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SURVEILLANCE - THE KEY TO SMALLPOX ERADICATION

by

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Smallpox surveillance represents the single most important component of the present global eradication effort - our success or failure depends, in fact, upon our capability to develop an effective surveillance activity in each national programme in each area of the country and on a global basis. Contrary to the prevalent concept, mass vaccination, while an important and necessary adjunct, represents no more than this. The reason for attaching such importance to surveillance I shall endeavour to develop in due course but a simple analogy may help to establish the perspective. We might consider the programme in terms of a military situation. When enemy troops are abroad in a territory, as the smallpox virus in an endemic area, two basic approaches may be used to rid the country of the unwanted invader. One may build defences to limit the extent and spread of devastation as one may do mass vaccination and, secondly, one may attack the invader wherever he is to defeat him by direct confrontation. To build defence installations sufficiently extensive and impregnable which will ultimately starve and destroy the invader requires a prodigious effort and expense; considerable time is required for these measures to take effect. To vaccinate 100 per cent. of a population is an impossible task; 90 per cent. is attainable only with considerable difficulty. However, if one provides some defence and at the same time aggressively attacks the invader, the task can be accomplished in a comparatively short period and at far less expense. Since in most of the presently endemic countries, previous vaccination and natural infection have already served to construct a substantial defence, our attention is focused primarily on seeking out and destroying the invader - of case detection and containment of outbreaks and cases wherever they may occur - these activities are, of course, the essence of surveillance.

Surveillance of smallpox infection is probably easier than for any other communicable disease. A distinctive rash is produced which is wholly characteristic in the great majority of cases;[1] the rash is most dense over the face and hands, the unclothed readily visible portions of the body; persons with subclinical infections are rare and are of little importance since they do not appear to be able to transmit the disease to others.[2] In brief, the disease characteristics are such that there is little difficulty in detecting visually whether or not infection is present. The rash is sufficiently characteristic in the great majority of cases that laboratory confirmation is academic. In addition, in the instance of variola major, fully 75 per cent. of cases are left with visible scars,[3] most notable over the face. Thus, in Asian countries, for example, where variola major is the principal if not the only form of the disease, we can determine the extent of infection in the past by simple surveys to determine the prevalence of the characteristic facial scars. By relating these observations to the age of the individual, we can also determine the most recent period when infection was present. If, for example, none below the age of 15 years have facial scarring characteristic of smallpox, it is reasonable to assume that there has been little or no infection in the area in the preceding 15 years.

The first requisite for dealing with the unwanted smallpox, knowledge of precisely where the disease exists, is thus comparatively simply achieved. How best to suppress transmission and thus make areas smallpox-free is best understood in the context of the development of the programme and the epidemiology of the disease.

The Nineteenth World Health Assembly decided to embark in January 1967 on an intensified global programme of smallpox eradication with the objective that it be completed within a decade. We are now in our second year. Although smallpox was once a problem in all countries, increasingly extensive vaccination employing ever-improving vaccines has reduced its endemic boundaries. By 1950, considerable areas of the world including most of Europe and North America no longer experienced the disease except as occasional importations (Fig. 1). By 1967, many additional countries in Central and South America, in the Middle East and in Asia no longer recorded cases of smallpox (Fig. 2). A recent appraisal reveals that not more than 27 countries experience endemic smallpox (Fig. 3).

Successful smallpox eradication efforts in many countries with limited health services, difficult terrain and few medically trained personnel provided the impetus to embark on the global eradication effort. Favourable epidemiological conditions strengthened this resolve. Particularly to be noted are the following:

1. Smallpox is transmitted solely from man to man. There are no known animal reservoirs;[1,4] insects appear to play no role.

2. Detection and recognition of the disease is a comparatively simple matter. As I mentioned, subclinical cases are rare and of little importance epidemiologically since they do not appear to be able to transmit infection.

3. The infected individual is capable of transmitting infection during a comparatively brief period - from emergence of the first lesions until the scabs have fallen off. Following this, he has a solid, essentially lifetime immunity against subsequent infection. The period during which he can transmit infection is thus not more than four weeks.

4. Epidemics develop comparatively slowly. There is an interval between generations of cases of two weeks or more. Normally, each infected person does not himself serve to infect more than a few additional persons.

5. A potent vaccine is available whose efficacy is excellent. Although there is still no precise measure of its degree of efficacy over extended periods, we do know that in endemic areas today, fully 80 to 95 per cent. of cases bear no scar of primary vaccination.

These characteristics which, as a group, are unique to smallpox, permit us to attack directly the chain of transmission of the disease rather than to depend exclusively on systematic vaccination of an entire population. I will go further by noting that in the less successful programmes to date, the principal cause of failure has been the reliance on a blind and dogged vaccination effort with little consideration given to active efforts to interrupt transmission.

