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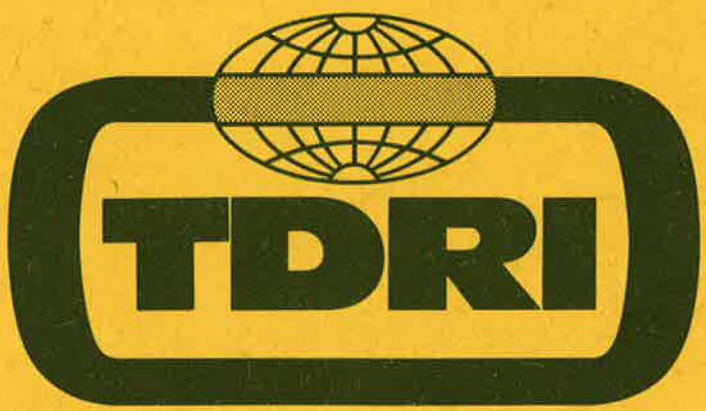

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Distribution, frequency of attack and seasonal incidence of the African armyworm *Spodoptera exempta* (Walk.) (Lep.: Noctuidae), with particular reference to Africa and southwestern Arabia

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SUMMARY

Distribution, frequency of attack and seasonal incidence of the African armyworm *Spodoptera exempta* (Walk.) (Lep.: Noctuidae), with particular reference to Africa and southwestern Arabia

Spodoptera exempta (Walk.) is recorded very widely in Africa south of the Sahara and in adjacent parts of southwestern Arabia. It occurs intermittently through the oceanic countries of South East Asia and the Pacific as far east as Hawaii, but not in the Americas. This distribution is mapped in detail. The areas from which infestations have been reported and the frequency of attack have increased since 1970.

This paper aims to help those concerned with monitoring and control of armyworm by making available the wider historical data needed for anticipating outbreaks. For the pan-African region, the monthly distribution and frequencies of incidence are presented as twelve maps showing the number of years in which infestations have been recorded in each degree-square of latitude and longitude during the period 1940–1982. In the areas to the north and south of about 4°N, the periods of attack are roughly complementary and correspond with the seasonal rains. Thus from October–November until May infestations spread progressively northwards from southern Tanzania to northern Ethiopia and Yemen, and at the same time southwards from Malawi and Zimbabwe to the south of Cape Province. From June until September infestations occur intermittently from Senegal to southwestern Arabia, but very rarely south of the equator. The northward and southward progressions of outbreaks can be attributed to the migration of the moths on the wind. The scarcity of reports from all parts of the region in September–October and the start of the next season in the area between southeastern Kenya and Zimbabwe lend support to the alternative theory that outbreaks may develop from populations that remain at low density, particularly within this area. Evidence from other disciplines supporting both theories is outlined.

Sequencies of attack do not follow exactly the same pattern each season. To enable years with events analogous to the current one to be identified, the range of recorded variations is appended as a series of maps showing month by month the distribution of *S. exempta* infestations over the last 43 years. For each territory there is an index to the years and months when outbreaks were recorded, and a summary of the monthly frequencies of occurrence. The incidence and importance of *S. exempta* in each country is summarised.

RÉSUMÉ

La répartition, la fréquence des attaques et l'incidence saisonnière de *Spodoptera exempta* (Walk.) (Lep.: Noctuidées), surtout en Afrique et au sudouest de l'Arabie.

La présence de *Spodoptera exempta* (Walk.) est constatée partout dans les régions de l'Afrique situées au sud du Sahara et dans les régions avoisinantes de l'Arabie.

Elle est intermittente dans les pays océaniques de sud-est de l'Asie et en Océanie, où Hawaii en marque l'extrémité, mais absente des continents américains. Une carte détaillée fait voir cette répartition. Les régions qui en signalent des attaques ainsi que la fréquence des attaques se sont augmentées depuis 1970.

En présentant les données historiques d'ordre général, essentiel à la prédiction des invasions, cette contribution cherche à aider ceux qui s'occupent de la lutte et la surveillance contre *S. exempta*. Pour la région pan-africaine, la répartition mensuelle et la fréquence des attaques sont présentées sous forme de 12 cartes que indiquent pour châque dégré carré formé par les lignes de latitude et longitude le nombre des anneés d'invasions signalées au cours de la periode 1940 à 1982. Dans les régions situées au nord et au sud d'environ 4° N, les époques d'invasion sont à peu près complémentaires et correspondent aux pluies saisonnières. Ainsi, à partir d'octobre-novembre jusqu'à mai, les invasions partent de la Tanzanie méridionale pour s'étendre progressivement vers le nord de l'Éthiopie et le Yémen dans le nord et s'étendent en même temps du Malawi et du Zimbabwé vers le Cap dans le sud. De juin à septembre, les invasions sont intermittentes dans la région entre le Sénégal et le sud-ouest de l'Arabie, mais rares au sud de l'Équateur. On peut attribuer la progression septentrionale ainsi que méridionale des invasions à la migration des noctuelles dans le sens des vents. Le peu de rapports d'invasion partout dans ces régions en septembre-octobre et les premières attaques de la saison suivante, qui s'annoncent dans la région entre le sud-est du Kenya et le Zimbabwé, fournissent de l'appui à la contre-proposition selon laquelle les épidémies se développent à partir de populations qui se maintiennent à des niveaux bas, surtout dans cette region. D'autres témoignages à l'appui des deux théories sont indiqués.

Les attaques ne se déroulent pas de la même manière chaque année. Pour faciliter l'identification d'années aux évènements analogues, la gamme des variations déjà rapportées est présentée en appendice sous forme d'une série de cartes qui font voir la répartition d'invasions par *S. exempta* d'un mois à l'autre dans les 43 dernières années. On fournit pour chaque territoire un tableau indiquant les années ainsi que les mois ou des infestations ont été signalées et un résumé des fréquences mensuelles des invasions. La fréquence et l'importance de *S. exempta* sont présentées en résumé pour chacun des pays.

RESUMEN

Distribución, frecuencia de ataque e incidencia estacional del gusano de la esciara africano *Spodoptera exempta* (Walk.) (Lep.: Noctuidae), con referencia en particular a Africa y sud-oeste de Arabia

Spodoptera exempta (Walk.) se registra muy ampliamente en Africa hacia el sur del Sahara y en partes adyacentes del sud-oeste de Arabia. Ocurre intermitentemente en países oceánicos del sud-este de Asia y en el Pacífico tan hacia el este como Hawai, pero no en América. Se grafica esta distribución en detalle. Les áreas donde se han registrado infestaciones y la frecuencia de los ataques han aumentado desde 1970.

Se propone que este estudio sea de ayuda a aquellos procupados con el registro y control del gusano de la esciara, al hacer disponible la información histórica de mayor amplitud requerida para anticipar los ataques. Para la región pan-africana, la distribución mensual y frecuencias de incidencias se presentan en forma de doce mapas mostrando el número de años en que se registraron infestaciones en cada grado-cuadro de latitud y longitud durante el período 1940—1982. En las zonas hacia el norte y sud de aproximademente 4°N, los períodos de ataque son a groso modo complementarios y correspondientes a las lluvias estacionales. De esta manera, de octubre-noviembre hasta mayo las infestaciones se expanden progresivamente hacia el norte desde el sur de Tanzanía hasta el norte de Etiopía y Yemen, y simultáneamente hacia el sur desde Malawi y Zimbabwe hasta el sur del Cabo de la Providencia. Desde junio

hasta septiembre las infestaciones ocurren intermitentemente desde Senegal hasta el sud-oeste de Arabia, pero rara vez al sur del ecuador. Los progresos de los ataques hacia el norte y el sur peuden ser atribuídos a las migraciones de polillas con el viento. La escasez de reportes provenientes de toda la región en septiembre-octubre y el comienzo de la próxima temporada en la zona entre el sud-este de Kenya y Zimbabwe respalden la teoría alternativa de que los ataques peuden derivar de poblaciones que permanecen en baja densidad, particularmente en esta zona. Se describe evidencia de otras diciplinas respaldando ambas teorías.

Las secuencias de los ataques no mantienen exactamente el mismo padrón durante cada temporada. Para facilitar la identificación de años con eventos análogos al vigente, se acompaña la gama de variaciones registradas en forma de una serie de mapas mostrando mes a mes la distribución de infestaciones de *S. exempta* durante los últimos 43 anos. Para cada territorio hay un índice de años y meses en que se registraron ataques, y un resúmen de las frecuencias mensuales de incidencia. Se resume la incidencia e importancia de *S. exempta* en cada país.

Distribution, frequency of attack and seasonal incidence of the African armyworm *Spodoptera exempta* (Walk.) (Lep.: Noctuidae), with particular reference to Africa and southwestern Arabia

INTRODUCTION

The African armyworm *Spodoptera* (formerly *Laphygma*) *exempta* (Walk.) is the larva of a noctuid moth which migrates over tens and probably often hundreds of kilometres between its emergence site and the locality where the eggs of the next generation are deposited (e.g. Brown and Swaine, 1966; Brown, Betts and Rainey, 1969; Haggis, 1979; Riley *et al.*, 1983). Outbreaks occur sporadically; they are most commonly reported on grassland and on grain crops, particularly maize, sorghum, millet, rice and wheat, and to a lesser extent on teff, barley and sugarcane. There are a few observations of *S. exempta* feeding on plants other than Gramineae, mainly on Cyperaceae (Brown, 1962; Yarro *et al.*, 1981). The armyworm derives its name from the ability of the larvae to 'march' in vast numbers from, for example, surrounding grassland into a crop. It is also known by a variety of local names, particularly Mystery Worm, because of the sudden, unexpected manner in which the hordes of larvae appear and devour crops and pastures and as abruptly disappear, after causing at times such serious damage that cops have to be replanted. Quantitative estimates of the losses involved are rarely available, as attacks are most often on the crops of subsistence farmers – who themselves may be acutely aware of the damage caused, especially if subsequent rains are poor and a second planting of the crop fails. Also, infestations often occur on rangeland which is regarded as of lesser economic importance and is not costed. However it has been estimated for an infestation covering 65 km^2 of rangeland with larvae at a mean density of 28 m^{-2}, that the larvae consumed some 50 tonnes dry weight of herbage per day during the week they were in the final instar – a feeding rate equivalent to that of about 8,000 head of cattle (Odiyo, 1979).

The extent and seriousness of reported attacks by *S. exempta* have increased markedly in recent years in all parts of its distribution area. As agriculture expands, so the need increases for the ability to reduce the effect of armyworm attack by timely survey and control, and more governments are seeking assistance in monitoring the presence of this pest in their country (Rainey, 1979; Beevor, 1983; Murlis, 1984).

Experience in eastern Africa shows that larvae can indeed be found in the early instars, before they cause serious damage, when attacks can be forecast, on both regional and local scales, from a sufficiently wide data-base and forecasts are checked for accuracy. Because the moths are migratory, they may cross political boundaries, hence the need for the regional information and forecasting service which depends on and promotes a regular exchange of data between countries. The country or provincial officer, given information on the current situation beyond his immediate area in addition to detailed reports from the local monitoring service, and with experience of armyworm incidence locally, is well placed to identify within his particular area the localities most likely to be attacked (Betts, 1976). Thus for both scales of forecasting, the chief biological inputs for predicting armyworm infestations are a knowledge of present populations (from trap catches of moths and from information on recent and current larval infestations) and a knowledge (from historical data) of the likelihood and locations of infestations to be expected for the time of year, and especially of past events when the situation was analogous to the current one. In

compiling a forecast using all these data, current meteorological information is also taken into account. Methods for forecasting where and when armyworm infestations are most likely to occur and for improving the accuracy of forecasts by regular verification, have already been published (Odiyo, 1972 *et seq.*; Betts, 1976, Odiyo, 1979).

This paper is intended to make available the historical data of the pan-African region to those concerned with monitoring and control of armyworm, and who may have limited access to records for countries other than their own. The frequency of incidence of *S. exempta* infestations in each month of the year is summarised to whole territories, and mapped in greater detail, using area-units of 1°-square (about 12,000 km^2); these maps clearly show the seasonality of infestations in all parts of the region. Within this seasonality, in any country there is great variation in the incidence from year to year. The range of sequences of attack, month by month, is presented as a series of maps spanning the decades in which reporting has been more widely comparable, to enable years with events analogous to the current situation to be identified. An index to the years and months when infestations were recorded in each territory, is included.

DATA AND METHODS

Reports of armyworm infestations have been collected largely from the un-published and published records of various ministries of agriculture and agricultural research stations in many countries of Africa, especially the Kenya Agricultural Research Institute (formerly the East African Agriculture and Forestry Research Organization), Muguga, where the full records for East Africa are archived. Outbreak records have also been extracted from the extensive literature on pest incidence. Records of moths captured have been acquired primarily from museum collections and also from individual collectors, from trapping records and from literature.

Initially the data were plotted in detail on large-scale (1:5 m—1:¼m) maps for separate seasons and then summarised onto smaller-scale maps. For this compilation, distribution was assessed on two scales: by entire territories, and by using units of 1°-square of latitude and longitude, about 12,000 km^2, as a convenient and more regular geographical base which permits some detail in presentation. In the areas of Africa from Kenya and Uganda southwards, each season (roughly November—June) has been treated as a single year.

In some reports the species of larvae was not confirmed but evidence from other sources suggests that the infestation was likely to have been of *S. exempta.* Records that have been accepted for these analyses are shown as 's' (species unconfirmed) in the detailed presentations (Fig. 4 and Appendix). Similarly, reports with imprecise dates, such as 'early in the year', have been allocated to particular months only after consideration of all available data for that season from surrounding countries as well as the country concerned and after comparison with the seasonal pattern in other years; these reports are shown as 'm' (month unconfirmed) in Fig. 4 and the Appendix. In the analyses, such reports have often been accorded only one territory-month even though, particularly in earlier years, infestations may have lasted longer than that to warrant mention in e.g. annual reports. Unconfirmed reports, where accepted, are indicated as 'u' when no more reliable information is available for the area-month concerned.

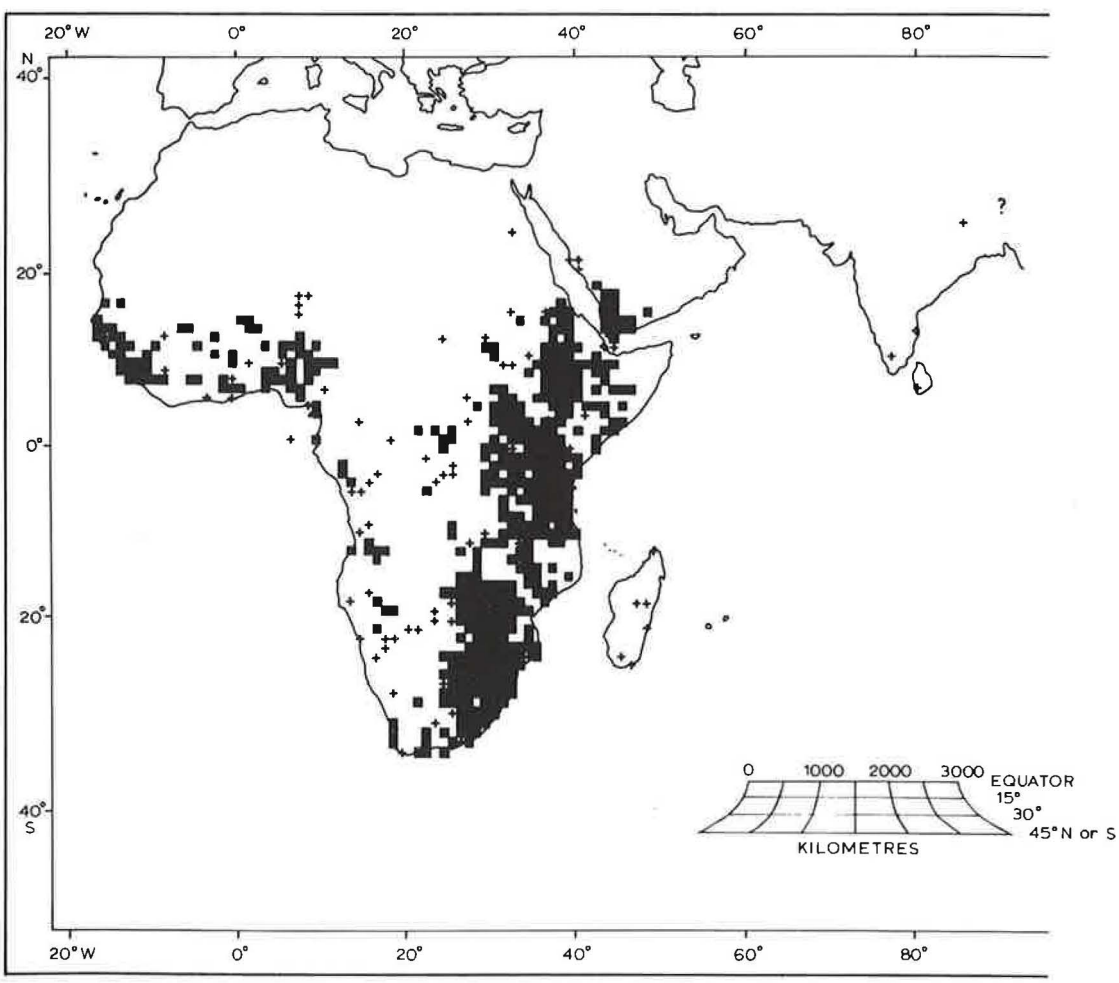
For present purposes, outbreaks are defined as those larval infestations that are at sufficiently high density to attract the attention of farmers and general public. Low-density populations of passive larvae (Whellan, 1954), found only by diligent searching by entomologists, are not included in these presentations and records of moths in small numbers are used only to demonstrate the total recorded distibution area of the species (Fig. 1).

TOTAL DISTRIBUTION

Spodoptera exempta has long been recorded as a pest both in Africa and in the Pacific region, but reports of its attacks are far more numerous and frequent in Africa. Perhaps the earliest (though the species is in doubt) is from Ethiopia where the inhabitants of Farso area told a travelling Portuguese priest, Francisco Alvarez, in 1520, 'Were it not for the worm, there would have been abundance for ten years' (Pankhurst, 1966). Other pre-twentieth century records come from Hawaii (1873), South Africa (1878), Sierra Leone and Ethiopia (both 1888); few details are included, but it appears that all of these were serious outbreaks causing heavy damage to crops or pasture. Adult moths, on the other hand, had been collected quite widely by the turn of the century in Africa (Sudan, Ethiopia, Somalia, Kenya, Uganda, Gabon, Mozambique) and Madagascar, in the Aden area of Arabia, in Papua New Guinea, Australia (Queensland and New South Wales) and Hawaii, in addition to several parts of Asia listed by Hampson (C.I.E., 1972) from which no subsequent records have come to hand.

Records and specimens currently available show (Fig. 1) that the species is widespread, if not continuously reported, throughout Africa and southwestern Arabia south of the Sahara and the Arabian desert – the pan-African region. Moths, but so far no

Figure 1. Recorded distribution of *Spodoptera exempta:*



larvae, have been positively identified in Togo, Ruanda and Djibouti. Thus Benin, Equatorial Guinea, Chad and the Central African Republic are the only territories south of the Sahara from which *S. exempta* has not been recorded at all. Moths and infestations have occasionally been found on islands in Lake Victoria and moths have recently been trapped on Likoma Island in Lake Malawi (G.K.C. Nyirenda, pers. comm.). Off the east coast of Africa, outbreaks have twice been reported on both Zanzibar and Mafia Island, and a swarm of moths, mainly *S. exempta,* was once observed out at sea in the Gulf of Aden (Laird, 1962). Although moths have been taken in several parts of Madagascar, larval outbreaks have never been reported there and the species is listed among those 'of no biogeographical interest' (Viette, 1962). On the Atlantic coast the only off-shore record is of a moth taken on the island of Sao Tomé (Fig. 1).

Outbreaks have been reported somewhere in Africa in almost every year since 1919. The total number of years and months with infestations in each territory since 1930 emphasises the relative importance of armyworm in the different parts of Africa (Fig. 2 and see below). There has been a general increase, particularly in recent decades, in the number of reports of outbreaks; maps showing the increases in distribution of larval infestations in Africa in each of four successive decades are to be presented elsewhere (Haggis, in prep.). Until recently there were relatively few records for West Africa, but in the last decade the number and extent of reports from individual countries there has increased markedly, as has the number of countries

■ Larval infestation + Moth specimen ? Species recorded in the country.

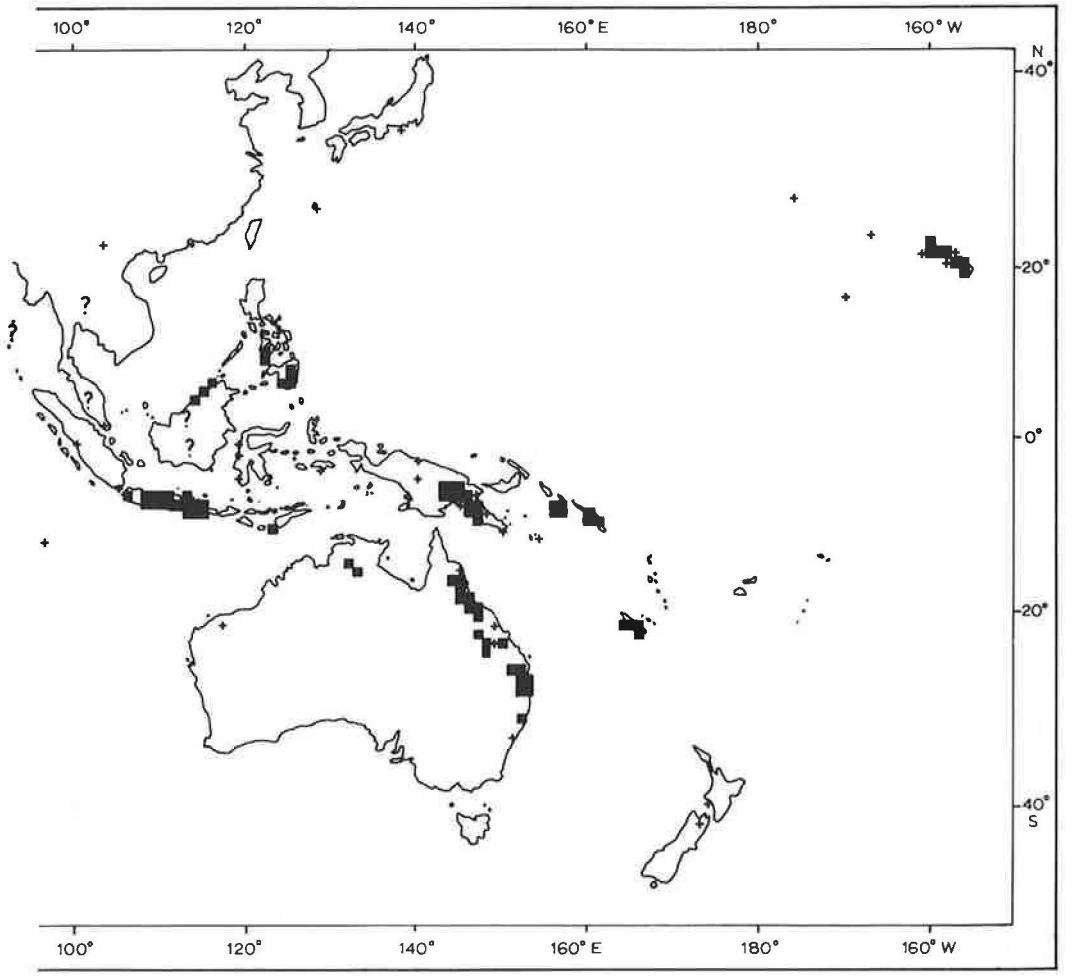
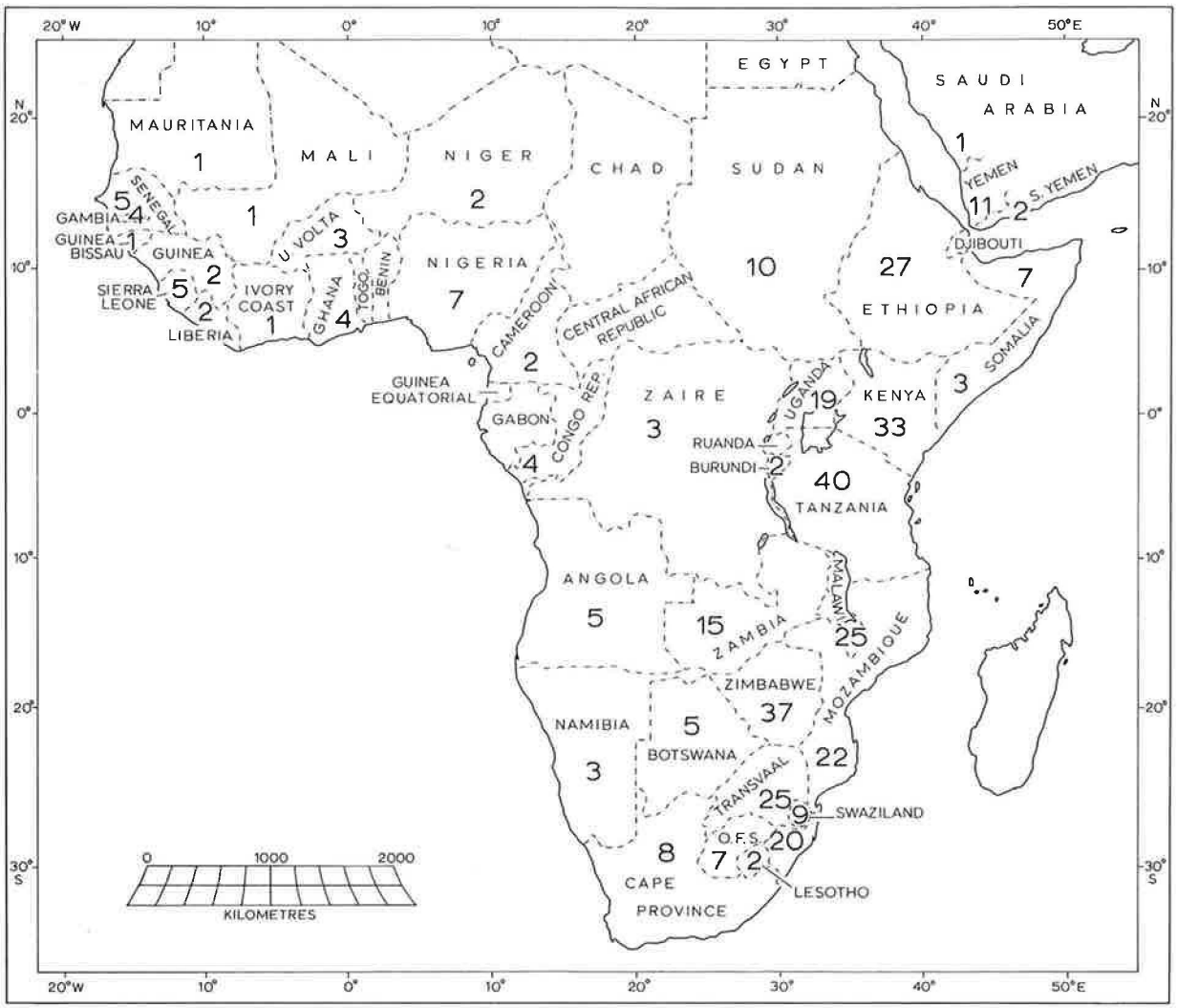


Figure 2. Number of years in which infestations were recorded in each territory during 1930–1982.



attacked in a single season. Slightly less extensive increases in distribution and frequency of attack have occurred in eastern and southern parts of Africa and in Arabia.

To the east, in the territories bordering and the islands of the Indian and Pacific Oceans, *S. exempta* is recorded much more intermittently than in Africa (Fig. 1), though in some areas, e.g. Hawaii, it was described as occurring somewhere in most years (Pemberton, 1948). The most serious infestations recorded in the oceanic region were in December 1930–January 1931, when widespread outbreaks caused considerable damage to maize and rice throughout Java and Madura (Van der Goot, 1931) and possibly also parts of Sumatra (Kalshoven, 1951). Little analysis has so far been attempted of the records of this region because they are so scattered, both spatially and in time, but here again there has been a marked increase over the last two decades in the number and distribution of reported outbreaks and of moths. The most notable recent increases are in Papua New Guinea where swarms of moths preceded outbreaks in March 1973 (Gray, 1972; Baker, 1978) and the Philippines (A. Yadao and A. Garcia, pers, comm.); first records from the Solomon Islands (TPM, 1982), New Caledonia (Delobel, 1978) and the Northern Territory of Australia (Baker, 1978); and the first records of moths reaching New Zealand (Fox, 1971, 1973a, 1973b), Japan (Sugi, 1970, 1976) and Cocos-Keeling Islands in the Indian Ocean (Holloway, 1982) – see Fig. 1.

No records or moth specimens have come from North, Central or South America.

Thus the known distribution of *S. exempta* has been extended very considerably since the original map published by the C.I.E. (1955). The updated version (C.I.E., 1972) corresponds closely with that discussed here (Fig. 1), the notable absences from it being more recent records mainly in the Pacific region. The C.I.E. map is deliberately generalised and the greater degree of detail in this paper in no way implies any inadequacy in that very useful series of distribution maps.

