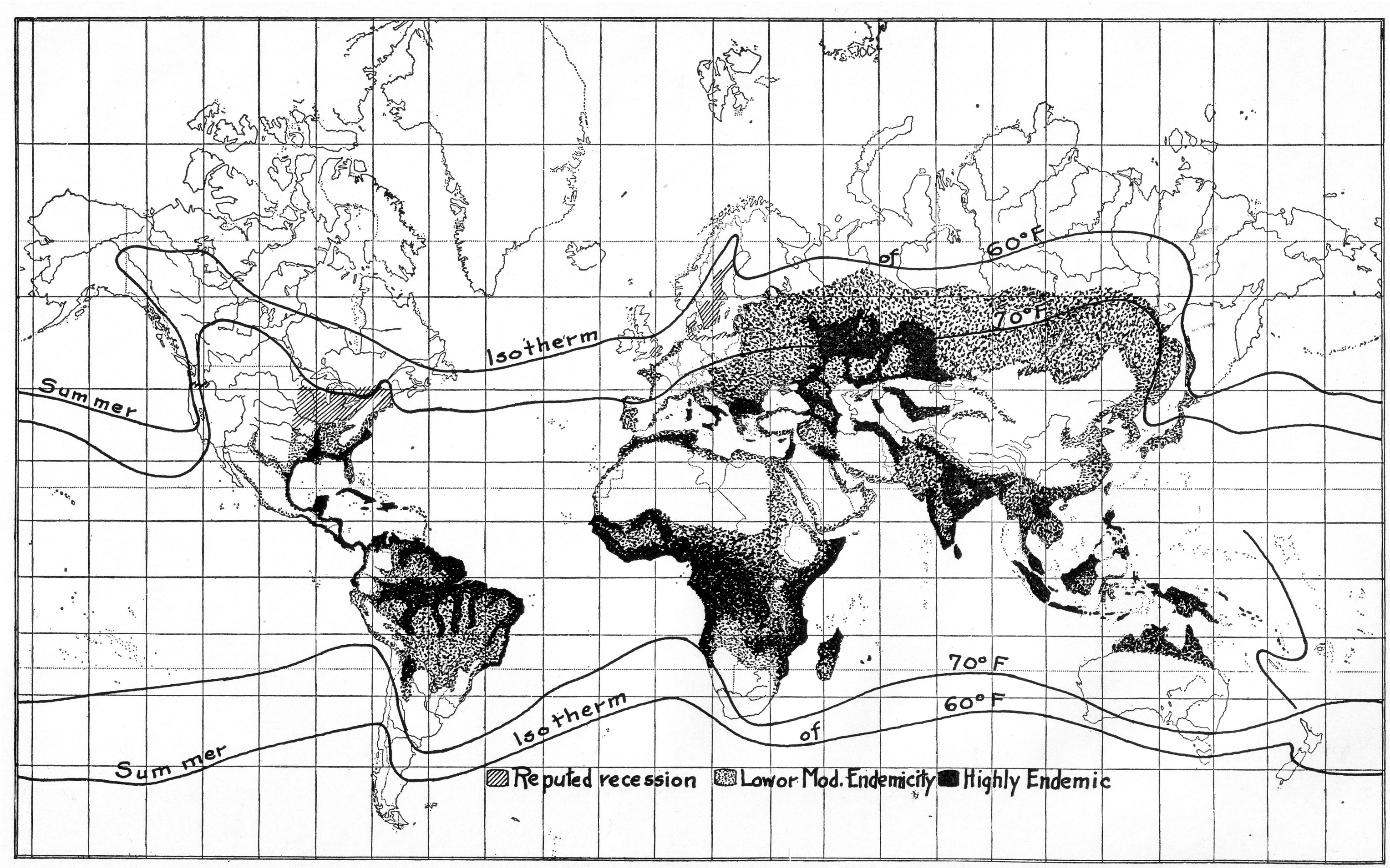


Figure 2.1 Geographical distribution of malaria throughout the world (Boyd 1930). [original size 7.75" x 5.75," shown here at the original size]

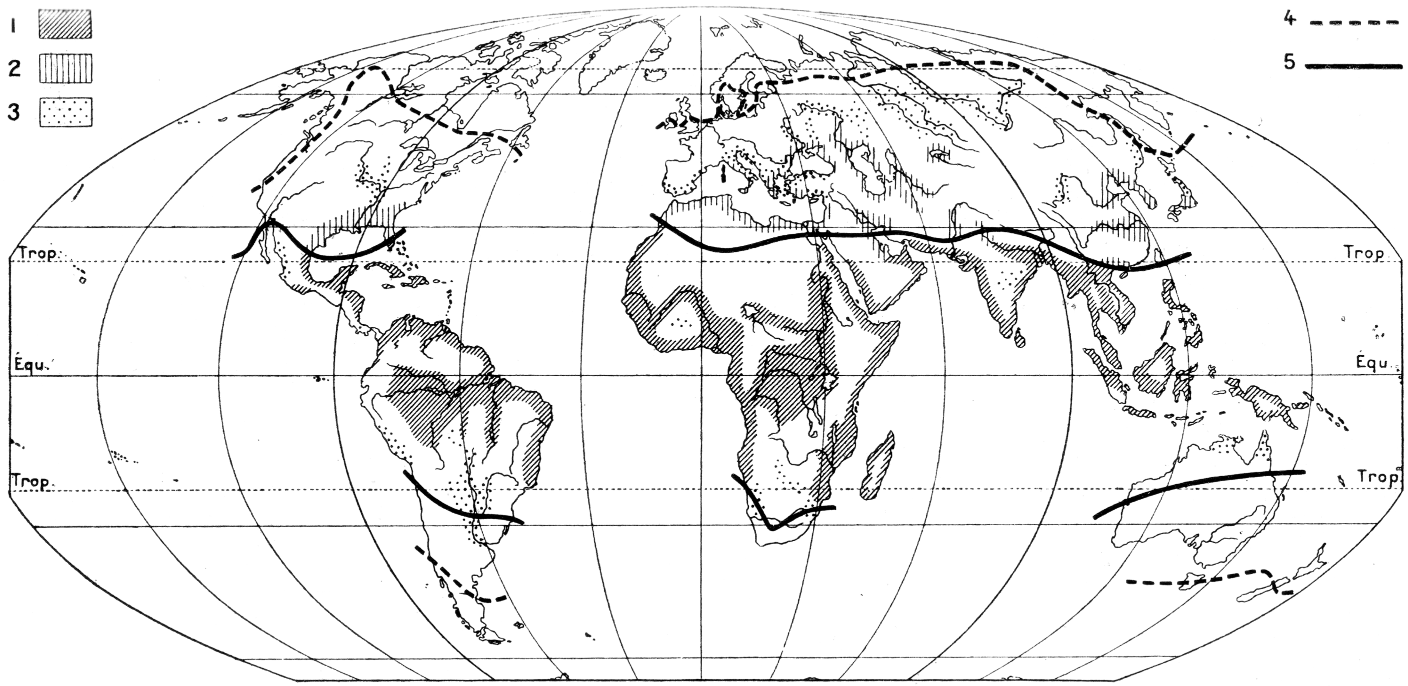


Fig. 2. — La malaria dans le monde.

1, Zones d'endémie tropicale permanente. — 2, Zones d'épidémies saisonnières graves. — 3, Foyers intermittents d'épidémies bénignes. — 4, Isotherme de 16° au mois le plus chaud. — 5, Isotherme de 16° au mois le plus froid.

Figure 2.2 La malaria dans le monde (*trans.* malaria in the world) (Le Lannou 1936). [original size 7.25" x 3.5", shown here at the original size] in the American South, and semi-permanent and permanent bases in the Caribbean, West Africa, tropical America, India, Burma, North Africa, southern Italy and the south Pacific (Simmons 1945).

Producing medical and sanitary surveys

One aspect of U.S. military medical intelligence was the need for better information relevant to the welfare of fighting men. In 1940, a survey was begun of health facilities and hazards for every foreign country by a newly established organization named the Division of Military of Intelligence, under the Preventative Medicine Service, as directed by the Surgeon General (Simmons 1942). According to Whayne, an early officer and eventual director of the Medical Intelligence Division:

> …nowhere in the United States – in libraries, the Library of Congress for that matter, foundations like the Rockefeller Foundation, military libraries or archives or any place else – nowhere was there reliable information on health and medical problems and developments on a global basis (Anderson and (Interviewer) 7 May 1981).

The Medical Intelligence Division's task was to collect and assemble "data regarding medical, health, and sanitary conditions in all areas to which troops might conceivably be sent" (Simmons et al. 1944). To compile this information, any source available was consulted:

> We literally picked up information anywhere we could get it – not only in the library, but by interviewing people, both knowledgeable people, not only in our own country but [also] from other countries. We actually sent some people out to some places we didn't know about (Anderson and (Interviewer) 7 May 1981).

Medical and sanitary surveys were then written for each country and used for medical and logistic training for combat operations. They were initially published internally for military planners as part of the Joint Army-Navy Intelligence Studies (JA-

NIS) series (Clemente 2005). They remained classified documents until 1944, when the first volume of *Global Epidemiology: a geography of disease and sanitation* was published. The published volume is said to exclude certain information germane to the then ongoing war. Yet the information it does contain still had great value to civilian agencies (Simmons et al. 1944, Anderson 1969).

A need for maps

To satisfy "a need for a simple graphic method of showing what diseases might be encountered in various areas (Anderson 1969)," the Medical Intelligence Division first produced maps of certain diseases which included malaria, in the fall of 1941. The maps were revised in early 1942. These maps, distributed by the Division, were made available to all medical schools and enlargements were made for lectures. Later, at the suggestion of the Commanding General, the maps were reproduced in a War Department pamphlet (United States War Department 1944, Figure 2.3) for widespread distribution to all troops (Anderson 1969). Significant and useful was the contribution made by the maps, yet several in the division were concerned about the design of the maps, and the quality of their malaria information. It has been said that the maps were prepared "conscientiously but inexpertly" (Jarcho 1991, p 503).

Jarcho (1945), a doctor who cultivated a life long interest in medical maps, penned a brief article on the importance of equal-area map projections during his tenure in the division. Similarly, Anderson (1969, p 315) provides a historical account of map production:

> The data then available were such that certain minor inaccuracies crept into these maps [in 1941]. Early in 1942, a revision was made but unfortunately without technical cartographic advice or assistance. The data incorporated in this revision were improved but were still inadequate for the precision that is desirable in map production. Additions and corrections were subsequently made, but no opportunity was afforded for the thor-

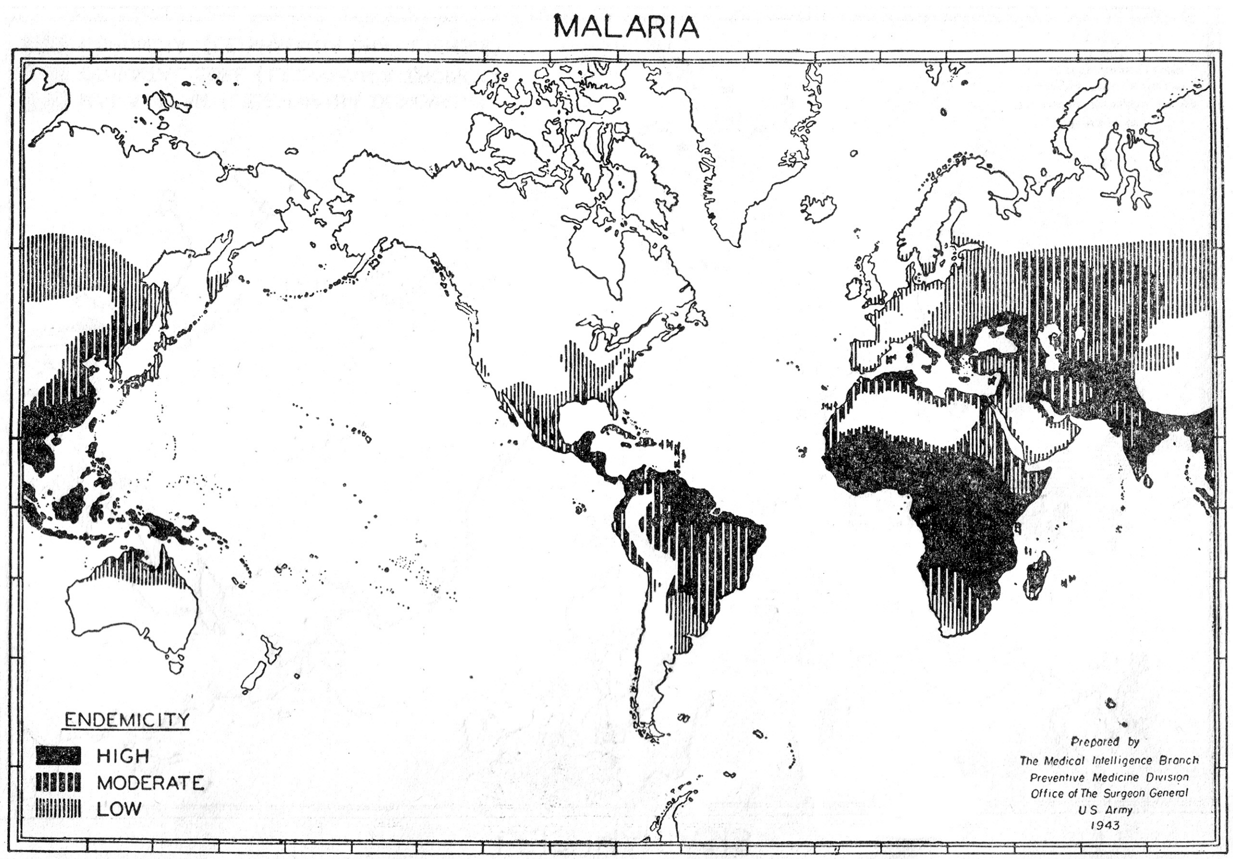


Figure 2.3 Malaria, United States Army (United States War Department 1944). [original size is 6.25" x 4.25," shown here at its original size]

> ough revision that was desirable and for which the services of a competent medical geographer were requested but denied.

The quotation above reveals that while there was a serious interest in producing good maps of global disease distribution, the effort was hampered by a combination of factors, notably lack of accurate data, technical cartographic skill, and support from senior officers. This last criticism appears in print a second time at the end of a review of a German disease atlas discovered by the Allies (Anderson 1947). Anderson is dismayed by (p311):

> … the willingness of the German Army to assign a large staff of senior officers to a task of this character, whereas the major burden of comparable work in the American Army had to be carried by personnel to whom the Army refused to accord so much as field rank and among whom it refused to include officers with geographical training.

Anderson's comments have particular weight. Before his military service, he already held the position of professor at the University of Minnesota, where he would return to, and eventually direct their School of Public Health over the course of a long and distinguished career. It must be concluded then that the compilation of global disease data and the production of disease maps was seen as a timely and significant scientific contribution, although the opinion was voiced by a small minority.

WHO annual malaria updates and maps

From the beginning of the WHO's Global Malaria Eradication campaign, an effort was made by the Malaria Section to produce an annual report with which to update WHO members at the annual World Health Assembly. Materials found during my 2007 research visit to the WHO Archives in Geneva, Switzerland suggests that this report was compiled from numerous types of statistical information requested from the various Regional Offices by the director of the Malaria Eradication (World

Health Organization 1962a). Along with the requested statistical information, the directors of the regional offices often supplied their own accounts of the malaria eradication activities which they oversaw. These were then edited and compiled into one document at the WHO headquarters. The final report often included several tables and line graphs presenting the statistical information, and frequently a global map showing the current distribution of malaria and WHO malaria eradication activity.

Prior to these WHO-produced maps of malaria, few groups had tried to compile accurate information about the occurrence of malaria at a global scale. The maps discussed previously were rarely updated or revised with new malaria data. Thus, the WHO maps which were produced somewhat consistently over time (26 maps from 1955-2000, Table 1) offer a unique perspective on the progress of the WHO's Global Malaria Eradication program. Recent researchers have tried to use these maps to study the impact on malaria, and consequently its reduced occurrence, over approximately the last 50 years.

In summary, from the experiences of the US Army Medical Intelligence Division discussed in this chapter, the need and utility of malaria maps for planning operations was established. The Medical Intelligence mapping experience sets a precedent in the history of mapping malaria at a global scale, with lessons on the importance of good data, and good design were recorded. About ten years afterward, the WHO Global Malaria Eradication Campaign got officially underway and they began producing their annual malaria maps. In the chapter that follows, several maps from the WHO map series will be examined to see how issues of map data and design were handled. Flipping through the 26 WHO maps, six general map styles appear. An example of each style will be examined more closely, with three maps in particular receiving a thorough critique.