An understanding of the manner in which the chain of infection is sustained and its characteristics is important to the execution of this strategy. For smallpox to persist, an infected person with clinically apparent disease must infect a second person who similarly must develop clinically apparent illness and so on to subsequent generations. Since there is a lapse of two to three weeks between generations of cases, we can by simple arithmetic determine that the most tenuous chain of transmission in a country requires that at least 15 to 25 cases occur annually. If fewer cases than this are recorded, only two explanations are possible: reporting is incomplete, or the cases represent reintroductions of smallpox. It is also apparent that when any country reaches the level of perhaps 200 to 500 cases in a year, there are few chains of transmission extant and that fairly simple containment procedures could readily and rapidly interrupt subsequent transmission.

In this context, it is interesting to note recent observations in India and Pakistan, two countries which account for two-thirds or more of all recorded cases of smallpox. In Pakistan, during the course of last year, Mack and his associates,[3] as part of a research study, established an intensive surveillance programme in a rural district of 1.2 million persons. During the year, over 500 cases occurred, an incidence as high as that observed anywhere in Pakistan. However, throughout the course of the entire year, less than 10 per cent. of the villages were infected with smallpox. In December 1967, an assessment survey in a highly endemic district of India,[5] similarly revealed that during the course of the year only 101 of 2331 towns and villages were afflicted with smallpox. At no time were more than 20 (1 per cent.) of the villages afflicted and, at the seasonal low point of smallpox, only seven villages recorded disease. Thus, even in these highly endemic

areas, smallpox occurred not as a widely dispersed sporadic disease but as concentrated pockets of infection sustained by a tenuous chain of transmission. Prompt case investigation coupled with active efforts to trace infection sources and comparatively simple containment activities could have had a major impact on disease incidence and might well have terminated all transmission. One effective epidemiological team could have dealt with the problem.

In tracing the chain of infection, I should like to recall again that each person who has acquired infection has necessarily been in contact with someone who similarly has been obviously ill. In contrast to most other diseases, subclinical infections play no role. Identification of the preceding case is comparatively easy - normally he will show scabs or evidence of recently separated scabs or he will have died with an acute fulminating illness. Tracing of infection in this manner may reveal other cases which have not been notified. It is to be observed that one or a few cases of clinical smallpox do not suddenly and mysteriously appear, as happens with poliomyelitis or diphtheria, diseases in which subclinical infection plays a major role.

Transmission most commonly occurs as a result of close contact as in a household, hospital or school. Contrary to common belief, casual contact as might occur in markets and on public transportation comparatively infrequently results in transmission. This obviously facilitates greatly the tracing of the chain of infection. Noted below are four illustrative outbreaks.

Locale of infection	Locale of infection of cases in four outbreaks			
	United Kingdom 1961-1962[6]	Sweden 1963[7]	Kuwait 1967[8]	Abakaliki Nigeria 1967[9]
Imported	5	1	1	1
Household (or compound)	17	13	1	30
Hospital and other medical	39	13	32	0
Other and unexplained	6	0	8	1
	67	27	42	32

Despite the fact that in each of these outbreaks, there were several patients who were ambulatory following the onset of illness and in casual contact with many persons, comparatively few cases occurred which could not be readily traced to household or hospital contact. Often disregarded in the tracing of cases, the hospital must always be considered as an important source as illustrated in the first three outbreaks. Similar observations with respect to hospitals have also been made recently in outbreaks in Brazil, Afghanistan, Nigeria and other countries. Although in the outbreaks cited above, contact in schools played no apparent role, studies in Brazil have clearly shown that the schools may also be instrumental in some circumstances in disseminating infection throughout a community.[10]

It is evident that the greater the number of susceptible contacts with whom an individual is in contact, the more likely is transmission to occur. Not surprisingly, we find in several countries that continuing transmission persists particularly among poorly-vaccinated, crowded migrant populations in the lower socio-economic areas of cities and towns. Infected persons who migrate to the city usually settle among other migrants. These people, often from less well-vaccinated rural areas, are highly susceptible. Vaccination programmes in urban areas rarely make provision for intensive and repeated vaccination in these mobile, rapidly changing groups. Accordingly, smallpox has little difficulty in sustaining transmission in these areas.

If the age-distribution patterns of cases in endemic areas is examined, it is apparent that smallpox normally occurs with disproportionate frequency among those less than 15 years of age. The percentage of cases by age is shown below for several different areas.

Age	Per cent. distribution of cases by age			
	Brazil Ceara State 1968	Afghanistan 1965-67	West Pakistan 1966	India Madras State 1966
(No. of cases)	(98)	(107)	(2 936)	(978)
< 1	4	19	11	12
1-4	20	33	45	26
5-14	41	31	30	27
>15	35	18	14	35

Recent studies in Brazil[11] and India[12] also show that those between five and 14 years of age are much more prone to disseminate infection to others than are cases which are older or younger. This group, therefore, is of particular concern when efforts are made to interrupt transmission.

Of even greater importance is the need to assure that all contacts have been vaccinated. Vaccination even in the remote past significantly impedes subsequent transmission. This is most vividly illustrated by studies conducted by Rao in Madras[12] who found that in 103 unvaccinated household contacts, 37 per cent. contracted the disease while among 1108 who had at some time been vaccinated, only 1 per cent. contracted smallpox.