Table 1

Number of years in which infestations were recorded in each territory each month, 1930–1982

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Western Africa												
Mauritania	–	–	–	–	–	–	–	–	1	–	–	–
Senegal	–	–	–	–	–	1	2	2	2	–	–	–
Gambia	–	–	–	–	–	3	2	3	1	–	–	–
Guinea-Bissau	–	–	–	–	–	–	1	–	–	–	–	–
Mali	–	–	–	–	–	–	–	–	–	1	1	–
Upper Volta	–	–	–	–	–	2	2	–	–	–	–	–
Niger	–	–	–	–	–	1	1	1	–	–	–	–
Chad	–	–	–	–	–	–	–	–	–	–	–	–
Guinea	–	–	–	–	1	2	2	–	1	–	–	–
Sierra Leone	–	–	1	1	5	4	1	2	2	–	–	–
Liberia	–	–	–	–	–	1	1	–	–	–	–	–
Ivory Coast	–	–	–	–	–	–	–	1	1	–	–	–
Ghana	–	–	1	1	1	–	–	–	–	2	–	–
Togo	–	–	–	–	–	–	–	–	–	–	–	–
Benin	–	–	–	–	–	–	–	–	–	–	–	–
Nigeria	–	–	–	–	4	4	4	2	3	1	–	–
Cameroon	–	–	–	–	2	–	–	–	–	–	–	–
Central African Republic	–	–	–	–	–	–	–	–	–	–	–	–
Arabia – Northeastern Africa												
Saudi Arabia	–	–	–	–	–	–	–	1	–	–	–	–
Yemen	–	–	–	–	2	8	5	4	–	–	–	–
South Yemen	–	–	–	–	1	1	2	1	–	–	–	–
Djibouti	–	–	–	–	–	–	–	–	–	–	–	–
Somalia (Norther Region)	–	–	–	1	5	5	–	1	–	–	–	–
Ethiopia	1	–	1	12	18	19	16	14	12	4	1	–
Sudan	–	1	–	1	3	2	2	–	2	2	–	–
Equatorial Africa												
Guinea Equatorial	–	–	–	–	–	–	–	–	–	–	–	–
Gabon	–	–	–	–	–	–	–	–	–	–	–	–
Congo Republic	–	1	–	–	–	–	–	–	–	2	1	–
Zaire	–	1	–	1	2	1	–	–	–	–	–	–
Ruanda	–	–	–	–	–	–	–	–	–	–	–	–
Burundi	–	1	1	–	1	–	–	–	–	–	–	–
Somalia (Southern Region)	–	–	–	–	1	1	–	–	–	–	3	1
Uganda	2	9	14	8	6	3	1	–	–	–	–	–
Kenya	13	18	20	22	18	16	5	1	–	2	4	10
Tanzania	30	25	21	19	11	1	–	–	–	2	6	21
Central Africa												
Mozambique	12	13	4	3	3	–	–	–	–	–	1	1
Malawi	13	6	7	8	7	1	–	–	1	2	6	10
Zimbabwe	26	15	14	9	1	1	–	–	–	3	7	18
Zambia	8	1	5	3	1	–	–	–	–	1	2	7
Angola	–	1	2	1	2	–	–	–	–	–	–	–
Southern Africa												
Namibia	1	2	1	1	–	–	–	–	–	–	–	–
Botswana	–	3	3	2	1	–	–	–	–	–	–	–
Transvaal	11	20	16	7	–	1	–	–	–	–	–	6
Swaziland	1	4	3	–	–	–	–	–	–	–	–	2
Natal	7	5	11	3	2	1	–	–	–	–	–	–
Lesotho	1	–	1	–	–	–	–	–	–	–	–	–
Orange Free State	3	4	4	–	–	–	–	–	–	–	–	–
Cape Province	1	4	4	4	3	1	–	–	–	–	–	–

MONTHLY DISTRIBUTION AND FREQUENCIES OF INCIDENCE

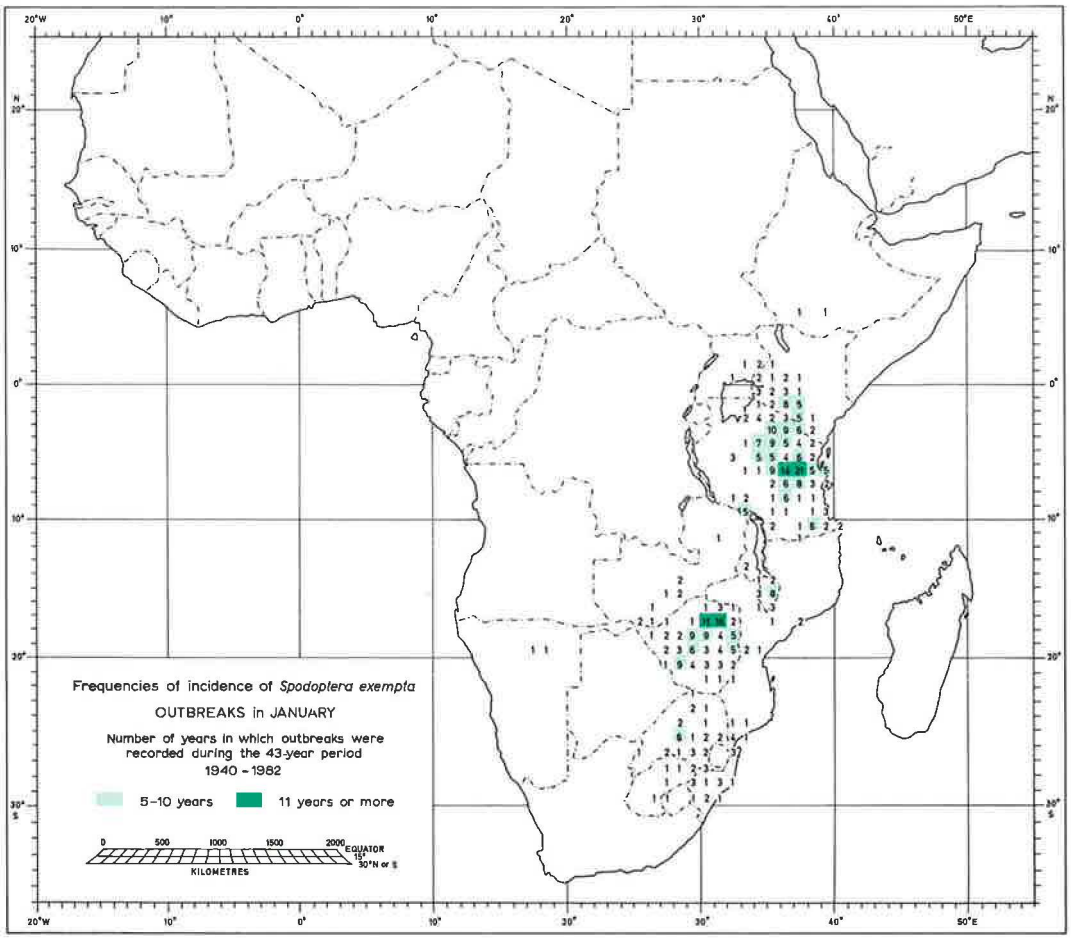
The frequency of attack in each territory is indicated in Fig. 2 by the number of seasons between 1930 and 1982 in which outbreaks were recorded. Tanzania and Zimbabwe show the highest number, with respectively 40 and 37 seasons out of 53 when outbreaks were recorded – almost 4 in every 5. Kenya, Ethiopia and Transvaal follow, with respectively 33, 27 and 25 years with outbreaks, roughly 3 years in 5, and then Malawi, Mozambique, Natal and Uganda with variously 19–25 years with infestations, or on average about 2 years in 5. Most other territories have recorded outbreaks in less than one year in ten.

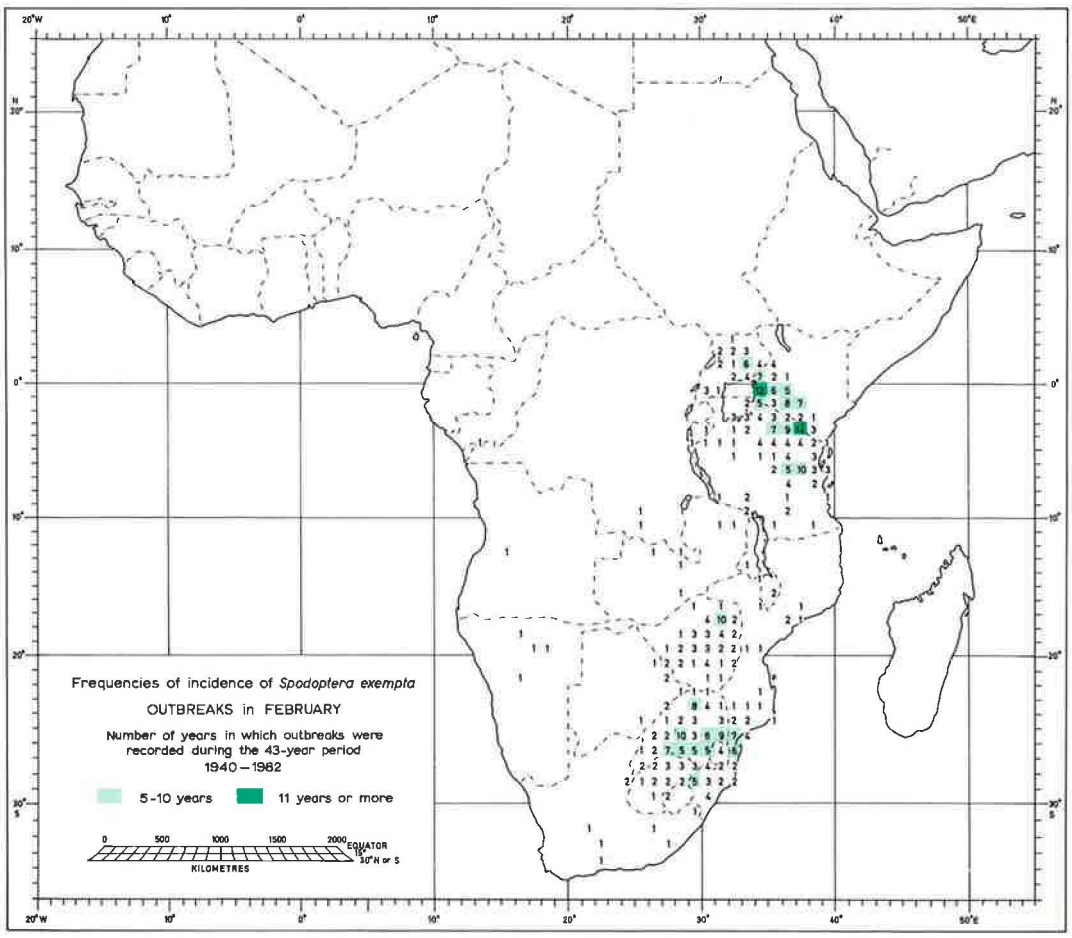
Neither the incidence nor the severity of attack has ever been regular in any locality. Moreover, outbreaks have not been reported in all twelve months in any one part of Africa. Rather, in all parts the period of attack is strongly seasonal and in the areas to the north and south of about 4°N the periods of attack are roughly complementary. This can be seen even from units of individual territories, when the data of Fig. 2 are broken down to show the monthly incidence in each territory (Table I). In the Table, within each zone the territories are listed in roughly latitudinal bands. Countries with records for only a few years none-the-less show a seasonal pattern reflecting that of neighbouring countries more fully documented. The seasonal incidence of outbreaks is very similar in Western and Northeastern Africa and Arabia and of shorter duration in the northern latitudes of each. In the other period of the year, in Equatorial, Central and Southern Africa, the incidence is also very similar, again the armyworm season becoming progressively shorter in higher latitudes (towards the south).

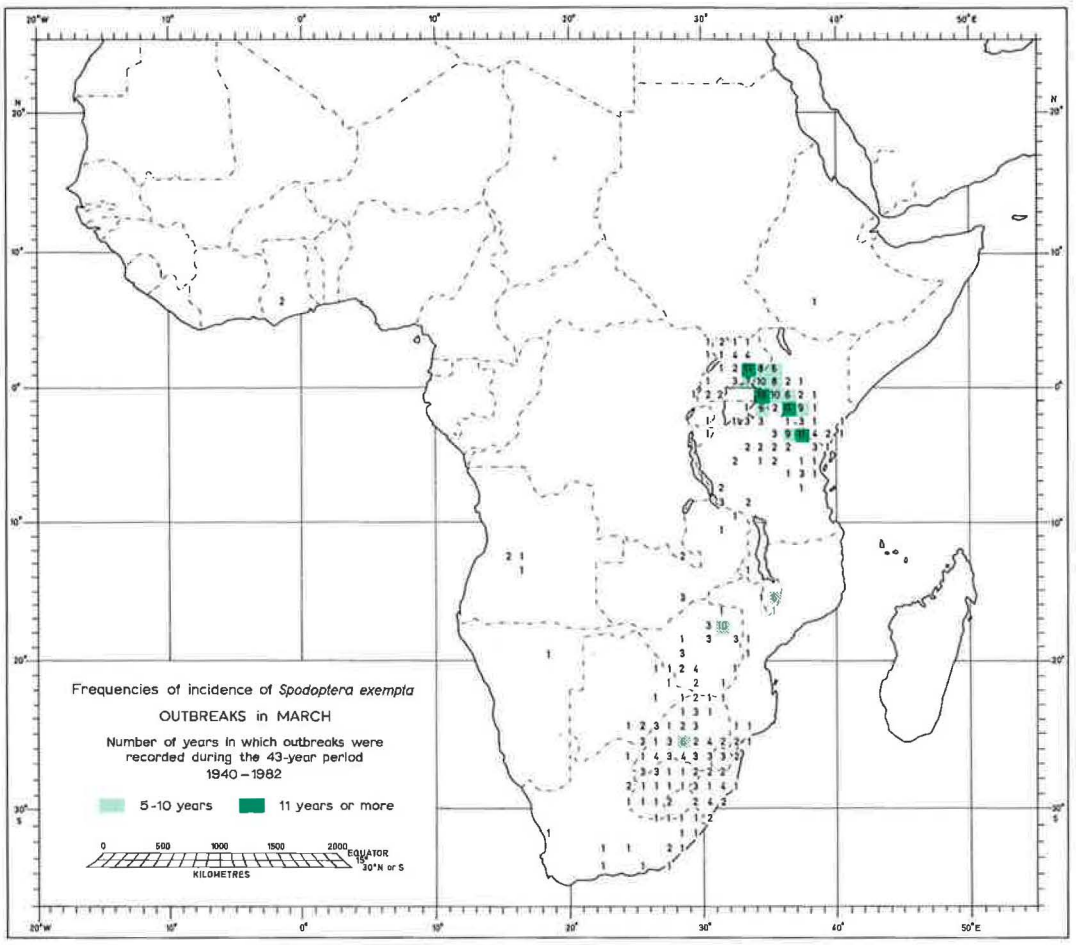
The data for the more fully documented years since 1940 have been analysed in greater detail, by 1°-squares. The maps of Fig. 3 show for each month the number of years in which outbreaks were reported in each 1°-square during the 43-year period 1940–1982. These maps clearly show the seasonality of attack in all parts of the region and serve as a quick guide to the seasonal incidence and frequency of armyworm attack to be expected at all times of year. The following summary of overall month-to-month changes in the distribution of infestations is based on these maps.

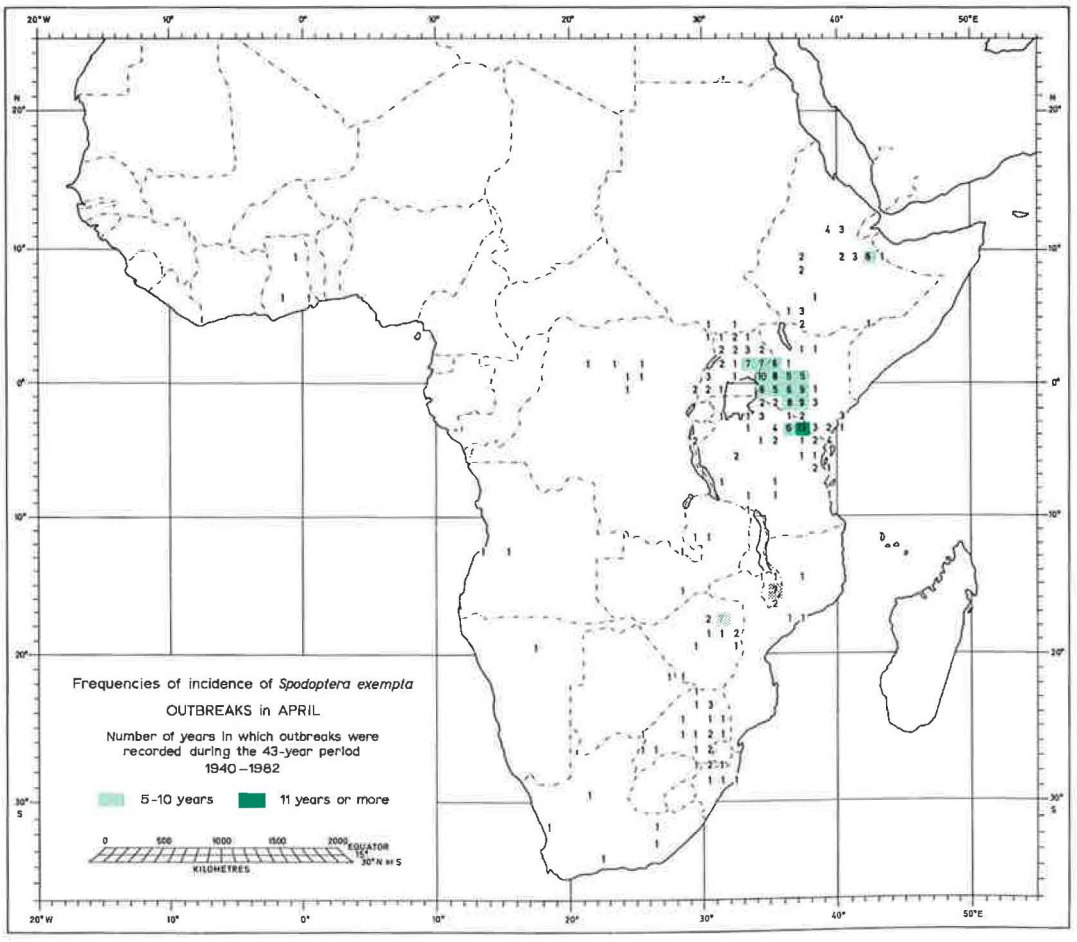
The spatial extent of armyworm infestations is most restricted in September, when most reports have come from Ethiopia; these outbreaks occurred over 12 different years (Table I). In October outbreaks have been reported from wider-spread areas but in a total of fewer years, and most localities have been infested only once in 43 years. Apart from unusual records from the Congo Republic (Brenière, 1954), October records can be subdivided into end-of-season reports from Mali (1947), Ghana (1958, 1980), Nigeria (1965), Ethiopia (1945, 1948, 1963, 1978) and Sudan (1938, 1978); and start-of-season reports from Kenya (1961 – unconfirmed, 1980), Tanzania (1961 – also unconfirmed, 1971), Zimbabwe (1956, 1961, 1976), Zambia (1971) and Malawi (1976, 1980) (Table I and see below, Fig. 4). In November outbreaks have been more widely reported in East and Central Africa, while a few had not yet finished in Mali and Ethiopia. Through December and January the main change in distribution is a marked southwards extension into South Africa and a slight extension westwards in Kenya, Tanzania, Zambia and Zimbabwe and northwestwards into Uganda. In February and March the spread continues northwards and westwards in East Africa and southwards and westwards in Southern Africa. April is generally the month of most marked northward extension into Ethiopia and across Uganda into southern Sudan, and when outbreaks appear in Western Africa; reports from Central and Southern Africa begin to dwindle. Infestations are first recorded in the Arabian peninsula in May, and outbreaks are more widely distributed at this time than in any other month. June sees a further northward spread in Western Africa and through the highlands on each side of the Red Sea, and the very last reports of the season from Tanzania southwards. Indeed, with the exception of late infestations in southwestern Kenya, only one outbreak has been recorded in Africa south of the equator in July, August or September and then the species was not fully confirmed as *S. exempta*. Infestations in Western Africa, Ethiopia and Yemen reach their northernmost limits in July and August, when the E–W spread of records is also greatest.

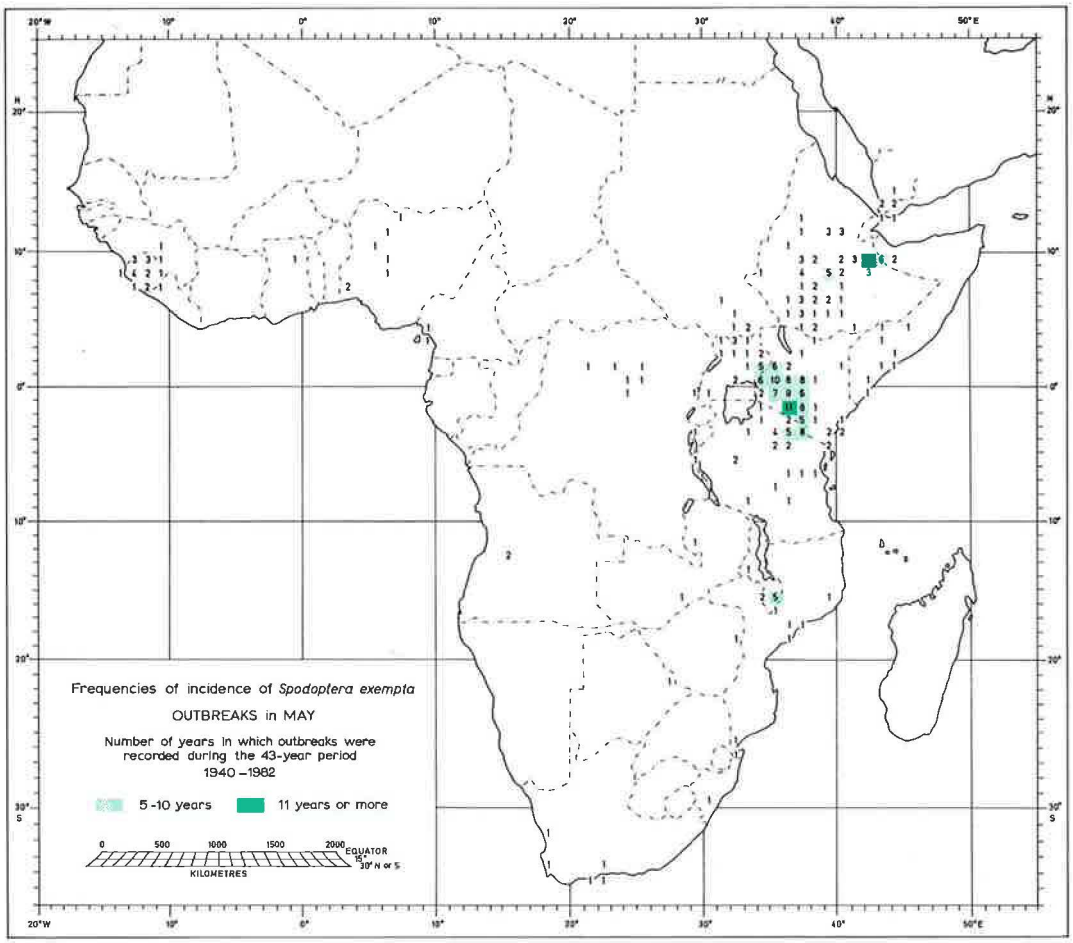
Figure 3. Frequencies of incidence of *Spodoptera exempta* outbreaks.

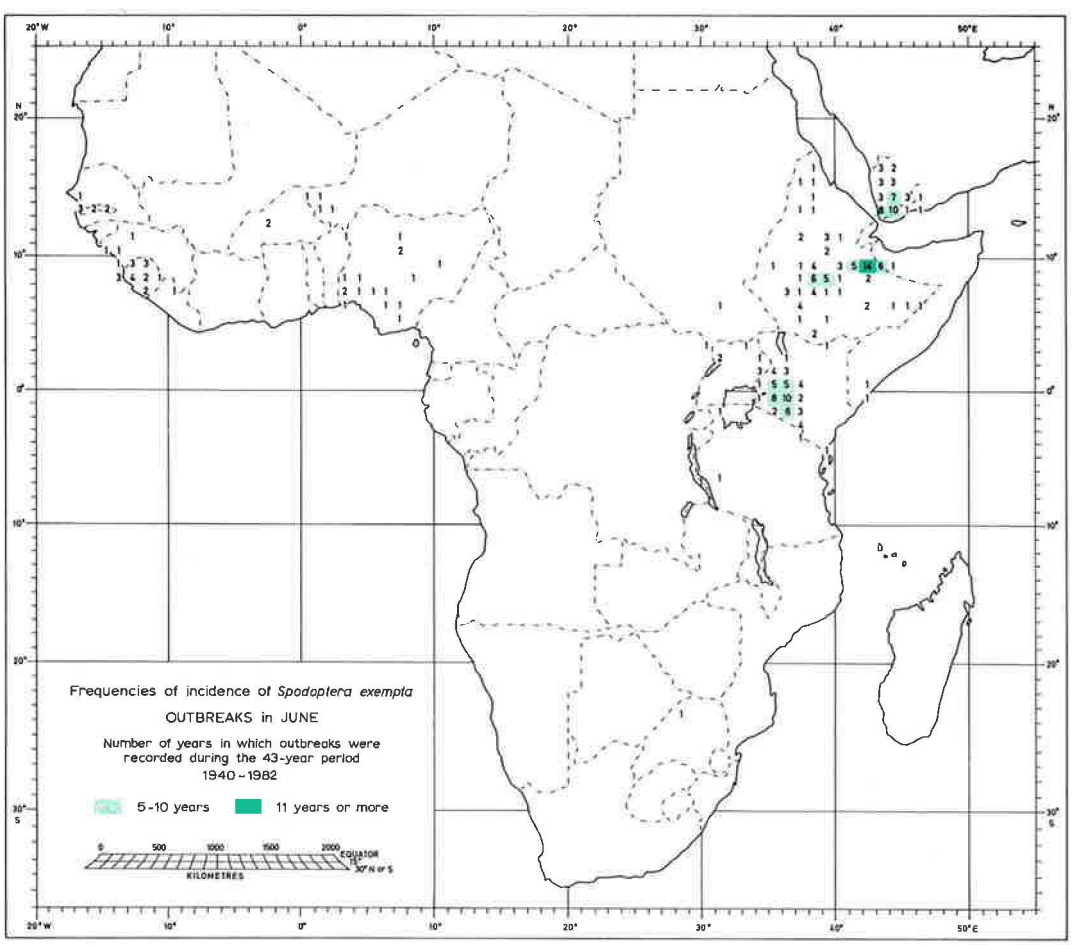


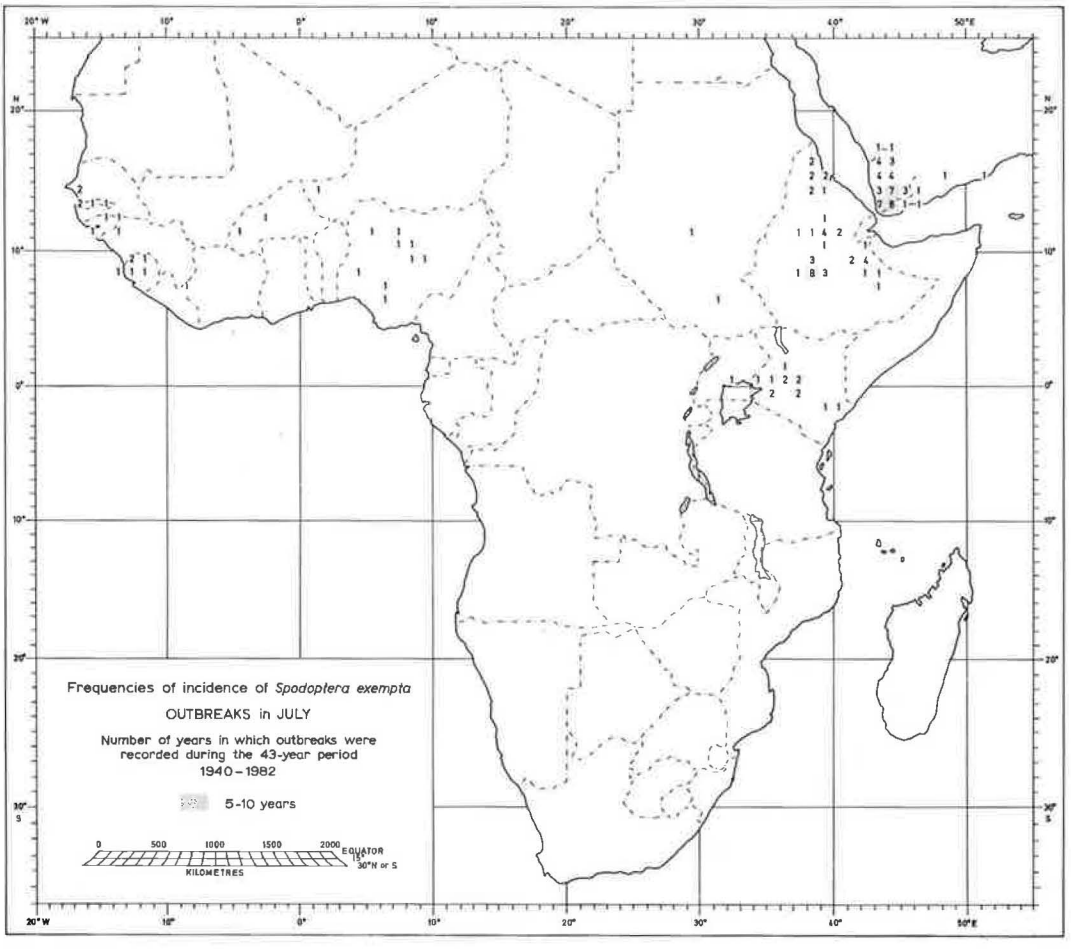


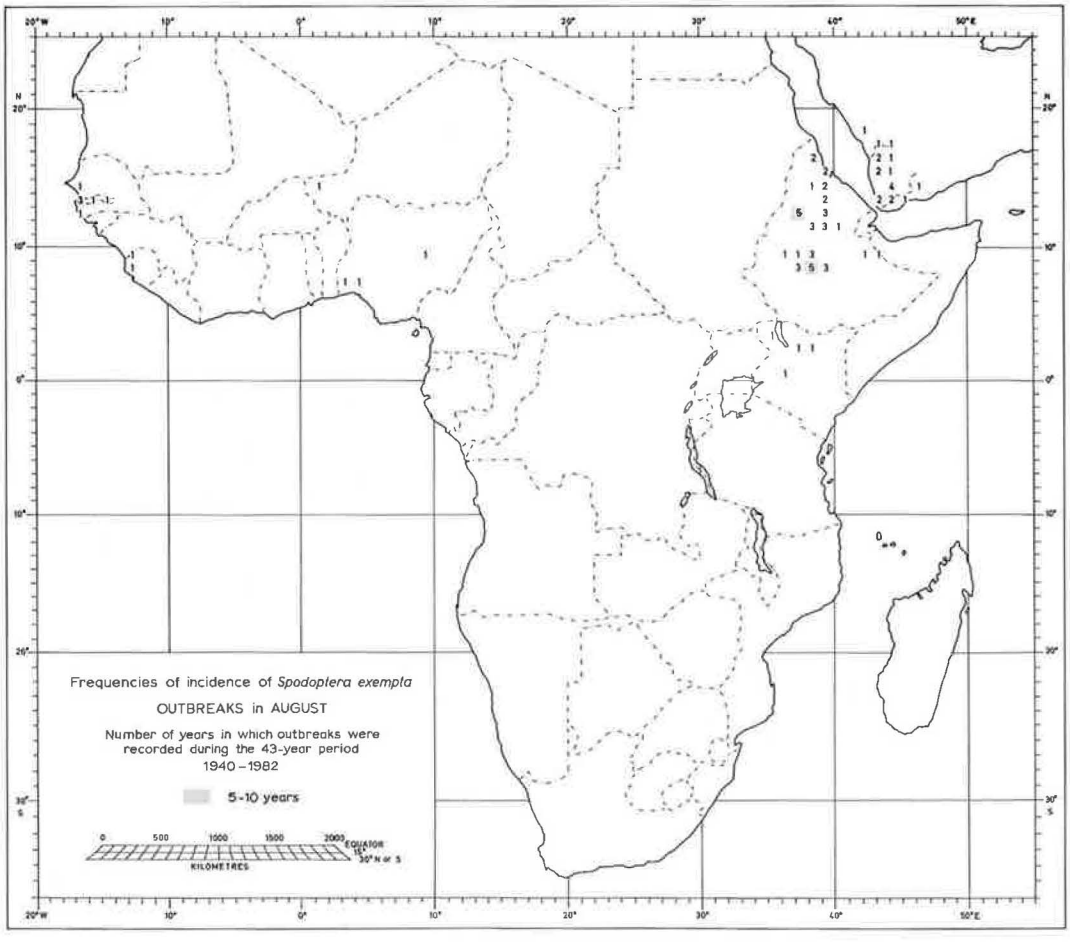

Frequencies of incidence of *Spodoptera exempta*
OUTBREAKS in MARCH
Number of years in which outbreaks were recorded during the 43-year period 1940–1982
5-10 years
11 years or more
0 500 1000 1500 2000 KILOMETRES
EQUATOR
15° 30°N or S

