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ASSESSMENT OF VACCINATION COVERAGE AND SMALLPOX IN FIVE AREAS OF WEST AFRICA - A SUMMARY OF TERMINAL ASSESSMENT RESULTS

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I. INTRODUCTION

In 1968 and early 1969, staff from the Regional Office of the Smallpox/Measles Programme carried out evaluations of the attack phases of several countries. During the evaluation, a survey of the population residing in vaccinated areas was conducted to determine vaccination coverage (based on the history of vaccination by jet injector) and the proportion of persons with vaccination scars and pox scars. This report summarizes the data obtained from five such surveys which were conducted in areas highly endemic for smallpox prior to the initiation of the programme, and in which smallpox incidence has subsequently fallen to extremely low levels. These areas are Sokoto and Katsina Provinces in Northern Nigeria, Western Nigeria, Niger, Dahomey and Togo (Figure 1). Excluded from the sample within these areas were those localities not vaccinated by the programme at the time of the survey. In Niger, a small vaccinated area inhabited almost solely by desert nomads was also excluded for logistical reasons.

II. METHODS

A random sample of at least 1100 persons was drawn from each area evaluated, using a one stage cluster sampling technique specifically adapted for use in rural West Africa. The surveys were designed to provide results accurate to within $\pm$ 10% except for a one in 20 chance. A detailed description of the methodology is presented in Appendix I.

The surveys were directed at villages which, except in Western Nigeria, contain 90% or more of the population of the assessed areas[4]. The social class within these villages is more or less uniform. In Western Nigeria, the most highly urbanized area in West Africa, about 60% of the population reside in towns of over 5,000 persons. A separate survey of towns was conducted in the West which is not presented in detail in this report. Although the definition of the size of aggregation of persons which constituted a village differed in each survey (Table I), the results are believed to be broadly representative of the rural populations of each of the five areas.

The sample surveys were conducted by five to eight assessment teams, each led by an NCDC/USAID advisor or a national professional staff member, and were generally completed within two weeks. Most of the team leaders came from countries other than the one being assessed. The authors led at least one assessment team in each of the surveys, and personally trained all other team leaders and interpreters.

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[4]From available National Census data, 1961-1963

Each person sampled was interviewed and examined by one of the assessment team leaders. All questions were asked in a local language in which both the assessor (or his interpreter) and the person sampled were fluent. To determine vaccination coverage during the programme, all persons were asked "Have you ever been vaccinated?" Those who responded affirmatively were then asked, "When was your last vaccination?", and "How were you vaccinated?" If the person did not understand what was meant by the third question, the assessor was then instructed to ask "Were you vaccinated by the jet injector or with the needle?" There were usually words in the local language for both "jet injector" and "needle," the latter term being used to denote the device used in performing multiple puncture, multiple pressure or "scratch" vaccinations. If the person interviewed was still uncertain about the meaning of the question, a pantomine was performed, first making the motion of pushing a foot pedal while bringing the right hand towards the person's left arm as though holding an injector, and then making the motions associated with a "scratch" vaccination. In the vast majority of cases, the answers given were unequivocal, and left no doubt in the assessor's mind whether or not the person had been vaccinated and by which method.

In looking for smallpox vaccination scars, both arms were examined. In a few instances, a parent would indicate that his child had been vaccinated on the thigh, in which case the thigh was examined. In certain areas many persons had been vaccinated in BCG campaigns. Since these vaccinations were usually given on the forearm, there was little difficulty in distinguishing them from smallpox vaccination scars. Occasionally, burn scars intentionally induced as a sign of bravery, and traditional skin tatooing or scarring were a source of confusion.

A person was recorded as having smallpox scars if he had at least five pock marks of two millimetres or more in diameter on his face.

III. RESULTS

A. General

The percentage of selected sample sites which could be completed is shown in Table 2. In Northern Nigeria, 134 sites were selected since Sokoto and Katsina Provinces were each surveyed separately. The results presented in this report combine the two surveys by weighing the results from each in proportion to its population (4,500,000 persons for Sokoto, 2,650,000 persons for Katsina). Six of the assigned sites were inaccessible owing to the onset of the rainy season, and one site was inadvertently overlooked by one of the assessment team leaders. These missed sites would have been accessible to the vaccination teams during the dry season (when most of the vaccinating was done), and the bias introduced by the incompleteness of the survey is probably negligible.

Two surveys were also carried out in Western Nigeria, and their results have similarly been combined. One of these two areas had been more severely affected by the recent rainy season than had the other, making the assessment work slower and more difficult, with the result that only 37 of the 67 assigned sites were completed. Of the 30 sites which were missed, 18 were omitted because of insufficient time, 11 could not be reached, and one village which had been selected was unknown to all persons asked of its whereabouts. Fortunately, this difficult area contained only 18% of the total village population of the Western State. The areas which were inaccessible to the assessors should have been accessible to the vaccination teams at the time of the mass campaign and thus the bias introduced is believed to have been small. It was possible to reach all but two of the

67 sites selected in the second area surveyed in the Western State, which contained 82% of the population.

In Niger, all sites were visited, but the data for one site were misplaced. All sites were surveyed in Dahomey and Togo.

The percentage of the sampled population who lived in small villages, (arbitrarily defined as being less than 500 persons), and large villages (500 or more persons), is presented in Table 3. Data accumulated since the beginning of the Programme[5] indicates that small villages can be important in sustaining smallpox transmission. Additionally, it has often been found to be more difficult to achieve high levels of vaccination coverage in small villages, since they are usually the least accessible, and, in programmes which do not visit every village, their inhabitants, are the ones who are usually asked to walk the fartherest distance to be vaccinated. Thus, it seemed worthwhile to compare the survey results from small and large villages.

B. Number and Age Distribution of Sampled Population

The number of persons examined in each survey is presented in Table 4. The survey design was adequate to provide the estimated minimal sample size for each age group (see Appendix) with the exception of the 45 and over age group in Dahomey and Togo, and 15-44 year old males in Niger. In only one instance, determination of vaccination coverage in the 45+ age group in Dahomey was the number of persons obtained less than the actual minimal sample size needed which resulted in slightly diminished accuracy in this group.