Table 2.1 A list of annual WHO Malaria maps appearing in various WHO publications from 1955 to 2000

	Map title	Reference
1)	Geographical Distribution of Malaria before 1946 (before residual insecticides were used)	(Pampana and Russell 1955)
2)	WHO Malaria Eradication in the World [1956]	(World Health Organization 1956a)
3)	The state of malaria eradication, 1959	(World Health Organization 1959)
4)	Malaria eradication situation in December 1960	(World Health Organization 1961)
5)	Malaria situation, December 1961	(World Health Organization 1962b)
6)	Epidemiological assessment of status of malaria, December 1962	(Fogel and Eylan 1963)
7)	World malaria situation, 30 June 1963	(Wilkinson 1964)
8)	Epidemiological assessment of status of malaria, 30 June 1964	(Bentzen 1965)
9)	Epidemiological assessment of status of malaria, 30 June 1965	(World Health Organization 1966)
10)	Epidemiological assessment of status of malaria, 30 June 1966	(World Health Organization 1967)
11)	Epidemiological assessment of status of malaria, 30 June 1968	(World Health Organization 1969)
12)	Malaria Situation, 30 June 1969	(World Health Organization 1970)
13)	Malaria Situation, 30 June 1970	(World Health Organization 1971)
14)	Malaria Situation, 30 June 1971	(World Health Organization 1972)
15)	Epidemiological assessment of status of malaria, December 1975	(Noguer et al. 1976)
16)	Epidemiological assessment of status of malaria, December 1976	(World Health Organization 1978)
17)	Epidemiological assessment of status of malaria, 1982	(Malaria Action Programme 1984)
18)	Epidemiological assessment of status of malaria, 1983	(Malaria Action Programme 1985)
19)	Epidemiological assessment of the status of malaria, 1988	(World Health Organization 1990)
20)	Epidemiological assessment of the status of malaria, 1989	(World Health Organization 1991)
21)	Epidemiological assessment of the status of malaria, 1990	(World Health Organization 1992)
22)	Epidemiological assessment of the status of malaria, 1991	(World Health Organization 1993)
23)	Epidemiological assessment of the status of malaria, 1992	(World Health Organization 1994)
24)	Epidemiological assessment of the status of malaria, 1993	(World Health Organization 1996)
25)	Epidemiological assessment of the status of malaria, 1994	(World Health Organization 1997)
26)	Global Malaria Status [1998]	(World Health Organization Malaria Expert Committee 2000)

Malaria Studied

chapter three

In this chapter, a selection of six maps from the series of global malaria maps that were produced by the WHO from 1955 to 2000 will be examined. The first of these malaria maps was published in a report from 1955. It was not a major element in the report. In fact, while it appears (suggesting some importance) early in the document, there is no reference made to the map in the text that precedes and follows it. Such is the case with the half century of reports, and their maps, that follow. The maps are never used to supplement, complement, or provide a focus for the text.

The approach taken for evaluating the three prominent map styles will be that of the art critic; adapted here is the process used by Edmund B. Feldman in his *Varieties of Visual Experience* (1992). This study of WHO maps will require a similar understanding of the various elements which comprise map design. The design stage of the cartographic process is when the bulk of the cartographer's decision making occurs.

Feldman offers a systematic approach to the analysis of graphics. Having developed his method to enable art critics to gain maximum insight into the meaning and merit of artistic works (paintings, drawings, prints, sculpture, architecture (p469)), Feldman provides a four stage system "that makes the best possible use of … knowledge… experience and [the] powers of observation (p486)." The stages (modified by McCleary, 2005, for use in map analysis) are:

1. **Description**- an inventory of the elements found on the map, using terms which simply describe their form and the characteristics of their presentation

2. **Formal Analysis**- a description of the map structure which incorporates a sense of the way individual map elements are organized to form the graphic as a whole

3. **Interpretation**- map meaning, theme, and the problem/purpose of the map are determined, considering whether the graphic message relates to the intended message

4. **Judgment**- judge the map's final design solution to determine its excellence at communicating the map purpose, taking into account other possible design solutions

Description, formal analysis, and interpretation will be utilized here to critique three of the WHO maps.

WHO 1946

The 1946 WHO map, published in the organization's 1955 report, is a small-scale map (1:160,000,000) covering the earth's surface from approximately 62° N. to 57° S., and from 122° W. to 168° E (Figure 3.1). Drawn on the Mercator projection, the map has a rectangular shape, with the geometric center of the map rectangle located in south central Sudan. The focal center of the map, however, rests north and west of Sudan, in the Mediterranean Sea. This focal point is "the visual element or part of a page that is most emphasized and that first attracts and holds the readers attention" (Graham 2005, p299). Here, strong visual contrasts and image complexity, as well as proximity to the geometric center, contribute to the visual interest of the presentation. The data shown on the map include coastlines, islands, international boundaries, and three shaded area symbols.

The map is a black-and-white (monochrome) image. The coastlines are highly generalized using straight-line segments, giving the land masses an angular appearance. This contrasts sharply with the oceanic islands which appear as "specks"

FIG. 1. GEOGRAPHICAL DISTRIBUTION OF MALARIA BEFORE 1946 (BEFORE RESIDUAL INSECTICIDES WERE USED)

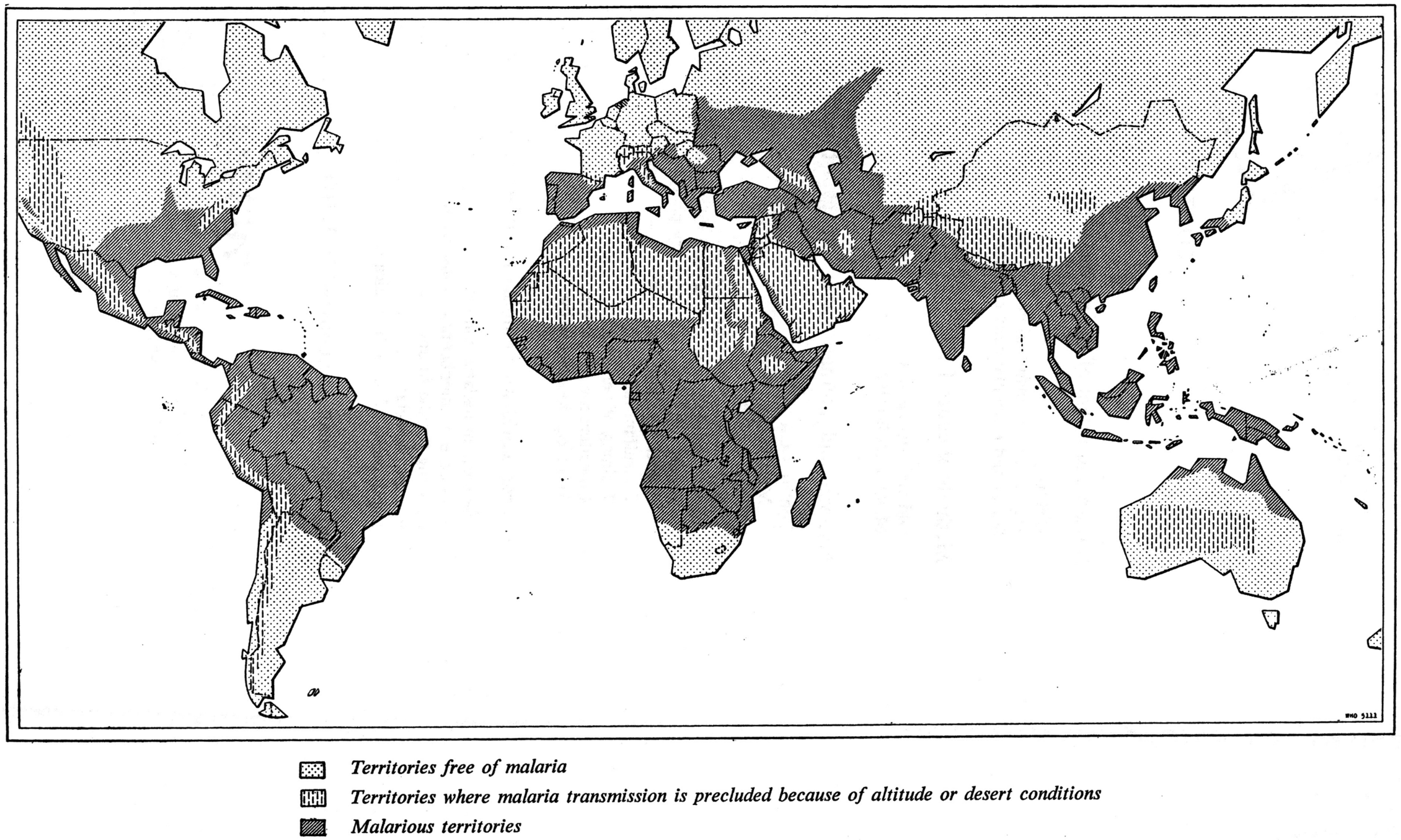


Figure 3.1 WHO 1946 malaria map (Pampana and Russell 1955). [original size 8.25" x 5.25," shown here reduced to approximately 95% of its original size]

of different sizes scattered in the oceans and seas. In terms of the visual hierarchy, the areas identified as "malarious territories" command most of the reader's visual attention. This is the first element of visual importance. Nearly a third of the total land area is designated as such, and symbolized with a flat dense area pattern composed of fine lines, appearing to be about a fifty percent tint. The visual hierarchy involves the organization of the elements on the map, in terms of size, tone, color, and texture, to create emphasis and, therefore, visual allure.

On the map, the malarious territories are dark in tone and contrast strongly with the other areas. Next in the visual hierarchy are "territories where malaria transmission is precluded because of altitude or desert conditions." Despite the fact that they occupy perhaps only eight to ten percent of the total land masses, their position in the visual hierarchy is enhanced because of their centrality (sizeable areas located near the optical center of the page), adjacency (abutting areas which are higher on the visual hierarchy), and symbology (dashed vertical line patterns provide a prominent texture that attracts the eye). The remaining land area (approximately 40 percent of the areal extent) is designated as "territories free of malaria," symbolized using a fine black dot pattern (only about a 10 percent tint).

In Figure 3.2, areas on a reduced image of the 1946 map have been numbered to illustrate the eye movement of a typical map reader. Attracted first to the central dark malarious area in Africa [1], the eye next moves northward to the north coast of the Mediterranean Sea and Europe, drawn by the complex shapes of coastlines and political boundaries [2]. The next eye movement may be either east to India or southwest to South America [3], where extensive blocks of dark malarious area again provide visual attraction. Finally, the map reader may move northward to North America or southeast to Australia [4], to look at the smaller patches of malarious territory there.

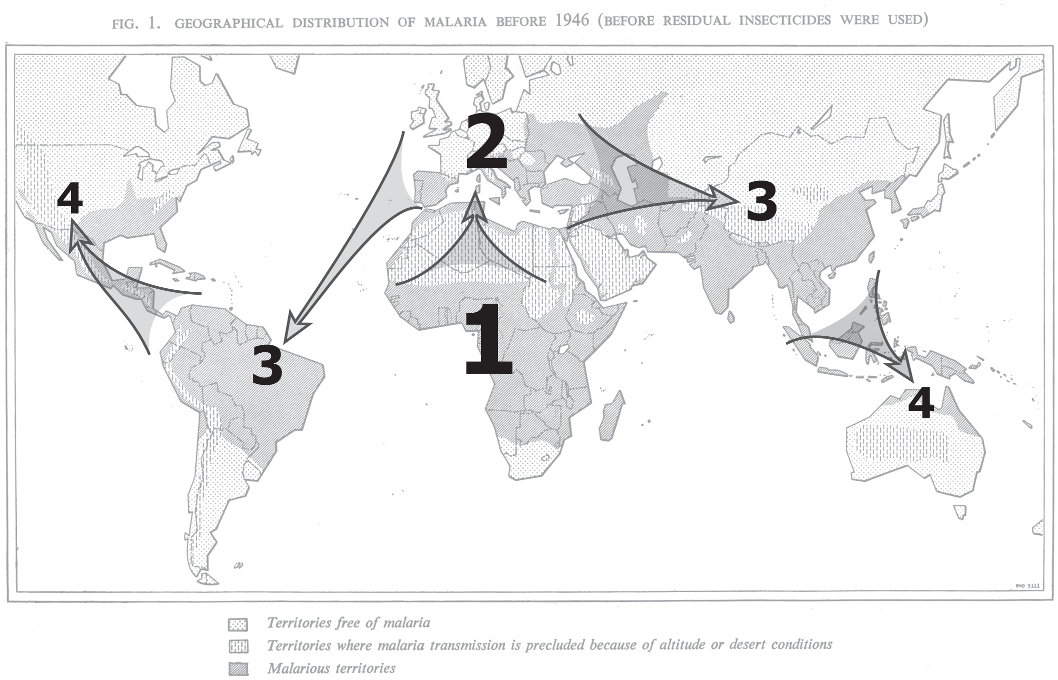


Figure 3.2 WHO 1946 map's path of visual analysis

The explicit purpose for which this map was made is open to interpretation; however, it is clear that the map lacks temporal accuracy. The vague title leaves much uncertainty as to how many years prior is meant by the words "before 1946" (e.g., one year, a hundred years, or a thousand years). Curiously, the map is never referenced in the text of the book, unlike another world map found in a later chapter. This is surprising, because the map is prominently placed at the front of the opening chapter, which discusses the history of malaria, beginning with the Egyptians in 3000 B.C. (Pampana and Russell 1955).

The representation of the malarious areas on this map is misleading too. The symbols suggest territories which have distinct boundaries with clearly defined edges. In reality these edges would be more diffuse and permeable based on the variability of local human and physical geographic conditions.

The Mercator projection is not an equal-area (equivalent) projection. As a result, the land area shown to be "territories free of malaria" is exaggerated as these areas lie in the mid-latitudes and higher. Because of the extreme areal exaggeration of the Mercator projection in the latitudes just mentioned, the reader is unable to make accurate inferences about the actual size or importance of different malaria categories.

This map is a moderately successful graphic for displaying the general (at continental or global scale) trends in malaria distribution. It is not of a sufficient scale or areal accuracy for commensurable map use activities.

WHO 1965

This map bears some similarity in appearance to the WHO 1946 map, appearing in a horizontal rectangular frame and printed in monochrome (Figure 3.3). Unlike the previous map, this map is split on a two-page spread, thus making it slightly larger in scale (1:100,000,000). Unfortunately, the gutter passes through Africa and Europe, visually dividing those continents. This map covers a slightly larger extent, reaching as far north as 75° in the center of the map (thus showing the entire European continent), westward to show most of then North American continent (excluding nearly all of Alaska), and it extends slightly further to the South (but still excluding Antarctica). Four larger-scale inset maps cover (1) Central America, (2) Portugal, (3) Greece, Turkey, and adjacent areas, and (4) Jordan, Syria, and surrounding areas east of the Mediterranean. Small circular callouts are used to show data for islands and a few small political regions (e.g., Hong Kong, Singapore, Swaziland). At a glance the data on the map appear similar to 1946; there are coastlines, political boundaries, and land areas shaded for three classes of malaria data. Studying this map in more detail, however, reveals that much has changed.

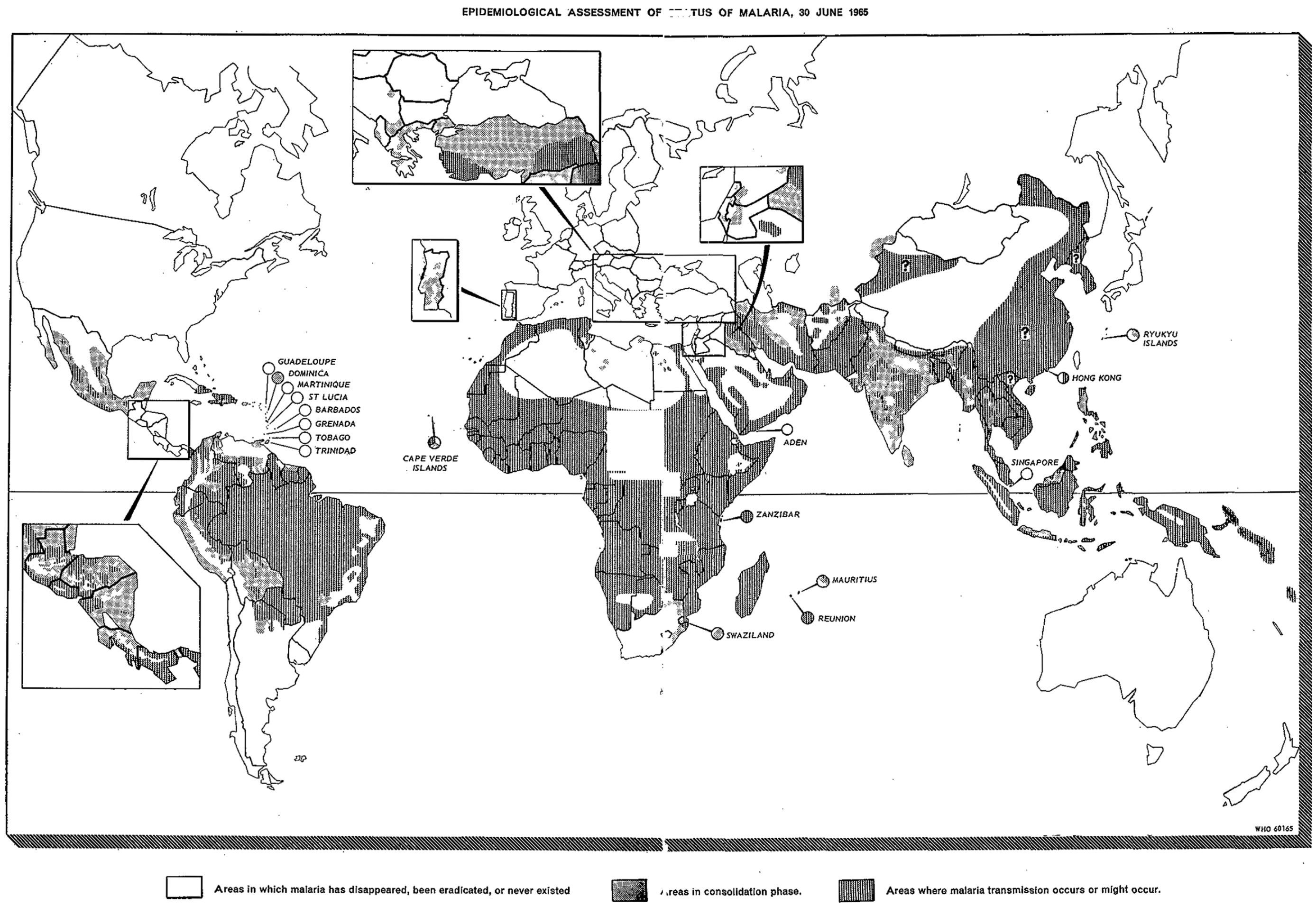


Figure 3.3 WHO 1965 malaria map (World Health Organization 1966). [original size 12" x 8.5," shown here reduced to approximately 60% of its original size]

The title has changed to reference a specific day "Epidemiological assessment of status of malaria, 30 June 1965." It is difficult to interpret this title, as, read literally, it suggests that the map shows the status of malaria for only a single day. However, we know that it is impossible to have such temporally sensitive data. The textual description of the mapped variables also differs. Nearly 50 percent of the land area shown now is mapped as "areas in which malaria has disappeared, been eradicated, or never existed." The second category (by total land area, approximately forty percent) is called "area where malaria transmission occurs or might occur." A small percentage of the remaining land area is called "areas in consolidation phase."