Age	Frequency of smallpox among vaccinated and unvaccinated contacts			
	No. of unvaccinated* contacts	No. of cases of smallpox	No. of previously vaccinated contacts	No. of cases of smallpox
0-4	57	23	118	0
5-14	18	4	287	2
15-44	15	9	543	10
45+	13	2	160	1
	103	38 (37%)	1 108	13 (1%)

* Unvaccinated at time of exposure.

Further, those previously vaccinated who did contract disease, were less effective in transmitting the disease to others than were the unvaccinated.

Frequency of transmission from unvaccinated and previously vaccinated cases to vaccinated and unvaccinated contacts, Madras, India[6]

	Contacts					
	Vaccinated			Unvaccinated		
	No.	No. developing smallpox	%	No.	No. developing smallpox	%
Case - previously vaccinated	527	2	0.4	32	9	28
Case - unvaccinated	619	12	1.9	71	29	41

Interruption in the chains of transmission in a country can occur abruptly - the results may be dramatic as depicted in Fig. 4. In each of the countries, within two to three years following initiation of a programme, the incidence sharply declined and then plummeted to 0. In Ivory Coast, Ecuador and Cambodia, it remained at 0 and except for a rare importation, no further cases occurred. Peru experienced a reintroduction of disease in 1963 which was not detected for some period. The disease became re-established but within a comparatively brief time was once again terminated. Madras State with a population of 36 million experienced an even higher incidence prior to 1964, the first year shown in the figure, but is rapidly approaching 0. Lastly, we might examine the current smallpox trend in the 19 countries of Western and Central Africa (Fig. 5). These countries have a population of 115 million persons in an area as large as Brazil of the United States of America. Programmes were initiated in these countries during 1967 - a few commenced as early as January but most did not move beyond the training and pilot stage until July or later. This was only a year ago. From the beginning, an emphasis was placed on surveillance and this emphasis has been gradually intensified. During 1967, the number of recorded cases actually increased - perhaps due to more complete reporting. In 1968, the incidence declined sharply - despite better reporting - and plans are now being laid to intensify the surveillance-containment activities during the seasonal low period in incidence which, as you will note, occurs in the September-December period. The hope - that these countries might be smallpox-free by 1969.

Is it possible that by then every last village will have been vaccinated? Clearly not. But this is not mandatory for an area to become smallpox-free - the strategy is to strengthen the immune barrier by vaccination while, at the same time, striking hard to interrupt the chains of transmission.

Concern has been repeatedly expressed that for a country to remain smallpox-free, an intensive country-wide maintenance immunization programme is required and that such is impossible without a fully developed general health service. Although a high immunity level in the population is undoubtedly of benefit, the important requisite for retaining this status is not immunization but surveillance. It may be instructive to examine the vaccination levels in certain smallpox-free countries which border endemic areas. Although it is assumed that these smallpox-free areas are maintaining active and highly effective vaccination programmes, recent surveys of smallpox immunity reveal a somewhat different picture (Fig. 6). Countries A, B and C, despite being adjacent to endemic countries, have all been free of endemic smallpox for a decade or more. Importations have occurred but the spread of smallpox has rapidly been terminated by active containment measures. These levels of immunization may be contrasted to those recently observed in three areas in the most highly endemic countries, illustrated by countries D, E and F. In these latter countries, vaccination activities have been and are far more intensive - and costly - and yet, to date, smallpox control only has been achieved. Maintenance of a smallpox-free state with an inexpensive surveillance system is obviously far cheaper and far more acceptable.

But how, in the developing countries today, can a surveillance programme be expected to function. Repeatedly, we are told that medical personnel are nil, that there is no-one who can report cases of smallpox and there are great uncharted sparsely populated areas in which there are few or no government authorities at all. If we keep in mind certain of the characteristics of smallpox epidemiology which we have discussed and bear in mind that there must be a chain of transmission for the disease to sustain itself, the problem may be seen to be much less impossible than would first appear. In the least developed countries, one consistently finds a surprising number of widely distributed government and mission hospitals, aide posts and the like which regularly attend to persons who are ill. The first step, therefore, in the surveillance operation is to identify the location of these and to promote regular and prompt reporting from each as to whether or not smallpox cases have been observed. In endemic areas, diagnosis is not usually a serious problem - even the local populace is frequently astute in smallpox diagnosis. This simple network may be augmented by reports of suspect cases received from schoolteachers, malaria workers, village headmen, etc. At the same time, the reporting network is being set up, mobile investigation and outbreak containment teams should be created, preferably headed by a physician, although a competent health inspector can do an excellent job. These teams can serve to investigate cases promptly, to undertake containment measures and to trace the source of infection of cases. If the incidence of disease is high, such a team may be able to take action only in the control of outbreaks, but as incidence falls, an increasingly greater proportion of cases and outbreaks can be attended to. The activities of such a team will serve automatically to stimulate reporting and the team itself will be engaged in case finding. Obviously all cases will not initially come to recognition. Outbreaks may occur in remote villages and be undetected. But, keeping in mind that smallpox transmission requires an uninterrupted chain of infection, outbreaks in remote areas will either die out or come to recognition when the sources of infection of subsequent cases are sought. As noted previously, smallpox does not erupt as a sudden conflagration involving thousands of cases overnight but, rather, outbreaks evolve comparatively slowly with intervals of two to three weeks between generations of cases and with comparatively few becoming infected from each successive case. Thus, although four, five or six generations of cases were missed, an outbreak at this point is numbered not in thousands but, at most, by a few hundreds or less and is manageable by isolation, rapid widespread vaccination and tracing of infection sources. As noted in the examples of the districts in India and Pakistan, comparatively few epidemiological "fire-fighting" teams are required - the cost of such teams is negligible compared to the costs necessary to increase immunization levels country-wide by even 5 or 10 per cent. If use of such teams were able to shorten the period of persistence of endemic smallpox by even a year, they would have more than paid for themselves. Without such teams, without a major interest and concern for the surveillance of smallpox, the probability of success in any programme is sharply reduced.