The age distribution of the population which was examined is presented in Tables 6 through 10. The age distribution of the population of West Africa (United Nations Demographic Yearbook 1965) is also presented for comparison. In all surveys, the percentage of males between the ages of 15 and 44 was less, and the percentage of females slightly more, than would have been expected from the published age distribution of the population of West Africa. All surveys also showed a slight excess in the percentage of children aged 0-4 who were sampled. All rates for vaccination coverage, frequency of vaccination scars, and smallpox scars were age adjusted, using the West African age distribution as a standard.

C. Proportion of Population with a History of Vaccination by Jet Injection

Since the Smallpox Measles Programme is the first in West Africa which has used jet injectors in mass smallpox vaccination campaigns, the history of having received a smallpox vaccination with a jet injector was a useful marker for assessing programme vaccination coverage.

In Niger, Dahomey, and Togo, however, a USAID sponsored measles vaccination programme which used jet injectors to vaccinate children from 6 months through 5 years had been in operation for about two years prior to the first smallpox campaigns using injectors. While this conceivably could have been a source of confusion with respect to vaccination history in children from four through ten years, the assessors' subjective impressions were that this was not a problem.

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[5]See the SEP Report issued periodically by the Smallpox Eradication Programme, NCDC, Atlanta, Georgia, USA

Vaccination coverage rates achieved in the programme (Table 5) were highest in Northern Nigeria, which had an overall rate of 92.9%. The lowest rate, 61.9%, was observed in Western Nigeria, and the other three areas had intermediate values. Age specific rates by area (Tables 6 through 10) show a similar pattern. The lowest rate of vaccination coverage was observed in children less than a year of age and the next lowest rate in the 45+ age group; the highest vaccination coverage was observed in the 5-14 year age group; the 1-4 and 15-44 age groups had intermediate values. Differences in vaccination coverage attributable to sex were not striking, although working males (15-44 years) were less completely vaccinated in Western Nigeria, and females in the 5-14 and 15-44 age groups were less completely vaccinated in Dahomey.

In all areas except Niger, where no differences were observed, coverage rates in small villages were 8-10% less than those in large villages (Table 3). This difference was significant at the .01 level by the chi square test.

This pattern was not observed, however, in all age and sex groups. The 1-4 year age group, in fact, had slightly higher coverage rates in small villages in all areas except Togo. The most consistent differences were seen in the 15-44 year age group in which vaccination coverage in all areas was lower in small than in large villages. Even here, coverage in males was markedly lower in Togo; coverage in females was markedly lower in Northern Nigeria, while in Dahomey, the coverage in both was significantly less. Although the differences are generally small, there were generally higher levels of coverage in females than males in small villages, while males had higher levels of coverage than females in large villages.

D. Proportion of Population with Vaccination Scars

The highest vaccination scar rates were observed in Togo (86.5%), while Western Nigeria again had the lowest (74.2%). Age specific rates by country are shown in Tables 6-10. In Northern Nigeria, Western Nigeria, and Niger, the rates follow the pattern described for vaccination coverage: the lowest vaccination scar rates are observed in the under one and 45+ age groups, the highest rates are observed in the 5-14 age groups; the 1-4 and 15-44 age groups have intermediate values. In Togo, however, the frequency of vaccination scars increased with increasing age. In Dahomey, the same pattern is seen, except for the 45+ age group, which has an intermediate rate for vaccination scars. As with the vaccination campaign coverage rates, the differences in scar rates by sex are not striking, although a lower frequency of scars, as with vaccination coverage, was observed in 5-14 year old females in Dahomey. Lower scar rates were also observed in females 45 and over in Northern Nigeria.

Vaccination scar rates were less consistently related to village size than were vaccination coverage rates. Small and large villages had the same rates of vaccination scars in Northern Nigeria and Niger, and Western Nigeria actually had higher vaccination scar rates in small than in large villages - a reversal of the pattern observed with vaccination coverage. Togo and Dahomey showed lower scar rates in small than in large villages. These differences were significant at the .01 level, and were largely accounted for by the 15-44 and 45+ age groups. Differences by sex and village size were not observed with respect to vaccination scar rates.

E. Proportion of Population with Scars of Smallpox

The highest frequency of smallpox scars (19.4%) was observed in Northern Nigeria. Western Nigeria (9.6%), and Dahomey (8.1%) had the next highest rates; Niger (5.3%), and Togo (3.0%) had the lowest rates. The differences between these three groups is significant at the .01 level. In most areas, few scars were observed among those less than five years of age. Rates increased with age thereafter, reaching maximal values in the 15-44 and 45+ age groups. While higher rates were observed in all areas among 15-44 year old males than among females, the difference was negligible in Northern Nigeria.

Smallpox scar rates were not consistently related to village size indicating that smallpox had afflicted the populations of small villages in these areas just as often as it had afflicted the populations of large villages. The greatest difference (8.6%) was observed in Northern Nigeria but this was probably due to an artifact in the analysis; the scar rates for all villages was 19.4% while the rate for villages with known size was only 14.1% indicating that persons from sampled villages of unknown size had a higher scar rate than those from sampled villages of known size. Northern Nigeria and Dahomey showed higher scar rates in small than in large villages (significant at the .01 level), Western Nigeria and Niger showed higher rates in large villages (significant at the .05 level), and no differences were seen in Togo. The frequency by sex of smallpox scars was similar in small and large villages.

IV. DISCUSSION

A. Proportion of Population with History of Vaccination by Jet Injector

It has been observed in West Africa that Smallpox outbreaks can occur in populations with immunity levels of over 88%[6], so long as the few smallpox susceptibles which exist have intimate contact with one or more cases, and that smallpox transmission can stop in populations with immunity levels of only 53%[7]. It is the frequency and intimacy of exposures to susceptibles which determines whether smallpox transmission will occur. However, the overall proportion of susceptibles does correlate with the probability that transmission will take place and this measurement has been found to be useful in defining minimum standards for the level of vaccination coverage which should be achieved in mass campaigns. The programmes in West and Central Africa have established as a minimum standard the figure of 80%. The survey results indicate that at least 80% of the population was vaccinated in Sokoto and Katsina Provinces, Niger, and Togo. In fact, the actual coverage levels achieved by the programmes can be considered to be 3 to 5% higher than those determined by the surveys, owing to the addition of newborns following the mass campaign. However, neither Dahomey nor Western Nigeria achieved 80% vaccination coverage.