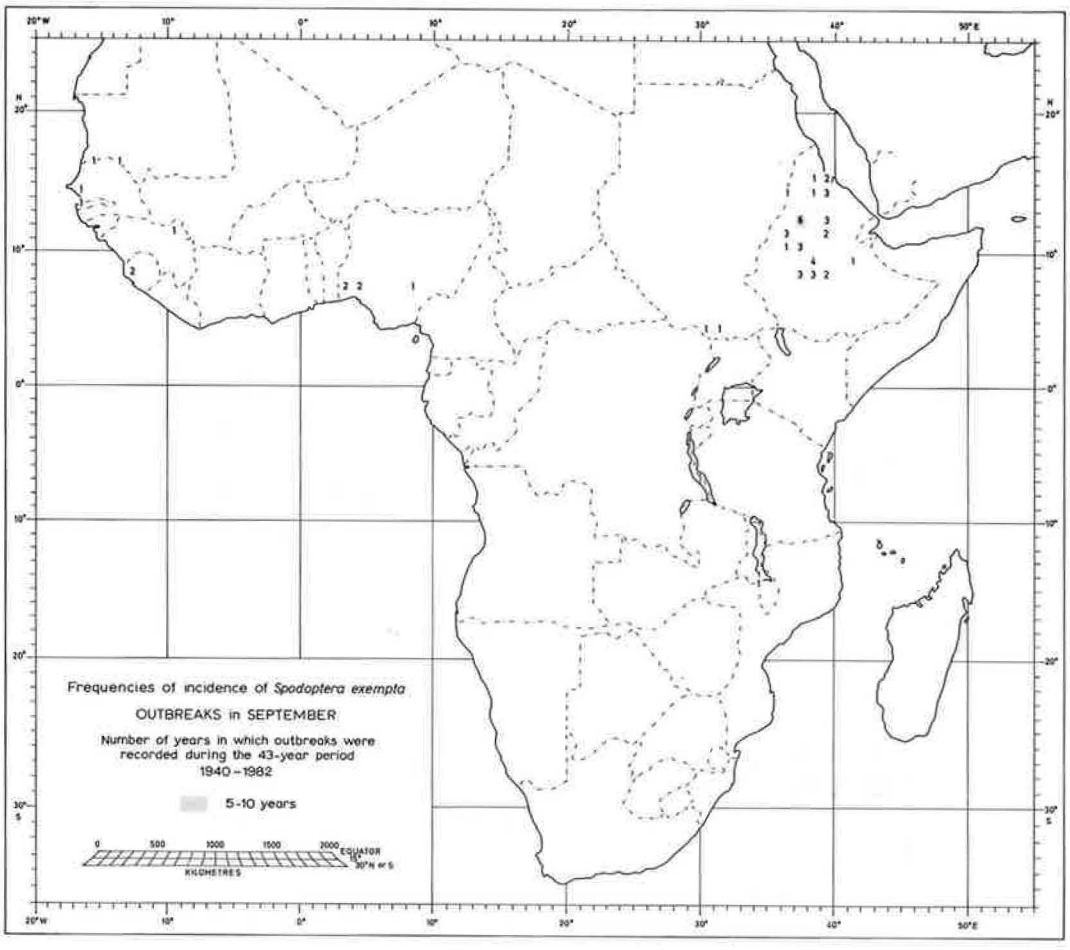

Frequencies of incidence of *Spodoptera exempta*
OUTBREAKS in APRIL
Number of years in which outbreaks were recorded during the 43-year period 1940–1982
5-10 years
11 years or more
0 500 1000 1500 2000 KILOMETRES
EQUATOR
30°N or S

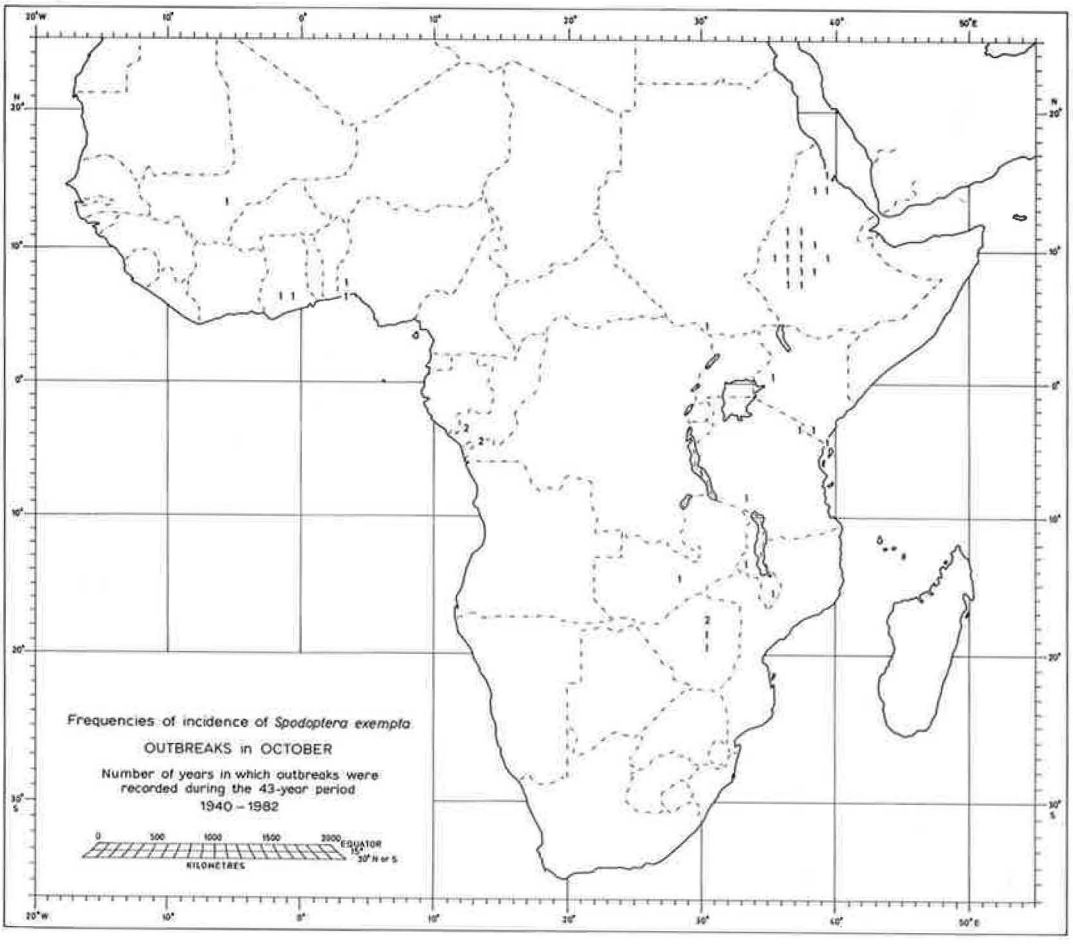

Frequencies of incidence of *Spodoptera exempta*
OUTBREAKS in MAY
Number of years in which outbreaks were recorded during the 43-year period 1940 – 1982
5 - 10 years
11 years or more
0 500 1000 1500 2000
KILOMETRES
EQUATOR
30° N or S

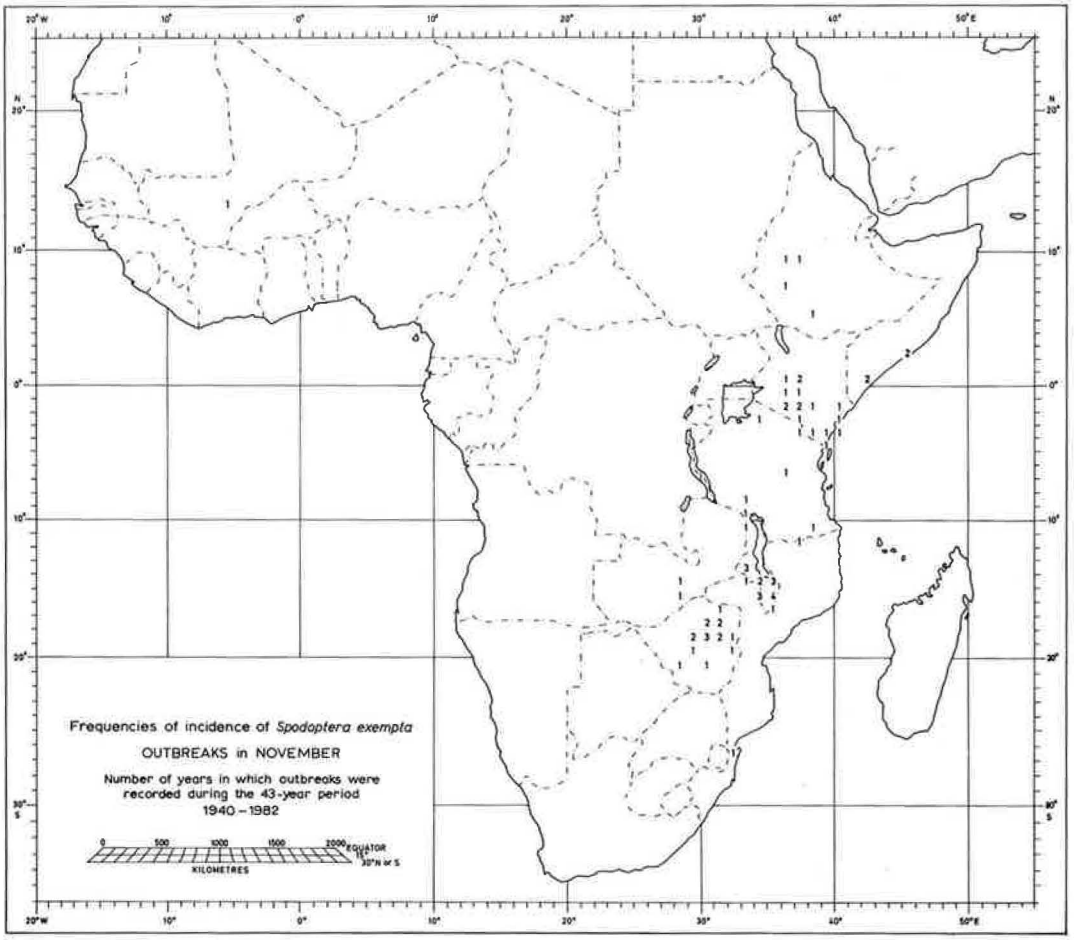

Frequencies of incidence of *Spodoptera exempta*
OUTBREAKS in JUNE
Number of years in which outbreaks were recorded during the 43-year period 1940 - 1982
5 - 10 years
11 years or more
0 500 1000 1500 2000
KILOMETRES
EQUATOR
30° N or S

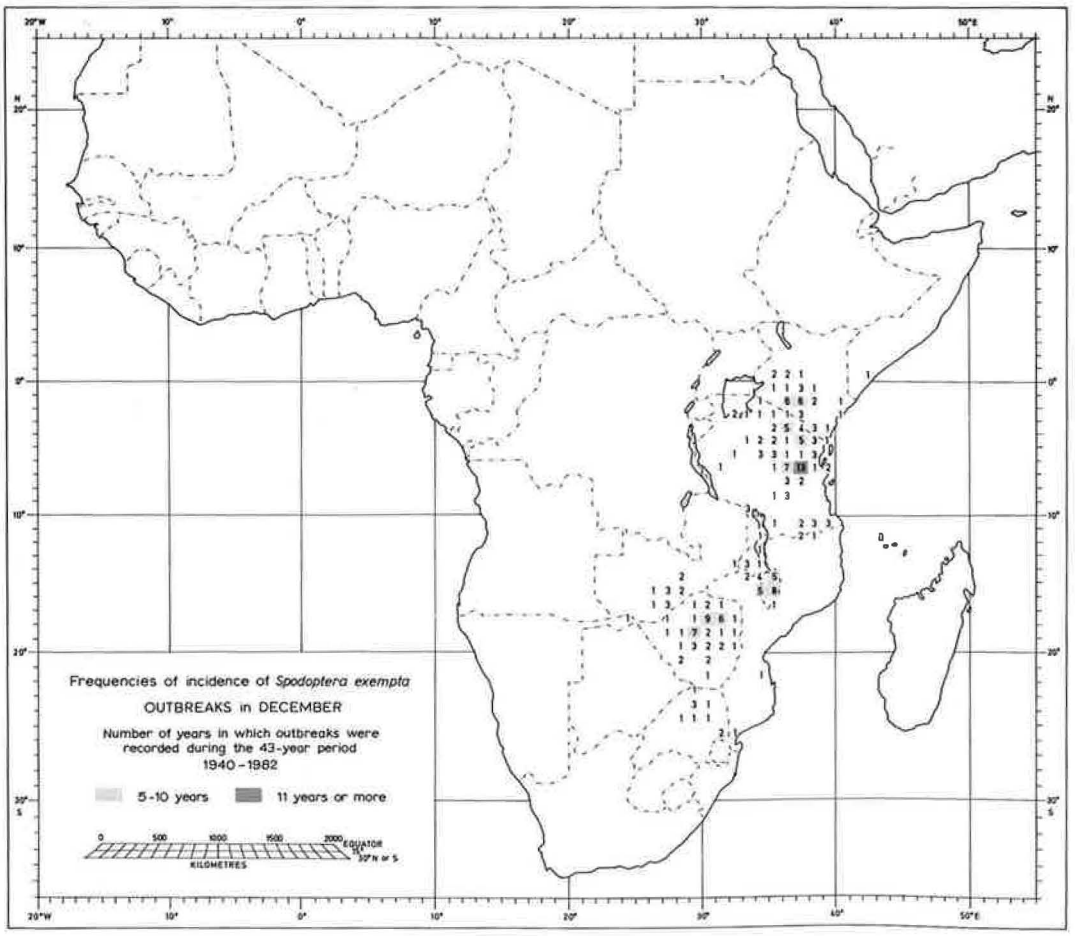

Frequencies of incidence of *Spodoptera exempta*
OUTBREAKS in JULY
Number of years in which outbreaks were recorded during the 43-year period 1940 – 1982
5-10 years
0 500 1000 1500 2000 KILOMETRES
EQUATOR
15° 30° N or S


Frequencies of incidence of *Spodoptera exempta*
OUTBREAKS in AUGUST
Number of years in which outbreaks were recorded during the 43-year period 1940 – 1982
5-10 years
0 500 1000 1500 2000 KILOMETRES
EQUATOR
15° 30° N or S


Frequencies of incidence of *Spodoptera exempta*
OUTBREAKS in SEPTEMBER
Number of years in which outbreaks were recorded during the 43-year period 1940 – 1982
5-10 years
0 500 1000 1500 2000 KILOMETRES
EQUATOR
30° N or S


Frequencies of incidence of *Spodoptera exempta*
OUTBREAKS in OCTOBER
Number of years in which outbreaks were recorded during the 43-year period 1940 – 1982
0 500 1000 1500 2000 KILOMETRES
EQUATOR
30° N or S


Frequencies of incidence of *Spodoptera exempta*
OUTBREAKS in NOVEMBER
Number of years in which outbreaks were recorded during the 43-year period 1940 – 1982
KILOMETRES
EQUATOR
30°N or S


Frequencies of incidence of *Spodoptera exempta*
OUTBREAKS in DECEMBER
Number of years in which outbreaks were recorded during the 43-year period 1940 – 1982
5-10 years
11 years or more
KILOMETRES
EQUATOR
30°N or S

YEAR TO YEAR VARIATIONS IN DISTRIBUTION

The number of territories attacked and the duration of outbreaks in any country vary greatly from year to year, as may be inferred from Table I and Figs 2 and 3. Fig. 4 shows in which months and years since 1930 *S. exempta* outbreaks have been recorded in each territory; earlier years, for which the data are rather intermittent, are summarised in Table 2.

The distribution month by month of infestations in each of the 47 seasons 1936–1982 and in selected earlier years that are well documented, is plotted on the monthly map series given in the Appendix. Here, so far as compactness allows, on each page the maps are arranged in similar order in the columns for the convenience of quick visual comparison of one season with another. Some pages therefore include blank maps in place of months when no outbreaks were recorded. For the earlier years, one or two seasons are shown on facing pages. No outbreaks have been recorded in months omitted from the map montage. Fig. 4 may be used as an index to the periods and territories in which outbreaks are plotted on the maps of the Appendix.

Table 2

Incidence, by countries, of *Spodoptera exempta* infestations up to 1929

Season (months not recorded)

c. 1520 Ethiopia (species uncertain)
1878 South Africa
c. 1888 Ethiopia (species uncertain) and Sierra Leone
1900 Gabon
1907 Ethiopia 'Summer' (species uncertain)
1908–09 South Africa
1914–15 Kenya and South Africa
1928 Kenya
c. 1930 Uganda (species uncertain)

Season (months recorded, or deduced – mth?)

	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
1910								Rhodesia				
1914					Uganda			Rhodesia Natal				
1914–15				Rhodesia	Rhodesia	Natal		Nyasaland	Nyasaland			
1919					Moçambique Transvaal Natal	Rhodesia Transvaal Natal O.F.S. Cape Prov.	Transvaal Natal Cape Prov.		Congo (Zaire)	Congo (Zaire- mth?)		
1919–20				Cape Prov.				Cape Prov.	Cape Prov. (mth?)			
1920–21			Rhodesia	Rhodesia	Rhodesia	Rhodesia Transvaal	Transvaal Natal	Transvaal				
1923										Sudan		
1924					Natal		Transvaal Swaziland					
1925–26				Tanganyika	Rhodesia	Rhodesia	Transvaal Natal (mth?)	Rhodesia Natal (mth?)	Transvaal Natal			
1926–27				Rhodesia	Rhodesia	Rhodesia		Kenya				
1927–28				Rhodesia								
1928–29				Rhodesia	Rhodesia Natal (mth?)							
1929–30				Nyasaland								

Sequences of attack do not follow exactly the same pattern each season. These maps give a visual impression of the range of variations that have occurred. They thus provide a guide to which seasons are most closely analagous to the current one and on the precendent of which a warning may need to be based (Betts, 1976). This map series also summarises the data on which the present analyses are based. Since 1936, in all of the years shown except 1941 and 1953, records are available for at least 5 territory-months. Outbreaks were particularly wide-spread and were reported from some part of the pan-African region in more than 8 consecutive months in 14 seasons: 1961, 1962–63, 1963–64, 1965, 1965–66, 1969–70, 1970–71, 1973–74, 1976, 1976–77, 1978–79, 1979–80, 1980–81, 1981–82. Again, this shows how much more frequent the re-occurence of attack on this scale has become in recent years.

The varying importance of one zone or another at different times of year and in different seasons is clear both from Fig. 4 and from the maps in the Appendix. The 'armyworm season' in Equatorial Africa southwards complements seasonally that in more northern latitudes, and widespread infestations have occurred in the Equatorial, Central or Southern zones individually more often than in two or all three zones simultaneously. In the north, Arabia has never had outbreaks without earlier or contemporary infestations also being reported in Northeast Africa, and usually after a bad season in East Africa. Usually, in years when outbreaks were reported in West Africa, there were infestations exceptionally far west (west of 33°E) in Tanzania and/or Uganda and Burundi earlier in the same year. The relationship between different zones in sequences of outbreaks will be discussed more fully elsewhere (Haggis, in prep.).

SUMMARY OF ARMYWORM INCIDENCE AND IMPORTANCE IN DIFFERENT COUNTRIES

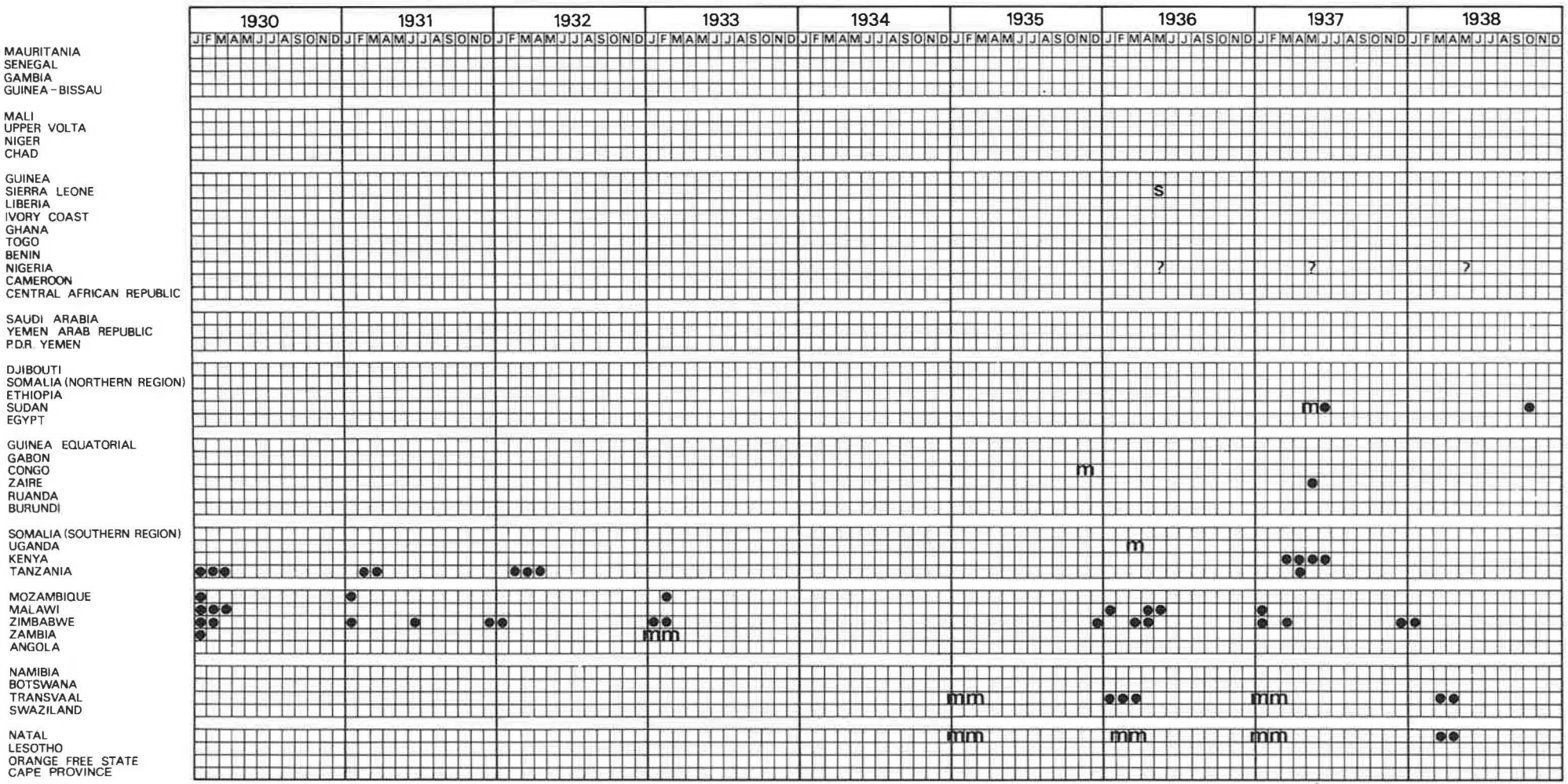
Equatorial Africa

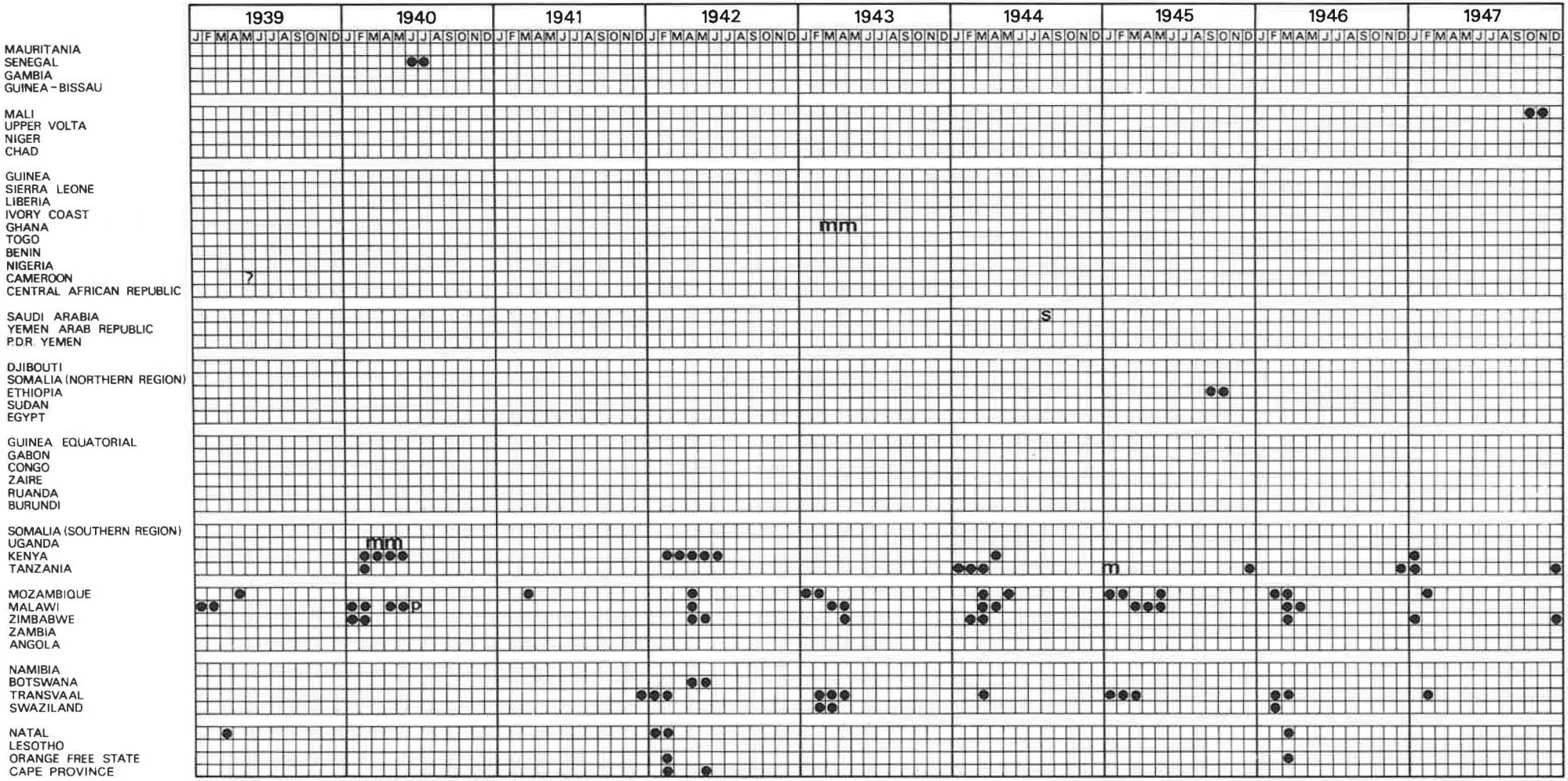
Tanzania has had the highest seasonal incidence of armyworm outbreaks, with infestations reported in 40 of the 53 seasons during 1930–1982 (Fig. 2). Few records of moths or larvae are available before the 1920s, but following an outbreak at Dar es Salaam in 1925 a special memorandum on armyworm was prepared and distributed. When outbreaks occurred 'over practically the entire Territory' early in 1930, the 'rain of worms' was described as 'a phenomenon well known to the natives and is viewed as a sign of plenty' (Ritchie, 1931). For several years outbreaks were less extensive, but in the first three months of 1944 armyworm was again 'prevalent over the greater part of Tanganyika' and the progression of outbreaks from south to north was very marked (Miller, 1945). Infestations were also reported on Zanzibar. Since that time outbreaks have been reported in all but four seasons (Fig. 4). During an extremely heavy outbreak in eastern and northern parts of the country in 1958–59, for the first time warning of the attack was provided by the catches of moths in mercury vapour light traps: this enabled the Kenyan authorities also to be alerted (Swaine, 1963). In 1961, however, large numbers of moths in northern Tanzania were not followed immediately by local infestations, so that no warning was issued of outbreaks which became particularly heavy and widespread throughout East Africa. (Regular forecasting for the region was established in Kenya in 1969–70). In recent years, infestations have been reported in Tanzania over areas exceeding 100,000 ha in 1965–66 and 1973–74 and over more than 1,000,000 ha in 1970–71 and 1974–75 (Brown *et al.*, 1967, 1972; Odiyo, 1976, 1977). In 1981–82, all 20 regions were infested; in Dodoma region alone, of 274,000 ha planted with cereal crops, 45,000 ha were attacked by armyworm and 20,000 ha had to be replanted, despite the use of insecticides worth some Tshs 1.5 million (Mushi, 1982).

There are records of infestations on Zanzibar and Mafia Island, but in only two years on each; these have all been in seasons of widespread outbreaks on the mainland.

In **Kenya,** moths had been collected in widely separated localities by 1900; the first recorded infestations were in 1914–15, but serious outbreaks were reported only

Figure 4. Incidence of *Spodoptera exempta* infestations in each territory, January 1930 – December 1982. ● Infestations of larvae **p** Pupae from earlier outbreak **s** Species of larvae not confirmed **u** Unconfirmed report **m** Month uncertain **?** Year uncertain (month recorded).