I trust by now that my introductory statement - that smallpox surveillance is the single most important component of the eradication effort - is more comprehensible and not so extreme as it may have originally sounded. Let me go one step further in saying that if all responsible for smallpox eradication activities throughout the world were to comprehend fully the importance of this concept as it pertains to smallpox and were to take definitive action along the lines noted - smallpox eradication within a period of as little as three to four years would be a practical reality in most if not all countries of the world.

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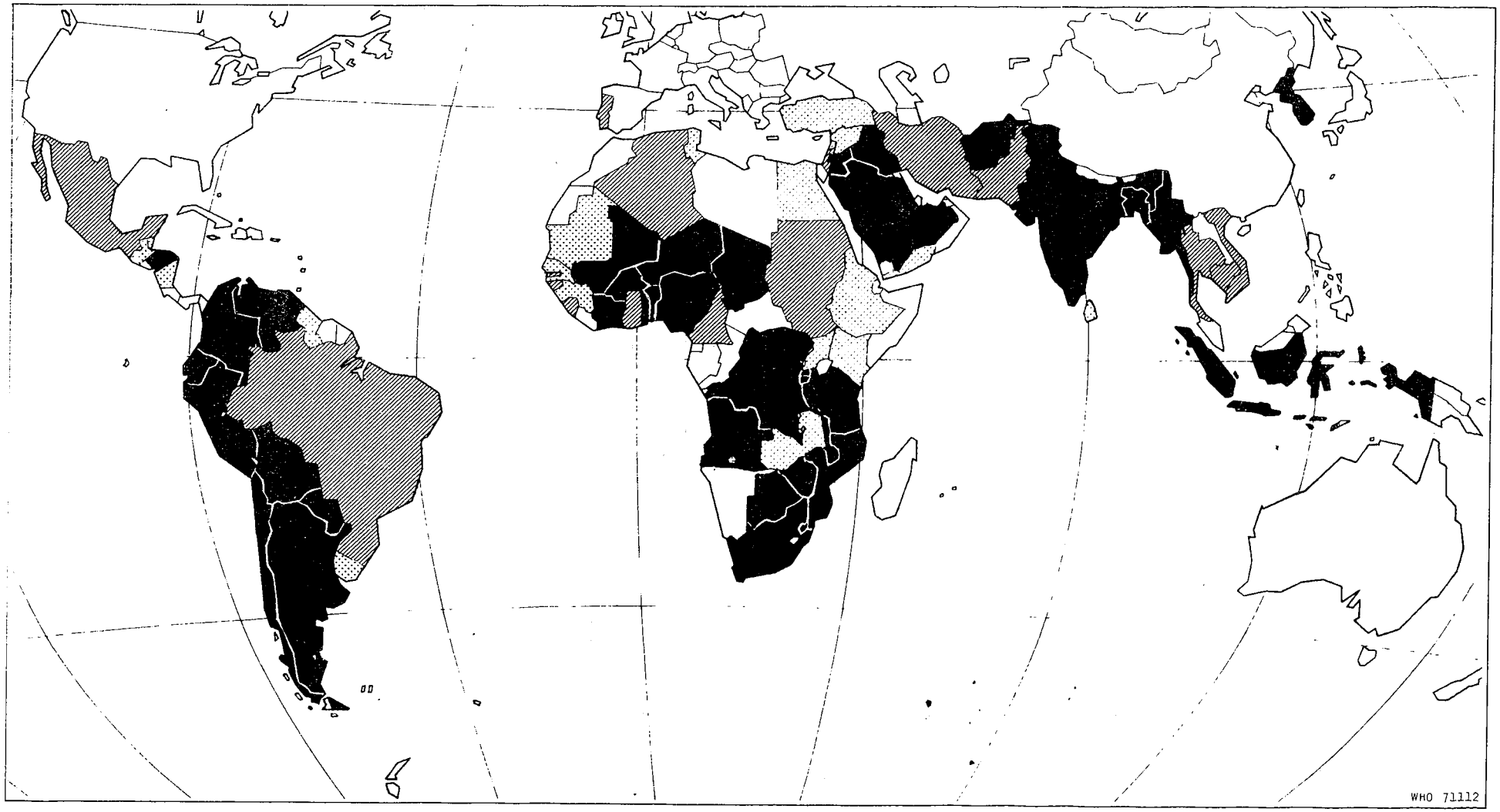
FIG. 1