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[6] Thompson, D. Faith Tabernacle Smallpox Epidemic, Abakaliki, Eastern Nigeria (unpublished paper)

[7] Henderson, R. H. and Yekpe M., Smallpox Transmission in Southern Dahomey, Am. J. of Epid. 90(5):423-428, 1969.

The most successful programme was that of Northern Nigeria. This is thought to have been due to the influence of the traditional authorities, the Emirs, with their highly organized and centralized system of local government. Information about the programme was effectively transmitted to the concerned population, and at the command of the local authorities the vast majority of people from surrounding villages came to a central vaccination point, and sometimes waited for hours for the vaccination team to arrive. An additional factor contributing to the programme's effectiveness was the fact that mass campaigns had been infrequent in the past, and the populations were eager to be vaccinated.

The lowest levels of vaccination coverage, on the other hand, were observed in Western Nigeria. As the direction, the calibre of the vaccination teams, and the calibre of the team supervisors of the programme in the West appeared to be comparable, if not superior to that in Northern Nigeria, it seemed that this difference was most readily explicable on the basis of differences in the ability of local authorities to motivate villagers to be vaccinated. Western Nigeria teams made the effort to visit <u>every</u> village, realizing that traditional authorities would have little success in motivating the people to travel to another village to be vaccinated. In spite of this, many villagers, informed of the team's schedule, chose not to be present when they arrived. Additionally, the system of advance notification was not very effective so that many other persons were unaware that the team was coming. Occasionally, entire villages fled from the vaccination teams. This seemed to be confined to small relatively isolated villages in which the residents had a general suspicion of strangers. This did not seem to be caused by a specific fear of vaccination. Such behaviour was rarely observed in the North. Notably, Western Nigeria achieved a vaccination coverage rate of 83.1% in towns of over 5,000. More effective advance publicity carried out in urban areas may have accounted for this. In Niger, Dahomey and Togo, an interplay of several factors appeared to account for the intermediate levels of vaccination coverage which were observed.

In all programmes, similar factors contributed to the differences observed in the age specific rates of vaccination coverage. The low rates in children of less than one year of age, as found in the survey were principally due to the fact that the majority of the unvaccinated had not been born at the time of the mass campaigns. Among the 45+ age group, which had the next lowest level of vaccination coverage, a considerable proportion had already been vaccinated several times or had had smallpox, and considered vaccination to be unnecessary. Others simply felt that they were too old to be bothered with it. The 5-14 year olds were best vaccinated in the programme presumably owing to their curiosity and their mobility. The arrival of the vaccination teams was a big event in the life of the village, and these children made every effort to be on hand to witness it. The somewhat lower coverage in the 1-4 year age group was probably related to the dependence of this group on a parent or older sibling to bring them for vaccination. The 15-44 age group was the one in which absenteeism from the village was most frequently responsible for their not being vaccinated. This absenteeism tended to affect males more than females.

Lower levels of vaccination coverage were generally observed in small villages. The fact that this difference was most pronounced in Northern Nigeria is most probably related to the campaign strategy, in which the vaccination teams visited only the larger villages, and requested those in the surrounding smaller villages to come to them. In all of the other areas, the attempt was made to visit every village. However, in Western

Nigeria and Niger, approximately 10% of the villages which were sampled had not been visited by one of the vaccination teams. These villages were predominantly small. Only two of the 135 sampled villages in Dahomey and Togo had not been visited by a vaccination team, and yet the discrepancies in coverage between small and large villages were more pronounced in these latter countries than they were in Western Nigeria and Niger. It would appear that other factors, such as the effectiveness of advance publicity, the willingness to cooperate with persons not well known to the village, or perhaps the normal rates of absenteeism, played the major role in accounting for this observed difference. Additional study would be required to clarify the relative importance of the various contributing factors.

B. Proportion of Population with Vaccination Scars

Smallpox vaccination scar rates were close to or exceeded 80% in all areas surveyed. Only two, Western Nigeria and Niger had rates below 80% and these were 78.8% and 75.2% respectively. Examination of the specific vaccination scar rates, however, reveals that none of the areas had rates above 40% in the under one year age group, and only Northern Nigeria and Niger had rates of over 80% in the 1-4 year age group. These findings emphasize the rapidity with which new susceptibles enter the population, and underline the importance of following the attack phase in these areas with a maintenance phase directed specifically at the 0-4 age group. All areas had scar rates of 80% or over in the 5-14 and 15-44 year age groups in both sexes with the exception of the 15-44 year old males in Western Nigeria, whose rate of 70.2% reduced the age group total to 78.2%. For the 45+ age group, Dahomey and Togo were the only areas in which scar rates of over 80% were observed.

In Western Nigeria, Dahomey and Togo, the number of persons who stated that they had been vaccinated by jet injector was less than the number who actually had a vaccination scar, and it is evident that past vaccination programmes have covered a proportion of the population which the jet injector teams missed. In Northern Nigeria and Niger, however, a significant number of persons lacked scars although stating that they had been vaccinated during the recent programme. This finding could have resulted from persons stating that they had been vaccinated by jet injector when they had not been, or could have been caused by the administration of a certain number of ineffective vaccinations by the teams. The second explanation appears to be the more likely. The best method for documenting this would be to determine vaccination take rates 6-8 days following vaccination. While this is being done with increasing frequency by the individual programmes, it had not been done often enough to permit an accurate comparison of take rates in the five surveyed areas. The fact that scar rates showed less dependence on village size than did vaccination coverage rates, suggests that past programmes achieved greater success in reaching small villages than has the present programme.

In appraising overall immunity to smallpox, several calculations were compared. In the survey in Niger, two indices were calculated. In one, all persons with a vaccination scar were considered to be immune; in the other, persons who had a vaccination scar and a history of vaccination within the past 10 years, and persons who had smallpox scars or scars of variolation were considered to be immune.