1939
1940
1941
1942
1943
1944
1945
1946
1947
J F M A M J J A S O N D
MAURITANIA
SENEGAL
GAMBIA
GUINEA-BISSAU
MALI
UPPER VOLTA
NIGER
CHAD
GUINEA
SIERRA LEONE
LIBERIA
IVORY COAST
GHANA
TOGO
BENIN
NIGERIA
CAMEROON
CENTRAL AFRICAN REPUBLIC
SAUDI ARABIA
YEMEN ARAB REPUBLIC
P.D.R. YEMEN
DJIBOUTI
SOMALIA (NORTHERN REGION)
ETHIOPIA
SUDAN
EGYPT
GUINEA EQUATORIAL
GABON
CONGO
ZAIRE
RUANDA
BURUNDI
SOMALIA (SOUTHERN REGION)
UGANDA
KENYA
TANZANIA
MOZAMBIQUE
MALAWI
ZIMBABWE
ZAMBIA
ANGOLA
NAMIBIA
BOTSWANA
TRANSVAAL
SWAZILAND
NATAL
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ORANGE FREE STATE
CAPE PROVINCE
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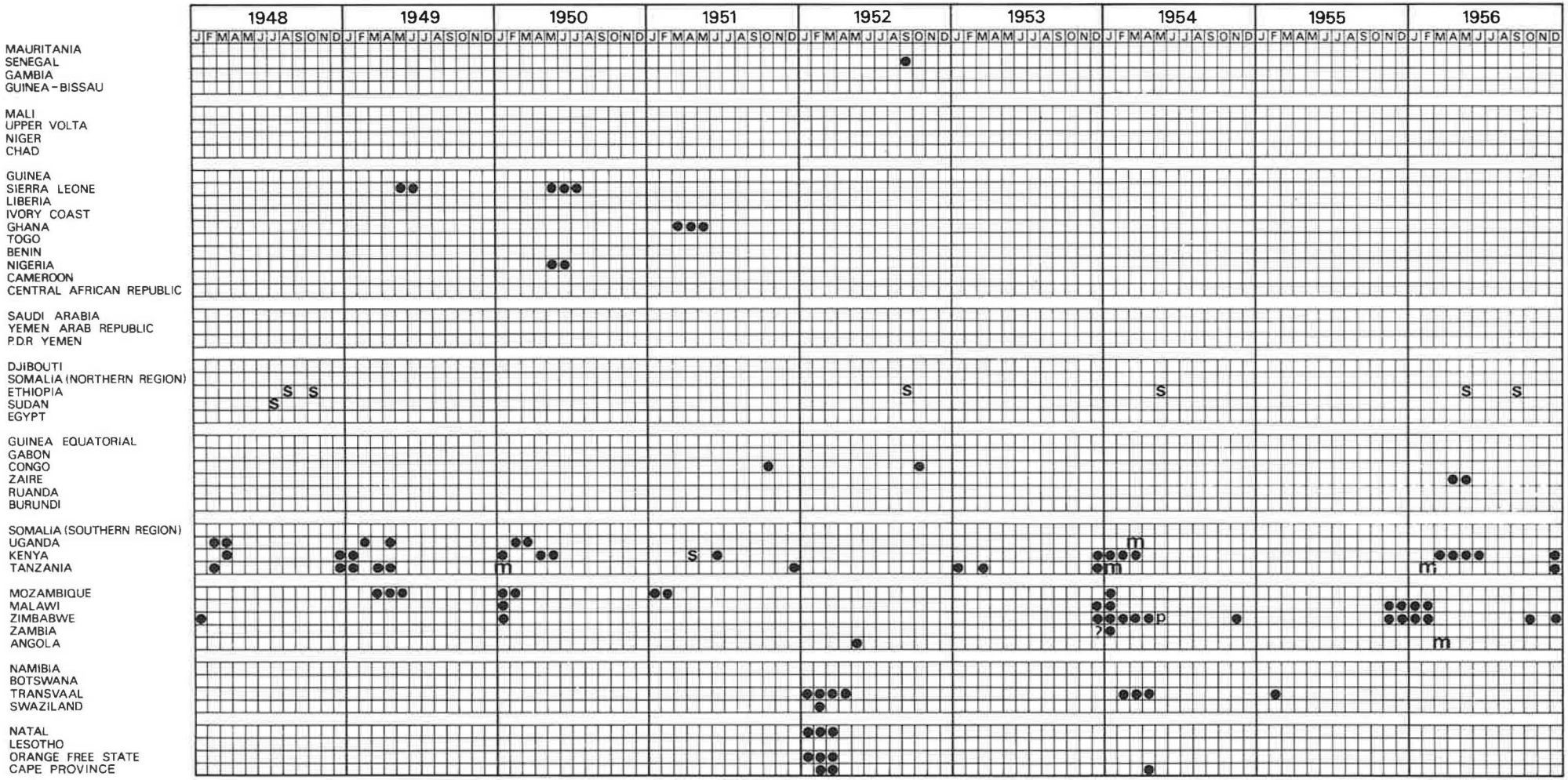
1948
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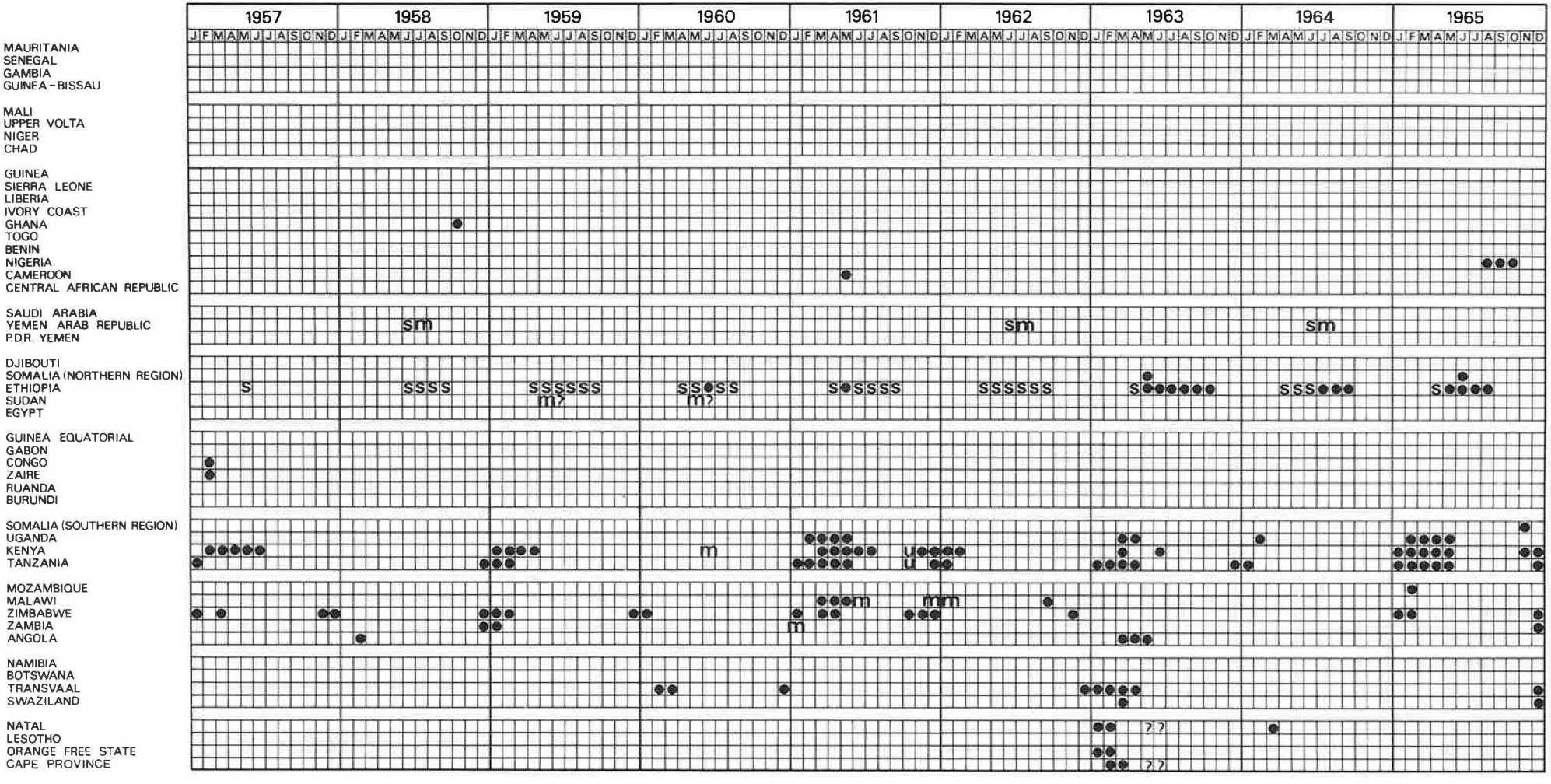
1954
1955
1956
J F M A M J J A S O N D
MAURITANIA
SENEGAL
GAMBIA
GUINEA-BISSAU
MALI
UPPER VOLTA
NIGER
CHAD
GUINEA
SIERRA LEONE
LIBERIA
IVORY COAST
GHANA
TOGO
BENIN
NIGERIA
CAMEROON
CENTRAL AFRICAN REPUBLIC
SAUDI ARABIA
YEMEN ARAB REPUBLIC
P.D.R. YEMEN
DJIBOUTI
SOMALIA (NORTHERN REGION)
ETHIOPIA
SUDAN
EGYPT
GUINEA EQUATORIAL
GABON
CONGO
ZAIRE
RUANDA
BURUNDI
SOMALIA (SOUTHERN REGION)
UGANDA
KENYA
TANZANIA
MOZAMBIQUE
MALAWI
ZIMBABWE
ZAMBIA
ANGOLA
NAMIBIA
BOTSWANA
TRANSVAAL
SWAZILAND
NATAL
LESOTHO
ORANGE FREE STATE
CAPE PROVINCE


1957
1958
1959
1960
1961
1962
1963
1964
1965
J F M A M J J A S O N D
MAURITANIA
SENEGAL
GAMBIA
GUINEA-BISSAU
MALI
UPPER VOLTA
NIGER
CHAD
GUINEA
SIERRA LEONE
LIBERIA
IVORY COAST
GHANA
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BENIN
NIGERIA
CAMEROON
CENTRAL AFRICAN REPUBLIC
SAUDI ARABIA
YEMEN ARAB REPUBLIC
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SOMALIA (NORTHERN REGION)
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SUDAN
EGYPT
GUINEA EQUATORIAL
GABON
CONGO
ZAIRE
RUANDA
BURUNDI
SOMALIA (SOUTHERN REGION)
UGANDA
KENYA
TANZANIA
MOZAMBIQUE
MALAWI
ZIMBABWE
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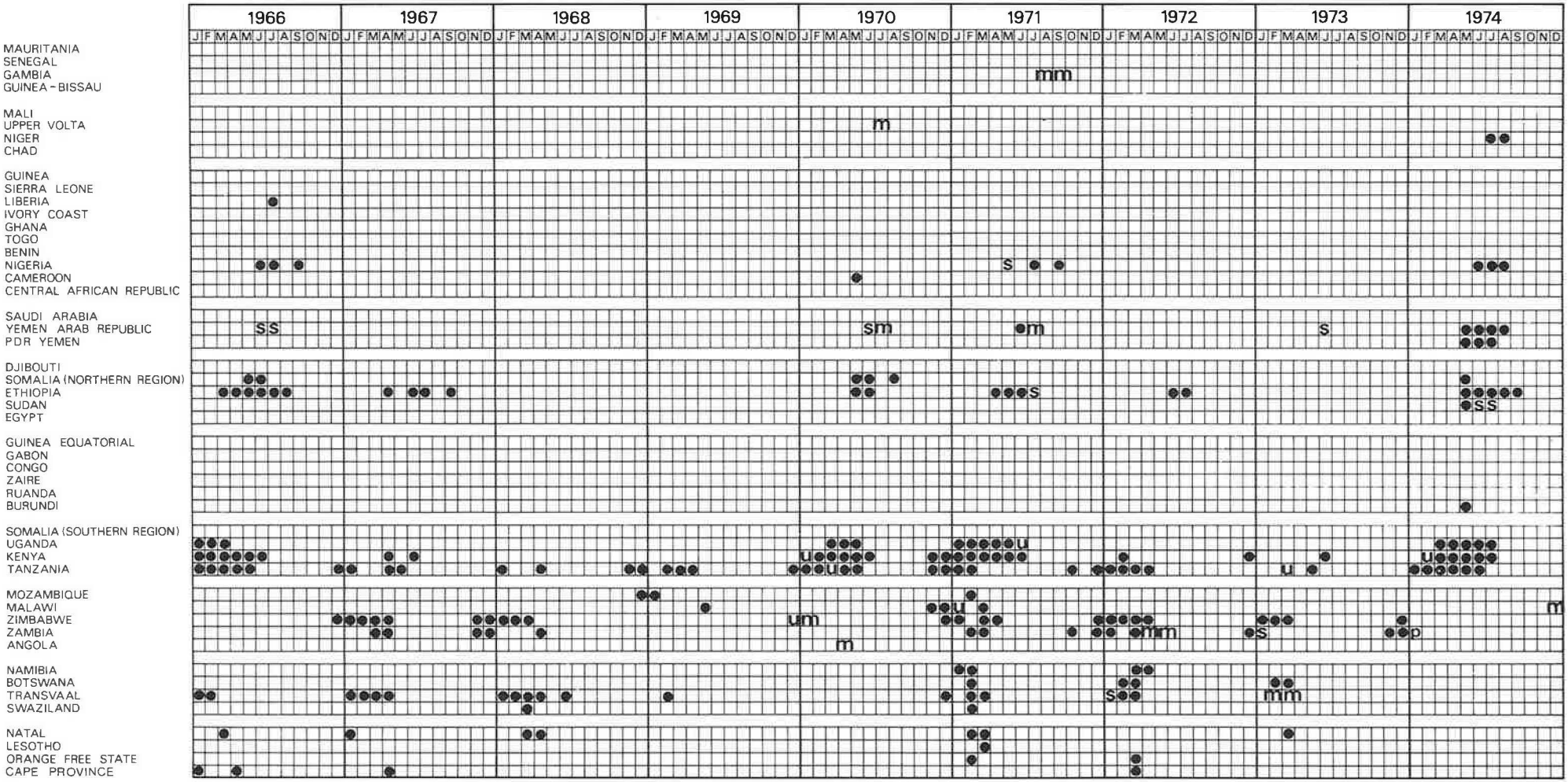
TRANSVAAL
SWAZILAND
NATAL
LESOTHO
ORANGE FREE STATE
CAPE PROVINCE


1966
1967
1968
1969
1970
1971
1972
1973
1974
J F M A M J J A S O N D
MAURITANIA
SENEGAL
GAMBIA
GUINEA - BISSAU
MALI
UPPER VOLTA
NIGER
CHAD
GUINEA
SIERRA LEONE
LIBERIA
IVORY COAST
GHANA
TOGO
BENIN
NIGERIA
CAMEROON
CENTRAL AFRICAN REPUBLIC
SAUDI ARABIA
YEMEN ARAB REPUBLIC
PDR YEMEN
DJIBOUTI
SOMALIA (NORTHERN REGION)
ETHIOPIA
SUDAN
EGYPT
GUINEA EQUATORIAL
GABON
CONGO
ZAIRE
RUANDA
BURUNDI
SOMALIA (SOUTHERN REGION)
UGANDA
KENYA
TANZANIA
MOZAMBIQUE
MALAWI
ZIMBABWE
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SWAZILAND
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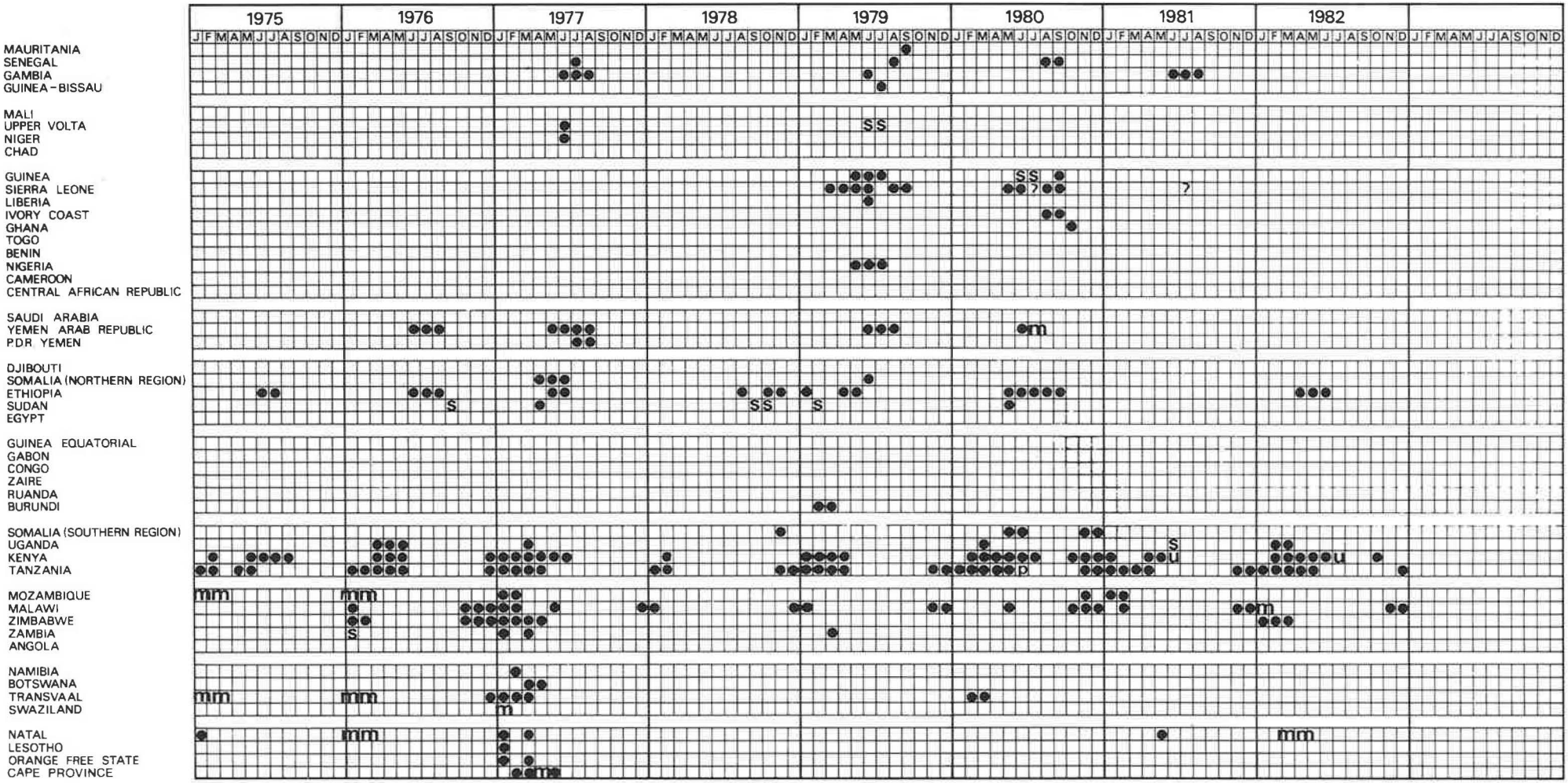
LESOTHO
ORANGE FREE STATE
CAPE PROVINCE


1975
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1981
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J F M A M J J A S O N D
MAURITANIA
SENEGAL
GAMBIA
GUINEA-BISSAU
MALI
UPPER VOLTA
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NAMIBIA
BOTSWANA
TRANSVAAL
SWAZILAND
NATAL
LESOTHO
ORANGE FREE STATE
CAPE PROVINCE

occasionally before 1940. In 1940, moths were seen 'in millions' on some farms. Since then outbreaks have occurred increasingly frequently (Fig. 4), with most disastrous effects in 1961. Following the severe drought of the 1960–61 dry season, infestations quickly became widespread and some were recorded at altitudes up to 2,530 m asl, some 250 m above the normal maximum altitude. Insecticides were imported from neighbouring countries as local supplies became exhausted, and instructions were also issued for making up concentrations of virus for farmers to spray. The second wave of infestations also was on an unprecedented scale; germinating crops were destroyed in a single day by early instar larvae. Altogether some 650,000 ha were affected; in four districts 8,500 ha of maize were destroyed and replanted and more than 29,000 ha of crops in other, mixed farming areas. The start of the next season was notable for the numbers of moths seen continuously over the length of the Rift Valley and between Lake Victoria and Voi, and estimated to cover many hundreds of square kilometres. In April 1965, another of the rare sightings of a swarm of moths again occurred on the edge of the Kenya Rift Valley, during a season of heavy if less widespread infestations (Brown, Betts and Rainey, 1969).

In subsequent years very heavy attacks have twice been reported in Kenya: in 1970–71 infestations extended over more than 700,000 ha in 30 districts and in 1979–80 there were infestations totalling some 911,000 ha over 29 districts (Brown *et al.*, 1972; Ashall and Chaney, 1982). Thus the Armyworm Forecasting Service that became operational in November 1970 was challenged from the outset to provide accurate and timely warnings to enable farmers to take appropriate control measures (Brown *et al.*, 1972; Odiyo, 1972 *et seq.).*

Since the installation in the mid 1960s of the light trap network (and later pheromone traps) by which populations are monitored for the forecasting service, *S. exempta* moths have been captured in all months of the year, though only in very small numbers outside the outbreak season. Outbreaks may start as early as October but more usually in December and are reported most frequently during February–June (Table I.); they sometimes continue into July and were once found in northern Kenya in early August. September is the only month in which outbreaks have never been recorded. In recent years low-density passive larvae (Whellan, 1954) have been regularly sought during the off-season, and found in the months of July, October, November and December when no outbreaks had been recorded (Page, 1982 unpubl.; Rose, pers. comm.).

Since 1965 reports have increasingly come from southern parts of the **Somali Republic**, mainly in November (Table I). In November 1978, 1,000 ha of maize and wheat were infested near Mogadiscio, and in November 1980 the first report of the new season was of control measures in the same area to protect 14,500 ha of maize. Infestations on the Lower Juba and Lower Shebelli in the preceding May–June appear to have been more devastating, with 75% damage reported to crops and rangeland, and control measures undertaken by both national and regional units. At that time outbreaks were widespread in Kenya and southern Ethiopia also.

As in Kenya, moths were first collected in **Uganda** in 1896, and in February 1914 moths were bred through from larvae collected on Nsadzi Island in Lake Victoria. Since the installation of the trap network in the 1960s, moths have been captured in small numbers in all months of the year. The first reports of serious outbreaks were in 1936, and the next occurred in 1948–50 in three successive years. In 1948 it was particularly noted that 'there appears to have been considerable uniformity in the time of the outbreak . . . . throughout a strip of country' covering five districts, and some replanting was necessary (Harris, 1950). The outbreak in 1961, as elsewhere in East Africa, was unusually severe and covered the entire country. Infestations have been reported in more than half the subsequent years: they were widespread and caused most serious damage in 1965, 1966 (over 10,000 ha), 1971 (over 70,000 ha), 1974 (3,600 ha) and 1982 (Brown *et al.*, 1967, 1972; Odiyo *et al.*, 1974). Outbreaks have been reported in Uganda only in those years when they were also widespread in Tanzania and/or Kenya. The season has never started in Uganda (Odiyo, 1979).

Further west, in **Ruanda** and **Burundi**, moths were captured in most years during the 1960s. The only outbreaks reported were in Burundi in 1974 and 1979, when there were contemporary infestations in neighbouring parts of Uganda and Tanzania respectively.

Few reports of outbreaks are available for the other countries of Equatorial Africa. In **Zaire**, moths were collected in many years between 1912 and 1967: they were taken most often in April (in 12 years) and in five or more years in each month from November to May. Moths have been recored only once in July (at Kinshasa) and August (at Kolwezi in Katanga). It may be inferred from notes of pupation and emergence attached to moth specimens that there were infestations during May–June in Kasai in 1919 and at Rutshuru near the Ugandan border in 1937. The only observations on infestations were in the northern and northeastern parts of the Central Congo Basin in April–May 1956; this followed an abnormally dry period before the start of the rains (Buyckx, 1962). In February 1957, reports reached the Government Entomologist in Zimbabwe of armyworm invasions in Katanga province of Zaire and in the Niari valley in **Congo Republic.** The latter area had been subject to infestations in October 1951 and 1952, when young rice cultivations were severely damaged (Brenière, 1954). There had also been 'an invasion of caterpillars' on cereals at Mateba, further north, in November 1935. The only record from neighbouring **Gabon** is of larvae attacking grasses at Libreville in 1900.

Northeastern Africa and Arabia

The most northerly report of *S. exempta* in Africa is of a moth captured at Shellal near Aswan in Upper **Egypt** (Fig. 1). This moth, with others from Southern Kordofan and Upper Nile Provinces of **Sudan,** was taken during an expedition in February–April 1914 (Rebel and Zerny, 1917), but the specimen is not available for the identification to be rechecked. The latitudes and months of capture are unusual compared with the pattern of seasonal distribution provided by other reports from northeastern Africa.

In Sudan, *S. exempta* moths have been captured between the southern borders and places as far north as Khartoum and Kassala, mainly during the months of April–August. Outside these months the only confirmed moth records are from Yambio in the extreme south, where a specimen was bred through to emerge on 1 November 1938, and one moth found at the end of the year at Kurmuk, close to the Ethiopian highlands, in 1928. Recently moths have been trapped near Jebel Mara in western Darfur. There are no records from Norther Province. The moth from Yambio is not the only specimen bred out (presumably) from local infestations: others dated June or July in five years up to 1948 came from southern Kordofan and from the Gezira Research Farm at Wad Medani. Since 1974 there have been reports in most years of armyworm infestations in the south of the country, mainly in May–July, but some in February, April, September and October also; not all of these have been confirmed as *S. exempta,* but here have been accepted as such where there are contemporary reports in neighbouring parts of adjacent countries. Up to the last decade, *S. exempta* may have appeared only occasionally in Sudan and it is of little economic importance there (Schmutterer, 1969), unlike the related *S. exigua* (Hb.) whose seasonal attacks on fodder crops in the south and cotton in the north have long been recognised (Tothill, 1948). The seasonal incidence and latitudinal distribution of *S. exempta* is similar to that in **Ethiopia** where its importance is much greater.

It was not until the 1960s that *S. exempta* was officially described as currently Ethiopia's most serious insect pest (IAR, 1967 unpubl.), though heavy attacks had been reported earlier. The Ministry of Agriculture began systematic observation and control of armyworm in 1952; in 1956 some 350,000 ha of crops were damaged in four Provinces and grain losses were estimated at Eth. $24m. In 1962, in a two-month period, armyworm infestations destroyed over 10,000 tons of cereals representing the annual consumption of about one million people. During 1963–67 more than 25,000 tons of cereals were lost and in 1971 some 20,000 tons. In 1974 the Government appealed for international assistance to counter a particularly heavy

outbreak that affected most of the country (Rainey, 1979). Its effect was worsened because of the repeated attacks on young seedlings in many parts of the worst drought-stricken areas, causing food shortages. Again in 1976, the outbreak in the eastern part of the country was so serious that nearly a thousand hectares of maize and sorghum seedlings were completely defoliated and in need of replanting. In several years of severe infestation the outbreaks in the east extended across the border into neighbouring parts of northwestern **Somali Republic.**

Outbreaks usually appear first in the south and east of Ethiopia in April—May and extend northwards through the Rift Valley and highlands during May—July. In some years they have continued through August—September to the northern highlands of Eritrea. The season is noticeably shorter in northern latitudes than in southern part (Fig. 3).

The only records of *S. exempta* on the coast are of two moths captured at **Djibouti** and three at Zaila in Somaliland in May 1895. (Another moth specimen was captured across the Gulf at Aden in April 1895).

The possibility that moths could cross the sea to Arabia is verified by the observations of Laird (1962) on board ship in the Gulf of Aden: on 10 June 1957, for one hour in which 30 km was covered towards Djibouti, a mixed flight of insects came aboard, including some 300 moths most of which were *S. exempta*. The sighting appears to be closely associated with the change of the monsoon (Brown, Betts and Rainey, 1969).

Some of the earliest of all moth specimens are from **South Yemen** around Aden and *S. exempta* is listed as a major pest of sorghum in nearby Lahej and Abyan (FAO, 1968), yet outbreaks have rarely been recorded in the area. Indeed, the only years for which there are references to serious infestations are 1974 and 1977, in both of which neighbouring **Yemen Arab Republic** was heavily attacked. There it was confirmed only in 1971 that infestations were of this species, though moths had been captured in Sana's in 1931 and 1941, and it seems likely that many of the outbreaks of the late 1950s and 1960s, remembered during the 1974 campaign (R. C. Rainey, pers. comm.), were also *S. exempta.* In this year, outbreaks appeared in early May in both Yemens and extended northwards during June and July across the Yemen Arab Republic almost to the Saudi border. Control was required on a scale that quickly exhausted available supplies of equipment and chemicals, and generated panic among farmers and a Government request to UNDP and other international bodies for assistance (Bartelink, 1974 unpubl.) An estimated 12,000 ha of crops were treated in the northern uplands alone, while in the south, Ibb and Taiz areas reported 60,000 and 38,000 ha of sorghum attacked in June. Serious infestations have occurred in several subsequent years, the most extensive were in 1977 (11,000 ha—Rainey, 1979) and 1979 (17,000 ha). While the areas most subject to attack have been the very intensively cultivated areas in the south, around Taiz and Ibb, infestations have been recorded in all parts of the highlands, but only very occasionally on the lower coastal reaches of the Tihama.

Yemen is almost at the northern limit of distribution of the species. Individual moths have been caught as far north as Jeddah, but no attacks by *S. exempta* larvae have yet been confirmed in **Saudi Arabia**; plagues of dark caterpillars seen in August 1944 at Abha and Khamis Mushayt in the southwestern highlands are likely to have been *S. exempta,* as moths were also found at the time – but together with moths of *S. mauritia* (Boisd.) (Rainey, 1979).

Western Africa

Assessments of the armyworm situation in western Africa have generally been limited to events and experience in individual countries by the intermittent occurrence of outbreaks and the scarcity of reports from beyond the immediate territory. Table I and Fig. 3 contain almost the fullest analyses practicable from such irregular and scattered reports; they suggest that, as in the Northeastern zone, the season is shorter

in more northerly latitudes. The accumlated data so far available are summarised here for all countries of Western Africa together, to indicate the importance of attack and the continuity of the species in this part of Africa.

Since 1900, *S. exempta* outbreaks have been recorded in 21 years, in the months March—November; most records are for May, June and July. Dated moth records span the same months, apart from a single specimen captured in Senegal in February 1939. Together these records relate to 36 years and come from all countries of West Africa except Benin. The most northerly records are of moths taken around and to the south of Agadès in Niger in July and August 1920 and September 1922; the only infestations recorded north of 15° N are one at a rice research station in the lower valley of the Senegal river in September 1952 (Appert, 1952) and one in Mauritania in September 1979 for which no details are available (Fig. 1).

Up to 1940 *S. exempta* was rarely included in published lists of pests or insects collected in West African countries. In subsequent literature varying opinions are expressed on its importance and frequency of occurrence in the region: it is listed among agricultural pests in French West Africa ('très commune'—Risbec and Mallamaire, 1949), Ghana (Forsyth, 1966) and Nigeria (the most important local species of armyworm—Golding, 1946), though in the latter *S. exigua* is the most common species (York, 1967) — at least, in light traps (J. Bowden, pers. comm.). *S. exempta* is described as occurring every year in northern Nigeria, but assumes outbreak proportions only one year in five or six (G. H. Caswell, pers. comm.); Bowden considers it a resident in the Ibadan area, but that the scarcity of records reflects the fact that no species of armyworm is 'common' in West Africa (pers. comm.).

Until 1974 successive generations of *S. exempta* had been recorded in Western Africa in only five seasons, usually within one country, and infestations had rarely been recorded in two west African countries at the same time. In 1974 widespread, heavy infestations totalling 500,000 ha in Nigeria were first reported in early June, and a second generation over more limited areas in July—August, when large numbers of late-instar larvae also damaged rice in the Niger valley further north. In June 1977 armyworms were reported in Niger, Upper Volta and Gambia: control was required on 30,000 ha in Niger and throughout Gambia where many fields had to be replanted in July—August. Senegal was also attacked in July.

By far the most devastating attacks were in 1979 and 1980: during six months of each year (Fig. 4) respectively 9 and 5 countries were affected. Some were obliged to seek international assistance, so badly were the local crops damaged. In Sierra Leone, armyworm was considered probably the most serious constraint to agricultural production in 1979: 35% of all rice growers lost their entire crop, causing scarcities which led to imports of 140,000 tons of rice — some 90,000 tons more than normal (National Development Bank, 1980; FAO, 1982). Eyewitnesses and police radio messages gave graphic descriptions of widespread devastation, with farmers fleeing their farms, and suggesting a scale of invasion comparable with that in Kenya in 1961. In both 1979 and 1980 Guinea Bissau Government sources reported massive attacks by the larvae, and in Guinea, in 1980 120,000 ha of crops were destroyed, amounting to some 15% of the total cereal area.

Central Africa

Zimbabwe has the highest annual incidence of armyworm attack, after Tanzania (Fig. 2). Moth specimens date back to 1902. In 1910 larvae were 'exceedingly abundant' in Salisbury and also caused much damage to native crops in eastern districts of the country (Jack, 1915). Since then, infestations have been reported in most years: the longest intervals between outbreaks have been March 1921—December 1925 and May 1977—December 1981, both a little less than five years. Among the early years, 1930 was most important: widespread outbreaks covered 'practically the whole of the maize-growing area' of the country, and instances were cited of a crop of maize disappearing 'between Saturday and Monday'. Advice to farmers, on control measures, emphasised the need for constant vigilance and early recognition of the larvae (Jack, 1930). Again, in 1954, outbreaks were widespread and were charac-

terised by appearing everywhere at one time. Investigations were renewed on the biology of *S. exempta* (e.g. Whellan, 1954) and in January 1955 the first light trap was started, to monitor moth flight and numbers. In that season few enquiries were received, but in 1955–56 there were widespread outbreaks, this time with overlapping generations. The earliest of these were in early November 1955, at two places where freak hailstorms had occurred some two weeks before (Rose and Law, 1976). Similar coincidences of early infestations following early rain or hail storms were noted in later years (Blair, 1972; Blair, Rose and Law, 1980). The armyworm outbreak which 'engulfed the whole of Zimbabwe' in January–March 1982 was the worst for many years and was classified as a 'natural disaster', with some 750 reports of infestations ranging from less than one to 20,000 ha in extent (Mlambo, 1982). The light trap catches initially failed to give warning of the infestations, which occurred at about the time of a cyclone over neighbouring **Mozambique.**

In Mozambique, by the 1930s *S. exempta* was known as a pest of maize and other cereals (Saraiva, 1939), though there are few reports of infestations up to that time (Table 2 and Fig. 4). Some occurred in most years in the 1940s (del Valle, 1950), but little information is available on the scale of these or subsequent outbreaks. An intensive campaign took place against *S. exempta* in the southern districts of Maputo and Gaza in February 1971, but the species was considered to be normally resident in small numbers (de Almeida and Ferreira, 1970). Outbreaks were again reported throughout Maputo province in 1980–81.