SMALLPOX INCIDENCE IN ENDEMIC COUNTRIES - CASES PER 100 000 POPULATION

1950



> 5.0 cases per 100 000 population

0.5 - 5.0 cases per 100 000 population

< 0.5 cases per 100 000 population

No reports received from China (mainland), Kuwait, Liberia, Morocco, Muscat & Oman, Nepal, Panama, Quatar, South-West Africa, Trucial Oman and Yemen

FIG. 2

SMALLPOX CASES PER 100 000 POPULATION - 1966

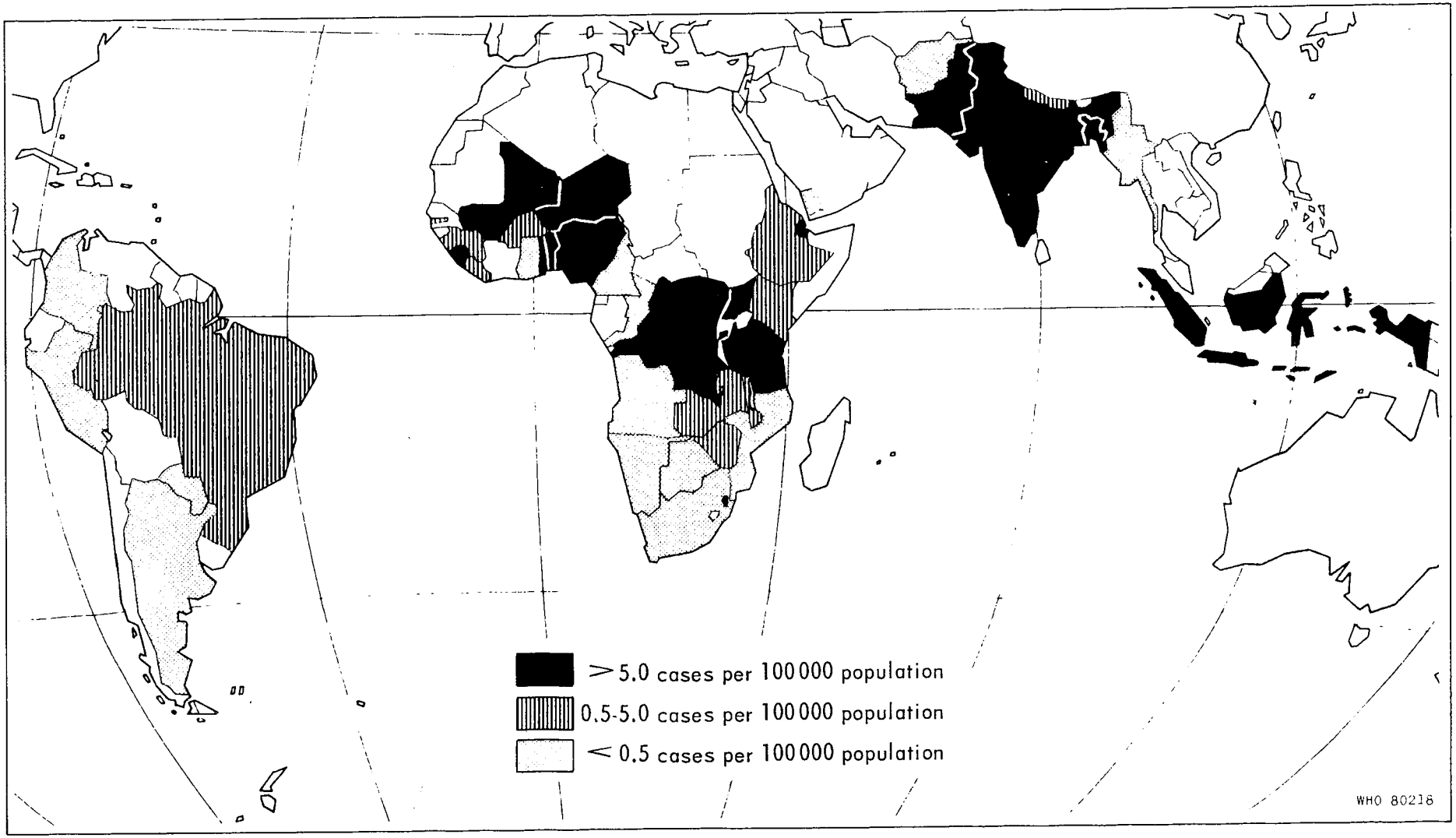
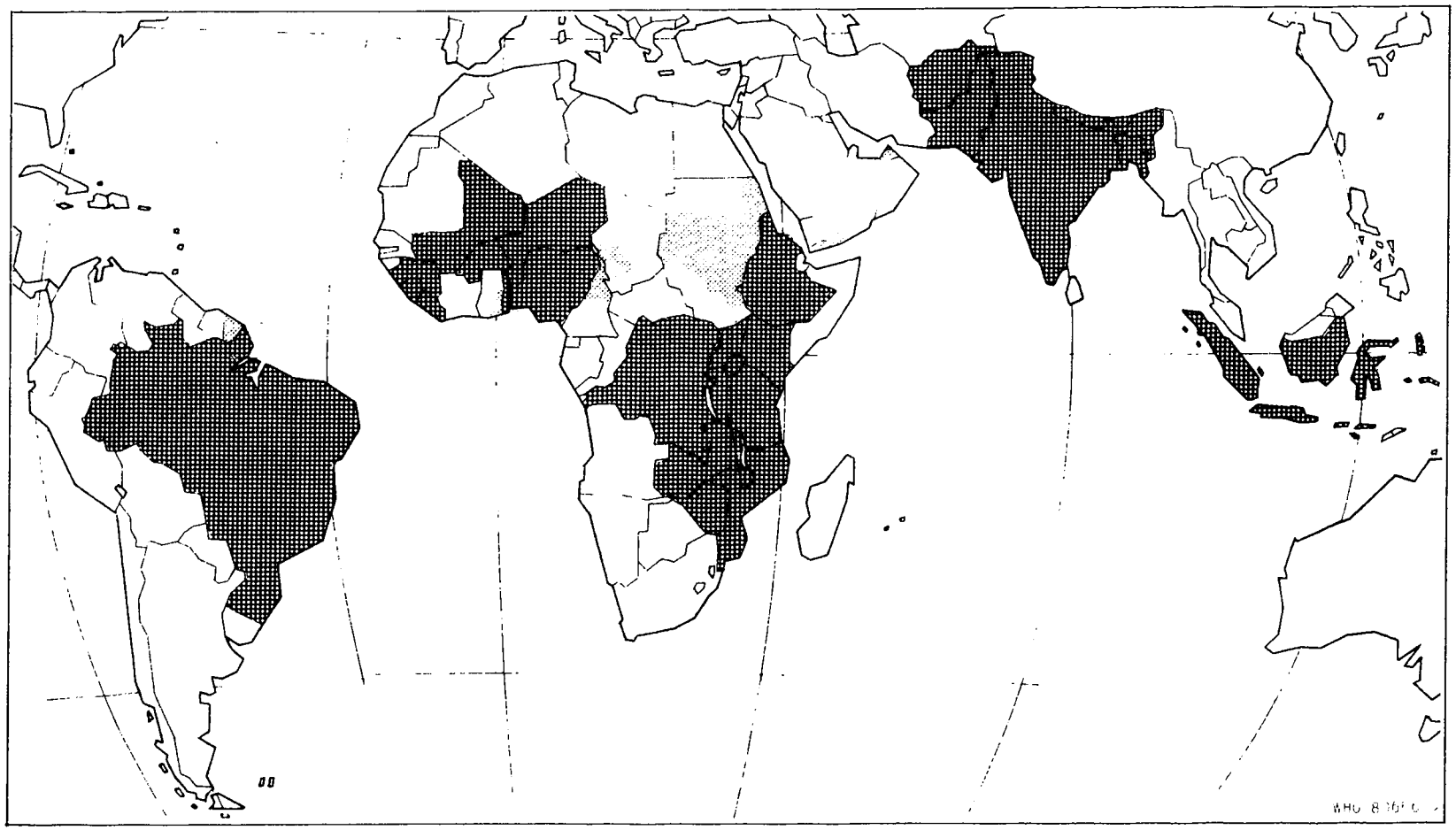