Two of the variables from the previous WHO 1946 map have been combined into one variable: "territories free of malaria" and "territories where transmission is precluded because of altitude or desert conditions" have become "areas in which malaria has disappeared, been eradicated, or never existed". This new composite variable is symbolized by a white fill, which creates much more visual contrast between the darkly shaded "areas where malaria transmission occurs or might occur" and the "areas in consolidation phase." The white fill, however, provides no contrast with the water areas of the earth. This is very different than the strong land-water differentiation in the 1946 map, a graphic structure that provides the reader with a very familiar global context. The significance of land-water differentiation for the map reader cannot be ignored. "This distinction has been suggested as the first important process in thematic map reading. Maps that present confusing land-water forms deter the efficient and unambiguous communication of ideas" (Dent 1999, p 260).

The visual hierarchy of this map is significantly different than that of the WHO 1946 map. Starting from the gutter, numbered [1] in Figure 3.4, the reader's eye travels to the area of malaria transmission, in Africa [2] and then outward to either side [3], attracted by its dark shading – this shading is an irregular mass, stretch-

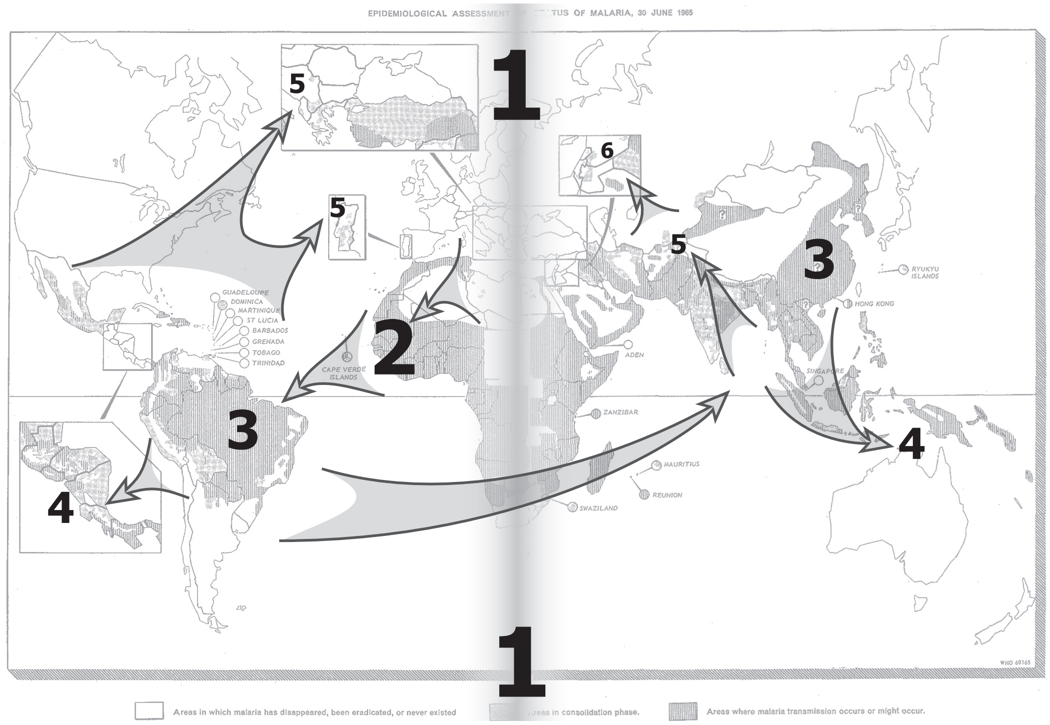


Figure 3.4 WHO 1965 map's path of visual analysis

ing diagonally across the surface of the map. Unlike the 1946 map, with its bold continental boundaries and lightly shaded areas without malaria, the familiar global land-water arrangement does not provide a touchstone for geographical recognition and identification. Intermingled with the darker malaria areas, are the intermediate zones ("areas in consolidation phase") mapped in lighter gray, the four inset maps, and the block of names for the eight West Indies islands [4-6]. There is relatively less value contrast between the dark and light grey area symbols than on the 1946 map, and the 1965 map looks rather flat and dull, lacking tonal emphasis, by comparison. The four inset maps require the reader's attention, because they show complex regions with great spatial variation among the three shaded areas. Here the "areas in consolidation phase" finally becomes relevant to the reader. Eventually the attention shifts to the lettering on the map, which identifies the circular callouts of fourteen island/island groups, and three small political regions (Hong Kong, Singapore, and Swaziland).

The reader's eye wanders more than on the 1946 map, because the lack of land-sea contrast on the 1965 map means that there is no clear overall graphic structure for the map. The difference in detail between Latin America and the rest of the world, but particularly Africa and many parts of Asia, suggest (appropriately) the more detailed knowledge of the situation by the WHO Regional Office of the Americas (PASB).

The map and the text of the article do not work together effectively. The opening text is trying to communicate the abstract idea about the millions of people who no longer live in malarious areas due to the WHO Malaria Eradication campaign. The report does this by referencing data tables of numerical values and calculated percentages, with only a single parenthetic reference to the accompanying map (page 286) in the entire article. Specifically, the table includes (and the text references) the variable "total population which was originally in malarious areas", relative to the "total population living in areas where malaria has been eradicated or eradication programs are in progress (p286)." Yet, the map does not help communicate the spatial distribution of these variables, as the variables are not displayed on the map.

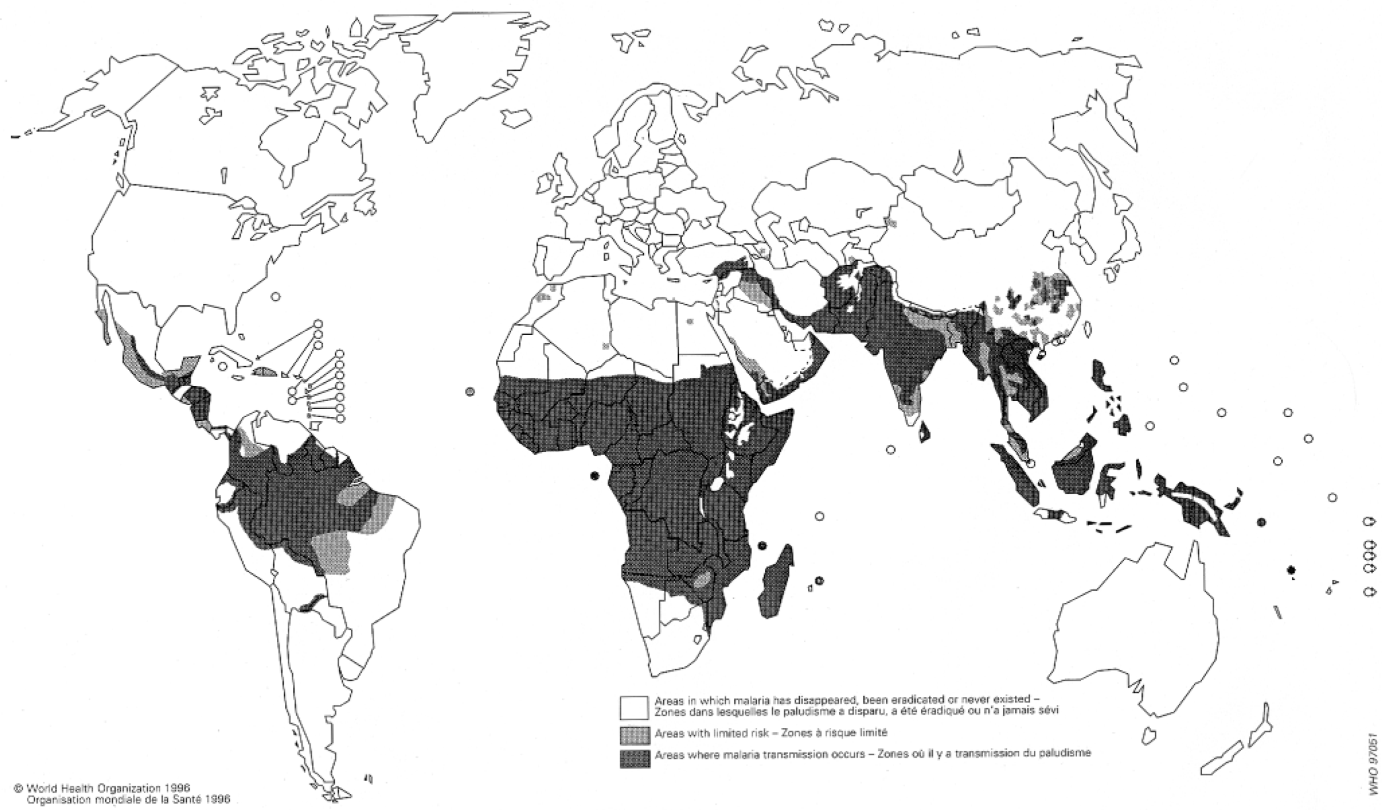
The table in the article distinguishes between two separate classes of people, those "originally in malarious areas,' and those in areas where it "has been eradicated or progress towards eradication." Yet persons in the latter of the two classes may actually be classified into two data classes shown on the map, "areas in which malaria has disappeared, been eradicated, or never existed," as well as "areas in consolidation phase" (consolidation phase being a recognized stage in the WHO's eradication program). Essentially, what the table identifies as a separate variable or group, straddles and consequently can exist in both the light grey areas on the map, and also in the dark grey areas on the map, “areas where malaria transmission occurs or might occur.”

The purpose and use of the map is confusing and problematic. If we are to assume, based on the title of the map, “Epidemiological assessment of status of malaria, 30 June 1965,” that the problem to be answered by the map is “the epidemiological status of malaria in 1965,” then the map at best gives us an extremely spatially and temporally inconsistent and vague answer. The text provides much discussion about various facets of the epidemiological landscape of malaria: locations where epidemics had broken out in 1965, locations where chloroquine resistance had been reported, locations where insecticide resistance had been reported, and spatial variation in slide-confirmation of malaria reporting. But none of these data appear on the map or are easily understood in relation to the data variables which are included on the map. The epidemiological situation for malaria was clearly complex in 1965, but much of that complexity is lost or simplified into obscurity by this map.

WHO 1994

The 1994 WHO map (Figure 3.5) created three decades later bears a close stylistic resemblance to the WHO 1965 map. Produced in monochrome, this map has been reduced to fit onto a single landscape-oriented page; consequently, it is at a smaller scale (1:130,000,000). In extent, it shows the entire North American continent, as well as all of the Eurasian landmass.

Not having a graticule makes the map’s projection and its properties difficult to determine. The projection used is somewhat like those in the Pseudocylindrical class, which have straight-line parallels and curved meridians. It has none of the extreme areal exaggeration found on the 1946 and 1965 maps, so it may be an equivalent projection with all of the areas represented in correct proportion, Map 1 Epidemiological assessment of the status of malaria, 1994   Carte 1 Evaluation épidémiologique de la situation du paludisme, 1994



The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Les désignations utilisées sur cette carte et la présentation des données qui y figurent n'impliquent, de la part de l'Organisation mondiale de la Santé, aucune prise de position quant au statut juridique de tel ou tel pays, territoire, ville ou zone, ou de ses autorités, ni quant au tracé de ses frontières.

Figure 3.5 WHO 1994 malaria map (World Health Organization 1997). [original size 10.75" x 7.25," shown here reduced to approximately 70% of its original size]

No large-scale area insets are included on this map. The circular callouts of the previous WHO maps have been simplified to circular shaped enlargements over three dozen islands and small countries. This map design utilizes displacement techniques only in the Caribbean. Coastlines, national boundaries, and three classes of malaria categorization are the only data on the map. With an eye towards the political sensitivity expected of a "world" organization, dashed black lines have been shown for parts of the national boundaries of Saudi Arabia (with United Arab Emirates, Oman, Yemen), and Bhutan where the boundary dispute continues. To complement these graphic considerations, a large disclaimer appears at the bottom of the map declaring that the graphic representations do not represent any expression on behalf of the WHO concerning the legal status of the borders shown.

The coastlines and national boundaries are more generalized than the boundaries on the 1965 map. Some segments are very angular, with straight-line segments joined by abrupt angles, while other line segments are more rounded. Overall, the generalization is inconsistent.

The map title is consistent with that of the previous map, "Epidemiological assessment of the status of malaria, 1994." The titles used for the three classes of malaria areas have changed, but the differences are largely semantic, yet still very important. Nearly 50 percent of the total land area is again classed as "areas in which malaria has disappeared, been eradicated or never existed," symbolized by solid white fill (the same white fill used for all of the oceans, seas, and other hydrographic features). The next largest class by total land area (nearly 40 percent) is described as "areas where malaria transmission occurs" (having dropped the speculative "or might occur" used on the WHO 1965 map) and is symbolized by the dark and densely packed hatch pattern (about 60 percent grey). The small portion of land area which

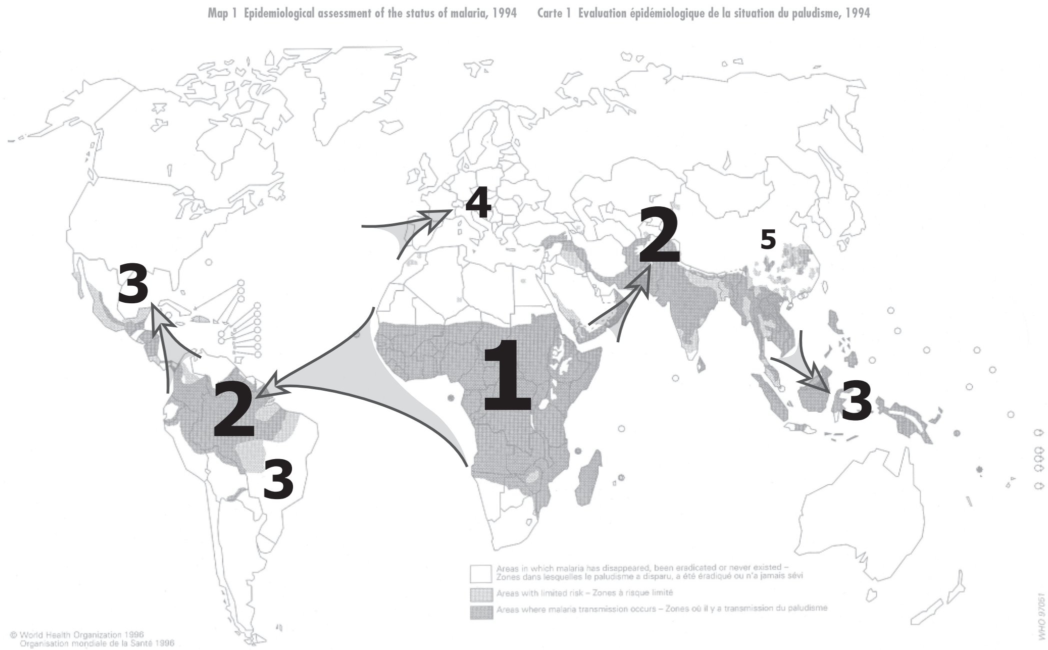


Figure 3.6 WHO 1994 map's path of visual analysis

remains falls into the middle class, called "areas with limited risk," and is symbolized by a twenty-five percent grey hatch pattern.

The visual hierarchy of the design style selected for this map is similar to the 1965 map. As on the 1965 map, the lack of a land-water differentiation compromises the overall effectiveness in the depiction of malarious areas on the map. The mass of dark grey symbolizing the "areas where malaria transmission occurs" within Africa dominates the reader's initial attention, because of the high figure-ground contrast, its size, and its centrality (area [1] on Figure 3.6. The same figure-ground relationships between the dark-grey and white areas then draws the reader's eye away from Africa laterally to South East Asia or South America [2]. Then the eye scans left from South to Central America [3], and, on the other side of the map, east through South Asia to the East Indies and the islands in the southwest Pacific Ocean [3].

The larger "areas with limited risk," symbolized by a lighter grey, stand out more than the circular island exaggerations (most of which are in the "disappeared, eradicated, never existed" category, represented by a black outline with a white center). Most of these "Areas with limited risk" and the circular island are imbedded or adjacent to the dark-shaded "malaria occurs" areas, and must be sought with a prolonged map inspection.

Like the previous WHO maps, this map struggles to support adequately the ideas expressed in the text of the article it accompanies. Unlike the previous articles, the text for this map functions simply as a verbal description of the malaria statistics collected by the WHO for malaria occurrence, mortality, testing, and treatment. The article is broken into parts and published over three separate issues of the *Weekly Epidemiological Record*. The article is organized into sections based on the WHO's preexisting world regional categories, having now been around for almost half a century. The text of the article adopts variable levels of risk as its lexicon. Like the discordance between the stages of malaria eradication on the table and the map in 1965, the text of the article is not consistent or coherent with the description of the data which appears on the map. The article opens with a statement about the estimated number of people in the world living in areas of malaria risk, yet we do not know from the map the extent or distribution of this population across the malaria categories depicted on the map. The phrase "high-risk" only appears once in the discussion of the Africa Region, to describe a war-displaced population. In contrast, "some," "low," "moderate," and "moderate/high" risk areas are all terms used in the text of the article while describing the malaria situation within countries throughout the Pan-American region.