Outbreaks in **Malawi** have generally occurred at about the same time as others in neighbouring countries. *S. exempta* is currently considered a major pest. Armyworm was little known in Malawi before the mid 1930s (Table 2 and Fig. 4), but its potential importance had been recognised by 1942, when plantings of wheat were entirely destroyed. Study of the weather conditions in outbreak years showed that in most of them the infestations were preceded by a hot and unusually dry period: this finding was immediately and successfully used to predict infestations in 1943 (Smee, 1943). After five successive years with outbreaks, infestations were again reported irregularly for two decades. Those in 1953–54 were severe enough to cause local food shortages in the central region. Serious outbreaks were not recorded again until 1976–77, when very dense infestations were reported throughout the southern region and in parts of the central region: more than 100,000 ha of crops had to be replanted. As a result, a network of pheromone traps was set up to monitor moth numbers and provide warnings of population build-up (Nyirenda, 1982). This trap network is the densest in Africa, comprising some 70 traps. Since 1977, moths have been caught in each month and at certain stations in almost every week, even through the off-season (G. K. C. Nyirenda, unpubl. data.). Infestations have been reported in each of these years: in many, though not all instances the larvae were found at an early enough stage to be effectively controlled. In 1981–82 some 350,000 ha of crops were affected and an estimated K940,000 (c. £600,000) spent on control (Murlis, 1984).

Armyworm outbreaks have been reported relatively infrequently in **Zambia** (Fig. 2). They have always occurred at times when neighbouring countries have also been infested (Fig. 4). Up to the late 1960s *S. exempta* was regarded as of little economic importance; the number of reports has increased since then. The most serious attacks occurred in 1971–72, and started on young maize germinating on freak October rains. It is thought that armyworms are present in small numbers in most years and that serious invasions come from outside the country. Few records are available for **Angola,** where *S. exempta* is the most important pest of wheat (Carvalho and Cardoso, 1968). The severity of attack usually justifies control (Fonseca Ferrao and Cardoso, 1972). Here too the species is considered a resident, and larvae have been observed to survive the cold season (Fonseca Ferrao and Santos, 1965).

Southern Africa

The earliest confirmed infestations of *S. exempta* were in **South Africa.** Hattingh (1941) reports 'Large outbreaks were recorded during the years 1878, 1908–9, 1914, 1919, 1929 and 1936. Newspaper reports during the year 1878 . . . mention . . . the caterpillars played such havoc that mealies were sold for £2 a bag.' Very severe damage was done and hundreds of square miles of veld denuded; this caused such

shortages of fodder and pastures that heavy losses of stock resulted. In later years outbreaks were particularly heavy and widespread in 1952, 1968 (c. 200,000 ha), 1973 (118,000 ha) and 1977 (860,000 ha). Outbreaks normally progress from the north and east southwards and south-westwards. They are thus reported more often in the northern Transvaal than elsewhere (Blair and Catling, 1974). Natal also has a high incidence of infestation. The Orange Free State and Cape Province have had outbreaks only when infestations were also present in Transvaal or Natal (Fig. 4). Swarms of moths have 'often' been seen at night and occasionally recorded in South Africa: at Kimberley in north-eastern Cape Province in March 1919 (Hattingh, *l.c.*); at Letaba in northern Transvaal in March 1943 (Faure, 1943); and near Nelspruit in south-eastern Transvaal (undated). Those at Kimberley and Letaba were seen at times when infestations were reported locally, and the latter during a period of disturbed weather (Brown, Betts and Rainey, 1969).

In **Swaziland,** outbreaks have always been coincident with infestations in the Transvaal. They were very severe in 1968: over 8,000 ha of grazing were completely ruined and some areas took 3½ years to recover. In 1977, infestations were so serious that the situation was discussed in Parliament and farmers requested that the armyworm should be declared a 'national pest' (UCS, 1977). Similarly, **Lesotho** has had outbreaks only twice, when they were widespread in the Orange Free State and Natal. The rarity of armyworm in Lesotho is likely to be because most of the country is above 2,000 m, which is normally above the range for *S. exempta* except at times of very heavy infestation (Brown and Swaine, 1966).

In **Botswana,** armyworms were reported only once before the 1970s (in 1942). Small outbreaks occurred in 1971, 1972 and 1973, but the most widespread and damaging infestations were in 1977. Outbreaks have always been reported in districts near the eastern borders of the country and in years when they were also present in adjacent territories. Moths, however, have occasionally been captured across the Kalahari (Fig. 1). To the west, there are several records of moths in **Namibia;** most were captured in the months of February, March and April. Infestations have been reported only in 1971 (over 550,000 ha), 1972 (320,000 ha) and 1977 (no details)—all years when they were generally widespread in southern Africa.

DISCUSSION

Causes of outbreaks

Research on the biology and incidence of *S. exempta* began in response to demands for predicting infestations, following devastating attacks in Southern Africa in 1930 and 1936. Early work concentrated on determining the development of the pest, which was noted to occur only during the summer rains (Jack, 1930). Under such conditions, the normal life cycle from oviposition, through egg, six larval instars and pupa to eclosion of the adult moth takes about 23–30 days, or longer for non-gregarious caterpillars at lower temperatures (Hattingh, 1941; Matthee, 1946; Whellan, 1954; Brown and Odiyo, 1968; Persson, 1981). While development is considerably retarded at temperatures below 20°C (Hattingh, *l.c;* Fonseca Ferrao and Santos, 1965; Khasimuddin, 1981), true diapause is unknown in this species (Matthee, 1946; Brown, 1962). This absence of a resting stage left two possible explanations for the sudden seasonal reappearance in a country of large numbers of moths and larvae after several months or even years when they had not been recorded: either they were there all the time in restricted, 'optimum habitats', but in insignificant numbers that suddenly exploded into outbreak proportions under extremely favourable conditions (Naudé, 1936 *in* Hattingh, *l.c.*); or outbreaks were caused by large numbers of moths migrating in from elsewhere (Hattingh, *l.c.*).

In the course of the early work, much effort was expended unsuccessfully on searches for low-density populations during the off-seasons in South Africa (Faure, 1943; Matthee, 1952), but in Central Africa such a possibility was still considered viable (Smee, 1943; Whellan, 1954, 1958; Rose, 1975, 1979). Later, in East Africa, it was concluded from observations of moths at emergence sites, and from the biogeograph-

ical analyses of the regular progressions of infestations through the region from southern Tanzania to northern Ethiopia in several seasons, that the sudden appearances of vast numbers of larvae of closely similar age were due to simultaneous oviposition by moths that had migrated in on the wind (Brown *et al.*, 1966 *et seq.*; Brown and Swaine, 1966; Brown, Betts and Rainey, 1969). More recently, the behaviour of emerging moths has been observed in the laboratory (Dewhurst, in press) and in the field (Rose and Dewhurst, 1979), and the flight capability of *S. exempta* moths studied (Aidley, 1974; Gatehouse and Hackett, 1980; Cooter, 1983). The dispersal of moths from an emergence site has been followed using radar (Riley *et al.*, 1981, 1983) and the distance of that dispersal measured by marking and recapture (Pedgley and Rose, 1982). All these studies have confirmed the role of wind-borne migration in the progressions of infestations season by season.

However, the migration theory appears not to explain all of the seasonal distribution patterns: as the maps of Fig. 3 and the Appendix show, the progressions of infestations come to an end with the cessation of the summer rains not only in Eastern, Central and Southern Africa but also in the countries to the north of the equator, leaving in most years a 'gap' of at least 2–4 months during August–November between the last reported infestations in northern latitudes (8–16° N) and the start of the new season in Eastern and Central Africa (2–20° S). This gap in the sequence of infestations has lent support to the other theory that outbreaks develop from resident, low-density populations (Rose, 1979). Recent biological research has also investigated the ability of *S. exempta* to survive on different host plants and under a range of conditions (ICIPE, 1977 *et seq.*; Persson, 1981), confirming that the species could over-winter in favourable areas, but with longer development at the lower temperatures. Efforts have been renewed to locate low-density populations during the off-season and, after much searching, very small numbers of solitary or 'passive' larvae (Faure, 1943; Whellan, 1954) have been found in East Africa (Page, 1982). The identification of the sex pheromone of *S. exempta* (Beevor, *et al.*, 1975) has enabled more extensive trap networks to be set up cheaply and with the advantage of being independent of electricity supplies (Campion, 1975; Campion *et al.*, 1972). Moths have been taken each month in East Africa, but perhaps more significantly, over several years moths have been caught almost continuously in a dense network of traps in Malawi (G.K.C. Nyirenda, unpubl. data).

Most probably both theories hold good, and the two mechanisms complement each other, at least in time, in many if not all parts of Africa. In the off-season, small numbers of *S. exempta* linger on, in favourable pockets. Once the armyworm season is under way, the typically widespread, locally heavy infestations provide the largest sources of moths which migrate on the wind and produce new infestations elsewhere. But, for the larvae to be at sufficiently high density to attract attention, both the moths emmigrating from outbreaks and the ones from low density populations need to be brought together by wind convergence before they lay their eggs (Rose, 1979; Riley *et al.*, 1983). This wind convergence may be on the synoptic scale, i.e. over a zone hundreds to thousands of kilometres in extent, or of local nature, of tens of kilometres at most (Haggis, 1971, 1979).

The role of biogeography in forecasting and control

Following the massive infestations in East Africa in 1961, a network of light traps was set up to monitor the numbers of adults, and detailed systematic plotting and analysis was undertaken of outbreak and moth records for each season for the three East African countries and elsewhere (Brown *et al.*, 1964 *et seq.*). From this, understanding of the changing distribution of *S. exempta* developed to the point where regular forecasting could be tried experimentally for Kenya, Tanzania and Uganda, using the trap network to monitor the main direction, extent and times of moth migration (Betts *et al.*, 1970, 1971; Betts, 1976). Operational forecasting for this area began the next season (Brown, Odiyo *et al.*, 1971 *et seq.*; Odiyo, 1979) and was later extended to include Ethiopia, Sudan, Somalia and Djibouti. Warnings of possible invasions have also been sent to Yemen. These forecasts are routinely verified each season to identify the strengths and weaknesses of both the forecaster and the operating system, so that lessons can be learned from the errors or omissions that

occurred and necessary improvements made. The high standard of efficiency attained and maintained is on record (Odiyo, 1972 *et seq.*, 1979; Betts, 1976).

Earlier attempts at forecasting in individual countries had inevitably been less comprehensive, based on data from one or two sites (Smee, 1943; Whellan, 1958; Swaine, 1963). Interest was renewed during the 1970s when regular exchange of information was initiated between the countries of southern Africa (Roome, 1974. Vermeulen and Catling, 1980), though no central forecasting was attempted for this region. Since 1977 a very dense network of pheromone traps has been installed in Malawi and warnings have occasionally been issued, based on the trap catches (G.K.C. Nyirenda, pers. comm.). Other countries also have recently installed traps to monitor the numbers of *S. exempta* moths present (Rainey, 1979; Beevor, 1983), and wider use of monitoring systems is recommended (FAO, 1982) None of these has included current mapping of armyworm distribution for comparison with earlier years.

Many early researchers drew attention to the observation that serious infestations occurred when the rainy season started late after a spell of high temperatures (e.g. Hattingh, 1941; Smee, 1943). Recent biometeorological studies in East Africa have shown a generally close association between early season outbreaks and early rainfall, and the progressions of outbreaks, like the rainfall itself, to be with the dominant winds (Tucker, Mwandoto and Pedgley, 1982; Tucker, 1983; Tucker and Pedgley, 1983). The confirmation of a negative association between the severity of armyworm attack and early season rainfall has opened the way to longer-term forecasting for the region (Tucker, 1984), but studies of the extent and intensity of armyworm infestations and of rainfall have not been systematically undertaken on the pan-African scale.

Case studies of infestations early in the season in Central Africa likewise have shown that the moths causing them were within zones of confluent windflow, and rainfall, at the time of oviposition; in some of these instances there had been no infestations reported previously and the sources of the moths were unknown (Blair, 1972; Blair and Catling, 1974; Rose and Law, 1976; Rose, 1979; Blair, Rose and Law, 1980). A case-study using detailed wind observations late in the season in Kenya has shown how moths dispersing from known source areas would have been reconcentrated after one night's flying within a zone of wind convergence some 200 km from those sources (Haggis, 1979).

It has been noted that the larvae of late season outbreaks sometimes show a high incidence of mortality due to virus (e.g. Jack, 1930; Graham, 1961; Brown and Swaine, 1965). The nature of the virus has been identified but its value as an artificial control agent is doubtful as it is slow-acting (McKinley, 1975; Odindo, 1977). As viruses are highly susceptible to ultra-violet light, in some areas and seasons their presence may become an important regulator of the numbers of larvae surviving in field populations (Persson, 1981). Larval mortality is also caused by various predators, mainly birds, and parasites (Brown *et al.*, 1965; Baker, 1978), and in certain conditions these can provide adequate control (Pemberton, 1951). But when *S. exempta* populations explode to outbreak proportions natural enemies are unable to multiply fast enough still to regulate armyworm numbers. This means that the caterpillars must be found within the first week of life and control measures undertaken immediately, if crop damage is to be averted (Brown and Odiyo, 1968; Brown, 1970, 1972). Currently available chemicals and methods of application have recently been evaluated (Maslen, 1977, 1978, 1980; Whitwell, 1982). *Bacillus thuringiensis* has also been found effective as a control agent (Taylor, 1968). Farmers need to be alerted to the possibility of imminent attack by armyworms, if they are to find such young larvae.

The advantages to the forecaster of ready access to accumulated data and analyses have already been expounded (Betts *et al.*, 1970; Betts, 1976; Pedgley, 1981). The seasonal incidence of *S. exempta* in individual countries is recorded in the annual reports of several Departments of Agriculture, and since 1963 has been regularly compiled for the wider area of East Africa (Brown *et al.*, 1964 *et seq.*). A number of case studies of outbreaks in relation to weather in certain seasons and sub-regions are now on record as described above, but nothing has previously been published on

armyworm distribution on the pan-African scale for individual seasons. A comprehensive abstract of recent research results is available (Pedgley and Rose, 1982).

It is hoped that the present paper will provide the necessary background information on seasonal trends and access to historical analogues on the pan-African scale to encourage monitoring and control units to extend their techniques to include forecasting, for the benefit of their farmers. This background knowledge can best be applied within the context of local experience of an everchanging situation, integrated with the relevant information from other disciplines.

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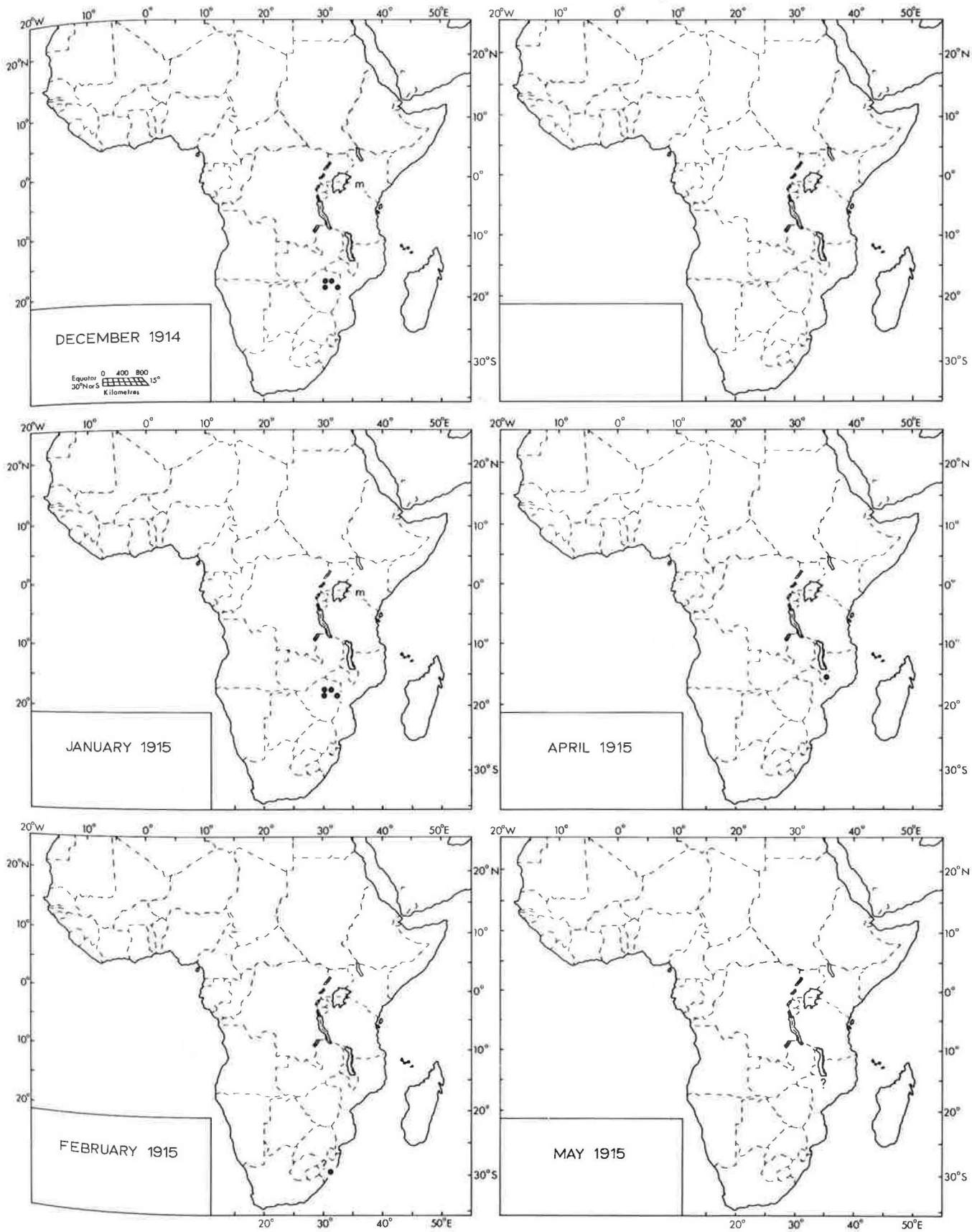
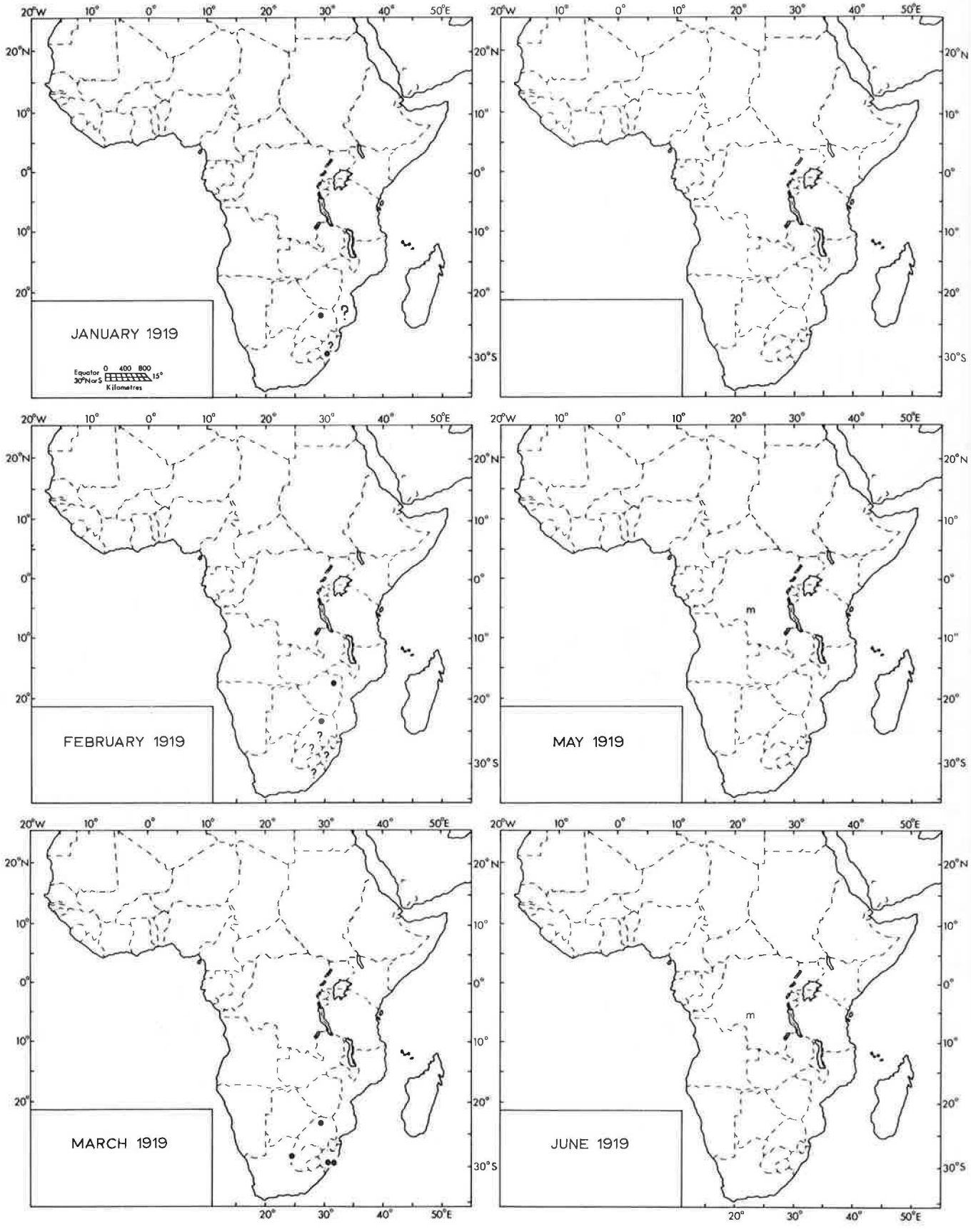
Appendix

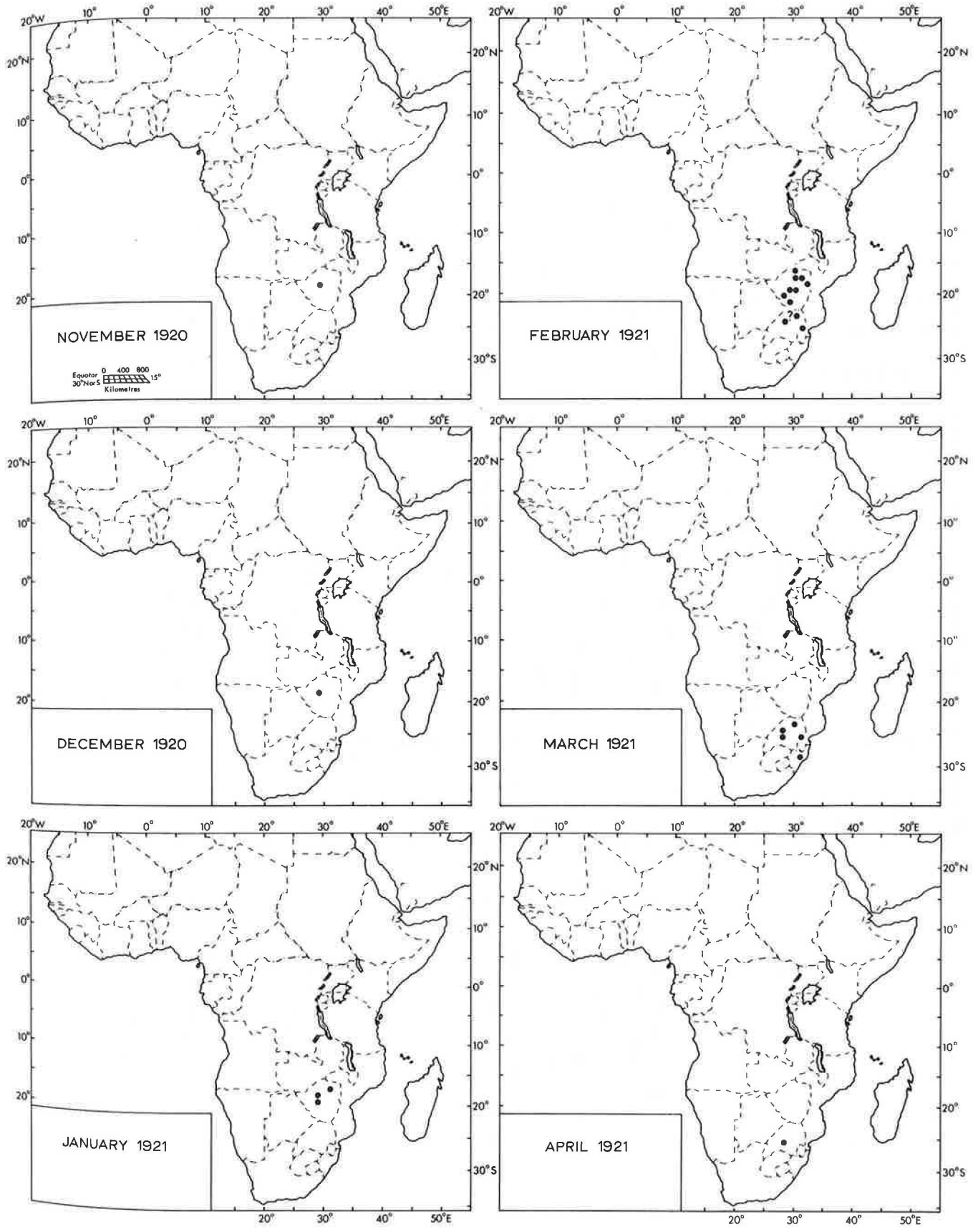
Month by month incidence of *Spodoptera exempta* infestations, 1940–1982 and selected earlier years.

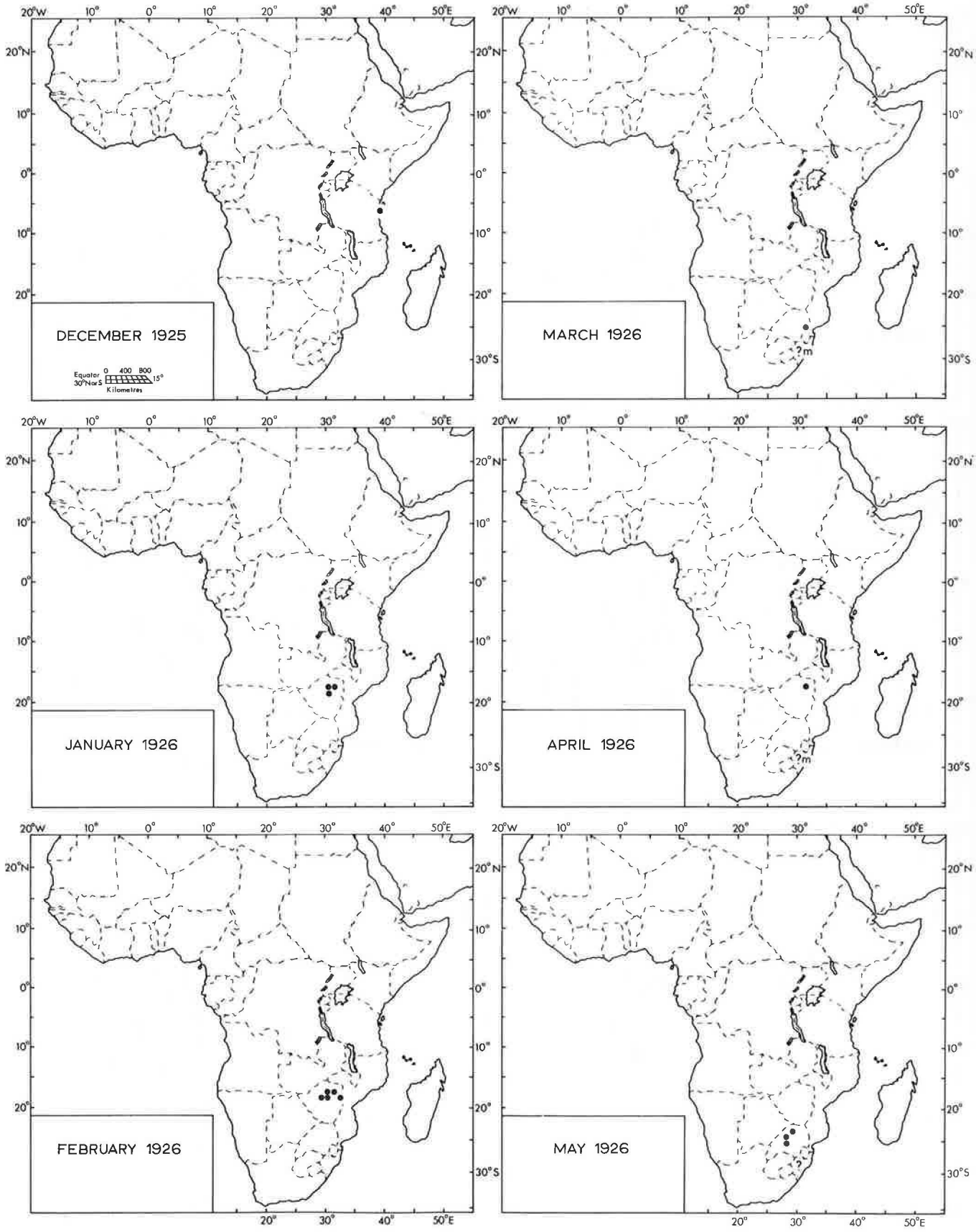
KEY TO SYMBOLS

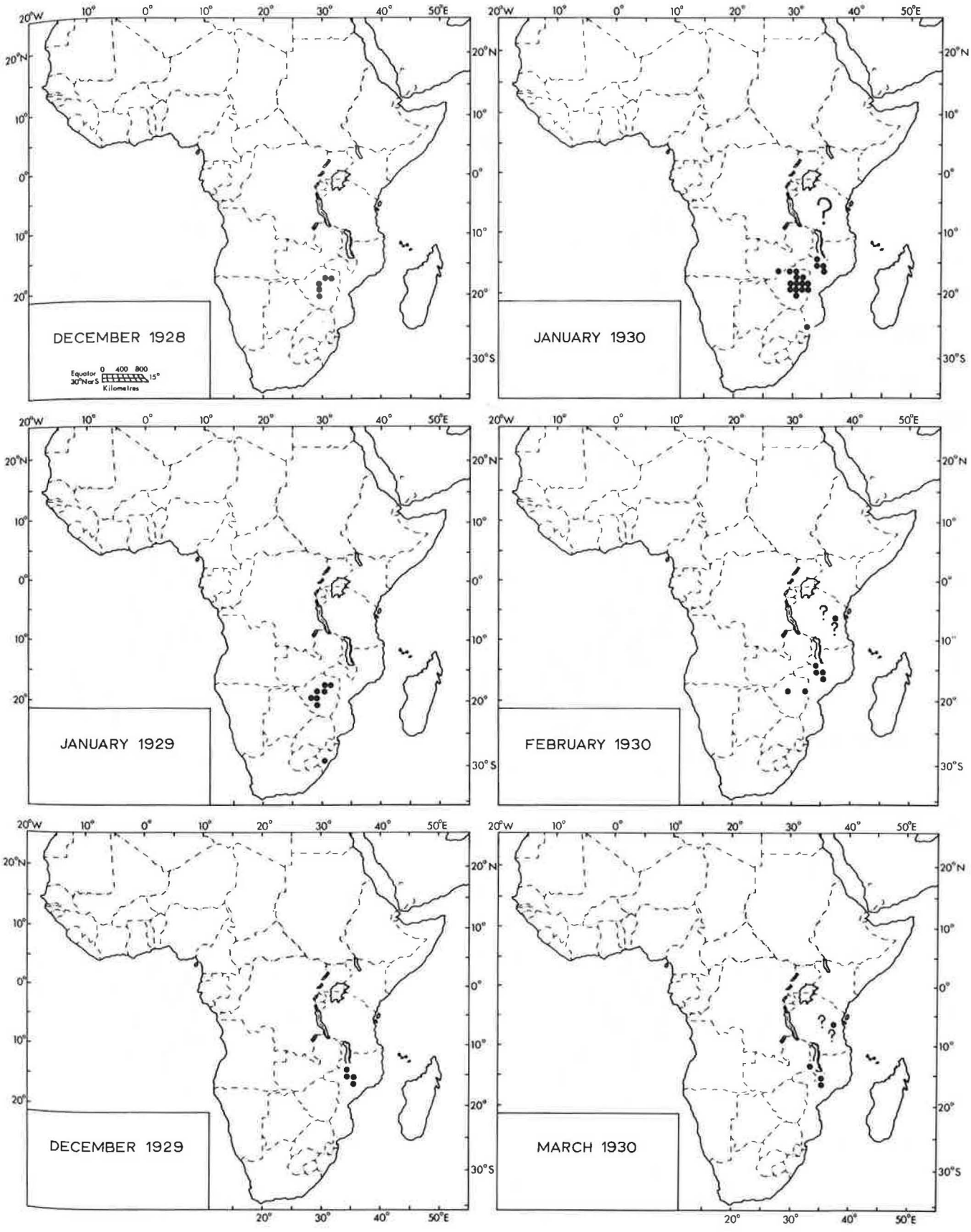
●	Infestations of larvae
p	Pupae from earlier outbreak
?	Locality of outbreak not recorded
s	Species of larvae not confirmed
u	Unconfirmed report
m	Month uncertain
yr?	Year uncertain (month recorded)