FIG. 3

AREAS IN WHICH SMALLPOX HAS BEEN REPORTED IN 1968



Countries presumed to be endemic for smallpox

Areas into which smallpox has been imported

Fig. 4
Disappearance of Smallpox from Endemic Countries
and Madras State, India
Incidence by Year

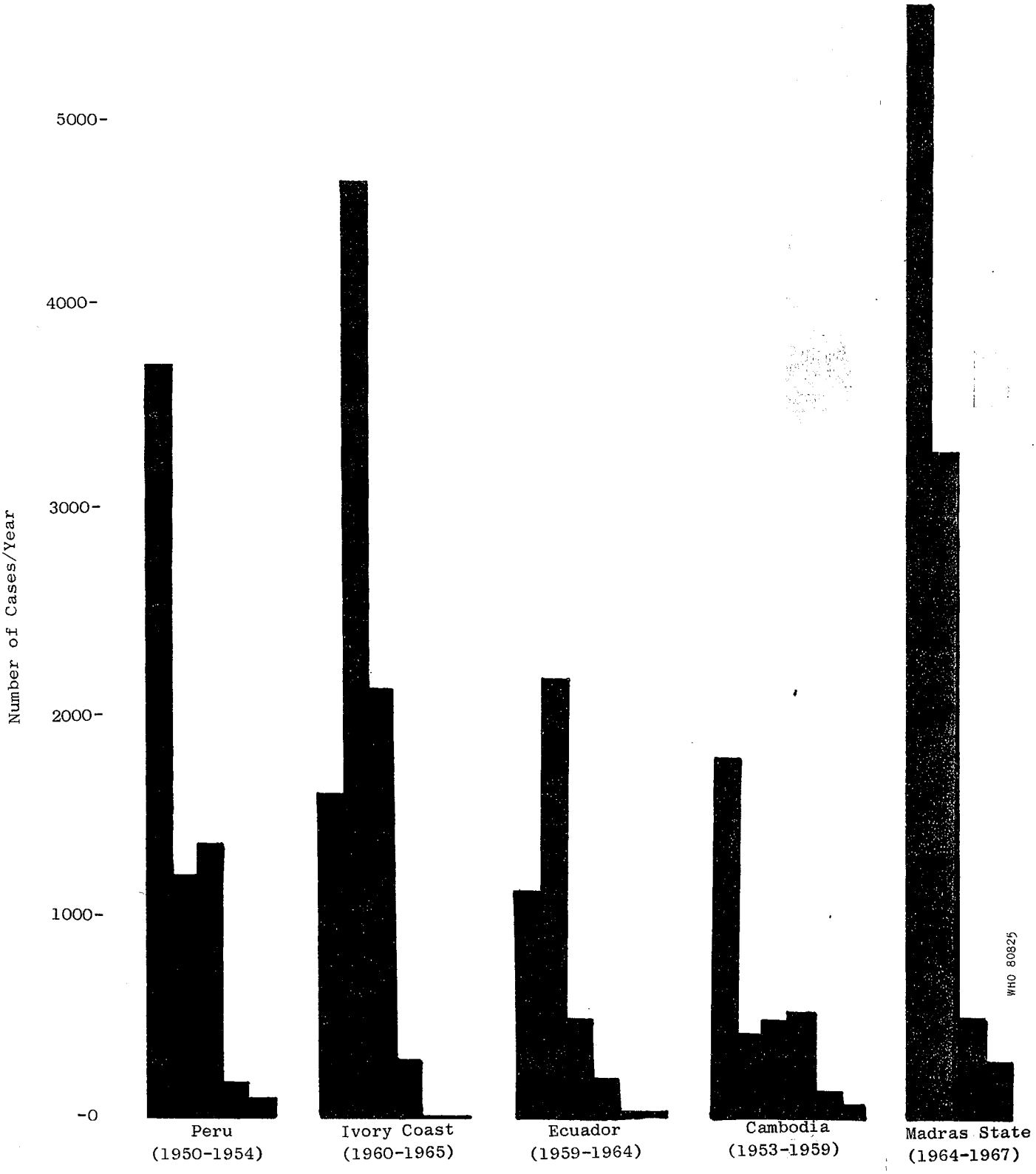