The spatial and statistical inconsistencies which exist in the reporting of malaria make it very difficult to create a coherent and accurate picture of malaria at a comparable quality for all regions of the world without large amounts of conceptual and spatial simplification and generalization.

Given these constraints, it seems questionable whether there is any utility to producing such a map at all. At best, this map can only be asked to provide a spatially and conceptually vague answer to questions about the geographic distribution of the occurrence of malaria.

Three other WHO global malaria maps

The three WHO maps (1946, 1965, and 1994) studied above give a clear indication of the variation in style and concept used in the half century of WHO malaria maps. They are important, and are discussed in such detail, because they are the primary data source for an analysis of the relationship between economics and malaria done by Gallup and Sachs. It is important to note, however, that there are many other maps in the WHO malaria map series. Three additional maps (1956, 1959, and 1989) require brief attention because of their unique design styles.

In 1956, “Malaria Eradication in the World” was mapped by countries, using national boundaries for all countries except China and the Union of Soviet Socialist Republics, in three categories (World Health Organization 1956a, Figure 3.7). More interesting is that the map is presented using an Interrupted Mollweide projection. This equal-area projection shows the areas on the earth in correct proportion (something that most other WHO maps do not do). One might say that this map is “trendy,” because the use of interrupted equal-area projections increased significantly at this time (Dahlberg 1962). Unfortunately, there are other problems with the map (including land-water differentiation). The map is small (a scale of approximately 1:248,000,000). Because of the small size of presentation, the names on the map, appearing in a very small point size and all capital letters, are nearly illegible. The map includes a fifteen-degree graticule, a distinct asset in understanding the organization

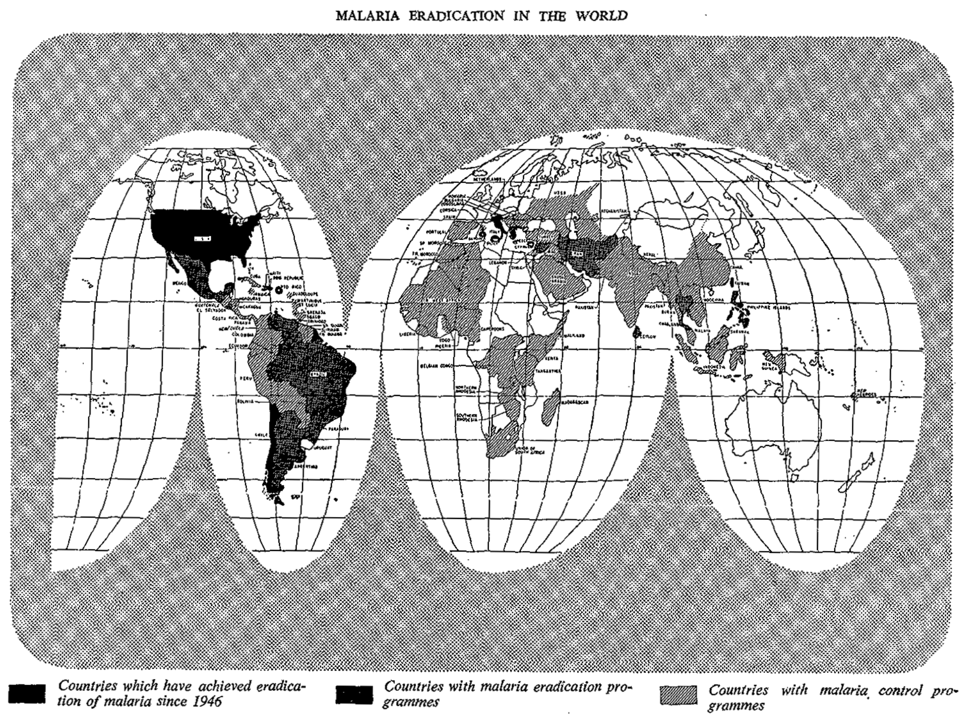


Figure 3.7 WHO 1956 malaria map (World Health Organization 1956a). [original size 5" x 3.75," shown here at its original size]

of the global surface, but the graticule running across the land surface is a nuisance in reading the national boundaries and does not aid land-sea differentiation.

In 1959 ("The State of Malaria Eradication, 1959"), the same projection was used (World Health Organization 1959, Figure 3.8). Here, however, there were significant improvements in graphic design. First, a variety of different line weights was employed, and country boundaries and coastlines were not the same line width as the graticule. Further, the graticule was drawn only over the oceans and seas. Six categories (never present …, eradicated, programme advanced …, programme begun …, plan approved…, and still without plan …) use visually distinctive shading patterns and the callout circles are employed for islands and small countries. There are problems with line generalization but, overall, it is a very successful graphic display.

THE STATE OF MALARIA ERADICATION, 1959

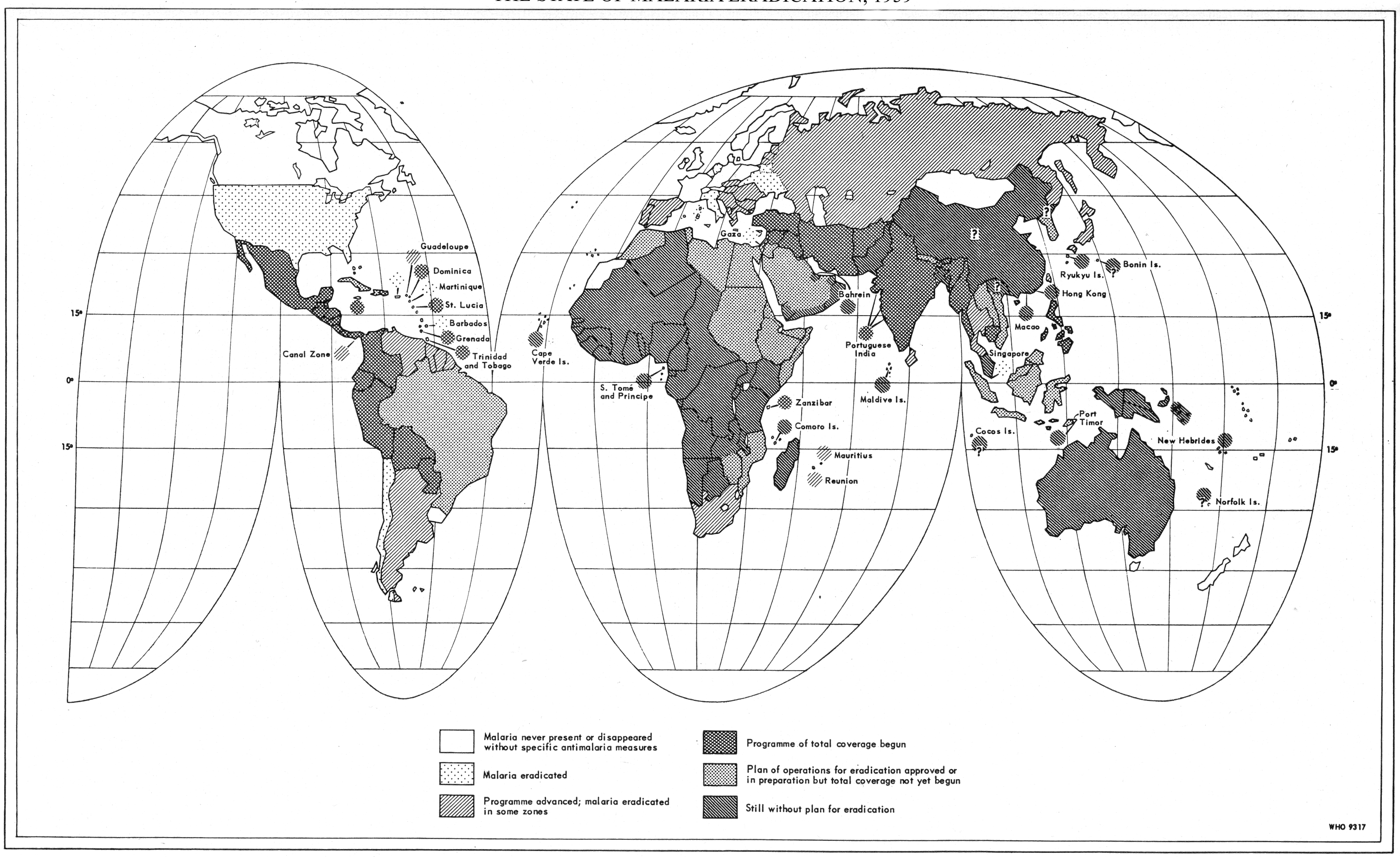


Figure 3.8 WHO 1959 malaria map (World Health Organization 1959). [original size 8.5” x 5.25,” shown here reduced to approximately 90% of its original size]

"Epidemiological assessment of the status of malaria, 1989" saw a return to the use of the Mercator projection (World Health Organization 1991, Figure 3.9). While the use of an equal-area projection was abandoned, the three-category system (disappeared …, limited risk …, and where transmission occurs …), is employed. Graphic design is enhanced with the graticule over only the oceans and seas, but the political boundaries are a heavy line weight, and this compromises the details of the two shades of grey, particularly in politically congested areas.

Some conclusions on the WHO maps

The task of this chapter has been to look at the long series of WHO malaria maps, to consider the problem they address, and assess how well they communicate this information to the map user. Six maps, ten percent of the total produced since the organization was founded, have been examined. Three of these evaluations were handled in detail, because the maps of 1946, 1965, and 1994 have come into further use. While the focus in this discussion has been on design, which involves the manner in which the data are represented, it is the data problem that will become the principal issue in the maps of Gallup and Sachs.

The three maps which exemplify radical change in the style of design and the approach to the problems involved in the cartographic process are presented to show that the WHO malaria map series has, like the global malaria eradication program, evolved over time. Important, though, when considering the maps together as a continuous historical record, is that the maps are not consistent in their design, or their data, across the time span they cover. As a result, while the maps do provide an important historical record for understanding malaria's change over time, because of the data used, it is not certain where accurate and meaningful comparisons, between

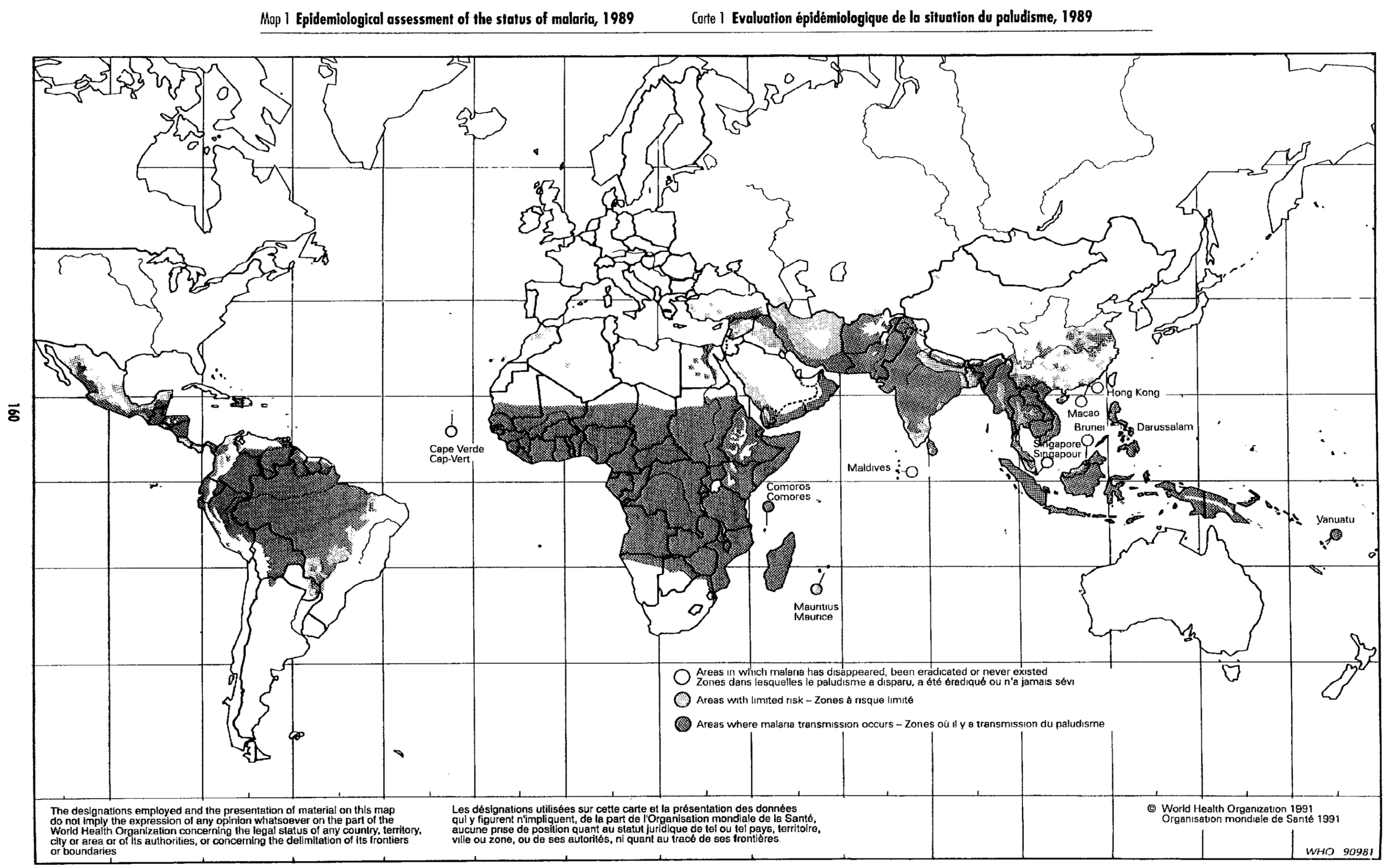


Figure 3.9 WHO 1989 malaria map (World Health Organization 1991). [original size 10.5" x 6.25," shown here reduced to approximately 75% of its original size]

regions or between years, may be made. However, a look at the total picture of this series of maps is a project for another, more extensive, period of time.

Malaria Homogenized

chapter four

Economist's Geography

In a series of published and unpublished work, Gallup and Sachs have utilized maps and GIS to consider relationships between geography, economics, and disease at the national level in the latter half of the 20th century. Entitled "Geography and Economic Development," their GIS analysis was first presented to the United States Agency for International Development (USAID) and The World Bank (Gallup et al. 1999b, 1999c, Gallup and Sachs 2000), two of the world's largest and most influential foreign aid donor organizations.

A smaller and slightly more focused portion of this work has appeared more recently under the title of "The Economic Burden of Disease" (Gallup and Sachs 2001, Sachs and Malaney 2002). This work has been highly cited, 83 times for Gallup and Sachs (2001), and 252 times for Sachs and Malaney (2002) (ISI Web of Science 2007).

Gallup and Sachs' analysis of the economic burden of disease considers the question of what effect, if any, malaria has on economic growth and poverty. They perform various statistical regressions on a dataset of numerous national variables which are used to summarize economic activity, and physical geographic characteristics for individual countries. The dataset covers the time period from 1950 to 1995 with variables such as: GDP, population density, population within 100km of the coast, socialism, urban population, open economic policy, and malaria incidence and prevalence.

Except for the Sachs and Malaney (2002) publication, all previous publications by Gallup and Sachs utilize the same series of maps (either in color or black and white): (1) “Malaria Risk 1946, 1965, 1994” and (2) “Malaria Index 1994.” The Malaria Risk map uses shaded areas to show a variable that Gallup and Sachs call the extent of “high malaria risk.” The boundaries for these shaded areas were digitized by hand from three maps originally published by the World Health Organization (Pampana and Russell 1955, World Health Organization 1966, 1997).

The Malaria Index was created “because of a lack of reliable data on the incidence or prevalence of malaria in the most severely affected countries” (Gallup et al. 1999b, p 220). It is a numerical value extracted after processing geographic data in a GIS, and serves as the independent value in their regression analysis. To generate the Malaria Index, the Malaria Risk map was first made. The WHO 1946, 1965, and 1994 maps discussed in the previous chapter were the sources of Gallup and Sachs malaria data (Figure 4.1). It appears as though Gallup and Sachs reinterpreted the original WHO data they extracted to be areas of “high risk malaria,” despite none of the data being labeled as such on the original maps.

The Malaria Index is defined by the authors as “the fraction of the population at risk of malaria multiplied by the fraction of cases of malaria that are falciparum (Gallup and Sachs 2001, p 85).” [2] To determine the population at risk of malaria, the areas identified on the Malaria Risk map were taken and overlaid on a raster database of estimated population (Tobler et al. 1995) for the two time periods studied. [3] For each country, the population with an area of high-risk malaria was summed, and divided by the countries total population to create a percentage. This percentage was then multiplied by the percentage of falciparum cases for each country, as reported by the WHO.