Among 2,726 persons, 77.3% had a vaccination scar, while 76.0% had either a vaccination scar and a history of vaccination within the past 10 years, or had smallpox or variolation scars. This difference is not significant at the .05 level.

In Northern Nigeria, information was not obtained regarding variolation scars or the proportion of persons with vaccination scars who had been vaccinated within the past ten years. Lacking this, a comparison was made between smallpox immunity as measured by the presence of a vaccination scar and/or smallpox scars and as measured by the presence of a vaccination scar alone. In a sample of 5,748 persons in Sokoto and Katsina Provinces, 88.9% had a vaccination scar and/or smallpox scars, while 83.8% had a vaccination scar. In a sample of 1428 persons in villages in Western Nigeria, 78.2% had a vaccination scar and/or smallpox scars, while 75.2% had a vaccination scar alone. These differences are significant at the .01 in Northern Nigeria, but not significant (at the .05 level) in Western Nigeria.

The data suggest that, except for Northern Nigeria where the smallpox scar rates are relatively high, an index of smallpox immunity based on the presence of a vaccination scar provides a reasonable estimate of smallpox immunity in the population.

In analysis of smallpox susceptibles (defined as persons lacking a vaccination scar) (Table 11) indicates that the 0-4 age group accounts for 32.2% of the total susceptible pool, while the 15-44 age group accounts for 35.7%. This, of course, was the situation which existed at the time of the surveys. Without maintenance programmes, the 0-4 age group will increase its contribution to the total susceptible pool by some 10% during the first year, and thereafter by a percentage which diminishes slightly each year as the total pool of susceptibles continues to grow.

Although these programmes have achieved a remarkable success in reducing smallpox transmission to very low levels, the survey results leave no doubt that disease which is re-introduced from outside the area, or which may still be smoldering in an undiscovered pocket within the area, still has a good possibility of becoming re-established as an endemic disease, particularly as the influx of newborns continues to increase the proportion of smallpox susceptible persons. While maintenance programmes can be expected to provide some measure of defense against this occurrence, they will clearly need to be supplemented by vigorous investigation and control of all suspect cases, and with a programme aimed at improving smallpox case reporting.

C. Proportion of Population with Scars of Smallpox

Northern Nigeria has for many years been regarded as a major focus for smallpox, and the fact that the smallpox scar rates observed in Sokoto and Katsina Provinces were more than double the rates observed in other areas supports this view. It is particularly of interest that the Niger population, a large proportion of whom live in a fertile strip of land bordering Northern Nigeria have such a low rate of smallpox scars. The fact that a higher frequency of smallpox scars was not observed in Niger probably relates to the success of past vaccination programmes which have concentrated for many years on protecting this border population.

Western Nigeria and Dahomey appear to have shared a similar smallpox problem: the Yoruba and Fon tribes in the two areas mingle across their common border, and share many beliefs, including the belief in a god of smallpox. While travelers to or from the North may have augmented the incidence of smallpox in these areas, it seems likely that this has been an important focus in its own right in the past.

Smallpox scar rates observed in Togo were the lowest in the five areas. Smallpox in Togo is proving to be a difficult adversary, however, since, in spite of having the highest vaccination scar rates, it has continued to be plagued by outbreaks of smallpox which have turned up in pockets of poorly vaccinated persons. Togo is one of the only areas of West Africa where smallpox incidence actually increased in 1968, in marked contrast to the majority of countries which were experiencing a decrease in incidence.

IV. SUMMARY

Smallpox incidence in West and Central Africa has declined dramatically since attack phase vaccination programmes have been carried out. Sample surveys were carried out in 1968 and early 1969 in Sokoto and Katsina Provinces in Northern Nigeria, Western Nigeria, Niger, Dahomey and Togo. Only in Western Nigeria and Dahomey did less than 80% of the population give a history of having been vaccinated during the attack phase, and vaccination scar rates were above 75% in all areas sampled. Children under age of five years accounted for 32.2% of all susceptibles at the time of the surveys, and will account for some 40% of all susceptibles within a year following the surveys in the absence of a maintenance vaccination programme.

The highest rate of smallpox scars (19.4%) was recorded in Sokoto and Katsina Provinces. Western Nigeria and Dahomey had intermediate rates (9.6% and 8.1% respectively), while Niger and Togo had the lowest rates (5.3% and 3.0%).

Table 1. Population Centres Defined as "Villages" for Purposes of Sample Surveys

Country	Definition of a "Village"
Northern Nigeria	All population centres of 10,000 or less persons
Western Nigeria	All population centres of 5,000 or less persons
Niger	All population centres of 1,000 or less persons
Dahomey	All population centres excluding Cotonou, (pop. 110,000), Porto-Novo, (pop. 70,000), Abomey, (pop. 23,000), and Ouidah (pop. 19,000)
Togo	All population centres excluding Lome, (pop. 121,000)

Table 2. Percentage of Selected Sample Sites which were Completed

Area	Sample Sites Selected	Sample Sites Completed	Percent Completed
Northern Nigeria	134	127	95
Western Nigeria[1]	134	92	90
Niger	67	66	99
Dahomey	68	68	100
Togo	67	67	100

[1]Two areas were surveyed. Area one contained 82 percent of the total village population. Sixty-five of 67 sites were completed (97 percent). Area two contained 18 percent of the total village population. Thirty-seven of 67 sites were completed (55 percent). The data presented in this report were obtained by weighting the results from area one by 82 percent and the results from area two by 18 percent.