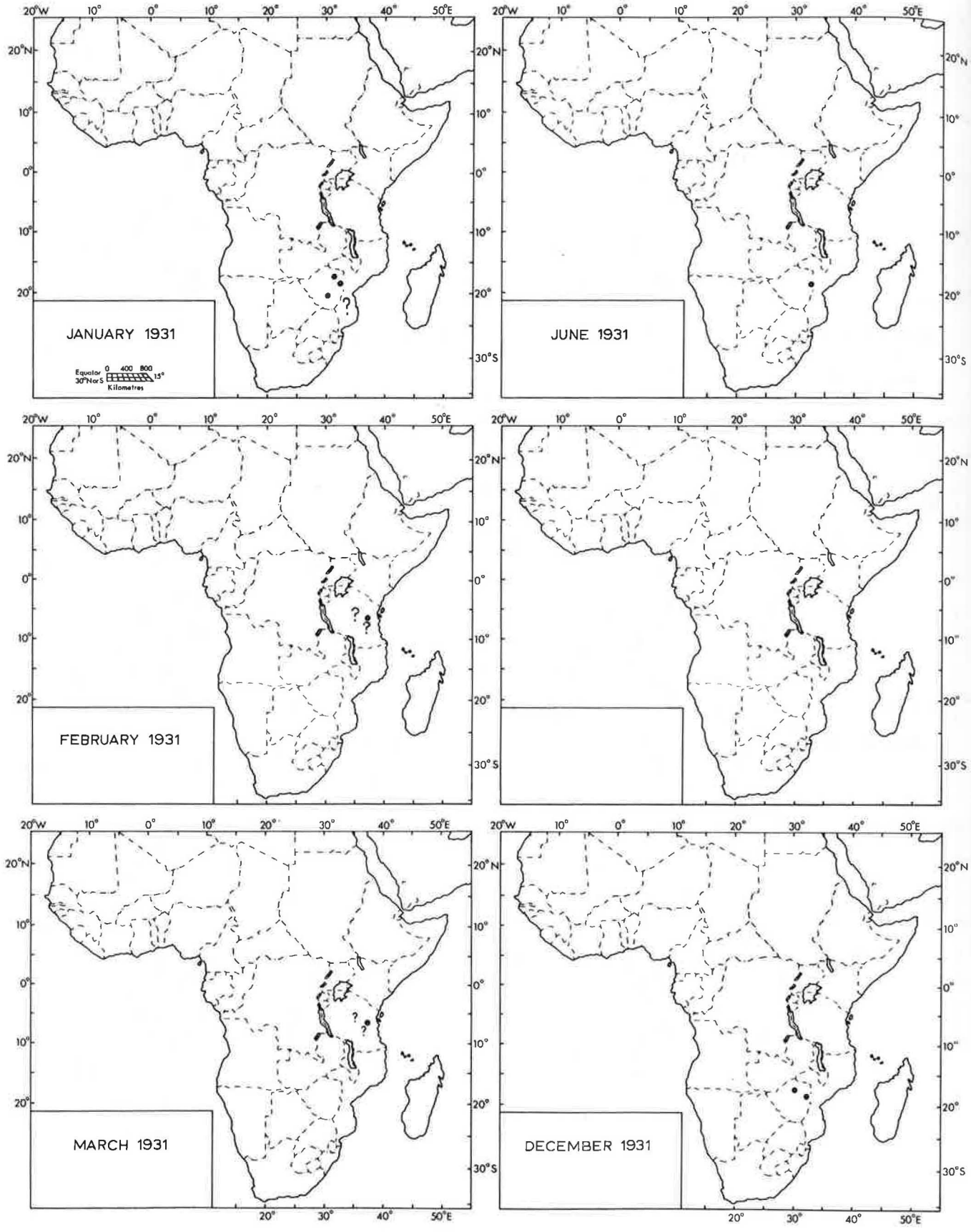

DECEMBER 1914
JANUARY 1915
APRIL 1915
FEBRUARY 1915
MAY 1915
Equator 0 400 800 15°
30°N or S
Kilometres

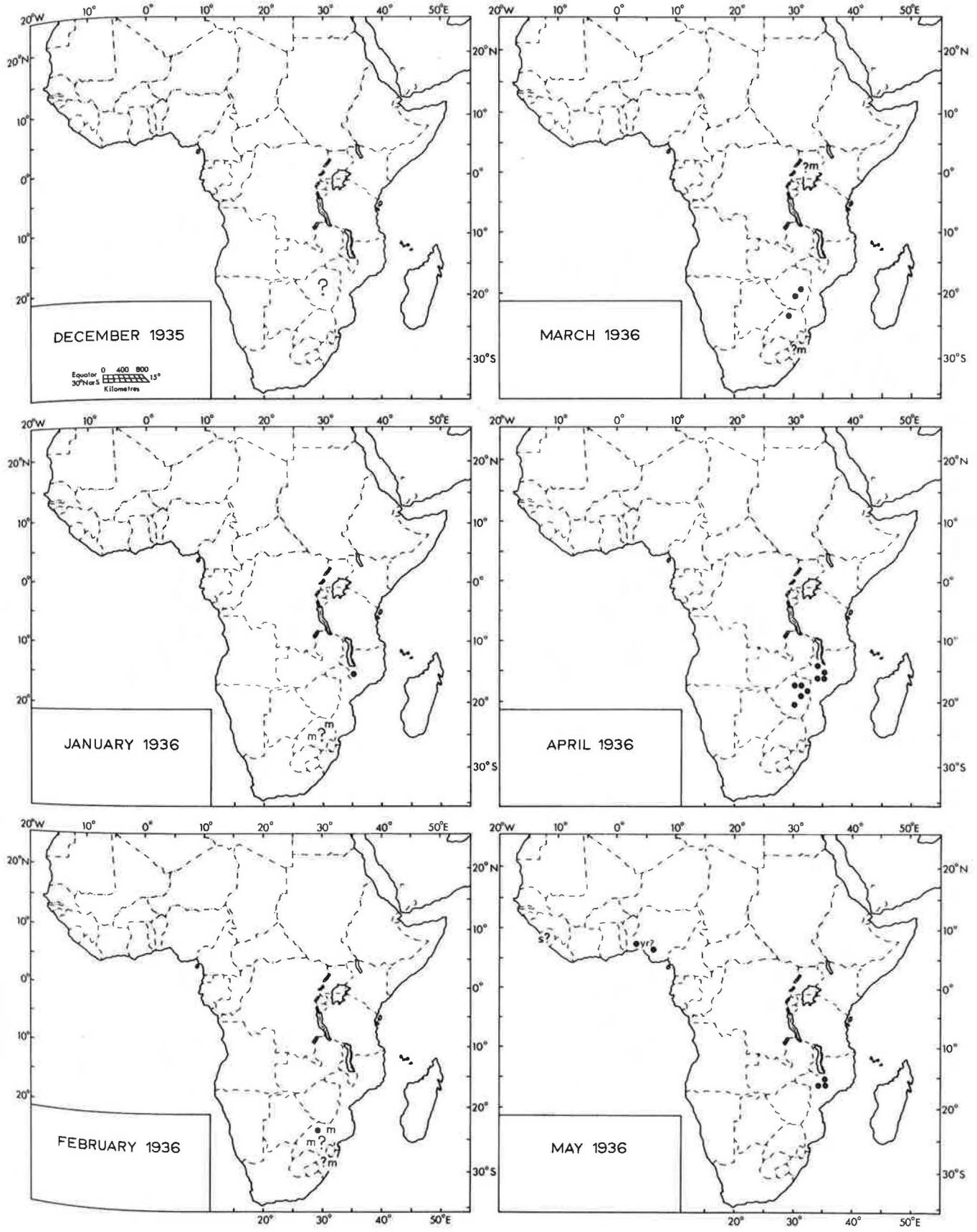

JANUARY 1919
Equator 0 400 800
30°N or S 15°
Kilometres
FEBRUARY 1919
MAY 1919
MARCH 1919
JUNE 1919

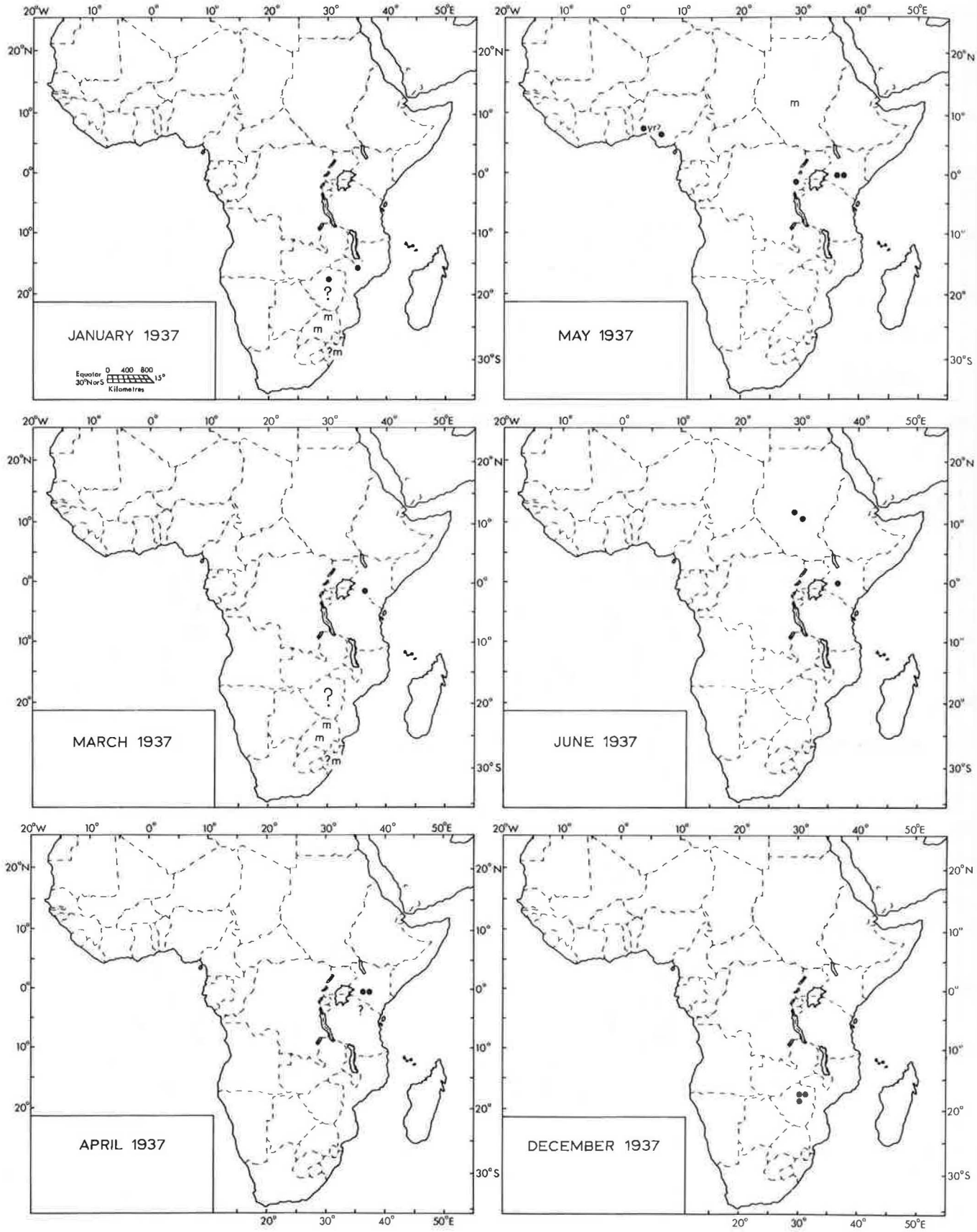

NOVEMBER 1920
Equator 0 400 800
30°N or S
Kilometres
FEBRUARY 1921
DECEMBER 1920
MARCH 1921
JANUARY 1921
APRIL 1921

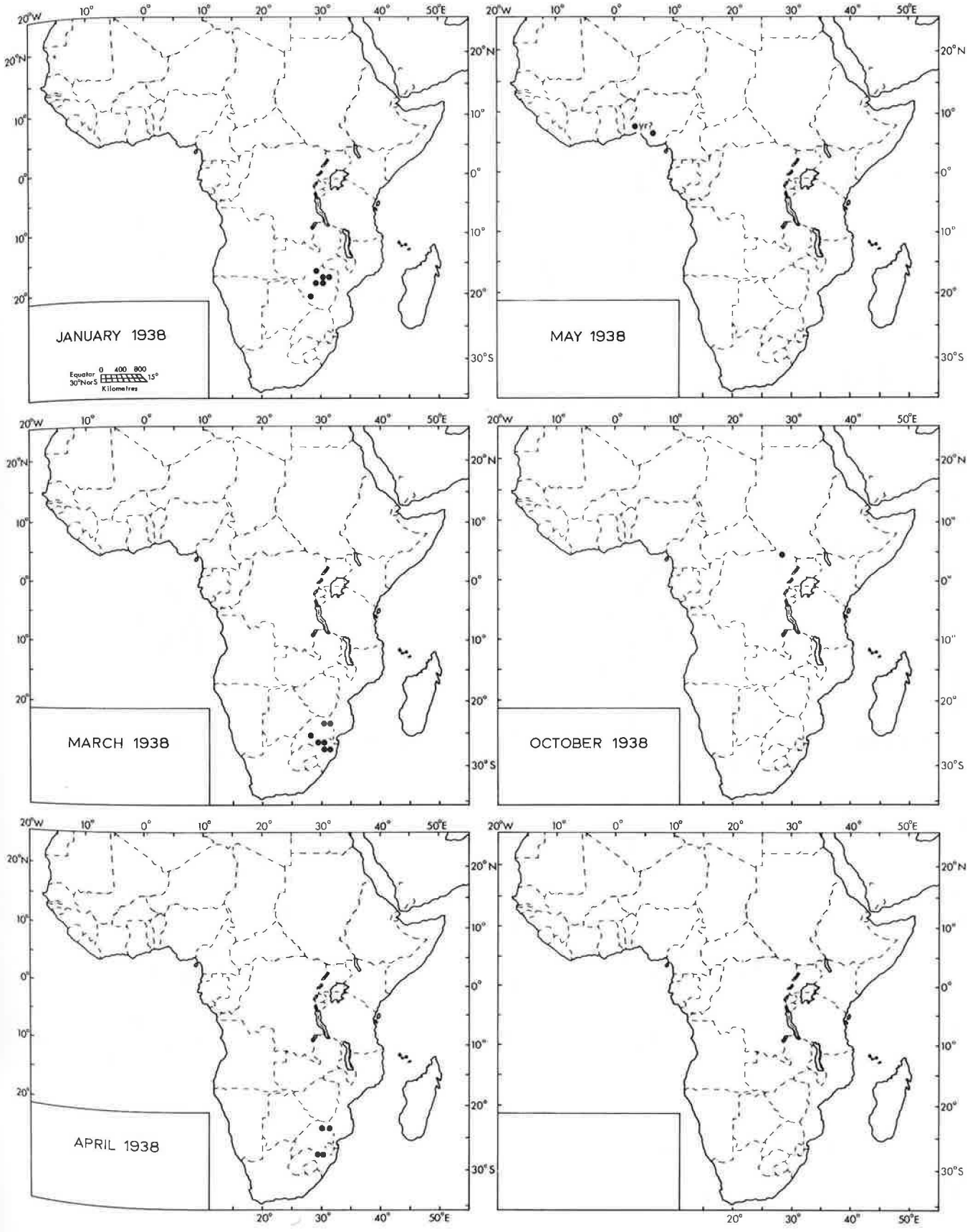

DECEMBER 1925
Equator 0 400 800 15°
30°N or S
Kilometres
MARCH 1926
?m
JANUARY 1926
APRIL 1926
?m
FEBRUARY 1926
MAY 1926
20°W 10° 0° 10° 20° 30° 40° 50°E
20°N 10° 0° 10° 20° 30°S

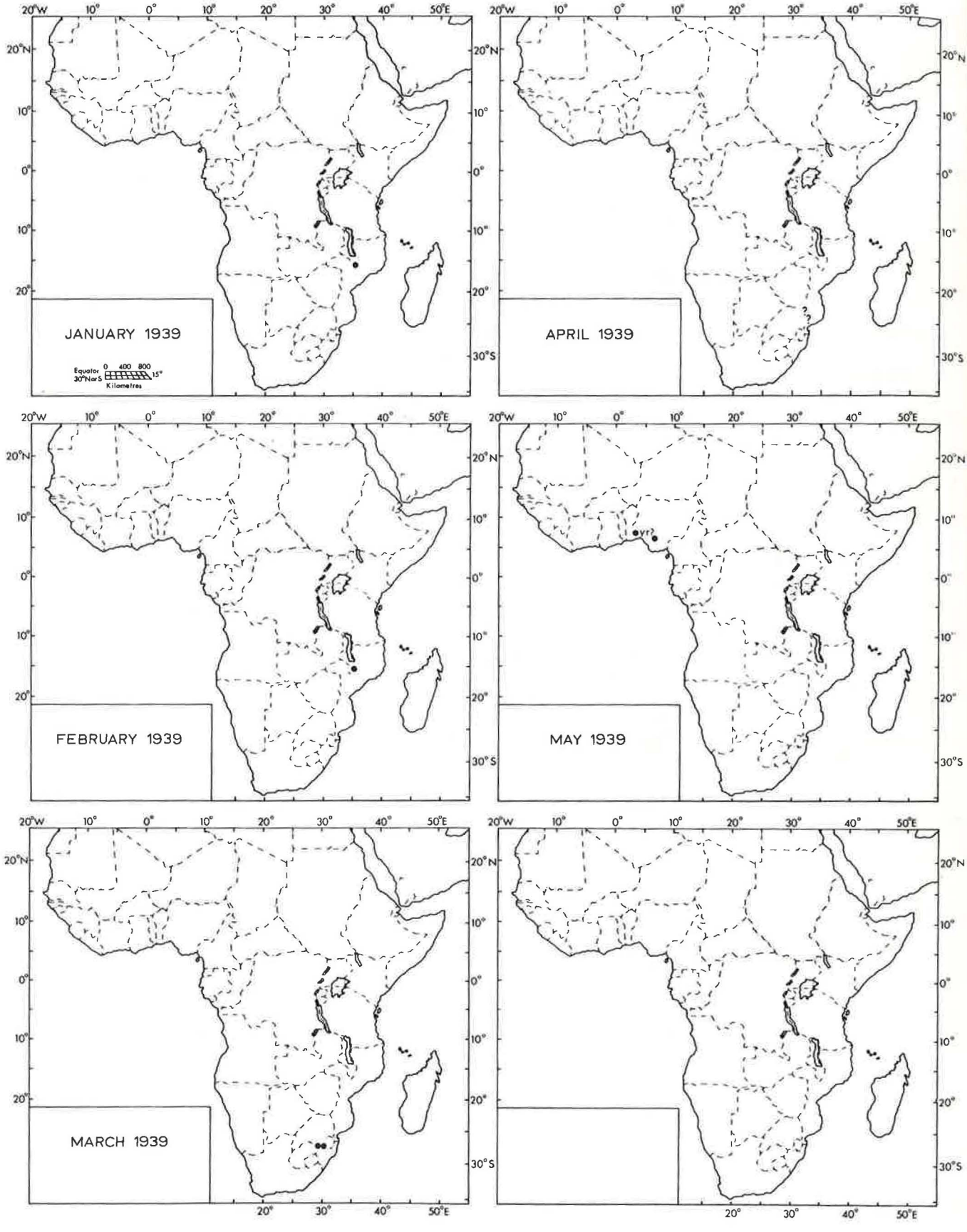

DECEMBER 1928
JANUARY 1930
JANUARY 1929
FEBRUARY 1930
DECEMBER 1929
MARCH 1930
Equator 0 400 800 15°
30°N or S
Kilometres

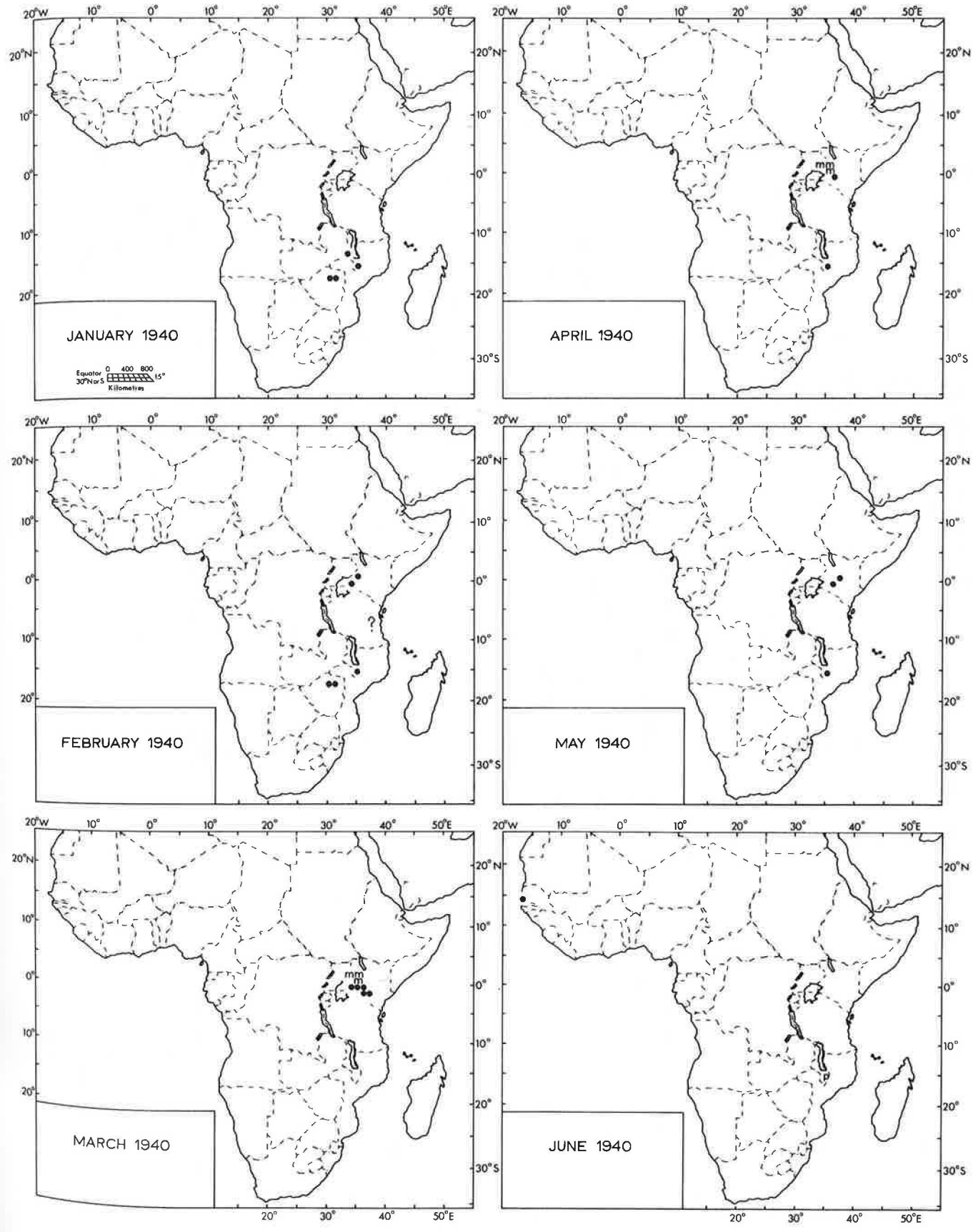

JANUARY 1931
Equator 0 400 800 15°
30°N or S
Kilometres
JUNE 1931
FEBRUARY 1931
MARCH 1931
DECEMBER 1931

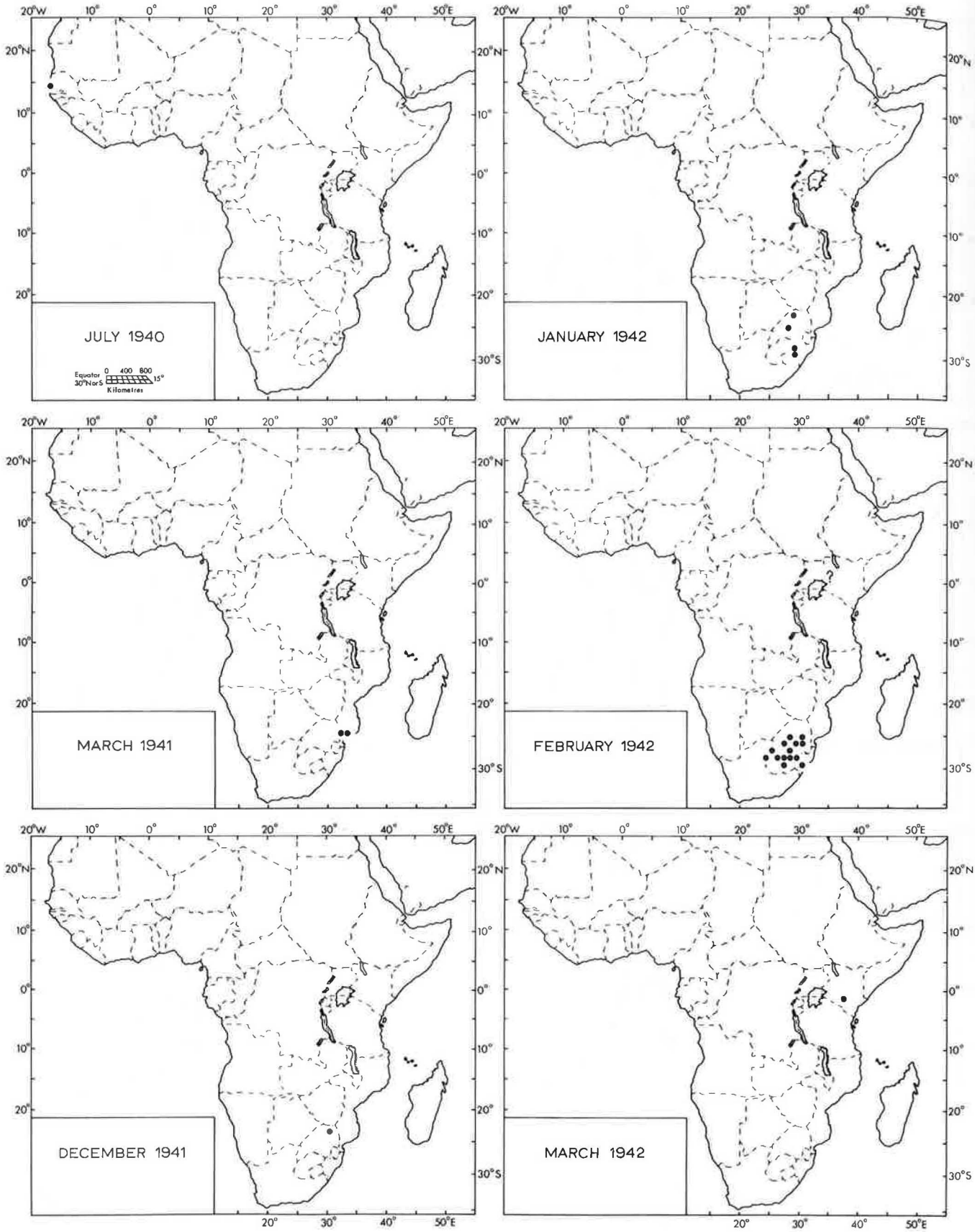

DECEMBER 1935
Equator 0 400 800
30°N or S 15°
Kilometres
?
MARCH 1936
?m
?m
JANUARY 1936
m
?
m
APRIL 1936
FEBRUARY 1936
m
m
?
m
MAY 1936
s?
yr?