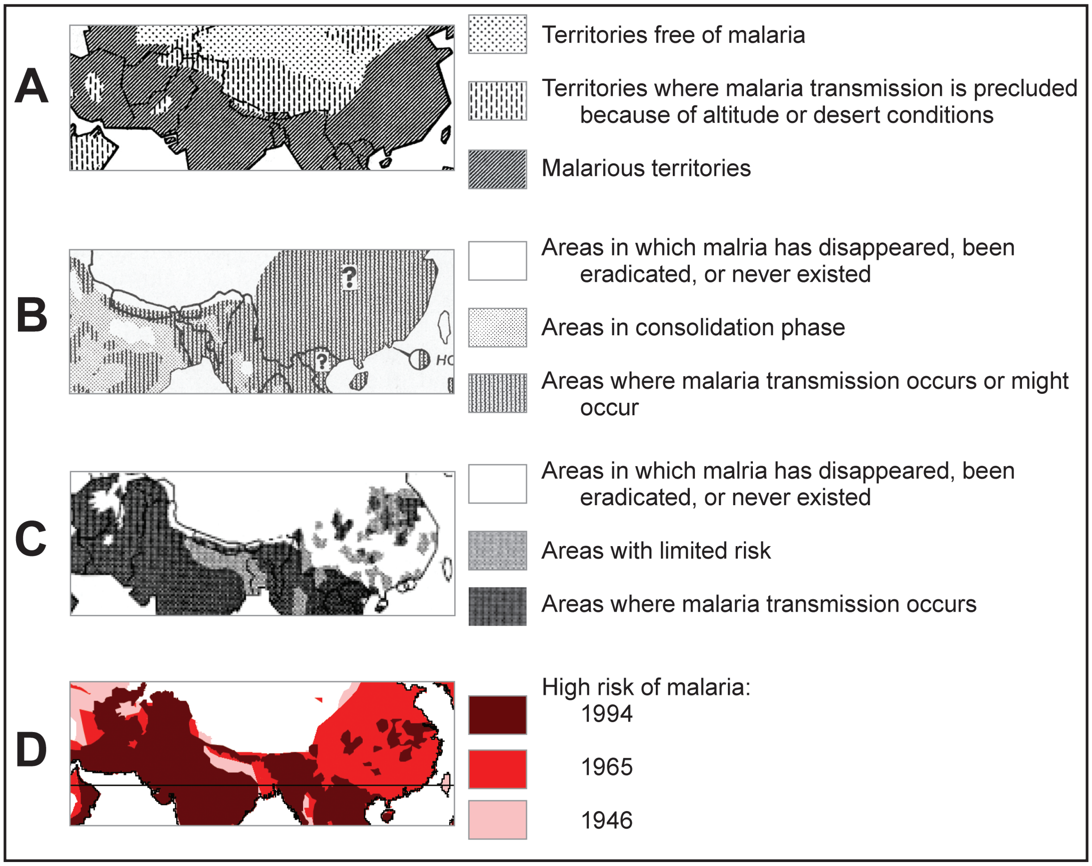


Figure 4.1 The 1946 WHO map [A], the 1965 WHO map [B], and the 1994 WHO map [C] were the data sources which Gallup and Sachs extracted their malaria data from.

Gallup and Sachs Risk Map

This map has been reproduced, sometimes in monochrome and at other times in color, at different scales depending on the format of the publication. The variation between color, monochrome, and size of reproduction, do not affect the visual hierarchy and the resulting interpretation of the map. The data is in fact identical on all maps. This data, which they digitized from the WHO maps and processed using GIS, is freely available on the internet (Gallup et al. 1998-1999).

The map used for my analysis appears in color and was selected because it could be reproduced here at the highest-quality reproduction of all the published maps (Gallup and Sachs 2000, Figure 4.2). The map extent is the same as that of the WHO

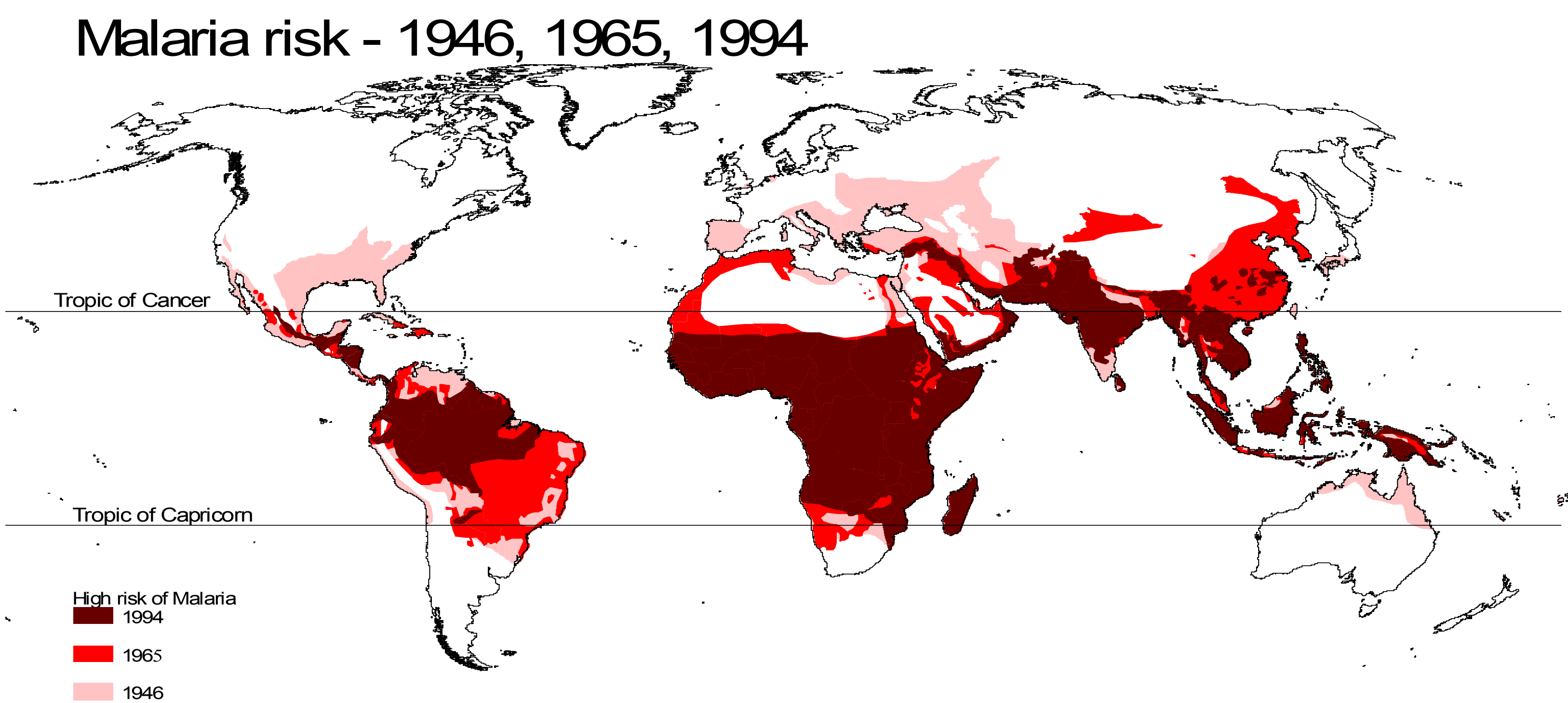


Figure 4.2 Gallup and Sachs Risk Map (Gallup and Sachs 1998). [original size 10.5” x 6”, shown here reduced to approximately 77% its original size]

1994 map, and the projections are similar, but definitely not the same. The map data consist of coast lines, lines for the Tropics of Cancer and Capricorn, and three sets of "high risk" malaria areas. Unlike the WHO maps, no national political boundaries are shown.

The map title is, simply, "Malaria risk - 1946, 1965, 1994." The coastline data are far more detailed than any of the WHO coastlines, comprised of millions of line segments compared to the hundreds of line segments for the coastlines in the WHO 1946 map, and perhaps a few thousand for the most detailed WHO 1965 map. The coastline is symbolized by a solid black line, and appears with varying thicknesses on the page due to the highly irregular shape of the natural coastline. Three classes of shaded areas appear on the map, each identified as "high risk malaria." The data for 1946 appear in light pink, 1965 in bright red, and 1994 in dark red.

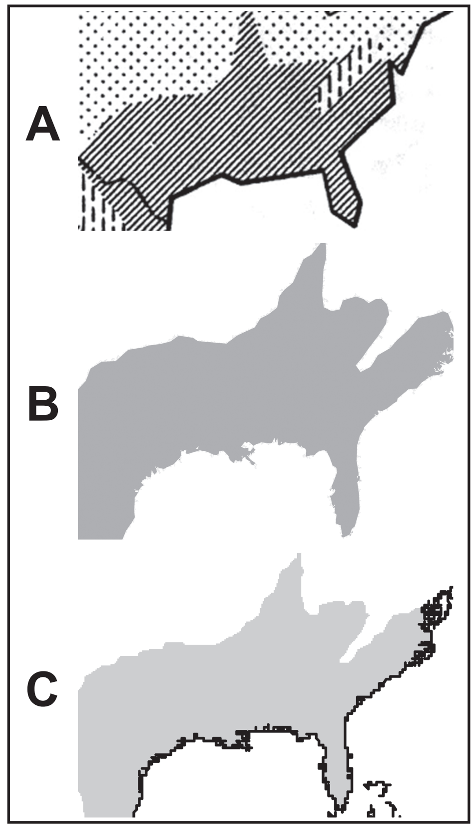


Figure 4.3 A subset of [A] the original 1946 WHO map which was digitized by Gallup and Sachs [B] and used in their final Malaria Risk map [C]

Problems exist in the way the malaria data was extracted from the WHO maps though (Figure 4.3). The inland portions of the malaria data extent are inaccurately digitized, failing to faithfully characterize the original WHO data. The result is that very simple and highly generalized lines have been digitized with more variation and detail than the original data contained. This fact evidences the cartographic ignorance inherent in this GIS analysis, yet more significant evidence of this ignorance can be found. The original coastline and that appearing in the Gallup and Sachs map show no resemblance to each other. This suggests that the authors compiled an alternative coastline from a much larger-scale data source than that of the malaria data, thus breaking a fundamental rule for map data compilation. Data should only be compiled from larger to smaller scales; compiling from smaller to larger scales can introduce error into the map and compound it (Robinson et al. 1995, p 426).

The dark red of the 1994 data boldly contrasts with the white background of the map, thus grabbing the reader's initial attention. The initial focus of the map is again Africa, as this color blankets nearly the entire continent, and it is centered on the map due to the projection chosen. From Africa, the reader's eye naturally falls outward onto the adjacent, data for successive years. Finally, the eye travels to the far left side, where the lines of latitude are labeled, and to the lower left where the map key is found.

The excess detail in the coastline is exacerbated by the way it is symbolized, reflecting poor understanding of map design. This problem is most apparent in the areas around the world where there are complex coastlines, including western North America, the Canadian Arctic islands, the northwestern European coast, and others. This problem of excessive coastline detail also exists in the West Indies, the East Indies, as well as the South Asian coastline. Coastal detail tends to obliterate risk data presentation. This is yet an another example of the land-water differentiation problem, where, in this case, the shaded area of the malaria areas are sufficient for discriminating the coastline and do not to need to be accentuated with the additional black line.

The graphic design of the map would generally be acceptable, if there were not the underlying issues of how the data on this map were selected and extracted from the WHO maps. It is unclear if and how the top layer of data (1994) overlaps with the preceding years of data. This could have been accomplished by using a transparent fill, or by creating additional data classes to show which and where multiple years overlap. As a result, their map fosters the idea that malaria's occurrence has receded over time. Yet in places like India (Figure 4.4), Honduras, and Nicaragua, a resurgence of malaria appears to have actually occurred when the original WHO maps are consulted. This important detail is lost due to the map design chosen. The map also does not utilize exaggeration or callouts for the islands which appear on the WHO 1965 and 1994 maps, and thus at this scale the status of these areas is not legible.

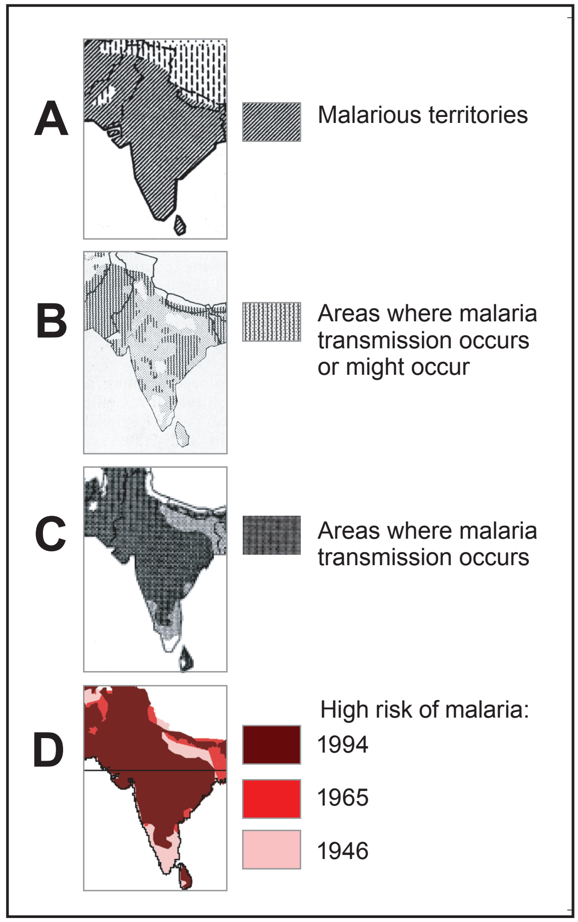


Figure 4.4 In India, malaria occurence appears widespred on the WHO 1946 map [A], consolidated on the WHO 1965 map [B], then widespread again on the WHO 1994 map [C]. These details are lost to the reader of the Gallup and Sachs map because of the map design they have chosen

The Risk Map is hardly referred to in any of the articles and book chapters in which it appears. It serves as the data base from which, by using GIS, quantitative data is extracted for the statistical analysis performed by Gallup and Sachs. No mention is made about differences or inconsistencies which exist between the three source maps used, or how and why they were modified when compiling the digital database. Inconsistencies within the individual maps are not addressed either. The reader is led to believe that for each year shown, the WHO maps the extent of malaria depicting areas of "high risk malaria."

Interpreting this map

Gallup and Sachs (2001, p 85) write:

> A basic problem when studying the macroeconomic impact of malaria is the lack of high-quality data on malaria incidence or prevalence in the most severely affected countries… Because the national reporting systems are systematically different between countries with high or low levels of malaria, this study does not use the WHO data on cases of malaria but instead uses the malaria index derived from malaria maps and falciparum prevalence data.

The authors, perhaps unknowingly, utilize the power of mapping and GIS to suggest that mapping malaria (or risk of malaria) is an unproblematic practice, seeing it as good alternative to "a lack of high quality empirical data."

Despite the popularity of this research, both the analysis and the results contain conceptual and cartographic errors. The authors create a variable and a level of detail which their cartographic data sources do not contain. They have taken malaria occurrence data labeled in various ways and renamed it areas "high risk malaria," a phrase which never appears on the original maps. The malaria occurrence data utilized is originally mapped at a very small-scale (globally), yet the authors compile the data at a much larger scale so they can carry out their analysis at the level of individual nations. Within these national boundaries, they have assumed that the lines delineating malarious regions are sufficient to determine what percentage of a countries population resides in a malarious area and what percentage does not.

An additional consideration of the global scale at which this economic research has been conducted is the fact that the process of malaria occurrence which they believe result in the "economic burden of malaria" has never been repeated at any other of the constituent scales (i.e. larger map scale with more detail) which comprise the global scale. That is to say that their analysis has never been repeated for a smaller spatial extent (a single continent, multi-country region, or a single country) with the larger-scale (more detailed) datasets necessary for more precise analysis. Such a study would be much more difficult to conduct, though, as health, economic, and demographic statistics outside of the western-developed world are often inconsistent and incomplete across large spatial extents. For this reason, the author's speculative conclusions about the causes of an economic burden of malaria can hardly be tested or independently validated. In the following section I will turn my attention, for purposes of comparison, to a different disease mapping project done by the American Geographical Society.

Malaria Cartography

chapter five

There is another map of global malaria occurrence that was produced at about the same time as the first WHO map. The American Geographical Society's (AGS) ambitious *Atlas of Diseases* was undertaken for the purpose of demonstrating the relevance of geography in understanding the global distribution of certain diseases (Light 1944). Before this time, tension had developed between medical doctors and geographers as to whom, and by which methods, scientifically based knowledge about disease systems could be produced. The two groups clashed over whether the etiology of diseases was best conceived by locating disease as a condition within the human body or a condition in the environment outside the body. Light (1946) argued that there may be several diseases where understanding the environmental conditions influencing a disease may be the key to understanding or controlling the disease. To that end, the 17 plates of the *Atlas of Diseases* may be seen as a demonstration of the utility of standard and special cartographic techniques and analytical tools.

This section examines the methods, standards, and results of the AGS project. In understanding the spatial and temporal record of malaria occurrence, the AGS malaria map raises new questions. The first is about the state of geographic knowledge of malaria in the 1950s, and the second challenges assumptions about the understanding of the historical distribution of malaria by Gallup and Sachs.

Atlas of Diseases: Malaria

The Atlas of Diseases: Map of the distribution of malaria vectors (May 1951) offers a strikingly different view of the knowledge of the occurrence of malaria. The cartographic prowess of the AGS is widely known and heralded. While the AGS project was called an *atlas*, it was never bound into a single volume; rather each individual map was published and distributed as they were completed by the AGS Medical Geography Department. Each plate was devoted to one disease or health condition and was designed to be a complete whole, not to accompany a specific text or an article as the WHO maps did.

Jacque May gets much of the credit for the *Atlas of Diseases*, but the accomplishment is probably as much a result of the work of established cartographers, O.M. Miller and William Briesemeister, and the geographical intellect of John K. Wright. May introduces the malaria map (1951) by stating that it is simply one plate of what could easily be an entire atlas dedicated to the geography of malaria. The large (38 by 25 in.) map includes text on the epidemiology of malaria, the natural history of the vectors shown, and a legend with explicit instructions about the way in which the three maps should be used and the data interpreted. References for the sources of the mapped data are found in a selected bibliography (144 references) covering the back of the map.