Table 3. Percentage of Sampled Population Residing in Small (1-500) and Large (501+) Villages

Area	Percent Residing in Small Villages (under 500)	Percent Residing in Large Villages (500+)
Northern Nigeria	26	74
Western Nigeria	51	49
Niger	61	39
Dahomey	21	79
Togo	37	63

Table 4. Number of Persons Sampled

	Age Group					
Area	1	1-4	5-14	15-44	45+	Total
Northern Nigeria	138	438	531	1,069	328	2,504
Western Nigeria	89	312	372	731	372	1,876
Niger	64	235	282	426	138	1,145
Dahomey	69	242	243	494	116	1,164
Togo	57	266	265	455	119	1,162

Table 5. Summary of Assessment Results

A. Proportion of Population (age adjusted) with History of Jet Injector Vaccination (in Percent)

	Village Population under 500	Village Population 500+	Total
Northern Nigeria	81.1	90.9	92.9 (88.0)[a]
Western Nigeria	56.3	63.8	61.9
Niger	80.1	77.4	79.3
Dahomey	63.9	72.4	70.4
Togo	74.0	83.7	79.7

B. Proportion of Population (age adjusted) with Smallpox Vaccination Scars (in Percent)

Northern Nigeria	86.5	86.7	84.3 (86.6)[a]
Western Nigeria	80.3	72.4	75.2
Niger	78.0	79.8	78.8
Dahomey	76.0	81.3	80.0
Togo	83.0	91.2	88.0

C. Proportion of Population (age adjusted) with scars of smallpox (in Percent)

Northern Nigeria	20.5	11.9	19.4 (14.1)[a]
Western Nigeria	7.4	11.2	9.6
Niger	4.4	7.2	5.3
Dahomey	12.7	7.1	8.1
Togo	2.6	3.3	3.0

[a] In Northern Nigeria, two of the assessment teams (one working in Sokoto and one working in Katsina Province), did not record the populations of the villages sampled. The figures in parenthesis and, of course, those for which village size is specified, are derived from the 86 sample sites for which the village size was known.

Table 6. Northern Nigeria (Sokoto and Katsina Provinces) Assessment Results

A. Population Examined

Age	Number Examined Male	Female	Total	Age Distribution of Examined Population (%) Male	Female	Total	Age Distribution of Population of West Africa (%) Male	Female	Total
<1			138 (76)[a]			5.5 (4.4)[a]			4.3
1-4			438 (292)			17.5 (16.8)			14.5
5-14	217	314	531 (379)	8.7	12.5	21.2 (21.8)	13.2	11.9	25.1
15-44	320	749	1,069 (754)	12.8	29.9	42.7 (43.4)	19.7	22.5	42.0
45+	116	212	328 (235)	4.6	8.5	13.1 (13.5)	7.4	6.6	14.0
TOTAL			2,504 (1736)			100.0 (99.9)			99.9

	Village Population under 500			Village Population 500-10,000			Total		
B. Proportion of Persons (age adjusted) with History of Jet Injector Vaccination (in Percent)									
<1			31.8			51.0			69.6 (46.0)[a]
1-4			94.9			93.3			95.4 (93.7)
5-14	100.0	93.1	95.8	96.8	96.3	96.7	98.7	96.2	97.1 (96.5)
15-44	86.1	65.0	73.6	92.3	93.6	93.2	91.4	94.4	93.6 (88.1)
45+	77.8	78.0	78.5	89.2	81.3	84.3	88.2	93.5	88.6 (82.8)
TOTAL			81.1			90.9			92.9 (88.0)
C. Proportion of Persons (age adjusted) with Smallpox Vaccination Scars (in Percent)									
<1			18.8			45.4			61.2 (38.5)[a]
1-4			91.9			89.6			89.1 (90.2)
5-14	83.5	98.5	92.1	98.6	96.3	97.2	91.9	93.9	93.1 (95.9)
15-44	94.6	89.5	91.0	90.8	86.4	87.5	86.5	82.9	83.5 (88.4)
45+	79.6	77.8	78.5	80.0	73.0	75.7	80.2	70.1	73.8 (76.4)
TOTAL			86.5			86.7			84.3 (86.4)
D. Proportion of Persons (age adjusted) with Scars of Smallpox									
<1			0.0			0.0			0.0 (0.0)[a]
1-4			2.3			0.7			2.3 (1.1)
5-14	2.9	7.3	5.7	0.4	2.9	1.8	9.6	7.5	8.6 (2.8)
15-44	39.1	34.8	36.2	23.1	19.2	20.5	30.6	29.6	30.0 (24.6)
45+	19.3	29.0	25.2	36.3	10.9	19.4	33.5	28.0	30.7 (20.9)
TOTAL			20.5			11.9			19.4 (14.1)

[a] In Northern Nigeria, two of the assessment teams (one working in Sokoto and one working in Katsina Province), did not record the populations of the villages sampled. The figures in parenthesis and, of course, those for which village size is specified, are derived from the 86 sample sites for which the village size was known.

Table 7. Western Nigeria
Assessment Results

A. Population Examined

Age	Number Examined Male	Female	Total	Age Distribution of Examined Population(%) Male	Female	Total	Age Distribution of Population of West Africa(%) Male	Female	Total
1			89			4.7%			4.3%
1-4			312			10.6			14.5
5-14	183	189	372	9.7	10.1	19.8	13.2	11.9	25.1
15-44	296	435	731	15.8	23.2	99.0	19.7	22.5	42.0
45+	169	203	372	9.0	10.8	19.8	7.4	6.6	14.0
TOTAL			1876			99.9%			99.9%

	Village Population under 500			Village Population 500 - 10,000			Total		
Age	Male	Female	Total	Male	Female	Total	Male	Female	Total

B. Proportion of Persons (age adjusted) with History of Jet Injector Vaccination (In Percent)

1			34.6%			33.4%			34.0%
1-4			70.4			68.0			69.2
5-14	74.1	62.7	67.0	80.2	83.7	81.9	77.1	81.6	79.9
15-44	50.5	57.1	54.9	51.0	66.0	59.1	50.8	61.6	52.6
45+	36.3	31.7	34.1	54.0	47.0	50.9	48.0	41.1	44.9
TOTAL			56.3%			63.8%			61.9%

C. Proportion of persons (age adjusted) with Smallpox Vaccination Scars (In Percent)

1			38.7%			30.9%			34.0%
1-4			71.3			68.8			69.8
5-14	83.2	81.1	81.9	83.8	90.2	86.9	83.5	85.5	84.1
15-44	88.0	89.0	88.6	64.1	80.0	72.4	70.2	84.1	78.2
45+	74.5	74.9	75.0	61.9	64.5	63.5	73.6	68.7	62.4
TOTAL			80.3%			72.4%			75.2%