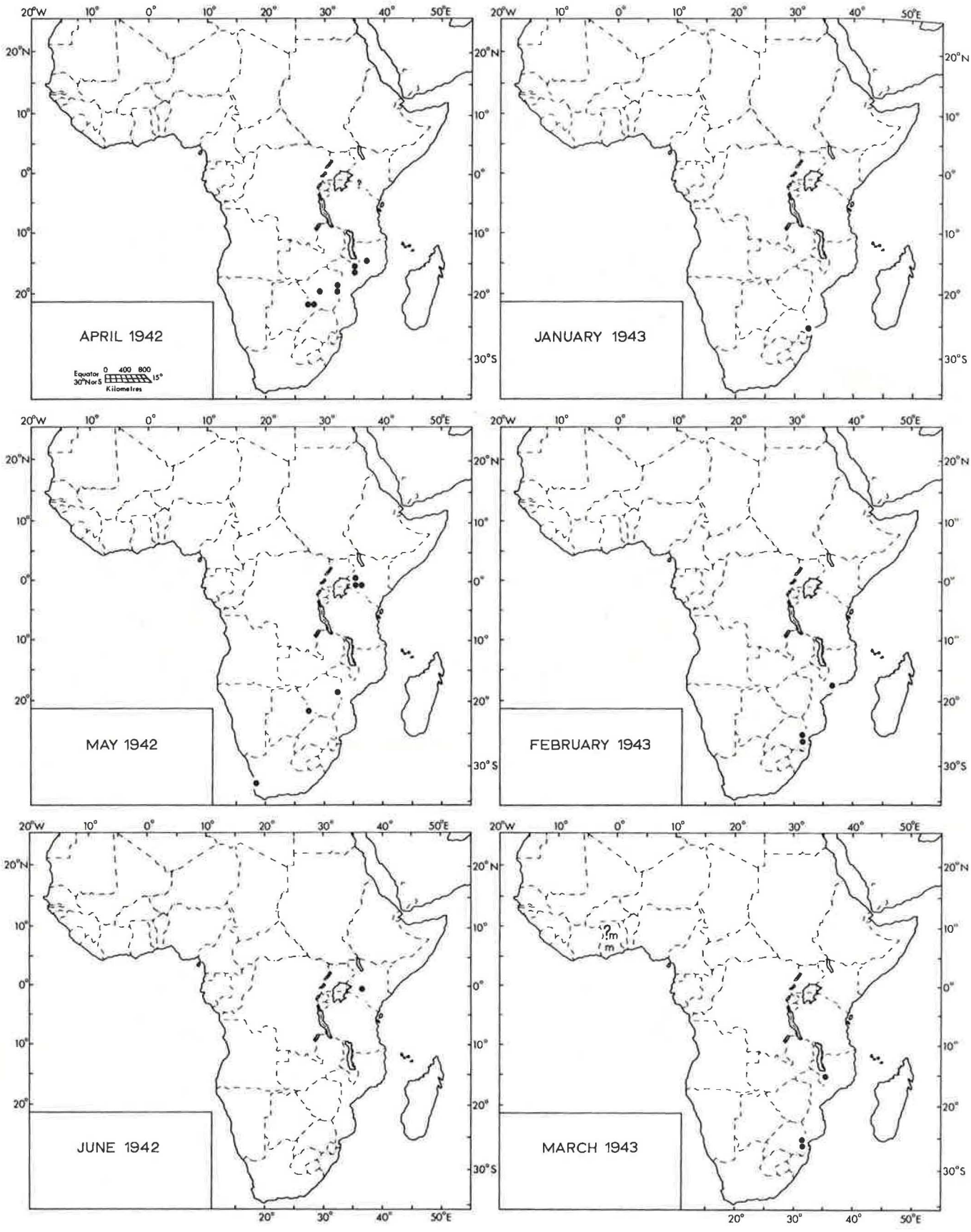

JANUARY 1937
MAY 1937
MARCH 1937
JUNE 1937
APRIL 1937
DECEMBER 1937
Equator 0 400 800
30°N or S 15°
Kilometres

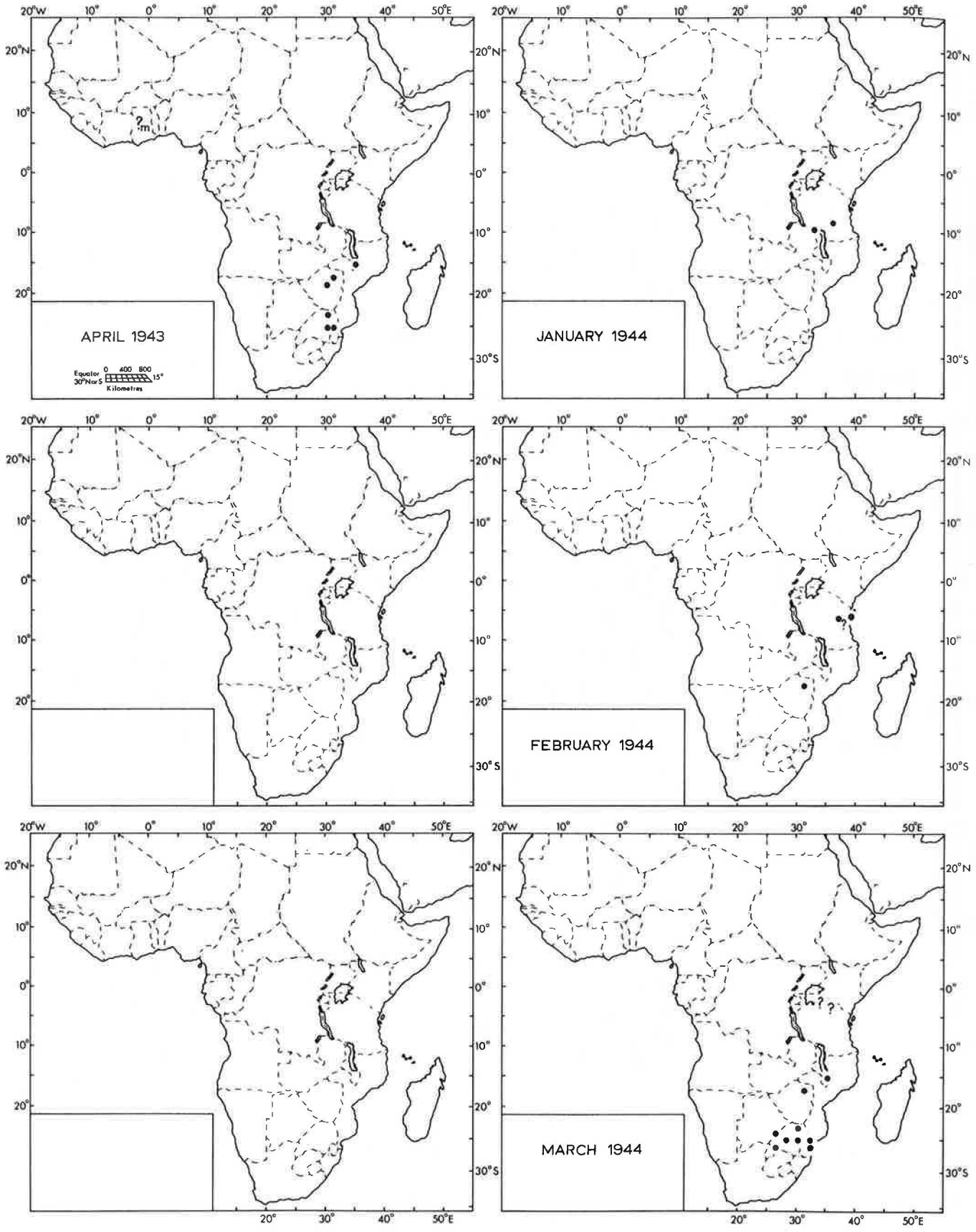

JANUARY 1938
MAY 1938
MARCH 1938
OCTOBER 1938
APRIL 1938
Equator 0 400 800 15°
30°N or S
Kilometres

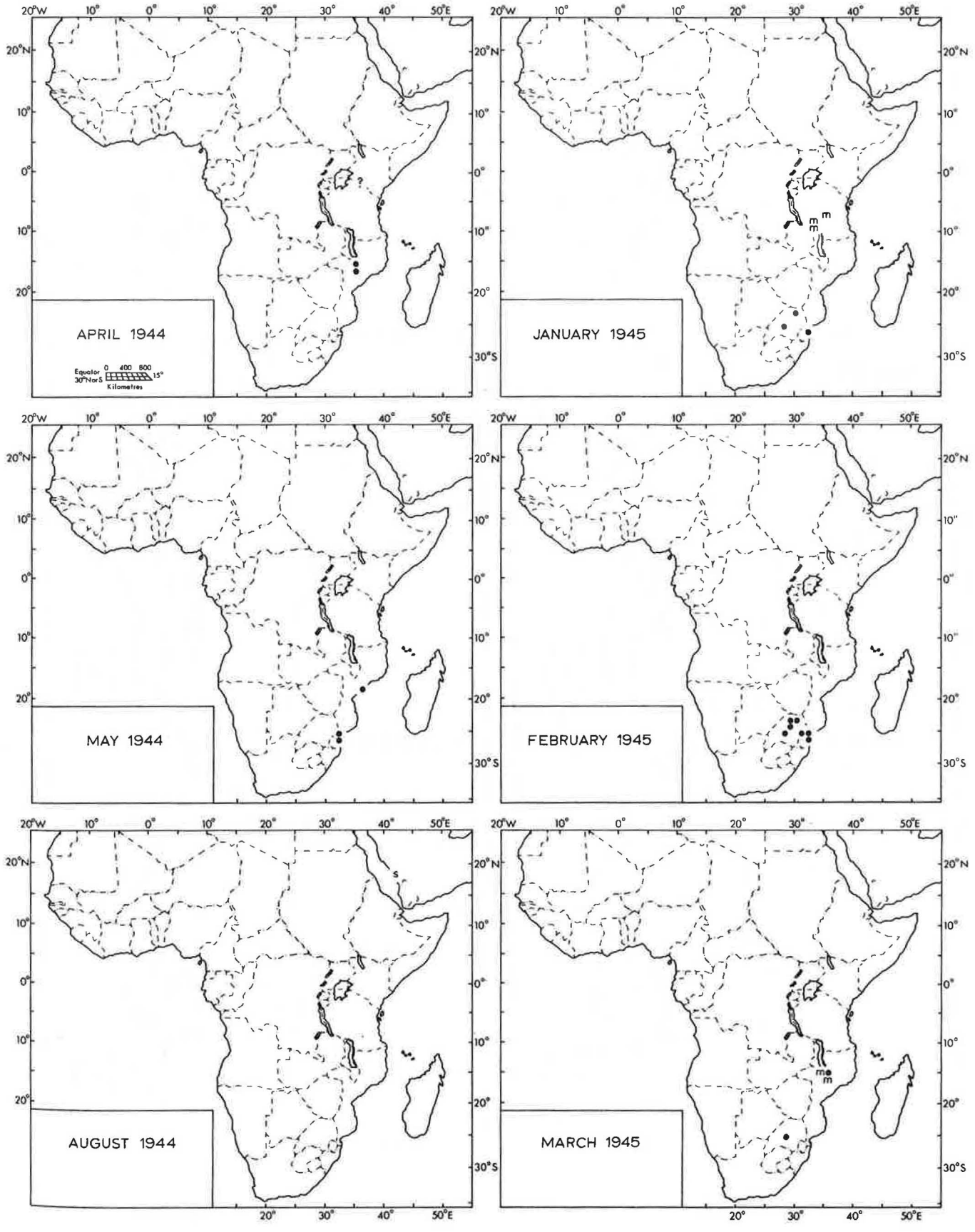

JANUARY 1939
Equator 0 400 800
30°N or S 15°
Kilometres
APRIL 1939
FEBRUARY 1939
MAY 1939
yr?
MARCH 1939

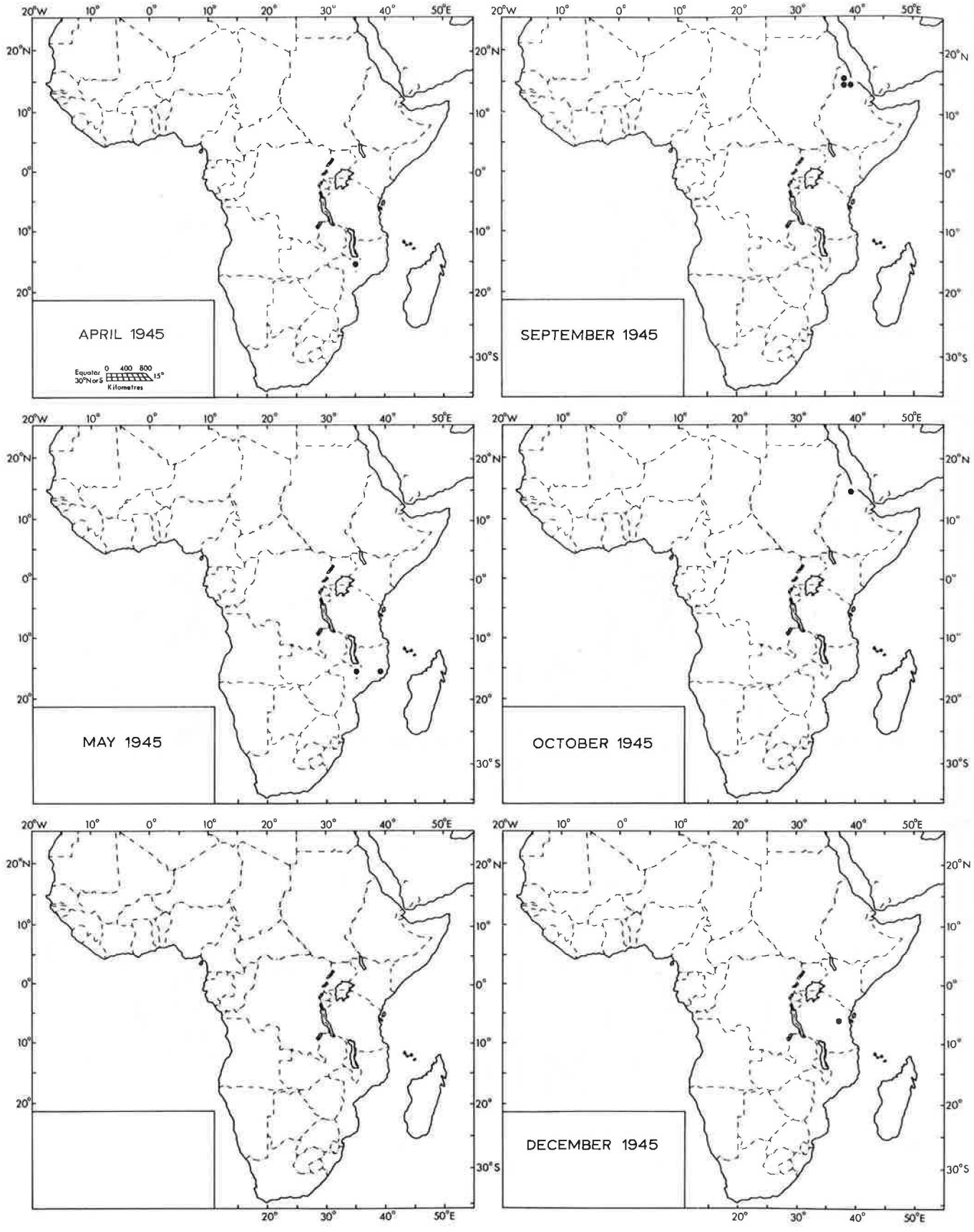

JANUARY 1940
APRIL 1940
FEBRUARY 1940
MAY 1940
MARCH 1940
JUNE 1940
Equator 0 400 800 15°
30°N or S
Kilometres

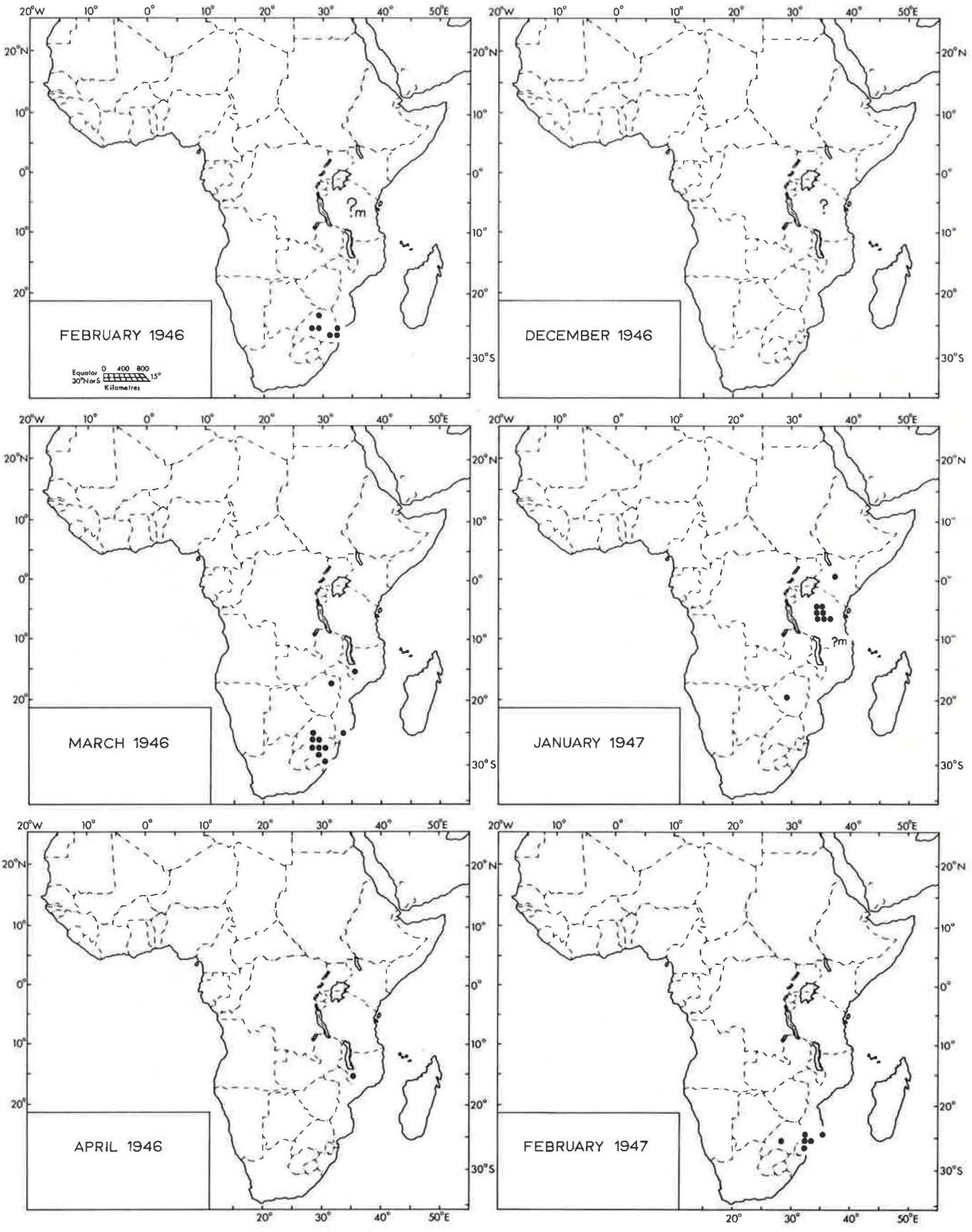

JULY 1940
Equator 0 400 800
30°N or S 15°
Kilometres
JANUARY 1942
MARCH 1941
FEBRUARY 1942
DECEMBER 1941
MARCH 1942

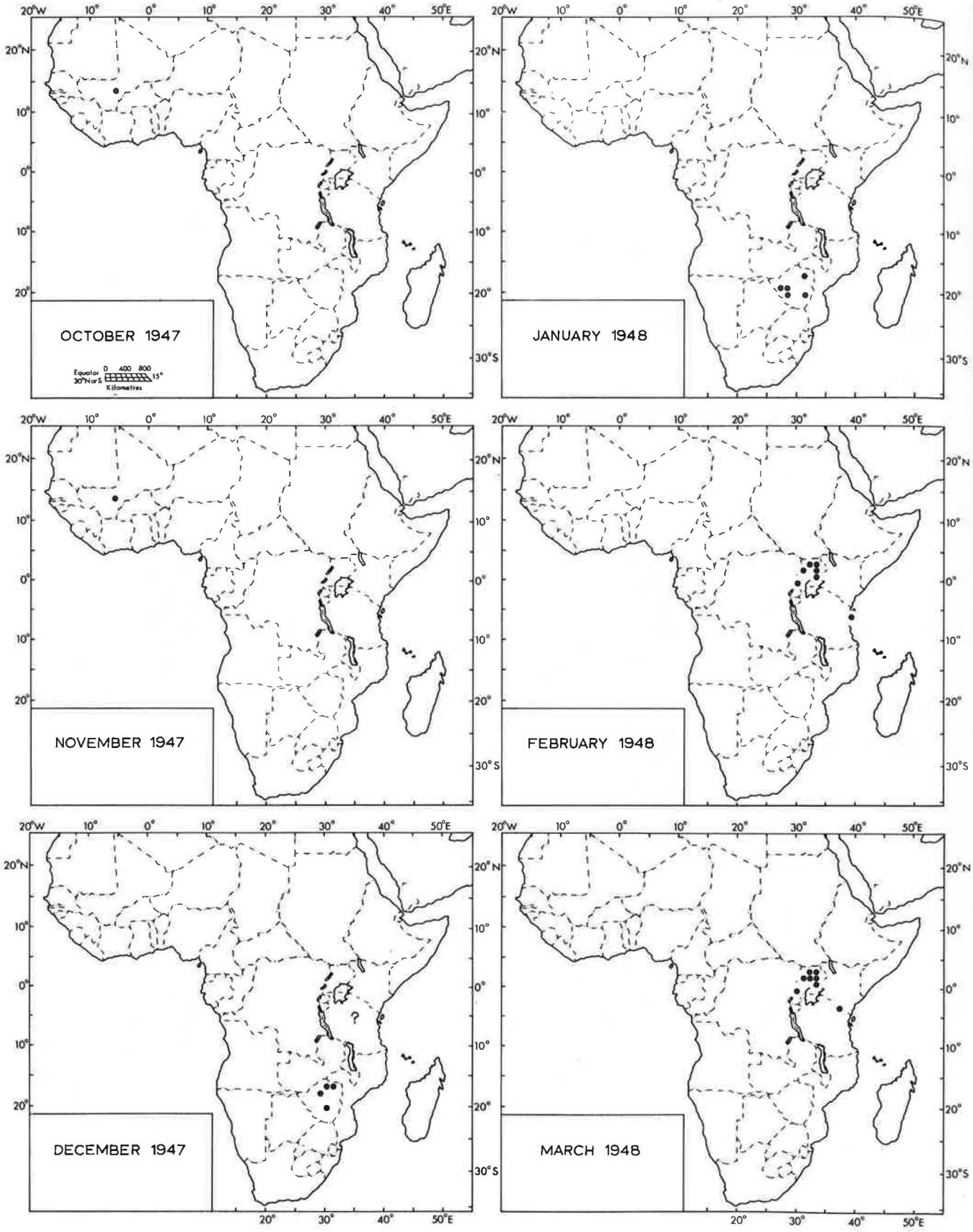

APRIL 1942
Equator 0 400 800
30°N or S 15°
Kilometres
JANUARY 1943
MAY 1942
FEBRUARY 1943
JUNE 1942
?m
m
MARCH 1943

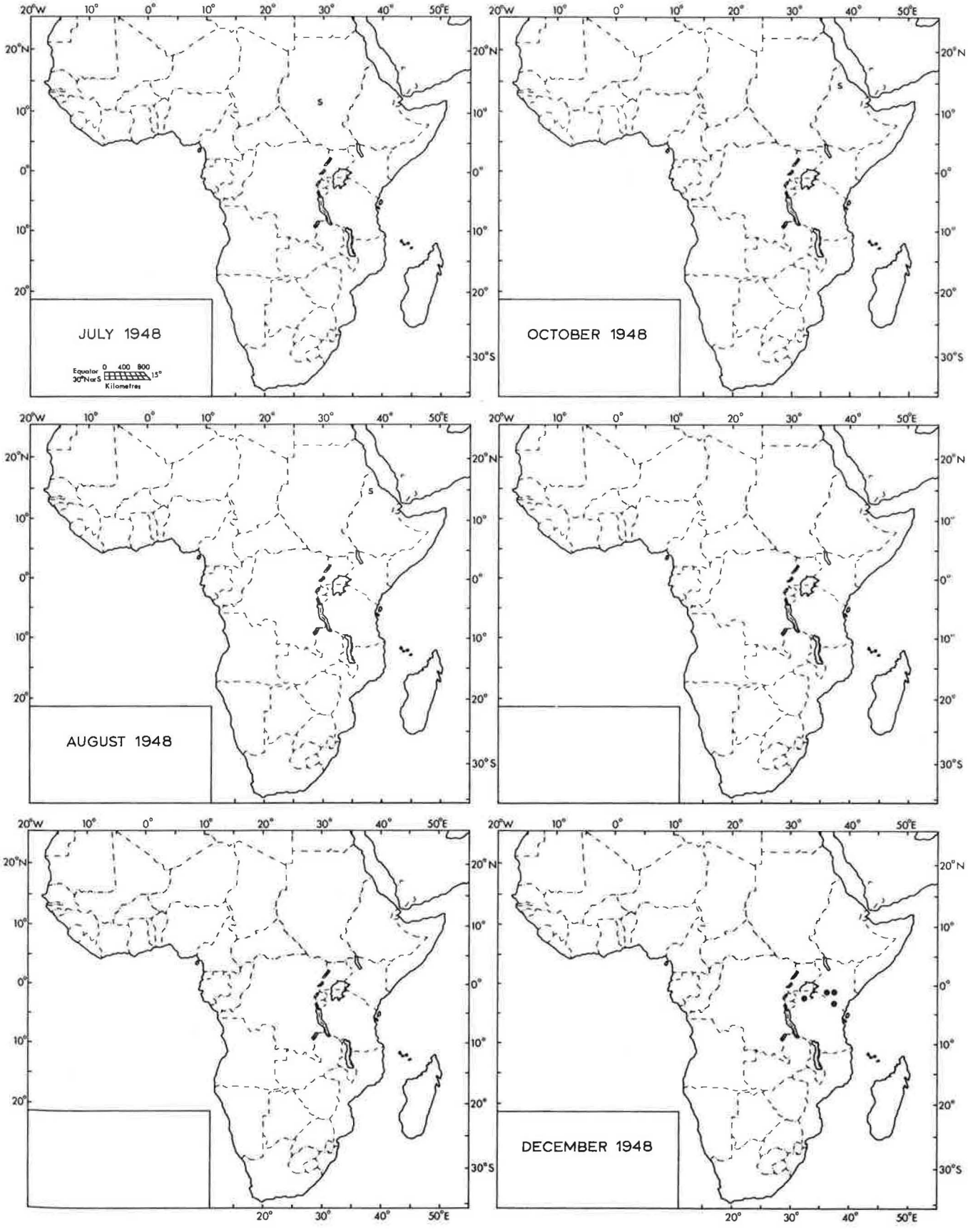

APRIL 1943
JANUARY 1944
FEBRUARY 1944
MARCH 1944
Equator 0 400 800
30°N or S 15°
Kilometres

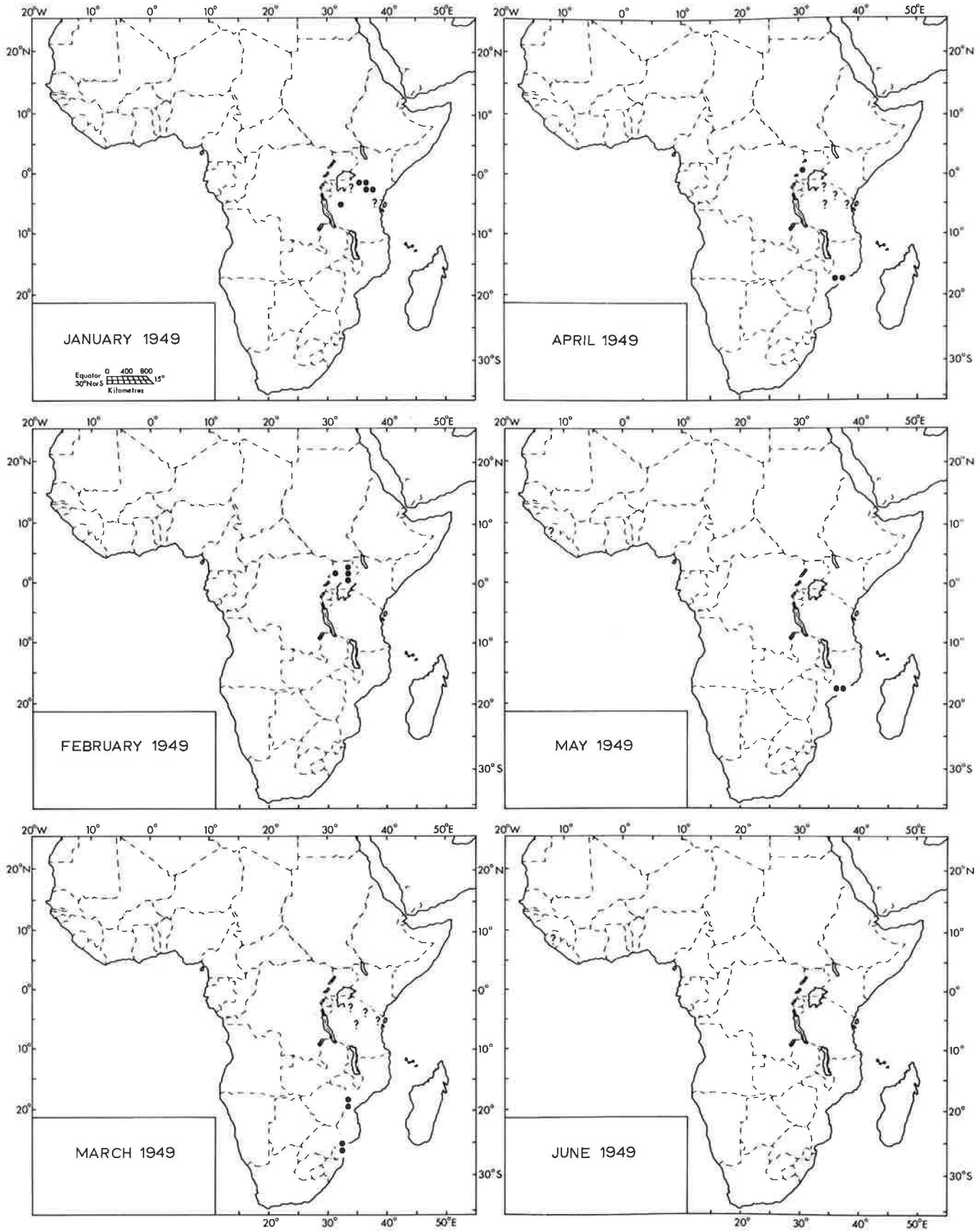

APRIL 1944
JANUARY 1945
MAY 1944
FEBRUARY 1945
AUGUST 1944
MARCH 1945
Equator 0 400 800 15°
30°N or S
Kilometres

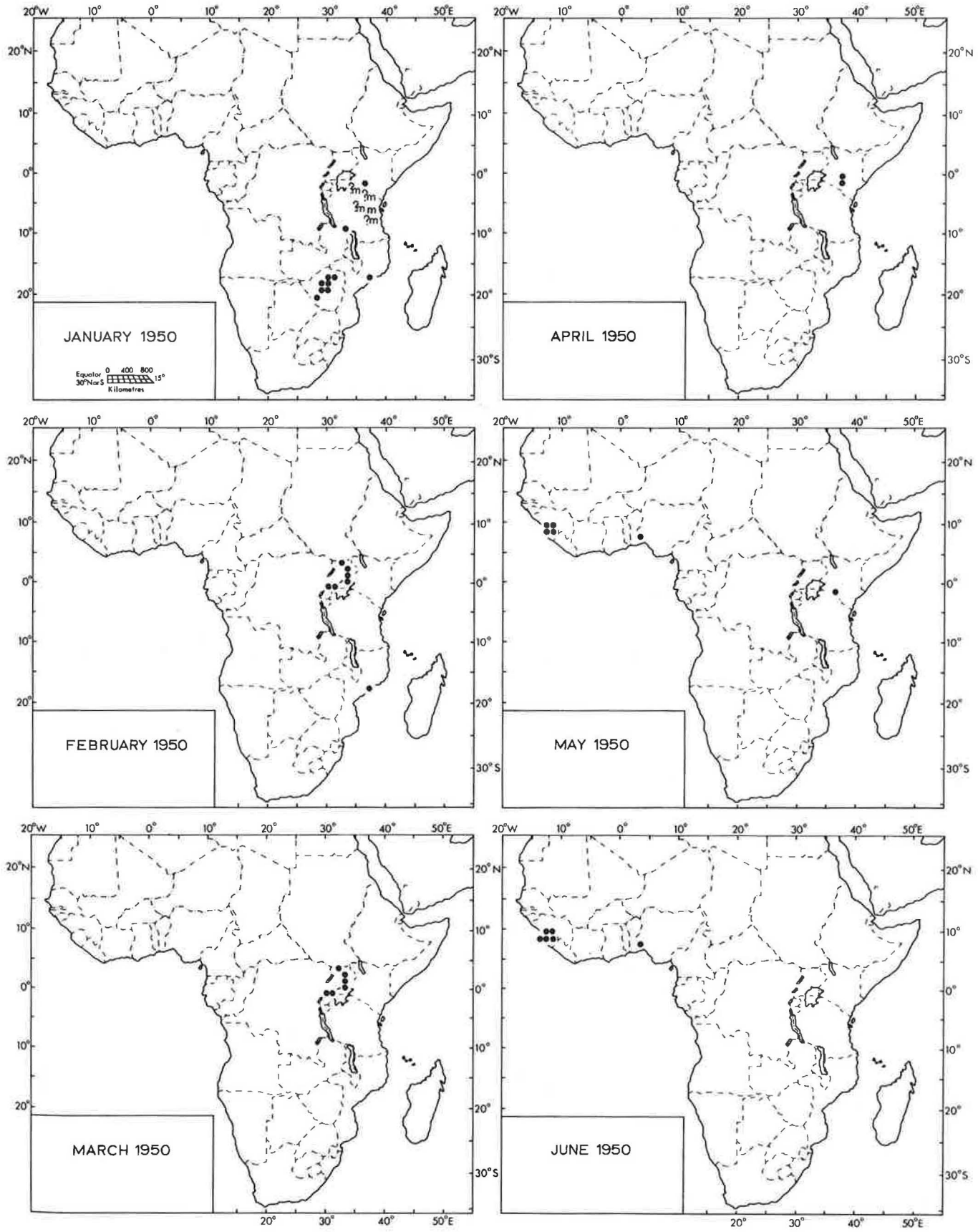

APRIL 1945
Equator 0 400 800 15°
30°N or S Kilometres
SEPTEMBER 1945
MAY 1945
OCTOBER 1945
DECEMBER 1945