The plate contains four maps (Figure 5.1); (1) world map of malaria vectors, (2) larger scale inset of African, Mediterranean, and Middle East malaria vectors, (3) a similar inset of South Asian malaria vectors, (4) and a smaller-scale world map showing the distribution of three types of malaria parasites. A large block of text in the upper-left corner of the map summarizes the epidemiology of malaria. A smaller block of text on the upper-right corner is a plate legend, which describes not only the content of each map, but also provides an explanation of the symbol systems used and discusses examples of appropriate and inappropriate map uses. A table on the left side, titled "Resume of Natural History," lists each species of mosquito shown, as well as details about the feeding habits of adult mosquitoes, their habitat, and the preferable water and light habitats for larval development. Also on the left side, a

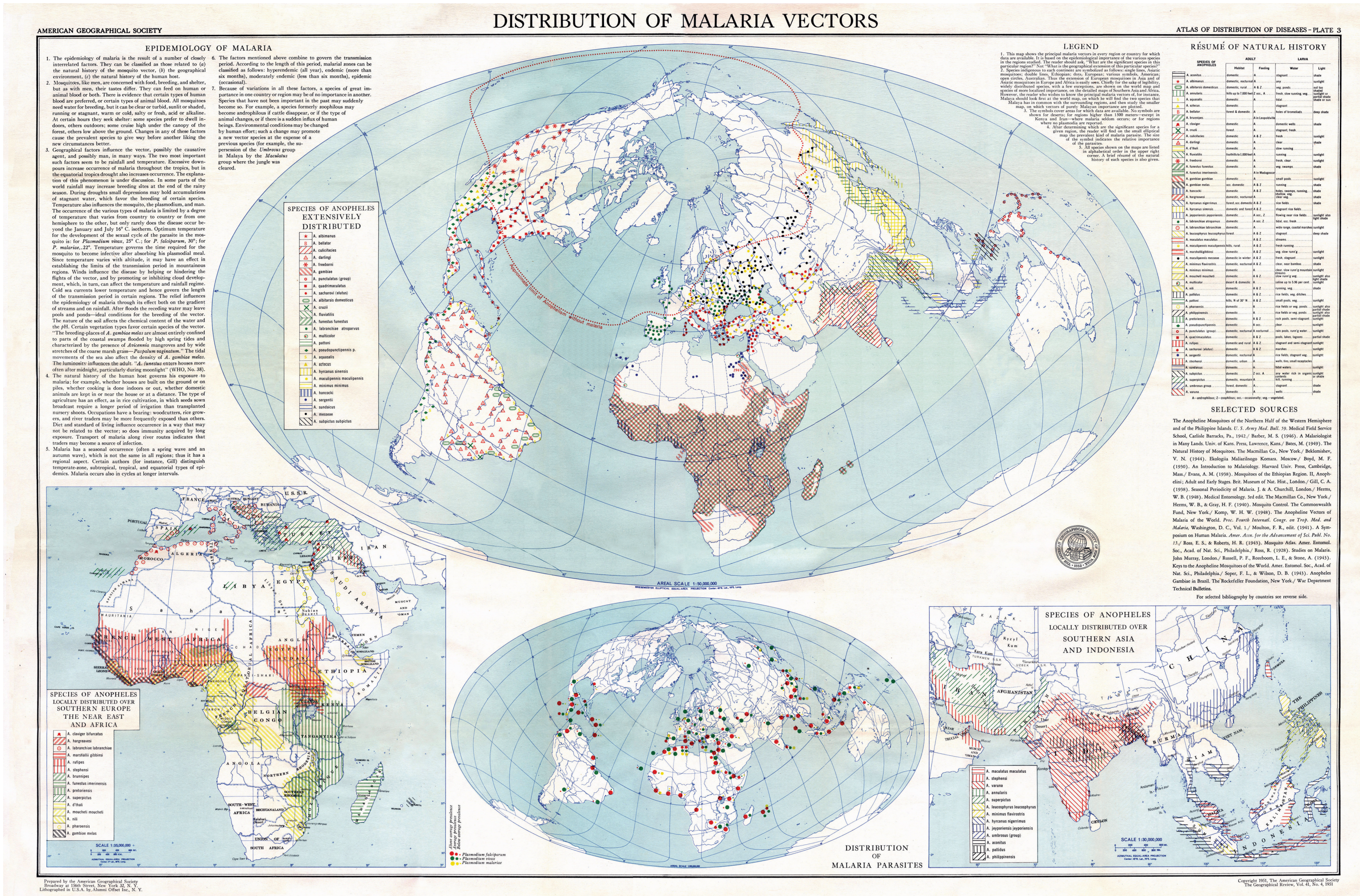


Figure 5.1 American Geographical Societies' *Atlas of Diseases*, Map of Malaria Vectors (May 1951). (original size 38" x 25," shown here reduced to approximately 20% of its original size)

small box summarizes primary information sources, with a more comprehensive bibliography on the back of the map organized by countries.

The plate legend gives precise instruction for the intended use of the three maps. Regarding the global map (extensively distributed anopheles species), the reader is told to ask of the map "What are the significant species in this particular region?" and not "What is the geographical extension of this particular species?" As different species shown on the inset maps than on the main map, the plate legend indicates that "chiefly for the sake of legibility, widely distributed species, with a few exceptions, are shown on the world map and species of more localized importance…" are found on the inset maps. After determining the significant species for a region, the small-scale graduated circle map can be used to identify "the prevalent kind of malaria parasite..." with the size of the circle showing relative importance in the area.

From this brief description, it is immediately apparent that the AGS work is of a very different nature than the maps and articles presented by the WHO. The work of producing and disseminating geographic knowledge done by the AGS in the first half the 20th century, particularly in cartographic form, was at a level of technical and intellectual sophistication which has few parallels. As much of this AGS history is not widely known, and its short-lived medical geography program and the atlas it produced have not been widely studied, the second section of this chapter will focus on providing a historical context to better understand, interpret, and eventually judge their contribution to knowledge about malaria distribution.

Extensively distributed malaria vectors

Printed in color, and utilizing a new equal-area map projection developed by AGS cartographer William Briesemeister (1953), this map of the global distribution of various types of anopheles mosquitoes contrasts sharply in appearance with any

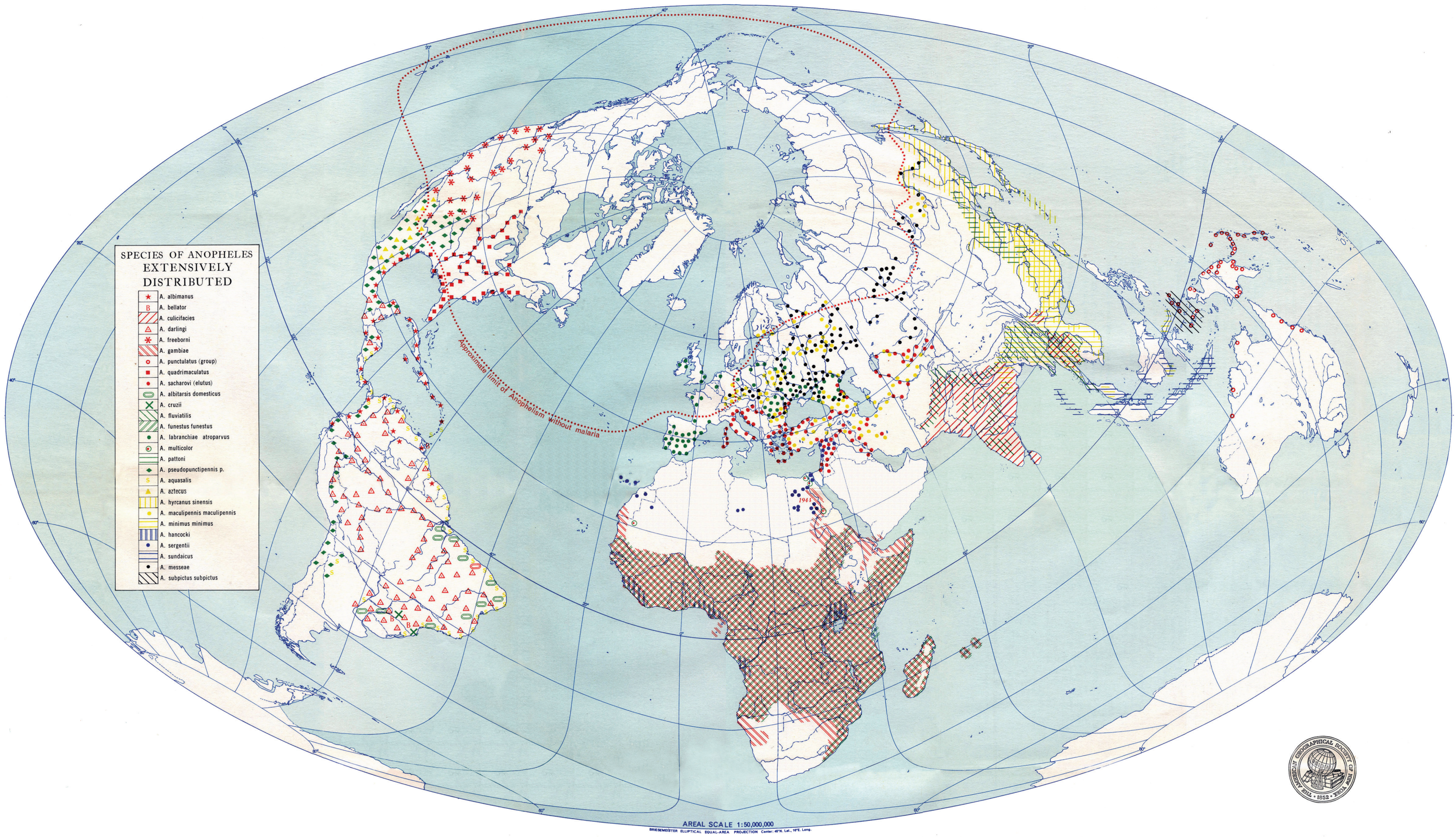


Figure 5.2 Distribution of Malaria Vectors from Plate 3 of the American Geographical Society's *Atlas of Diseases* (May 1951). [original size 26.5" x 15," shown here reduced to approximately 23% of its original size]

earlier malaria maps (Figure 5.2). The map demands careful study and consideration. The map is elliptically shaped, centered at 40° N and 10° E, with Antarctica being split into two parts shown in the lower right and lower left sides. In the northern hemisphere, North America and Eurasia surround the North Pole, as the goal of the new projection was "to preserve closely the true relationships of the northern continents" (Briesemeister 1953). A 20° graticule appears on the map. Both parallels and meridians curve with a high degree of elasticity; the parallels maintaining a concentric circular relationship in the center of the map. The nominal scale of 1:50,000,000 is two to three times larger than any of the malaria maps examined previously. The land is shaded white with a dark blue coastline, atop (in visual hierarchy terms) a light blue sea. A lot of information is shown on the map and in a highly sophisticated manner. The blue coastlines have been drawn with a consistent level of detail. Four different types of blue lines are used to symbolize six different types of linear data: coastlines, rivers, national borders, the graticule (parallels and meridians), intermittent streams, and ice shelves. 27 different mosquito species are shown using a combination of point symbols and area fills. A rectangular map legend near the far left edge of the map identifies the symbols used on the map with the names of each "species of anopheles extensively distributed" throughout the world. The only text on the map is graticule labels, a label for the dotted red line showing the northern extent of malaria, and the "Areal Scale" of the map.

The 27 anopheles mosquito species are symbolized using both point symbols and area patterns, a seemingly curious design decision. The plate legend (immediately adjacent to the map) explains that mosquitoes indigenous to certain continents are grouped accordingly: solid circles (of different colors) for Europe, single line area patterns for Asia, double line patterns for Ethiopia, a mixture of different forms of colored point symbols for North and South America, and open circles for Australia. Close study of the map reveals that these contrasting continental symbols are an effective device for showing areas of overlap between species on the different continents, like that found in Northern Africa, the islands of Southeast Asia, and along the border of China and Siberia. A high degree of precision is evident in the placement of point symbols for some species common along, for example, tributaries of the Amazon and Mississippi Rivers. Point symbols of species found only in coastal areas have been placed accordingly.

Africa is dominant when examining the visual hierarchy of the map. Despite being centered well below the visual center of the page, the double lines used to symbolize the two extensively distributed mosquito species create a dense network of hatching, while the green and the red lines lead to an overall dark appearance. Working down the hierarchy from maximum to minimum emphasis and visual contrast, the next focal point is in Western Europe which surrounds the optical center of the map. It is a complex convergence of rivers, coastlines, national boundaries, and dots of various hues. The Atlantic Ocean separates clearly the western hemisphere (both north and south) from the east. There is a uniformity to the malaria distribution that is found in the Americas. Once beyond the "European" dot mass, which extends into the Middle East, the eye scatters across Eurasia from the 'Stans into southern Siberia, attenuating as it reaches Manchuria and the northeastern extent of the east Asian area patterns. The area extending from India and Southeast Asia up through eastern China and throughout the East Indies has to be studied carefully, as this is where the ingenuity and aesthetic appeal of the AGS symbolization system shines through. The area patterns for large areas where there is continuous malaria, "evaporate" and become point symbols in Oceania/Australia and in northeast China and, moving westward, north of India in the 'Stans. The dotted red line tends to draw the eyes to either the left or right of the map in the northern hemisphere. Despite point symbols for vectors in the Americas and single lines for vectors in Asia, there is a good balance of color between the two sides of the map.

Very clearly, this is not a malaria map for simple visualization, but an astute reference map. Reading this map is purposefully complex, because the cartographers were committed to showing the data truthfully. Conceptually, despite the richness of the data, the data is quite well organized and discriminable.

Anopheles locally distributed in the African region

There are several design differences in this inset map from that of the world map (Figure 5.3). On the smaller scale world map, text appears only once on the map outside the legend, whereas seven text styles can be identified on this inset map. These text styles utilize variations in serif and sans-serif fonts, capitalization, point size, italics, and boldness, to identify cities, important islands, graticule, map title, nations or colonies, sub-national political regions, and physiographic features. There is an increased visual emphasis on the lines of the national/colonial boundaries. On the world map, these lines are shown simply as dash lines, similar in hue (blue) and weight to other data on the map. On the African inset, these boundaries are represented with a double-line style, one line using a dot-dash style (in blue), the other a solid linear stippling pattern, creating a wider gray line (the gray is very light, but the line is five or six times wider than the blue line that accompanies it).

The map extends across the entire African continent, Southern Europe, and the Arabian Peninsula. More specific geographic information is included, as is to be expected of a larger-scale map (1:35,000,000, compared to the 1:50,000,000 of the world map). The previous AGS world map showed five different species of anopheles in the areas covered by this map, with two species blanketing all of Africa south of the Sahara, except for a region on the southwestern tip. Contrastingly, the data on this

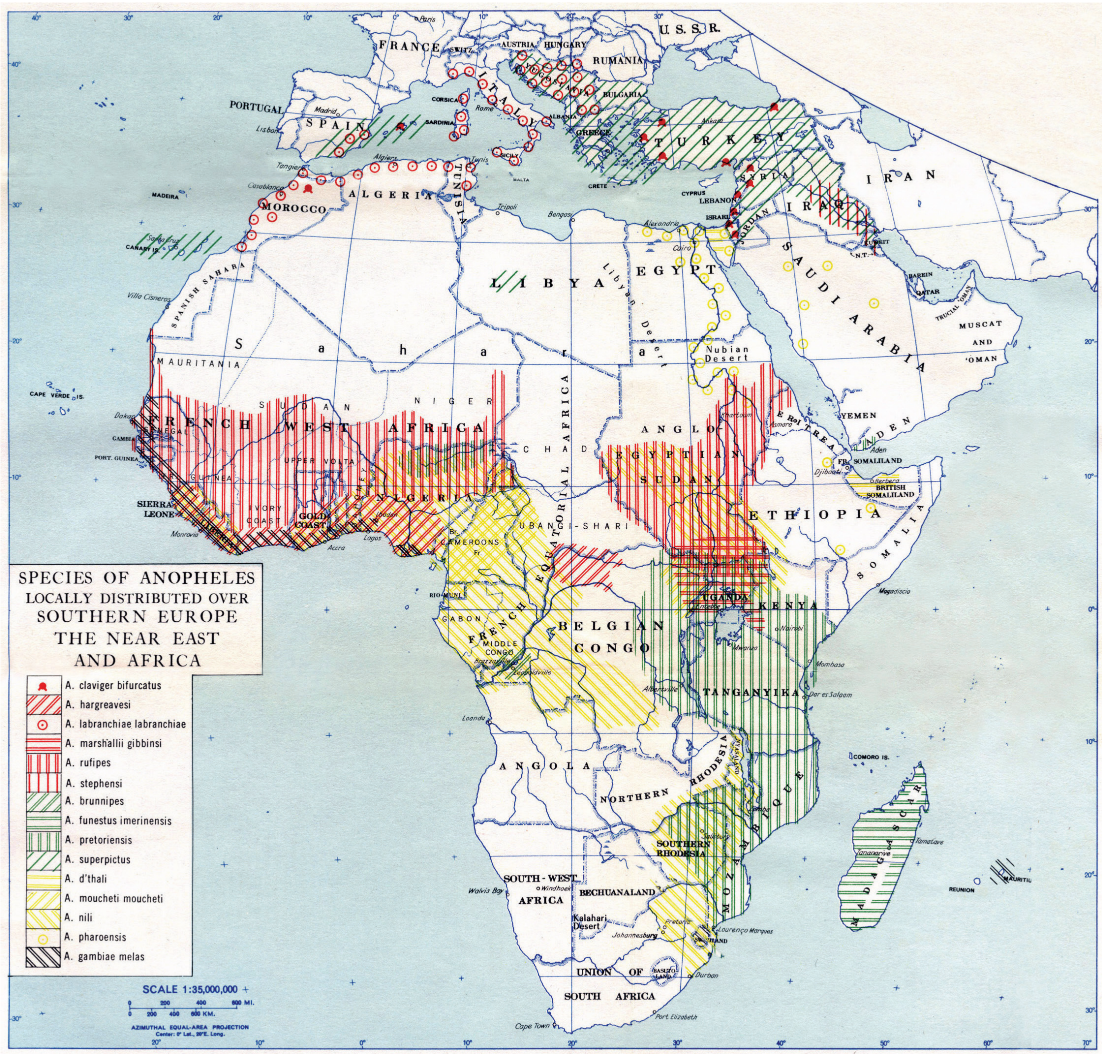


Figure 5.3 Distribution of Malaria Vectors from Plate 3 of the American Geographical Society's *Atlas of Diseases* (May 1951). [original size 11" x 10.5", shown here reduced to approximately 52% of its original size]

map has the appearance of a corridor down the center of Africa where no anopheles are shown. Curiously, several species shown on the previous AGS world map are not listed on this map (for example, A. *sergentii* is shown in several locations north of the Sahara on the world map, but is not found on this map, as is the case with A. *multicolor* appearing once in Egypt and Mauritania, but not found on the large-scale map).