D. Proportion of persons (age adjusted) with Scars of Smallpox

1			0.0%			0.0%			0.0%
1-4			1.2			0.0			0.6
5-14	0.0	2.6	1.6	4.2	5.8	4.9	2.7	3.8	3.3
15-44	13.9	10.3	11.4	18.5	15.4	17.1	17.1	13.3	15.0
45+	18.6	12.4	15.0	22.7	15.4	20.1	19.5	15.3	17.3
TOTAL			7.4%			11.2%			9.6%

Table 8. Niger
Assessment Results

A. Population Examined

Age	Number Examined Male	Female	Total	Age Distribution of Examined Population(%) Male	Female	Total	Age Distribution of Population of West Africa(%) Male	Female	Total
1			64			5.6%			4.9%
1-4			235			20.5			14.5
5-14	125	157	287	10.9	13.7	24.6	13.2	11.9	25.1
15-44	112	314	426	9.8	27.4	37.2	19.7	22.5	42.0
45+	61	77	132	5.3	6.7	12.0	7.4	6.0	14.0
TOTAL			1145			99.9%			99.9%

	Village Population under 500			Village Population 500 - 10,000			Total		
Age	Male	Female	Total	Male	Female	Total	Male	Female	Total

B. Proportion of Persons (age adjusted) with History of Jet Injector Vaccination (In Percent)

1			2.5%			12.5%			6.5%
1-4			84.0			78.6			81.0
5-14	91.9	93.9	92.7	93.5	88.1	90.5	92.7	92.6	92.6
15-44	79.7	85.4	83.9	86.8	85.3	85.7	82.9	85.5	84.8
45+	68.4	65.4	66.7	34.8	60.0	47.9	54.2	65.3	60.4
TOTAL			80.1%			77.4%			79.3%

C. Proportion of persons (age adjusted) with Smallpox Vaccination Scars (In Percent).

1			2.5%			12.5%			8.5%
1-4			68.3			67.0			67.4
5-14	88.6	89.0	89.3	91.1	93.1	92.2	90.9	89.9	90.3
15-44	91.9	86.4	87.9	92.1	84.4	86.4	92.0	85.9	87.5
45+	57.9	65.3	62.1	76.2	69.2	72.3	63.2	69.9	66.9
TOTAL			78.0%			79.5%			78.8%

D. Proportion of persons (age adjusted) with Scars of Smallpox

1			0.0%			0.0%			0.0%
1-4			0.0			0.0			0.0
5-14	0.0	0.0	0.0	0.0	1.7	1.0	0.0	0.7	0.4
15-44	6.7	6.3	6.4	21.1	6.4	10.2	11.5	5.9	7.4
45+	5.3	17.3	12.2	19.0	19.2	19.1	10.5	18.4	15.0
TOTAL			4.4%			7.2%			5.5

Table 9. Dahomey
Assessment Results

A. Population Examined

Age	Number Examined Male	Female	Total	Age Distribution of Examined Population(%) Male	Female	Total	Age Distribution of Population of West Africa(%) Male	Female	Total
1			69			5.9%			4.3%
1-4	111	131	242	9.5	11.3	20.3			14.5
5-14	100	143	243	8.6	12.3	20.9	13.2	11.9	25.1
15-44	186	306	494	16.0	26.5	42.4	19.7	22.5	42.0
45+	42	74	116	3.6	6.4	10.0	7.4	6.6	14.0
TOTAL			1164			100.0%			99.9%

	Village Population under 500			Village Population 500 - 10,000			Total		

B. Proportion of Persons (age adjusted with History of Jet Injector Vaccination (In Percent)

Age	Male	Female	Total	Male	Female	Total	Male	Female	Total
1			0%			11.1%			8.7%
1-4	73.7	66.7	69.3	67.4	70.3	68.9	68.5	69.5	69.0
5-14	54.6	72.7	76.1	83.9	72.7	77.7	84.0	72.7	77.4
15-44	61.2	59.2	60.0	85.4	75.9	79.4	79.0	72.1	74.7
45+	62.5	75.0	67.9	69.2	62.9	64.8	66.7	64.9	65.5
TOTAL			63.9%			72.4%			70.4%

C. Proportion of persons (age adjusted) with Smallpox Vaccination Scars (In Percent)

1			0%			11.1%			8.7%
1-4	78.9	66.7	71.4	69.6	72.3	71.0	71.2	71.0	71.2
5-14	100.0	75.8	82.6	92.0	80.9	85.8	93.0	79.7	85.2
15-44	79.6	77.5	78.3	92.0	89.0	90.1	88.7	86.4	87.2
45+	81.3	91.7	85.7	84.6	77.4	79.5	83.3	79.7	8.0
TOTAL			76.0%			81.3%			80.0%

D. Proportion of persons (age adjusted) with Scars of Smallpox

1			0%			1.9%			1.4%
1-4	0	10.0	8.2	0	0	0	0	0.8	0.4
5-14	0	12.1	8.7	5.8	4.8	5.2	5.1	6.5	5.9
15-44	16.3	18.3	17.5	15.5	7.4	10.3	15.7	9.9	12.1
45+	25.0	0	14.3	0	13.0	9.8	7.9	11.1	10.0
TOTAL			12.7%			7.1%			8.1%

Table 10. Togo
Assessment Results

A. Population Examined

Age	Number Examined Male	Female	Total	Age Distribution of Examined Population(%) Male	Female	Total	Age Distribution of Population of West Africa(%) Male	Female	Total
1			57			4.9%			4.3%
1-4			266			22.9			14.5
5-14	131	134	265	11.3	11.5	22.8	13.2	11.9	25.1
15-44	143	312	455	12.3	26.9	39.2	19.7	22.5	42.0
45+	50	69	119	4.3	5.9	10.2	7.4	6.6	14.0
TOTAL			1162			100.0%			99.9%