Fig. 5. SMALLPOX INCIDENCE - WESTERN AND CENTRAL AFRICA 1966-1968

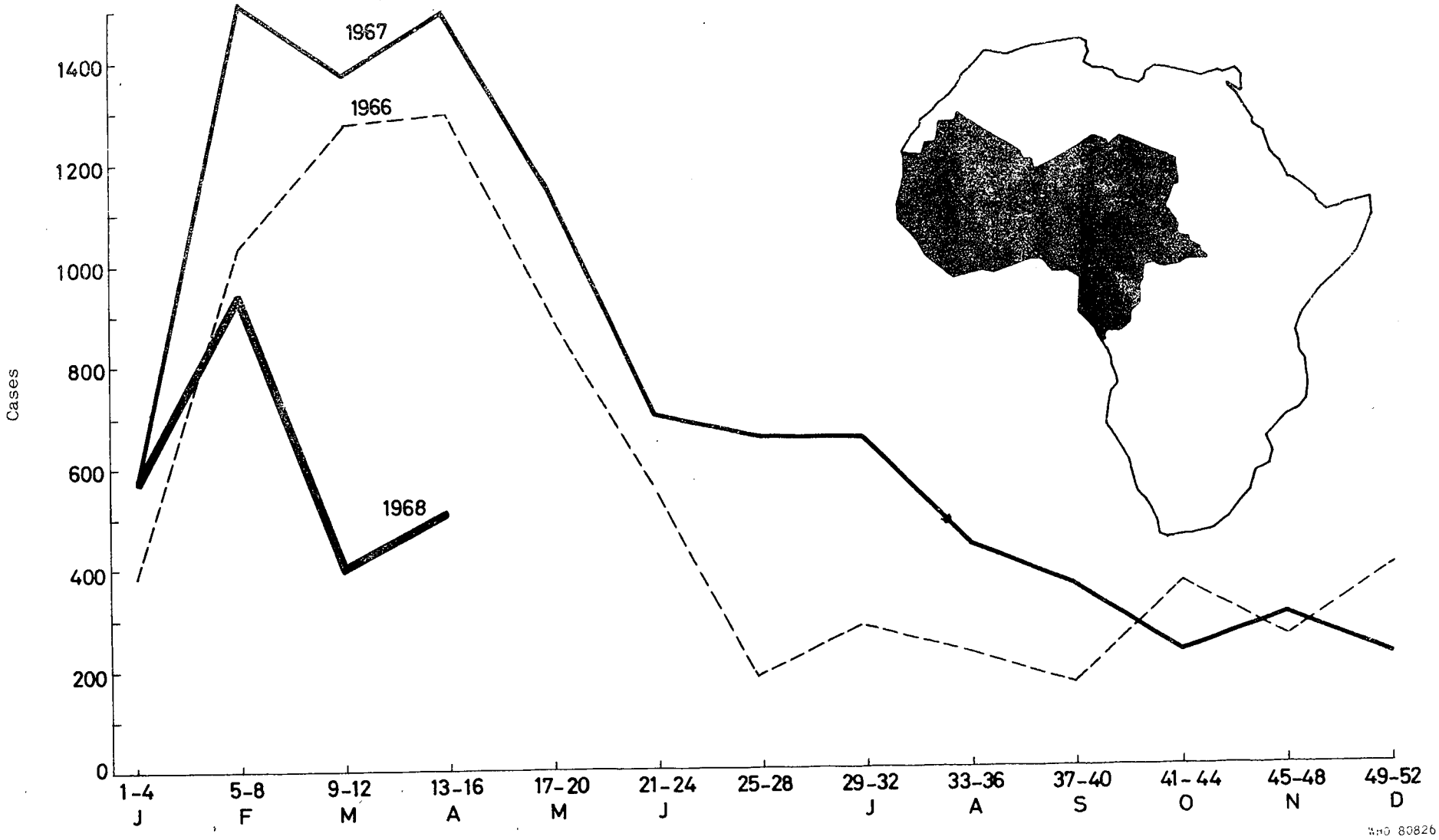
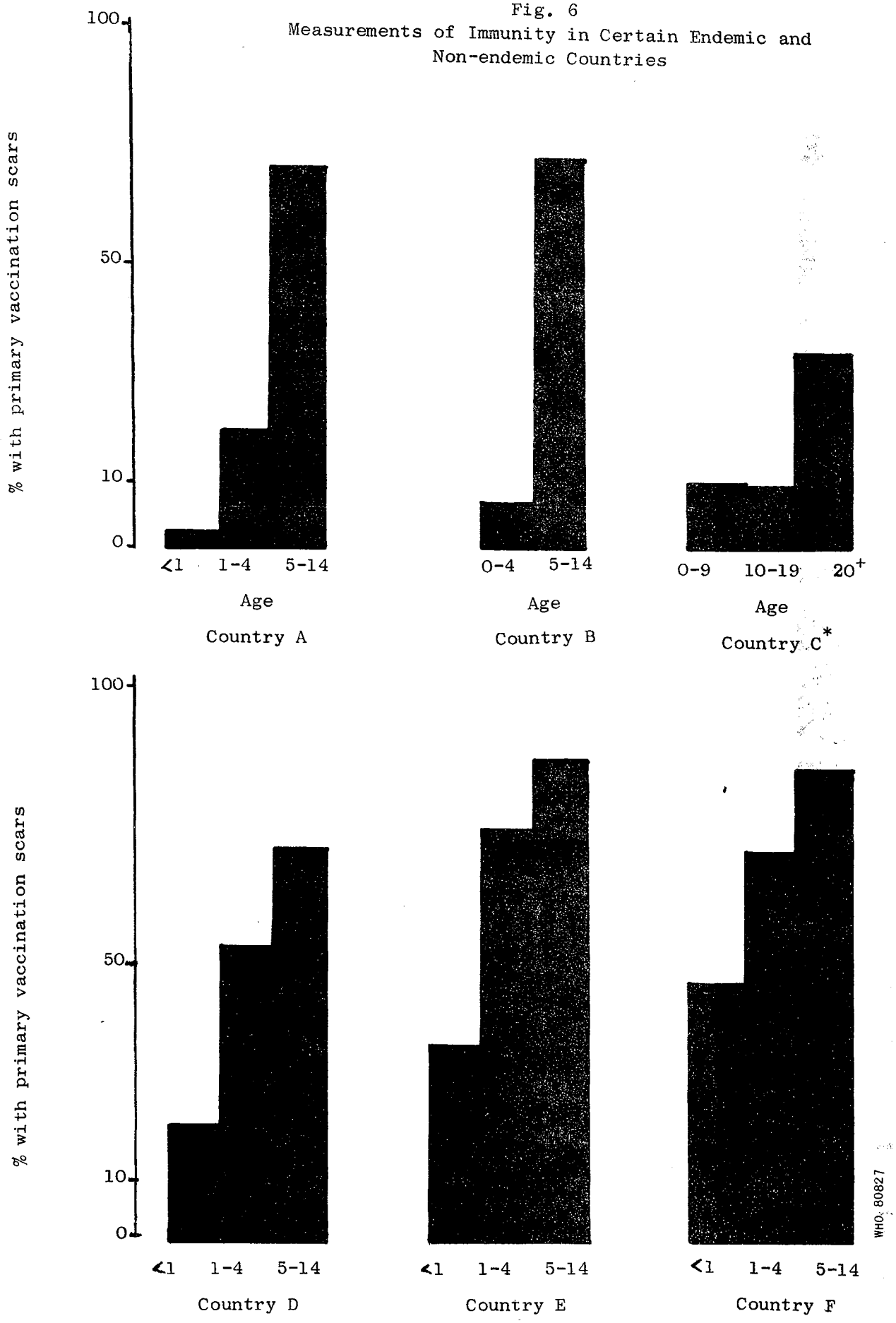


Fig. 6
Measurements of Immunity in Certain Endemic and Non-endemic Countries



* History of vaccination only.