Malaria Parasites

The map of the "Distribution of Malaria Parasites" uses graduated circles to indicate the "prevalence" of the three main types of parasites (Figure 5.4). Three hues are used to differentiate among the three types: red for *P. falciparum*, green for *P. vivax*, and yellow for *P. malariae*. The sizes of the circles represents above average, average, and below average prevalence. The choice of graduated circles suggests that knowledge about the occurrence and prevalence of malaria was highly localized, not broad like the areas that the WHO maps suggests. This is most striking when comparing the representation of malaria in Africa.

When constructing a graduated-circle map, the relationship between circle size, circle position, and map scale are important for accurate data communication. The circle generally represents data either aggregated to a particular unit of observation (Dent 1999, p 174) or situated at a particular location (Robinson et al. 1995, p 478).

On this map, it is not explicit what unit of observation is used for the data shown. An initial assumption might be that the data are aggregated to the national level, such that the graduated circles would be located centrally within the national boundaries it represents (e. g., Spain, France, Germany). This is not true, however, for the entire map, as there are some countries (Brazil, China, Egypt, and the Soviet Union) for which there are clearly multiple circles of the same malaria type. In other cases, such as the United States, Norway, and Nigeria, the position of the circle suggests a particular location in the country. It can be concluded that either the political unit of observation is inconsistent throughout the map, or that the data is aggregated to units of smaller spatial extents (i.e. cities, or regions).

There is really a lot of innovation to the execution of the American Geographical Society's *Atlas of Diseases Project*. It may be seen as an exemplary presentation

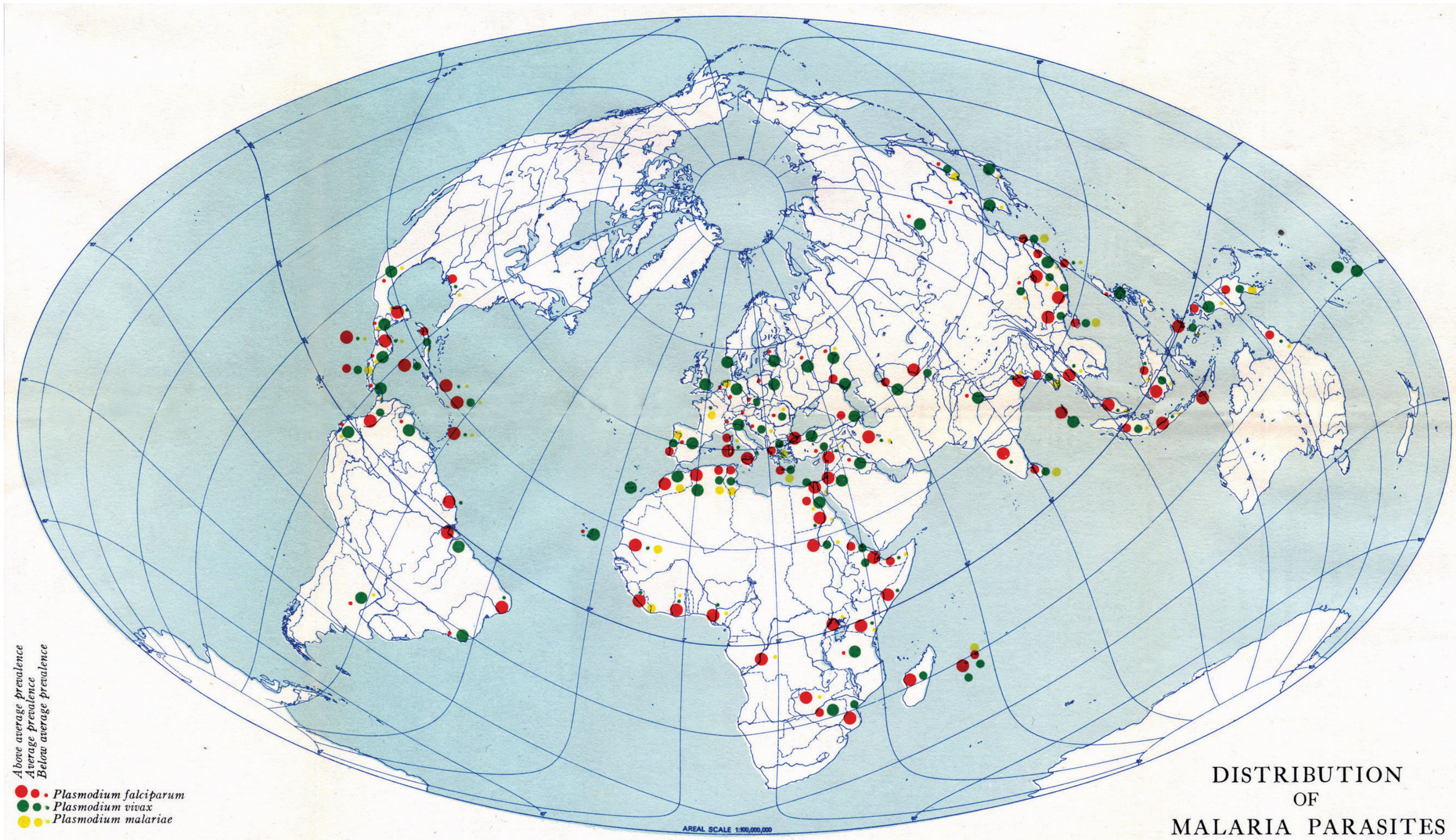


Figure 5.4 Distribution of Malaria Parasites from Plate 3 of the American Geographical Society's *Atlas of Diseases* (May 1951). [original size 13.25" x 7.5", shown here reduced to approximately 60% of its original size]

of information management and graphic communication skills. In the next section, the AGS malaria vectors map will be compared with the maps in the WHO malaria map series, to consider the similarities and differences in the way each map handles the inherent challenges of mapping malaria.

Malaria Conceptualized

chapter six

In the previous chapters, a selection of various malaria maps made throughout the twentieth century has been evaluated. These maps have been examined primarily based on the effectiveness of their design. The basis for that critique is rooted in the understanding that the primary goal of thematic maps is "to get across a concept or relationship" (Robinson 1953, p 13). Thus, the maps have been judged for their clarity of purpose, appropriateness of data and its symbolization, and the overall coherency of their visually communicated message within the text in which they appear. The analysis is scientifically based, as cartography comprises the "sciences of geodesy, geography, and psychology" (Robinson 1953, p 11). However maps do not exist in a vacuum.

Comparing the WHO and AGS maps

In this section, the focus will no longer be on the analyzing the design of the World Health Organization and the American Geographical Society maps. Instead, the aim of this chapter is on explaining the differences in purpose and organization of the two groups (WHO and AGS), which impact the marked differences in appearance between the two maps. The AGS map was published in 1951, and the first of the series of WHO malaria maps appeared in 1955, just four years apart.

The maps produced by the two organizations differ significantly in map purpose. While the initial idea for the AGS *Atlas* was as a tool for research (American Geographical Society 1944), with the arrival of Jacques May a more comprehensive program was conceived, focusing "on a general stocktaking of what is already known, through bibliographic study and questionnaires" (Wright 1952, p 268). In contrast, the WHO maps do not seem to have such an explicit purpose. The maps simply appear, mainly in the annual reports, where they help provide a general accounting of the happenings and progress of the malaria eradication project to the annual World Health Assembly. The WHO maps operate in similar fashion to the Boyd and Le Lannu maps as simple locational and visualization aids

Reader response to the AGS map

From correspondence found in the AGS archive, now housed at the University of Wisconsin-Milwaukee, it is apparent that the *Atlas of Diseases* project was widely known and well received. A unique find in this archive is correspondence received from Emilio Pampana, then chief of the Malaria Section of the WHO, dated the same month that the malaria map was published (May 1896-1975b). Appearing originally in French, it has been translated here as follows:

> I have seen the beautiful map of the global distribution of anopheles published in the October issue of the Geographical Review which Mr. Deutschman kindly called my attention to. I examined it with great interest, and allow me to congratulate you for the fine work that you have done. Indeed, a map of this sort must have encountered a lot of challenges; if there are some imperfections, they are only of a secondary order and the map undoubtedly constitutes a very useful tool for malaria information for which there has been a long felt need. I have already requested a number of copies of it and I am certain that it will be highly appreciated by those at the Organization involved with the malaria programs.

From this quotation, it is evident that the WHO Malaria Section was aware of the AGS map, but also that they had an appreciation for the difficulty of making such a map, and found the AGS malaria map to be a significant contribution to understanding the challenges posed by the disease. Also from the AGS archives comes a collection of comments from a group of scientists regarding the AGS malaria map that was sent to May from Pampana in August of 1953 (May 1896-1975a). The comments relate directly to the content of the map, focusing on corrections or updates to the locations of various anopheles species. The accomplishments of the AGS malaria map are numerous, and in many ways are reminiscent of the earlier and similar efforts of the Army Medical Intelligence Division. The cartographers have assembled detailed malaria data from a wide array of primary sources onto a printed map in a highly informative, legible, and transparent (by including bibliographic references) fashion. The map was then broadly disseminated, and eventually spurred additional scholarly conversation, debate, and eventually consensus on the "what" and "where" of malaria vectors.

The discussion above is meant to stimulate thought about the ways in which very small scale maps of global malaria distribution might have been used.

Reader response to WHO global maps

Few user accounts are immediately available to describe the way in which the WHO malaria maps were assimilated by individuals or used to inform and direct environmental behavior. Gallup and Sachs clearly demonstrate one example of the way in which the WHO maps may be used, but their use is far from that intended by the original map maker, and will be dealt with in more detail later.

One account of the use of WHO global maps comes from information collected at the WHO Archives. In an issue of the *WHO Chronicle*, there is a global map of protein-deficiencies in young children (World Health Organization 1965); it has an extent and scale resembling the WHO malaria maps. Shortly after publication of the protein-deficiencies map, the WHO Director-General received a letter from the Director-General of a state health department in Australia (Refshauge 1965-1966). The Australian Health Director-General took issue with the fact that the map had shown moderate prevalence of protein-deficiencies in the eastern part of Australia: "As there is no evidence of the existence of this condition in white Australians in any part of Australia." The protest was referred on to the Chief of the Nutrition section by the WHO Assistant Director-General. The Chief of Nutrition replied as follows:

> It is extremely difficult to draw accurate maps on the distribution of diseases. With regard to nutrition, it is perhaps even more difficult. The information on the frequency of protein-calorie malnutrition in Australia, which was taken from a publication of workers in Australia, unfortunately referred to New Guinea and not to the mainland. In drawing the map, a mistake was made by including references of cases in the mainland and not New Guinea."

The incorrect data for Australia were actually noticed by members of the Nutrition section before the Australian Health Director-General's letter was received, but too late to prevent the map from being published. A correction appeared in the next issue of the *WHO Chronicle*, and the map was corrected before being used in future WHO Nutrition publications.

The WHO must have confronted the same data challenges in regard to all of its global maps of malaria. No information has been published on the process of map making as practiced by the WHO. However, the documents and annotations from the protest over the protein-deficiency map offer insight. When the protest letter was received, a memo was promptly sent to the Chief of the Nutrition section, requesting the source of the data on the map. The section identified the source, and found where the error had occurred. A handwritten comment, addressed to the WHO Director-General, appears on a copy of the original protest letter:

> As you will see from Doc. EB35/9 [original map in error] this map has been taken from [our] EB document. It is not the first time that we are in trouble about maps- and not the first time either about Australia.

These quotations are revealing about the administrative structure of the WHO and its operation. If the Nutrition section is responsible for the content of the map, the same may be inferred of the Malaria section. Clearly the mapping of disease by the WHO was both a challenging and contentious task, perhaps most importantly, in the arena of international politics.

Metadata deficiencies of the AGS and WHO maps

Neither the AGS map nor the series of WHO maps is perfect. A shortcoming of the AGS map is the lack of bibliographic information on the Distribution of Malaria parasites. While a similar map of malaria parasites appears in Boyd (1930, p 15) using pie charts, the AGS map contains more localities than does Boyd. The attention to detail and bibliographic reference exhibited elsewhere on the map and throughout the cartographic process by the AGS group tends to suggest that the information was well founded. One possibility is that the AGS received this information through questionnaires, as mentioned above. If that is the case, then these data might reasonably represent similarly available information sources to those reporting information to the WHO regional office (i.e. national capitals and colonial administrative centers). Knowing the colonial legacy of many Africa countries, it seems reasonable to question whether African statistical data provides a representative sample for both Europeans and indigenous populations, or not.

In contrast, the WHO maps display a more serious lack of metadata. The reader has no knowledge of what the original source data were or how it was interpreted to make the variables finally mapped. It was mentioned during the discussion of the 1965 map that the article the map appears in also includes data table with different malaria statistics. The map appears to condense these variables into fewer classes, but as the names of the categories differ on these maps in other years, it is unclear how the statistical data, or its classification, changed.

Similar questions arise about the geographic extent of the data summarized on the map. Comparing the data on the AGS map of parasite types (Figure 5.4) with that of the 1945 or 1965 WHO map, provides two distinctly different views about the coverage of numerical, ordinal level, malaria data. More precisely, if the WHO data were based on statistical data collected from the different WHO regional offices, how were these data interpreted and organized for inclusion on the map? Given, for example, that the Pan American Health Office (PAHO) had been up and running for nearly 50 years before the Africa Region Office (AFRO) was established (World Health Organization 1958, p 31 and 78), it would seem probable that PAHO could report considerably more accurate and locationally specific information than AFRO. While cartographers are skilled in ways of working with inconsistent data, no trained cartographers can be identified as having ever worked at the WHO. Despite the specific inadequacies of the WHO maps and the AGS map, the maps function adequately overall.

Malaria Reconsidered

chapter seven

The appearance of the WHO malaria map annually for over 50 years has created a particularly alluring dataset for those interested in historical progress against malaria. This is due to the fact that no other cartographic series appears to record the status of malaria for the entire world at consistent temporal intervals. However, here it has been shown that between six of the WHO maps (spanning 48 years) major inconsistencies in data classification and generalization make comparisons from year to year virtually impossible. Nevertheless, Gallup and Sachs endeavored to make such a comparison using the technology of geographic information systems.

When undertaking their search for a causal link from malaria to economic poverty, these contemporary malaria map-makers and map users had a number of important decisions to make. Why did they select only three of the WHO maps if so many more were available? Why did they select three maps separated in time by 20 to 30 years? What evidence is there to support, or to suggest, that these years can satisfactorily represent the range of malaria occurrence? Can GIS bring new insight to old malaria problems?

Needing modern malaria maps

There are other contemporary malaria map-makers and map users, some of whom also see geographic technologies as promising solutions to malaria's challenge. Snow (1996, 1999a) promotes the idea of new and more accurate malaria map use for allocation of the limited resources available for malaria control. Another malaria research initiative, the Mapping Malaria Risk in Africa (MARA) project, views GIS and remote sensing as technological advances yielding more accurate maps when combined with empirical epidemiological information (MARA/ARMA 1998). Climate suitability for stable transmission of malaria has been intersected with raster population databases in another study to estimate disease morbidity and mortality, because national statistics for these areas have been shown to be unreliable (Snow et al. 1999b).

Hay and Snow (2006) argue, like Snow (1996) had previously, that public health resources should be allocated on the basis of "quantifiable need," which maps from their Malaria Atlas Project (MAP) will facilitate. The stated purpose of the project is to "develop the science of malaria cartography." This is to be accomplished by, first, determining the global limits of contemporary malaria transmission; second, using these limits to model endemicity using a global evidence of parasite prevalence; and third, using the endemicity model with population data to model populations at risk and make more credible predictions of disease burden (p2204).

Former colleagues of Gallup and Sachs' still at Harvard continue to work with GIS and maps as well. Kiszewski et al. (2004) chose to identify dominant malaria vectors for the entire globe from information collected through an extensive literature review and estimates calculated from a malaria vector stability index. A vector base map using national boundaries served as the preliminary unit of analysis. Then a dasymetric mapping approach (see Wright (1936) for a brief explanation) was taken where nations were subdivided into ecological regions, using remotely sensed landcover data. The vector stability index was calculated on a 0.5° raster grid. The likeness of the final map to the 1994 WHO malaria map was noted.

All of these current researchers have sought solutions through the modern technologies of computerized mapping and modeling with data from space-borne remote sensing, and digitally compiled population datasets. Gallup and Sachs' economic research in particular has been well received and has aroused considerable interest.

Earlier economic assessments of malaria

However, all of these contemporary malaria researchers (Snow et al. 1996, Gallup and Sachs 2001, Kiszewski et al. 2004, Hay and Snow 2006) share in the symptoms of historical amnesia. They all conclude that current malaria statistics reported by most malaria endemic countries are unreliable, and insufficient by the standards of western aid organizations. Yet none of them acknowledge that this data problem has always been there, failing to point out that it was widely recognized by the Army's Medical Intelligence Division (Simmons et al. 1944, Simmons et al. 1951, Simmons et al. 1954, Anderson 1969), if not earlier.