	Village Population under 500			Village Population 500 - 10,000			Total		
B. Proportion of Persons (age adjusted) with History of Jet Injector Vaccination (In Percent)									
Age	Male	Female	Total	Male	Female	Total	Male	Female	Total
1			16.0%			43.8%			31.6%
1-4			70.6			79.6			75.6
5-14	74.3	85.7	81.3	96.9	88.5	93.1	90.8	87.3	89.1
15-44	62.5	79.7	75.0	87.4	83.2	84.6	79.0	81.7	80.3
45+	94.7	70.0	79.6	77.4	84.6	81.4	84.0	78.3	80.7
TOTAL			74.0%			83.7%			79.7%
C. Proportion of persons (age adjusted) with Smallpox Vaccination Scars (In Percent)									
1			16.0%			50.0%			35.1%
1-4			73.1			81.6			77.8
5-14	74.3	87.5	82.4	96.9	89.7	93.7	90.0	88.8	89.8
15-44	91.7	89.8	90.3	97.9	95.7	96.4	95.0	93.3	94.1
45+	100.0	90.0	93.9	96.8	92.3	94.3	98.0	91.3	94.0
TOTAL			83.0%			91.2			88.0%
D. Proportion of persons (age adjusted) with Scars of Smallpox									
1			0%			0%			0%
1-4			0			0			0
5-14	0	1.8	1.1	0	6.5	2.7	0	4.2	2.1
15-44	8.3	0.8	2.8	6.0	1.3	2.9	6.8	1.0	2.9
45+	5.3	10.0	8.2	14.3	6.3	10.0	10.7	8.1	9.2
TOTAL			2.6%			3.3%			3.0%

Table 11

Contribution of Each Age Group to Total Smallpox Susceptible Pool
(Combined Results from Northern Nigeria, Western Nigeria, Niger, Dahomey and Togo)[a]

Age	A Age Distribution of Population of West Africa [b] (%)	B Percent Susceptible to Smallpox	C Contribution of each Age Group to Total Susceptible Pool $\left(\frac{A \times B}{A \times B} \times 100\right)$
1	4.3	65.3	14.1
1-4	14.5	24.8	18.1
5-14	25.1	10.5	13.1
15-44	42.0	17.0	35.7
45+	14.0	27.4	19.1
TOTAL	99.9	-	100.1

a) The combined results were obtained by weighting the results from each area by its population, as estimated for July 1969, according to the following figures:

Area	Estimated Population July 1969	Percentage of Total Population of Area
Sokoto and Katsina Provinces	6.8×10^6	26.3
Western Nigeria	10.9 x "	42.1
Niger	3.8 x "	14.7
Dahomey	2.6 x "	10.0
Togo	1.8 x "	6.9
Total	25.9×10^6	100.0

b) United Nations Demographic Yearbook, 1965

Table 12

Estimated Sample Size Required using a Cluster Sampling Technique

Age	Sample Size Needed Without Clustering c/	Clustering Coefficient b/	Sample Size Needed With Clustering (Col. 1-2)	Estimated Number of Persons Obtained from Total Sample of 999 a/
0-4	96	1.85	178	188
5-14	96	2.03	195	251
15-44	96	1.51 (Age 15-39)	145	420
45+	96	Not given	145(?)	140
TOTAL	384		663	999

a/ Derived from formula $n = \frac{t^2}{d^2} pq$ See text for definitions and values of symbols.

b/ Serfling, R.E. and Sherman, I.L. - Attribute Sampling Methods USPHS Publication No. 1230, (1965). pg 144.

c/ Derived from age distribution of population of West Africa, United Nations Demographic Yearbook, 1965.

APPENDIX I - SAMPLE SURVEY METHODOLOGY

I. Sample Size

In the assessment surveys, information was desired for each of the following age groups: 0-4, 5-14, 15-44 and 45+. It was decided that the data obtained should be accurate to within ± 10%, except for a 1 in 20 chance. Sample size was determined by using the formula:

$n = \frac{t^2 pq}{d^2}$ where 'p' represents the proportion of the target population having been immunized, and 'q' is 1.00 minus 'p'. The value for 'n', the number of persons required in the sample, is maximized when the value of 0.50 (50% vaccination coverage) is given to 'p'. 'd', the accuracy, has a value of 10%, and 't' has a value of 1.96, indicating a chance of 1 in 20 that the sample was non-representative of the population being surveyed. In solving this formula for 'n' ($n = \frac{3.84\ (0.50)\ (0.50)}{0.0100} = \frac{0.9600}{0.0100} = 96.00$) 96 persons are shown to be needed in each of the age groups about which information is desired.

A cluster sampling method was decided upon, since it is known that the vaccination status of one member of a cluster is likely to be related to the vaccination status of other members of that cluster, the sample size determined above needed to be increased to correct for clustering. From immunization surveys in the United States, Serfling[1] has estimated that the correction factor for clustering for smallpox vaccination is 1.85 in 1-4 year olds, 2.03 in 5-14 year olds, and 1.51 in 15-39 year olds. These clustering co-efficients pertain to members of a single family. No estimates are currently available for West Africa. Lacking this information, Serfling's estimates were applied (Table 12).

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[1] Serfling, R.E. and Sherman, I.L., Attribute Sampling Methods, USPHS Publication No. 1230 (1965), pp 144

With these assumptions, a survey designed to sample a total of 1,000 persons should include a sufficient number in each age group (with the possible exception of the 45+ age group), to provide results accurate to within ± 10%, except for a 1 in 20 chance. This size of sample also provides a large enough number in the 15-44 year old age groups to permit males and females to be analyzed separately.

The same formula which had been used for determining sample size was used to determine the number of clusters needed. For this determination, vaccination coverage was estimated to be 80% and no correction for clustering was necessary. The formula is thus: $n = \frac{t^2 pq}{d^2} = \frac{3.84(0.80)\ (0.20)}{0.0100} = 61.4$

To provide a margin of error, 67 sites were selected in each area and the assessors were asked to examine a cluster of 16 persons at each site. If all sites were completed, this would provide a total sample population of 1,072 persons.

II. Selection of Villages from which to draw Clusters

A list of villages located in areas vaccinated by the programme was obtained for each of the surveys. A list was constructed which contained in three columns the name of each village, its population, and a cumulative total of population for this village and all villages preceding it on the list. A "sampling interval" was obtained by dividing the total population of these villages by 67 the number of sample sites desired. A number between one and the "sampling interval" number was chosen from a random number table, and this served as the starting point. The village whose cumulative population total spanned this number became the first sample site chosen. The "sampling interval" number was added to that determined from the random number table and a second village was selected, and so on until 67 sites were selected.