Further evidence about this has come to light recently in the WHO Archives. This information is significant because it affirms that the insufficiency of data for quantifying and mapping malaria's impact has long been known. This finding casts doubt on the Gallup and Sachs assumption that the WHO malaria maps are a good source of malaria data.

In 1958, Emilio Pampana, then director of the Malaria Eradication section of the WHO, was asked by the WHO Assistant Director-General if a report showing the economic benefit of malaria eradication could be furnished to the UNICEF Executive Board to ensure UNICEF's continued financial support for malaria eradication (Assistant Director-General 1958a). Pampana then sought the input of others outside of WHO Headquarters, knowing that examples of the economic success of malaria were available there but being concerned that "many of them could hardly withstand critical evaluation" (Pampana 1958). One of those consulted was Carlos Alvarado of the Pan American Health Organization, who replied that while his office had considered similar studies, the examples they came up with could not withstand critical evaluation (Alvarado 1958).

Another staff member of the Malaria Eradication section was eventually assigned the job of preparing the UNICEF report, a task which entailed "collecting, classifying and interpreting all the data that is available on a global scale from different countries" (Dakshinamurti 1958). Information was sought from officials at the Tennessee Valley Authority, Harvard School of Public Health, the Ross Institute at the London School of Hygiene and Tropical Medicine, and other WHO Regional Offices, but these efforts were not fruitful. His draft of the report was unacceptable to the Assistant Director-General, and consequently a decision was made to seek the skills of an "experienced economist" (Assistant Director-General 1958b).

In January of 1959 the new draft of the paper with the input of an experienced economist was deemed decidedly "too stiffly economic" (Weeks 1959). Memos between two WHO Assistant Director-Generals refer to this draft as disappointing, failing to serve the WHO's purpose of informing "interested readers, who are not professional economists, on the economic impact of malaria, and to show that eradication is a necessary and good investment" (Siegel 1959). In conclusion, it was suggested that they seek "a first-class economist, with a flair for writing in understandable terms." By April of 1959, nearly a year after the initial request for an economic assessment of malaria eradication had been made, the WHO was still without a report. The Assistant Director-General summarized the events in another letter to Paul Russell (Director-General 1959):

> We ourselves feel that it is important that some information of this kind be made available to the [UNICEF] Board in support of their contribution to the malaria effort. Such a report would also be of great value to convince many other organizations, and the governments, of the necessity of contributing more for the Malaria Eradication Program… We do recognize that there would be difficulties in preparing such a report, but we did not realize the enormous complexities of the problem until we actually began to collect material. We now realize that the data we have is all very vague, and the presentation is most difficult.

The year 1959 was still very early in WHO's Malaria Eradication program; correspondence from 1972 shows that quantifying the social and economic effects of malaria eradication control continued to vex the interested parties (Farid 1972).

The purpose of presenting this archival information makes two points. The first is to show that performing a global economic assessment of malaria effects was not an idea original to Gallup and Sachs, but had been a long-standing desire of the WHO. Similarly, the quote from the Assistant Director-General reveals that such a study was a critical part in persuading donors to continue funding malaria eradication. While such attention to the politics of funding may be seen as the reality of WHO's humanitarian efforts, it also tends to suggest that donors have focused too narrowly on quantifying the "success" of anti-malaria programs, a criticism also supported by archival documents of discussions in 1959.

The second point relates to overcoming the "vague data" problem which WHO finally recognized. It is recognized that the fieldwork necessary for accurate topographic mapping can also be a rich source of additional geographic data collection simply due to the time spent directly experiencing the place of interest. A statement by former Director of the American Geographical Society, George Kimble, expresses this view, "The fact is that we must have more surveys and maps of every kind before we can even begin to examine our acutest economic and social problems - let alone solve them" (1952-1953, p 107). This presentation by Kimble to the annual meeting of the American Congress on Surveying and Mapping, goes on to say that detailed information, germane to understanding economic and social conditions, is obtainable while doing large-scale mapping and surveying which would typically require extensive field work. For example, modern, highly detailed coastlines have been compiled from large-scale surveys carried out for several centuries. If such large-scale data are impossible to produce for social and economic problems, it again seems reasonable to infer that similarly detailed information was unavailable for studying presumed causal factors, such as the occurrence of malaria. In the absence of comprehensive large scale source maps on which to base good-quality data, the small-scale global malaria maps produced by the WHO from 1955 to 1994 became less credible. The cartographers who compiled them would have to make a great number of assumptions and generalizations, filling in information gaps with their educated guess work for areas from which no large scale source maps were available.

The perils and pitfalls of GIS

Gallup and Sachs first presented their GIS analysis of the economic burden of malaria at a World Bank meeting as part of a larger presentation titled "Geography and Economic Development" (Gallup et al. 1999a). Following their presentation, a discussant commented on their work as follows: "Geography matters, and more research is needed on the issues raised in the [Gallup et al.] article" (Venables 1999, p 241). I concur with this comment, and in the following sections I would like to explain how cartography, as geography's art and science, could be better utilized to understand the modern context of malaria.

Geographic information systems have been in use for nearly 40 years, but they are still developing. What began as software to use in the production of maps underwent a number of conceptual reorganizations, eventually merging with the conceptual ideas involved in database design structures. This development has so far overlooked established principles of cartographic design in the creation of default settings; little guidance is given to non-cartographer GIS users, such as the economists Gallup and Sachs.

The WHO maps show a nuanced picture of malaria in that its extent moves from year to year, seeming to shrink in some areas and to grow in others. However, comparison of maps and interpretation of such trends is a delusionary activity, because the data classification system used on the annual map has changed from year to year. At the same time the graphic design and visual structure of the maps has often been altered from one year to the next in a way that affects the user's perception of the global distribution of malaria.

Gallup and Sachs have overlooked these defects in the WHO maps and have compounded them. Although their computer-supported mapping activities are significant beyond the web-based mapping identified in a recent *New York Times* article (Helft 2007), they are nevertheless caught in the illusion. It's not that "you gotta know the territory" (the geography of the situation… the data), but you also have to understand the software. On their maps only areas of apparent malaria decrease are shown and any sense of spread or re-occurrence is hidden by the overlapping next layer up in the visual hierarchy.

Contesting the cartographers role

Maps are needed because they are able to communicate certain phenomena better than words or numbers. Distance, size, proximity, and shape are all information that maps can more easily communicate to an audience than words or numbers. Geography has spent much of the last 30 years grappling with the criticisms leveled against its naturalist and positivist origins by Marxist and post-structuralist scholars. Many aspects of post-structuralism (Foucault 1980) and the development of deconstructionist methodologies argue cogently that maps are social documents that must be read and interpreted within the social and cultural context in which they were produced (Harley 1989). Those in favor of this new more critical geography have tried to bring light to parts of the map production and interpretation process which they find particularly problematic (Pickles 1995, Crampton 2001). The wider struggles of geography with these new critical theories have reached cartography as well, and are summarized succinctly by Hallisey (2005).

One subset of the above mentioned critical geography includes the idea of a new critical cartography (Koch 2004). Koch's work is an insightful case study of the way in which cartographic concepts have an impact on the understanding of place, people, and process. Analyzing various cartographic re-interpretations of the original map accompanying Dr. John Snow's survey of a London cholera outbreak in 1854, Koch demonstrates the importance of the cartographer's design decisions in shaping the ultimate interpretation of the map. During the design process, cartographers are responsible for numerous decisions, trying to balance map purpose, data, and symbology. Koch's work is unique, in that it highlights numerous instances where the original map has been redrawn using slight variations in data, symbology, and context to imbed meanings very different from the original. Thus, he concludes that (p13):

> maps reflect specific phenomena of interest to map-makers... Each map results from the selection of data by the map-maker from a greater set of potentially relevant data. Map-making is not a value-free science that somehow stands apart from social, cultural, economic, and professional prejudices. Like all other sciences, and other forms of exposition, map-making is mired in the myths and assumptions of the individuals who promote this or that map within the culture(s) the map-makers served.

Considering Koch's concluding ideas, I would now like to consider the ways in which the malaria maps presented in this thesis reflect not only the interests of their supporting organizations, but also the interests of social, governmental, and scientific institutions.

The consequence is that the WHO maps perpetuate the colonial myth of inexorable technological progress, as exemplified by malaria eradication. This study provides evidence to support the need for a postcolonial re-evaluation of the historical impact of the WHO's malaria eradication campaign, as well as the cartographic methods of portraying its work from year to year in a way that is comparable and meaningful. It is imperative that there be more thoughtful application of technology, such as GIS, to process and present malaria data in map form. Gallup and Sachs have over-simplified data already generalized to the point of falsehood. Stepping the cartographic process back to a more detailed and qualitative presentation of the information which is sensitive to data inconsistencies and deficiencies will result in cartographic depictions that are more effective instruments for displaying the changing conditions and extent of malaria worldwide.

Limited map use

Defined in part by the scale of the maps previously selected, as well as the format in which the maps appear, all of the malaria maps discussed previously (excluding Gallup and Sachs) are used to "show the spatial distribution or location" (Dent 1999, p 8) of a chosen subject. Their subject has been malaria. The idea illustrated by these maps, or in the organizations making the maps, is that malaria exists out there in an environment beyond the practical observational level of the individual. Consequently, the focus then becomes the individual or organizational role in managing the environment to prevent malaria transmission. Environmental management is one primary map use, which can be facilitated by maps designed for a range of purposes, from visualization to cartometric. Using this terminology, all of the malaria maps made and discussed in this thesis (excluding the Gallup and Sachs maps) can be classified as geographic visualization tools used for environmental management.

McCleary (1987) has constructed a model to explain the user-environment relationship, and the operation of the map within this relationship (Figure 7.1). Maps communicate information about the location of malaria (in the environment) to the user, which is a vicarious experience. A form of technology (verbal description,

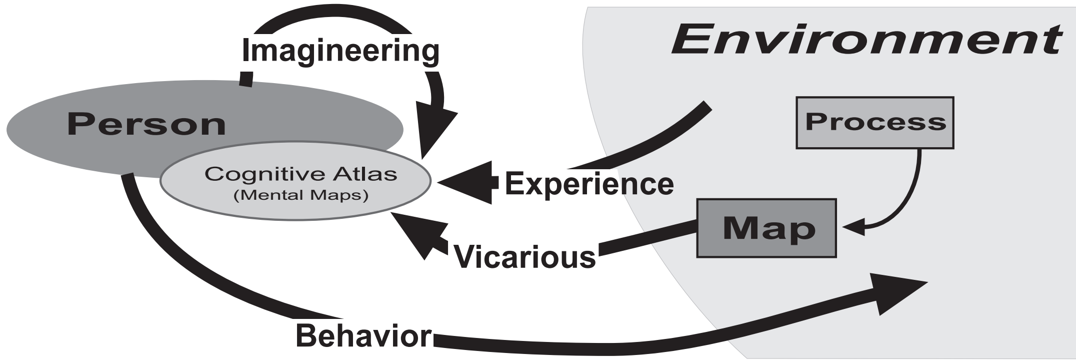


Figure 7.1 The user-environment relationship model as constructed by McCleary (2007)

numerical table, or map) is necessary to do this because the malaria parasite is nearly imperceptible to humans without the use of some sort of environmental measuring tool. Its presence or absence in the local environment is very difficult to perceive through direct experience. Thus, it is vicariously received information about malaria that is more significant, and this is processed to become the most significant element in the user's cognitive atlas. As the user considers possible behaviors with respect to malaria and their outcomes, the vicariously received map information is probably recalled first. It provides the foundation on which the map reader's "image" of the malaria situation is constructed. Consequently, while the user may have visited, thus experienced directly, one or more malarious location, his/her behavior is determined by conclusions drawn from the overall image that has developed from the individual's cognitive atlas. This cognitive atlas is the repository for direct experiences with the environment, vicarious events (e.g., map or satellite interpretation, text and table reading), and new data generated by the individual using information stored in his or her memory through a process that McCleary calls "Imagineering."

The McCleary model is highly abstract. It can be made clearer when illustrated with a hypothetical example of how a malaria map would be used in the following scenario:

> Public health officials at a regional health office (RHO) have been given money to distribute to 300 communities for residential insecticide spraying. There is not enough money to cover every house in every community, so a well informed geographic decision is needed to determine and justify the way in which the funds to be allotted. While it is recognized that three of the communities have an equal number of houses, it is not known if they share the same malaria burden.
>
> Two out of the three communities are surrounded by highly fertile mosquito habitat. Of these two communities, one community has implemented a program for widespread screening of homes. Recognizing the complexity of the three different community environments, the RHO decides to consult with a cartographer to map the significant variables at different locations, and then the office could determine if all communities should receive equal funding, or funding apportioned to their share of malaria burden, or some alternative formula for fund allocation.

To begin, the cartographer produces maps of population, number of households, malaria habitat, and mosquito screening. After studying each map, the RHO concludes the following: (1) Population is evenly distributed, (2) the number of households is not evenly distributed, (3) mosquito habitat (used to infer relative malaria incidence) is unevenly distributed, (4) screening is also unevenly distributed. The RHO realizes that they are spraying buildings and not people, so the population variable is not relevant. It is decided then to divide the money preliminarily based on the number of households. More malaria exists where there are more mosquito habitats, so those communities receive proportionally more money. Additional money is needed where screening has not been widely done. The RHO concludes that while communities with more mosquito habitat deserve more money, and communities with no screening deserve even more money. Thus, community *A* with little mosquito habitat gets the least amount of money, community *B* gets twice as much money as *A* because of the increase in mosquito habitat, and community *C* gets three times as much money due to the high amounts of mosquito habitat, and large numbers of un-screened houses.

The appropriation of money, weighted to account for a combination of factors determined to comprise a share of relative malaria burden is a form of geographically informed user behavior. It is, in McCleary's scheme, environmental management at the cartometric level. It is not a simple matter of visualization, a qualitative perusal of the graphic display. It is a map reading and interpretation task. The simple scenario described above could have been accomplished using another form of technology (verbal description, numerical data table), but the end behavior would have been the same. Mapping's superiority is clearly established over the other types of technology when there is a greater number of communities being considered (involving increased amount of data, and detail) as well as the possibility of greater variation within the variables in question.

It should be noted that the accuracy-checking and letter-writing behavior demonstrated by the WHO malnurition map is clearly a very different map use than the one described in the hypothetical discussion used above. With a critical perspective, it is apparent that the environment being managed with that map is not the actual physical location in Austrailia, but something quite different. This place is influenced more by political and intellectual geographic components over physical geographic components (conceived earlier as mosquito habitats, or place of malnutrion). Interestingly for malaria today, understanding the geography of the place where malaria actually occurs may be equally as important as understanding the geography of the international institutions empowered to manage and make changes there.

Conclusion

The complexity of understanding malaria's geographic occurrence throughout the world cannot be understated. Jacques May noted when introducing the AGS malaria map that "a whole atlas, comprising several dozens of maps, could justifiably be devoted to the cartographical representation of what we now know about malaria and its geographical significance" (May 1951, p 638). Considering this quotation and the behavioral model of cartography just discussed, it seems quite reasonable to question whether the maps of malaria studied and referenced here represent all the cartographic representations we could include in such an atlas of malaria. I think not. The unique contribution of a well trained cartographer is the ability to synthesize and communicate a clear, robust, and truthful message about the environment.

I have argued that the cartographer and the map-maker/GIS user are responsible in all of the same ways for maintaining these standards. What is troubling about the most recent malaria mapping efforts utilizing GIS and remote sensing is that they have justified their projects by citing the inconsistencies and inaccuracies contained in data reported by countries where malaria occurs. The contradiction is one of scale, in that they believe they can produce reliable information about malaria with the data available, never advocating for new data collection.

Some (Dobson 1983, Richards et al. 1999) might argue that data collection is one of the things which GIS use in public health systems can facilitate, but others (Pickles 1993, 1995) point out that GIS is not a simple mapping activity for everyone. Field research in Dakar, Senegal has shown me that basic infrastructure, such as electricity and internet access, along with political and cultural resistance, make GIS utilization a far solution to the entrenched challenges of malaria. Additionally, that field experience taught me that malaria risk is not experienced the same way by locals and foreigners. To this end, I propose that much information could be gained, if not simply personal understanding, from efforts to better understand the malaria landscape as mapped by an individual who confronts malaria on a daily basis. To the individual cartographer, or to the institution interested in producing and using maps of malaria, I would remind them that the care, skill, and attention to detail once necessary to make an individual map by pre-computer methods still remains important today in the GIS environment, where many more maps are produced, analyzed, and used. It is imperative that those using or studying GIS take the time to study more carefully the art and science of cartography as well.

Notes

[1] Gallup et al. (1999a, 1999b) calculate the Malaria Index 1994 in a different manner elsewhere than described above, as the product of the percent of a country's total land area at high risk of malaria, times the percent of malaria cases reported as malignant falciparum to the WHO in 1990. The Malaria Index for 1966/1965 is calculated in the same way, but since no data is available on the percentage of falciparum cases in these years, they assume that the percentage of malaria cases reported as malignant falciparum is unlikely to have changed, and consequently reuse the WHO data from 1990. No estimate for human population is included in the index calculations appearing in these publications.

[2] As census data is inconsistent and incomplete for much of the world, estimated population maps of Africa for 1960, 1970, 1980, 1990, and 2000, extrapolated temporally at a logarithmic rate which is based on two (rarely three or four) census dates, across the 50 years for which the maps have been produced (Nelson 2004).

[3] It is important to distinguish here between what is meant by the terms "small-scale" and "large-scale," as the cartographic versus common usage meanings are antonyms. Cartographically, small-scale refers to small map scales (i.e., 1:15,000,000) where 1 inch on the map represents 15 million inches in reality. By comparison, a large map scale (1:1,000) means that 1 map inch equals 1,000 inches in reality. The terms large spatial extent and small spatial extent will be used to mean the same as the common usages of "small-scale" and "large-scale." Further explanation may be found in Robinson et. al (1995), ch. 6.

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