It was recognized that the list of villages which had been obtained was very likely to be incomplete, and every effort was made to assure that all habitations in vaccinated areas would have an opportunity of being sampled. At each of the 67 selected villages, the assessors were instructed to make as complete a list as possible of all habitations usually grouped in small hamlets which fell under the authority of the village and the population of each. This information was ordinarily obtained without difficulty from the village authorities. A list like that previously constructed was then prepared showing hamlet population and cumulative population. The area from which the cluster of 16 persons was to be selected was chosen by using a random number table as previously described. This method gave each area on the list a chance for being selected which was proportional to its population. This procedure was not used in Dahomey and Togo, where the village initially selected from the total list of villages was the one from which the cluster was drawn.

III. Selection of the Cluster

The assessors were instructed to go to the centre of the area selected, i.e. one of the 67 villages initially selected or one of the hamlets or habitations nearby. Each assessor was provided with a paper on which was drawn a circle, marked at 30 degree intervals from 0 through 360 degrees. The assessor oriented himself by pointing the zero degree reading towards the east, a direction which could always be determined by asking the inhabitants, if the sun were overhead or not visible. Using this paper "orientation compass", the direction of a "cluster line" was established by drawing a number between 0 and 360 from a random number table. The assessor then walked in the direction of this line to the edge of the village, counting the number of dwellings which it intersected. A random number table was again used to select one dwelling from the total number counted. The assessor interviewed and examined all persons present who had spent the previous night in this dwelling, attempted to summon any absentees. If less than 16 persons were present, he continued walking in the direction of the line away from the centre of the village and examined the occupants of the remaining dwellings encountered. If the cluster had not been completed by the time he had reached the edge of the village, he moved clockwise from the line to the next dwelling and continued to sample, establishing a new line back towards the centre of the village.

FIGURE 1
AREAS ASSESSED IN WESTERN AFRICA

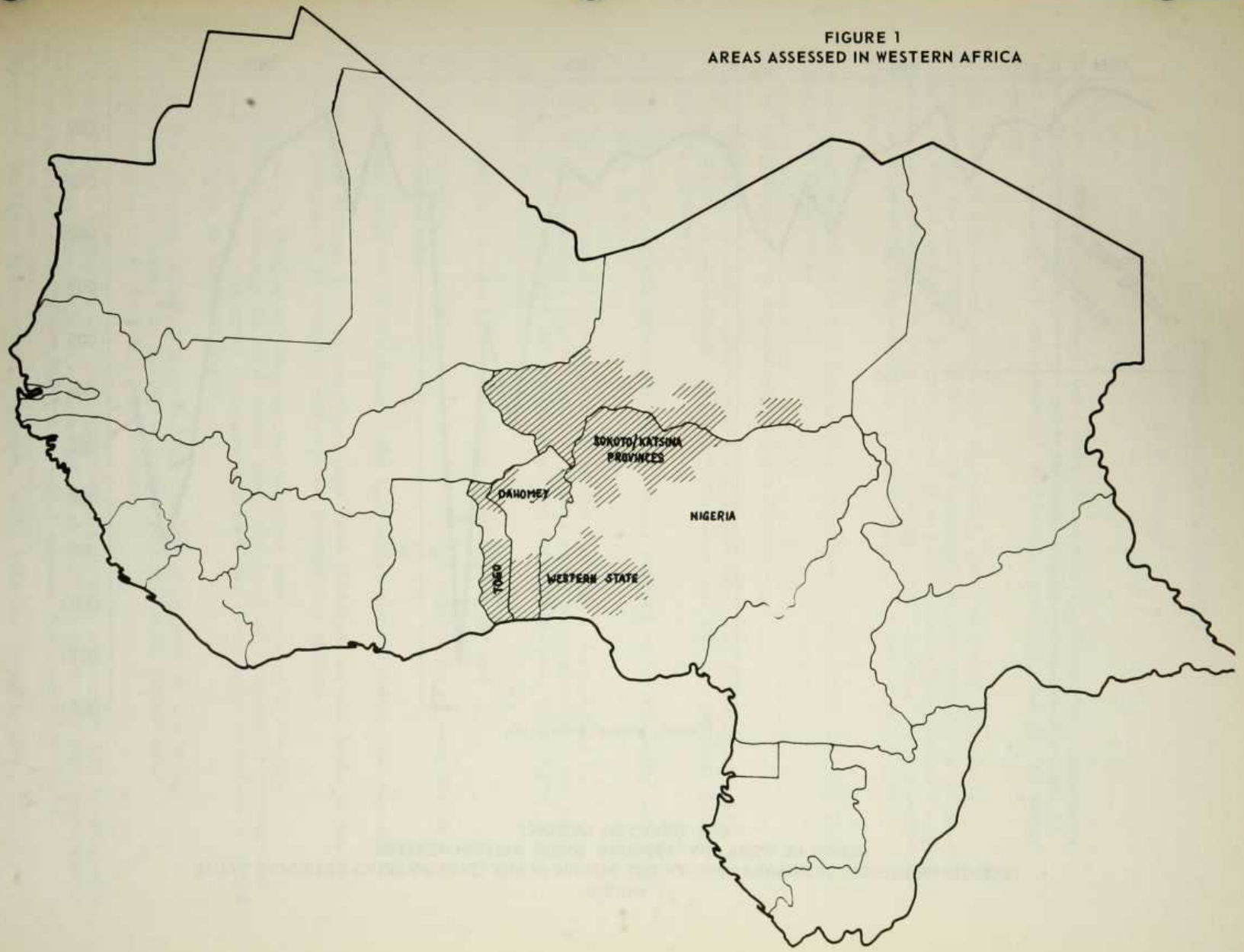

FIGURE 2
TOTAL REPORTED CASES OF SMALLPOX IN SOKOTO AND KATSINA PROVINCES (NORTHERN NIGERIA), WESTERN NIGERIA, NIGER, DAHOMEY, AND TOGO, BY MONTH
JANUARY 1966-APRIL 1969