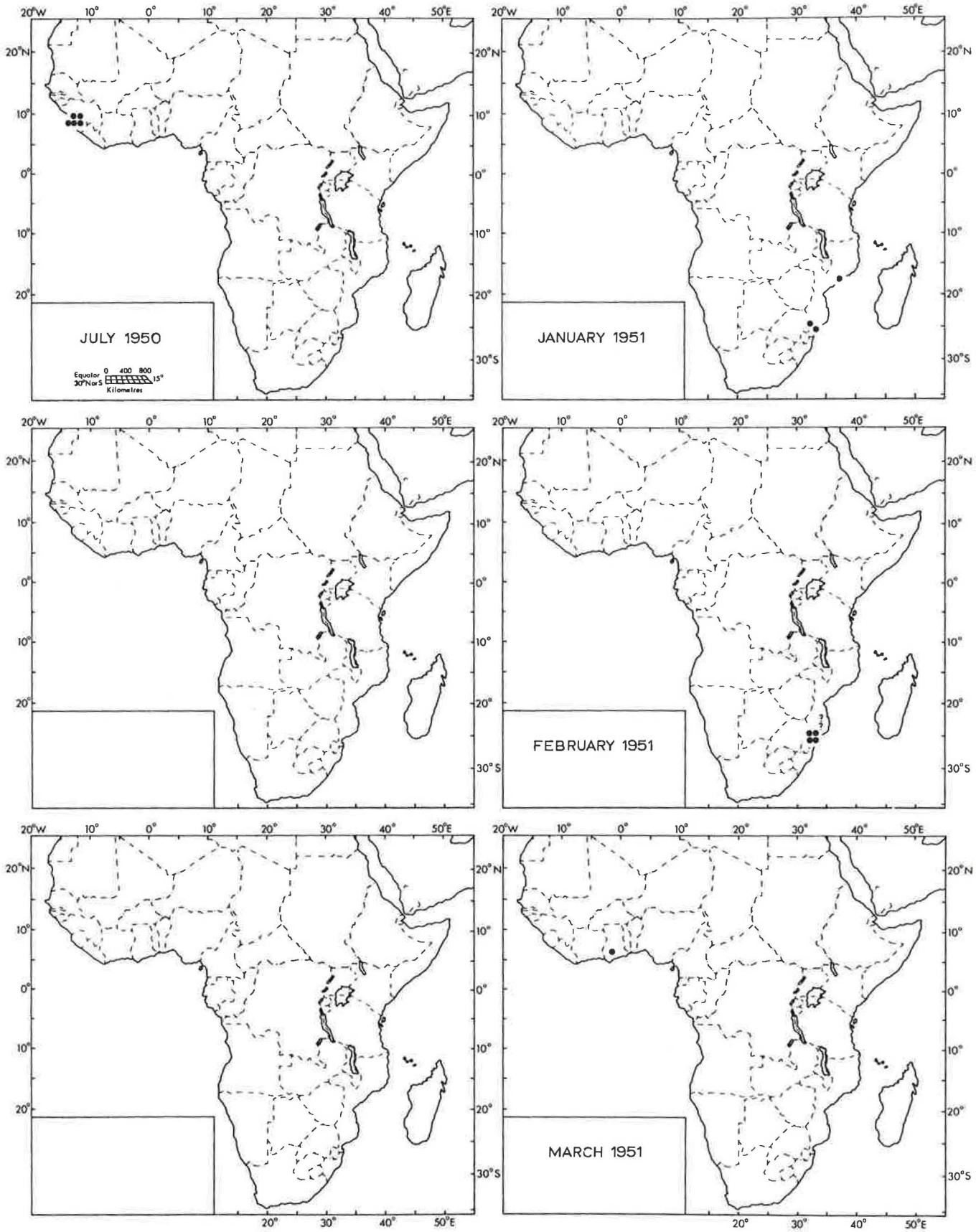

FEBRUARY 1946
?m
Equator 0 400 800
30°N or S 15°
Kilometres
DECEMBER 1946
?
MARCH 1946
JANUARY 1947
?m
APRIL 1946
FEBRUARY 1947
20°W
10°
0°
10°
20°
30°
40°
50°E
20°N
10°
0°
10°
20°
30°S

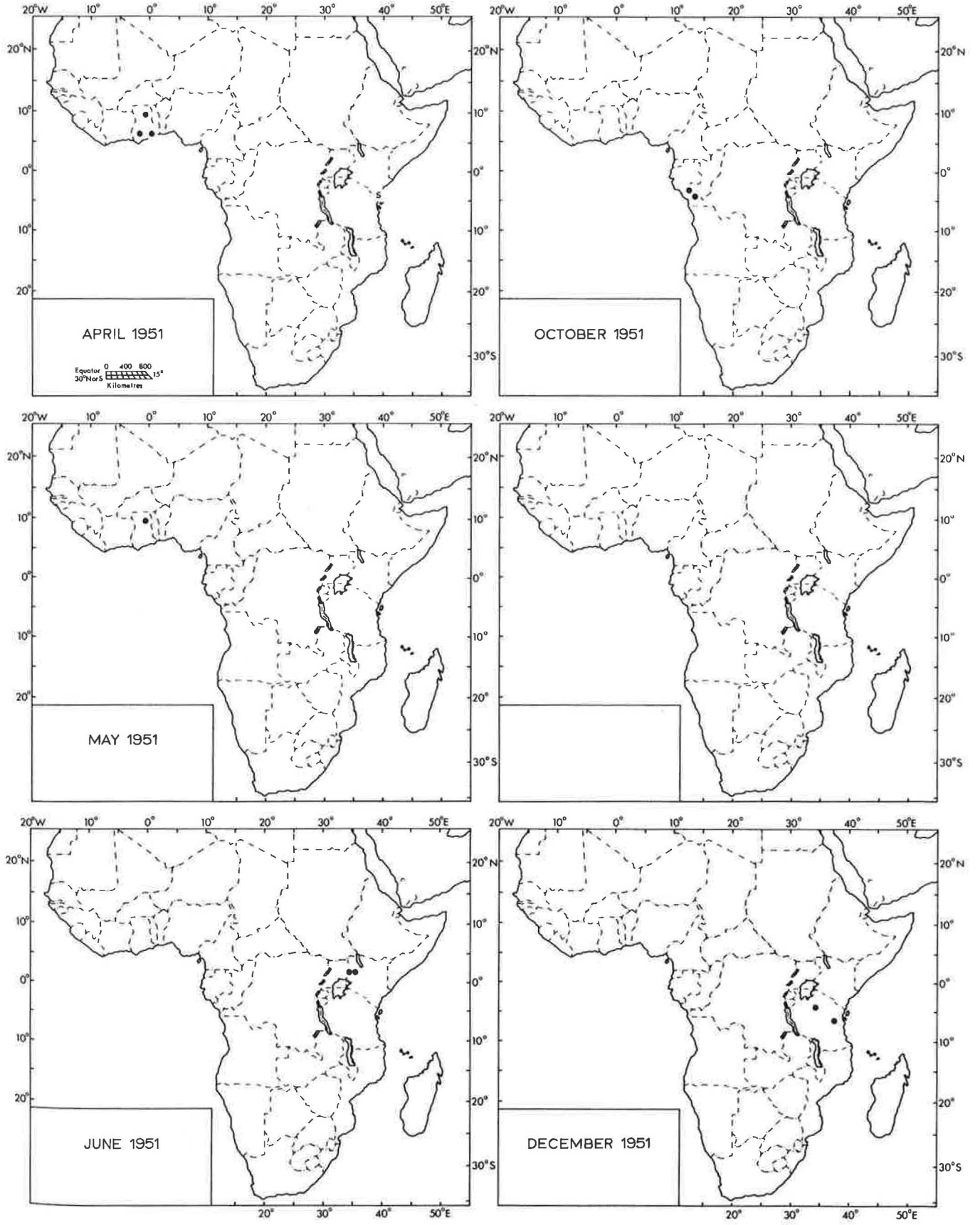

OCTOBER 1947
JANUARY 1948
NOVEMBER 1947
FEBRUARY 1948
DECEMBER 1947
MARCH 1948
Equator 0 400 800 15°
30°N or S
Kilometres
20°W 10° 0° 10° 20° 30° 40° 50°E
20°N 10° 0° 10° 20° 30°S
?

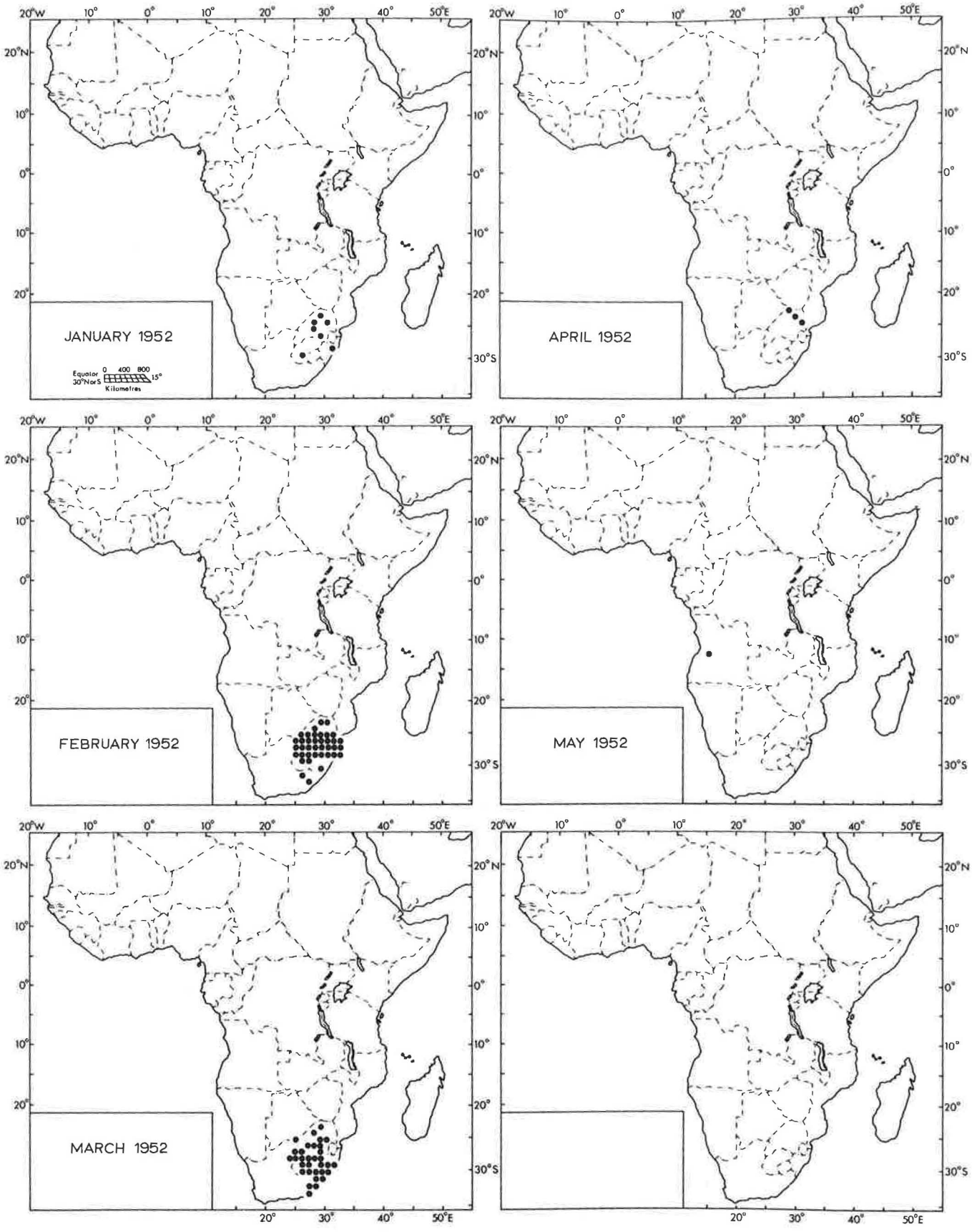

JULY 1948
Equator 0 400 800
30°N or S 15°
Kilometres
OCTOBER 1948
AUGUST 1948
DECEMBER 1948

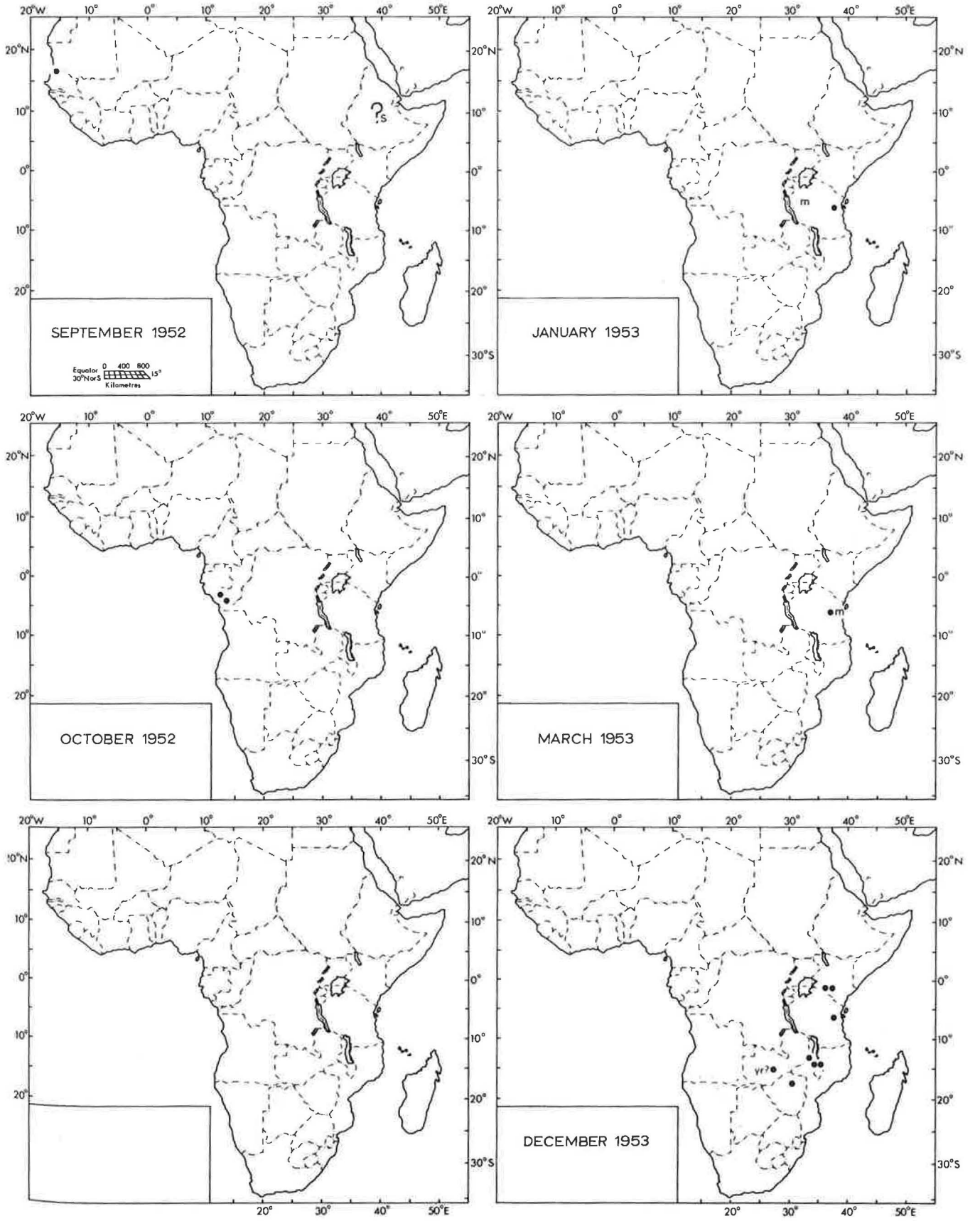

JANUARY 1949
Equator 0 400 800
30°N or S 15°
Kilometres
APRIL 1949
FEBRUARY 1949
MAY 1949
MARCH 1949
JUNE 1949

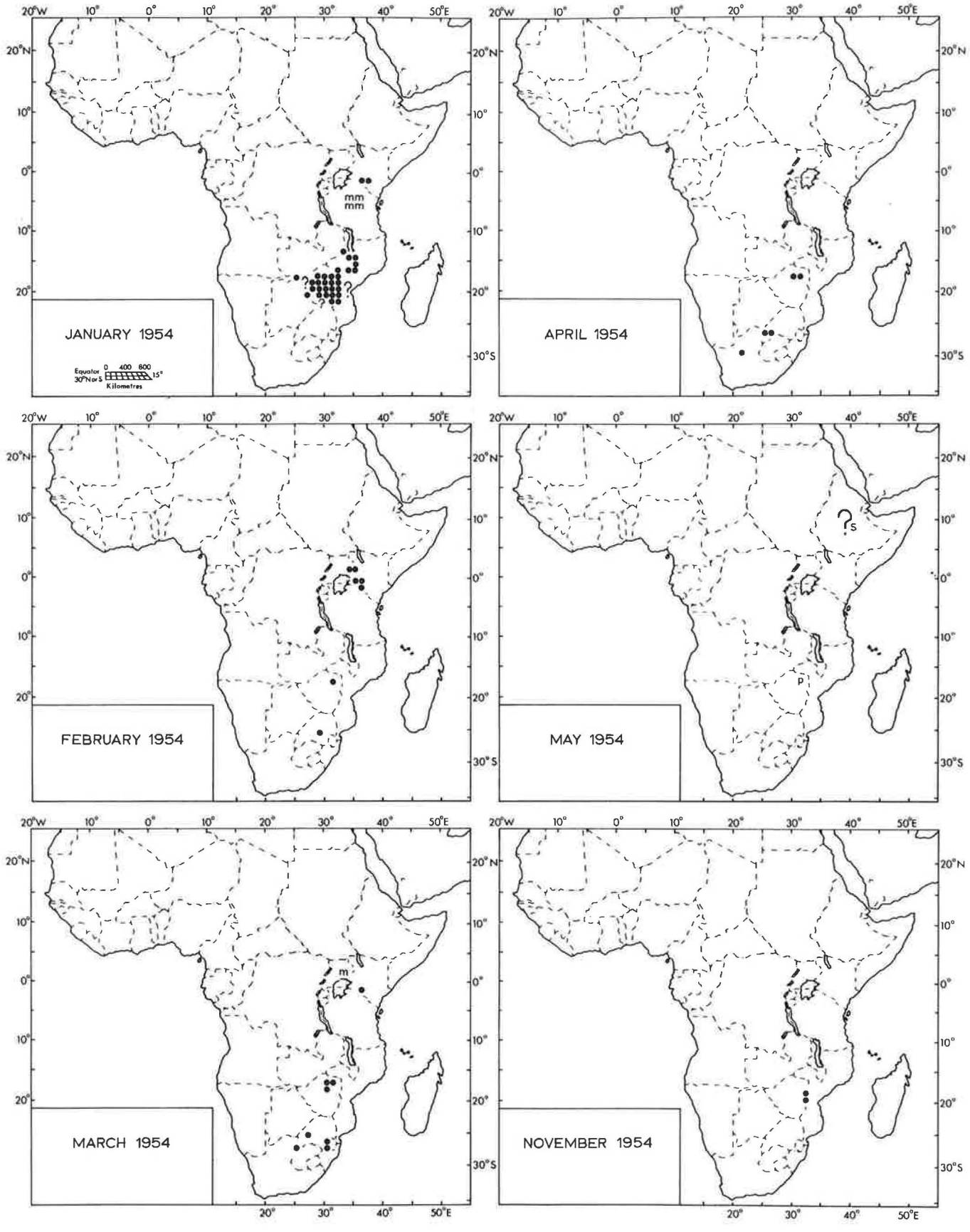

JANUARY 1950
APRIL 1950
FEBRUARY 1950
MAY 1950
MARCH 1950
JUNE 1950
Equator 0 400 800 15°
30°N or S
Kilometres

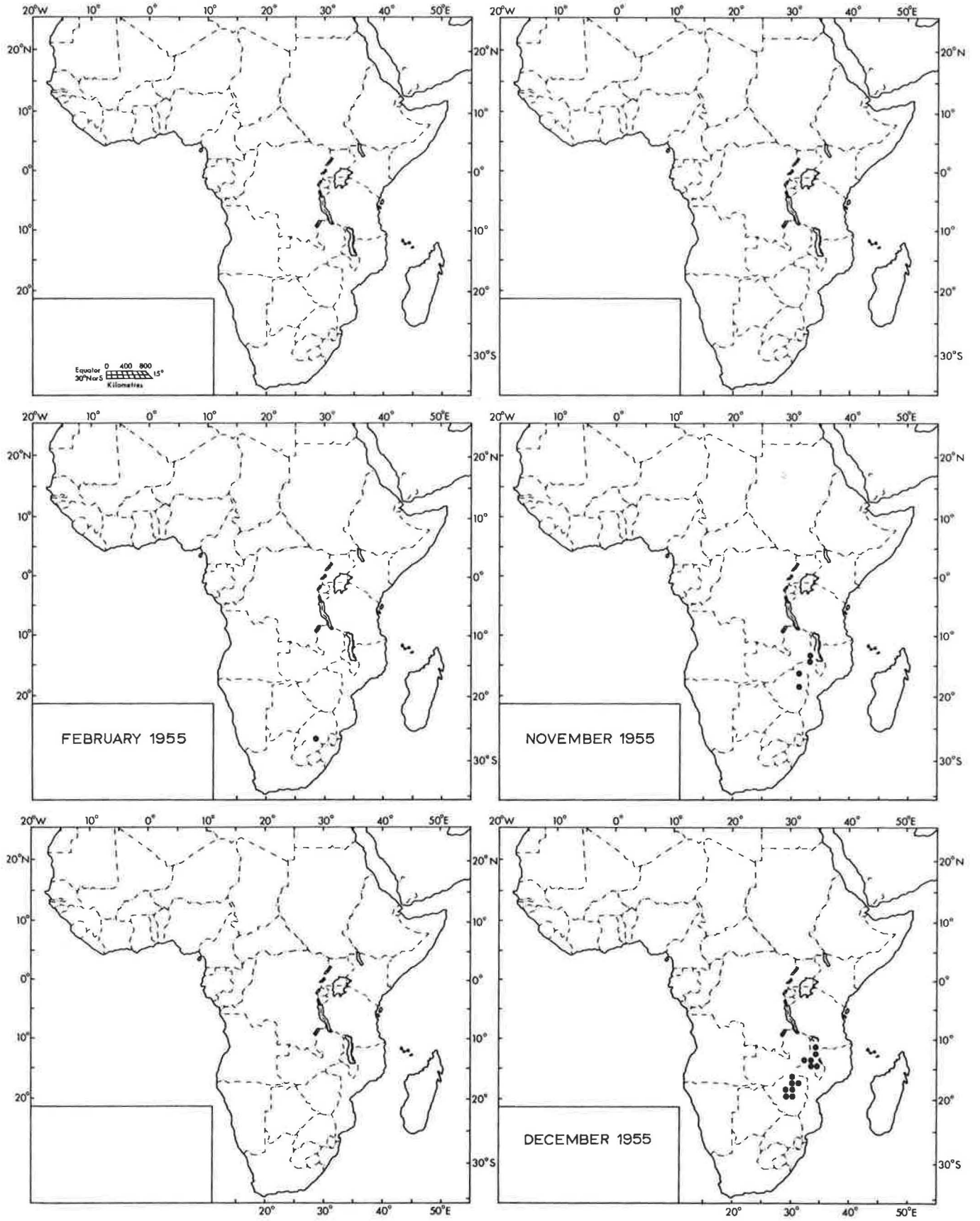

JULY 1950
Equator 0 400 800
30°N or S 15°
Kilometres
JANUARY 1951
FEBRUARY 1951
MARCH 1951

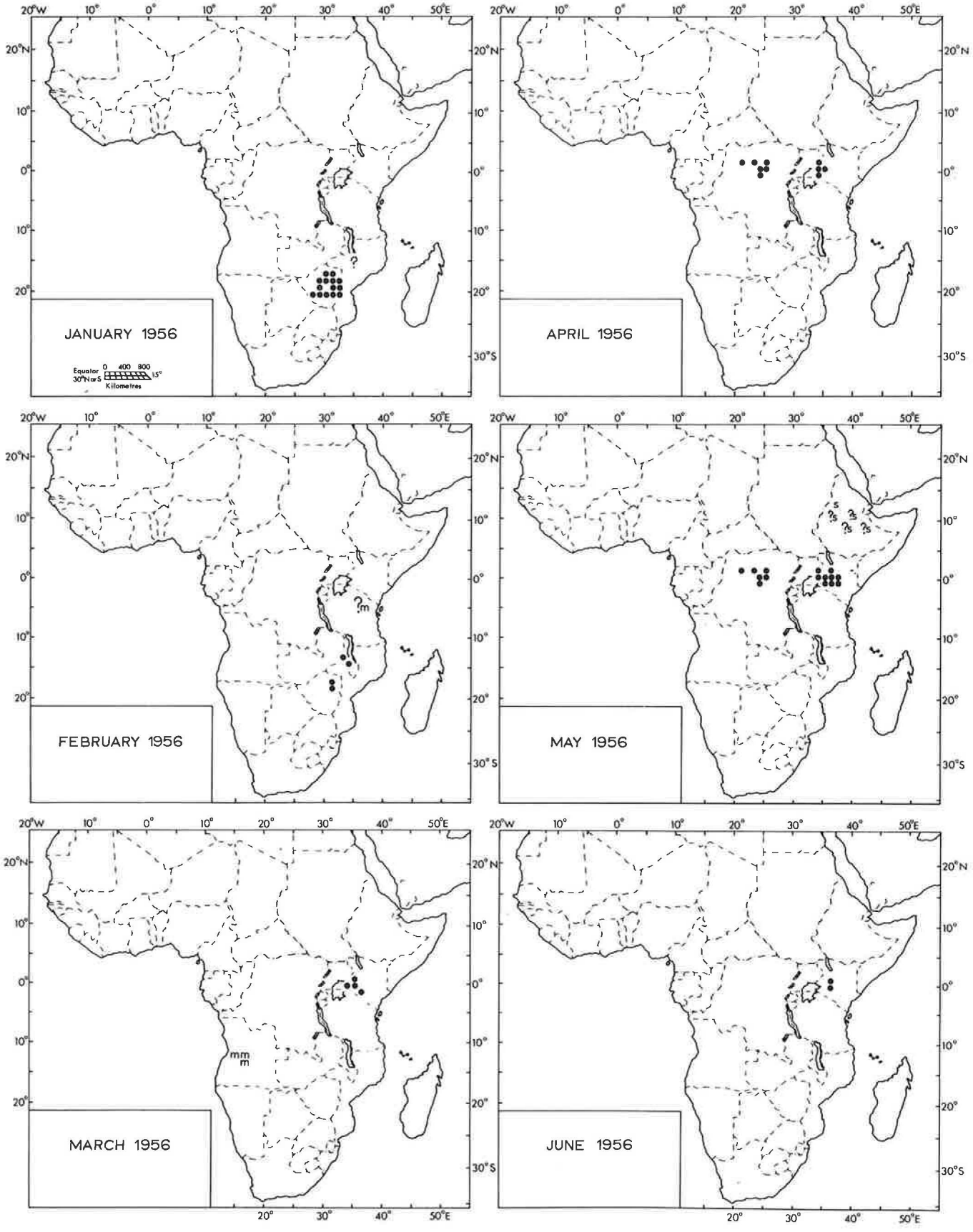

APRIL 1951
OCTOBER 1951
MAY 1951
JUNE 1951
DECEMBER 1951
Equator 0 400 800
30°N or S 15°
Kilometres

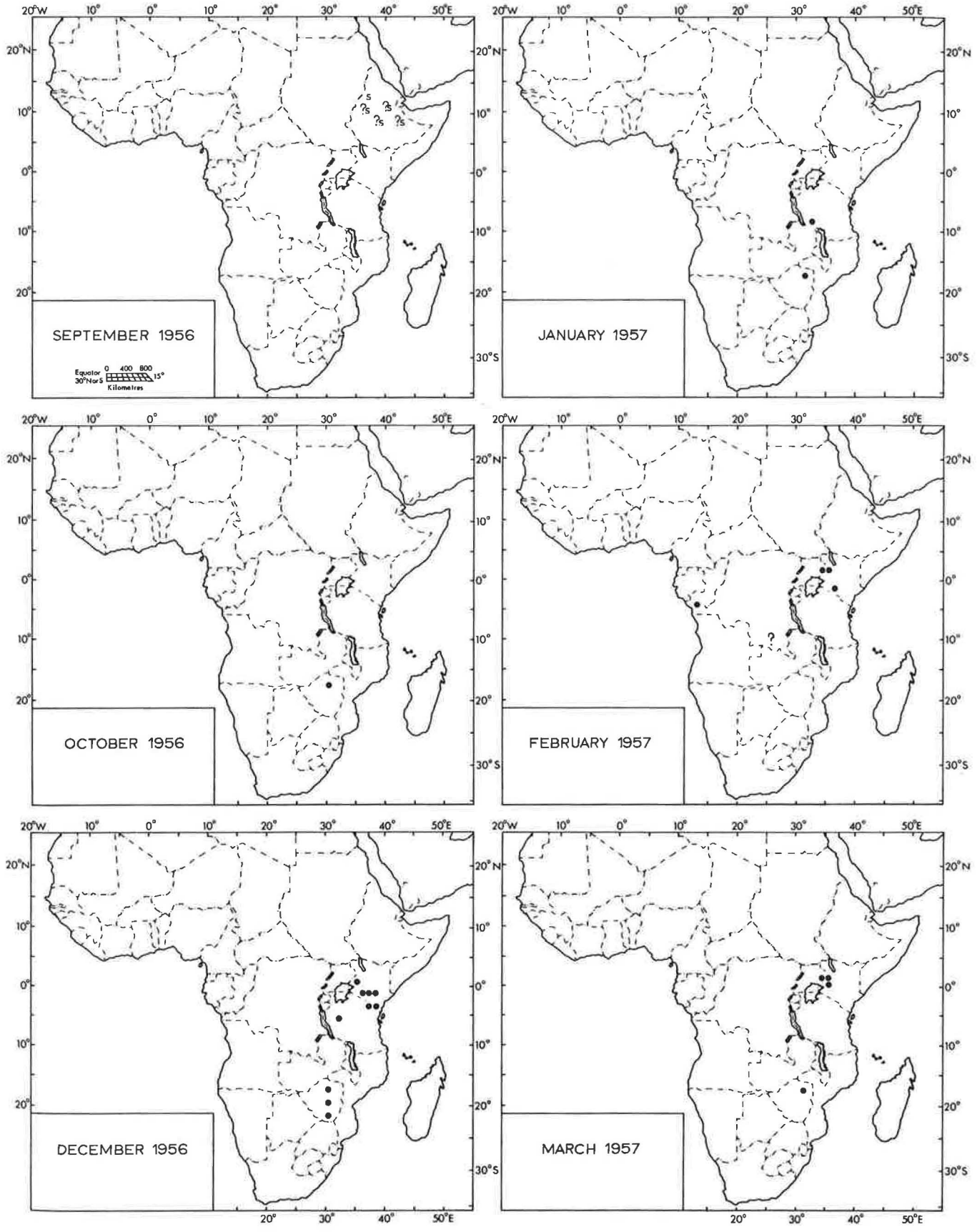

JANUARY 1952
Equator 0 400 800 1200
30°N or S
Kilometres
APRIL 1952
FEBRUARY 1952
MAY 1952
MARCH 1952

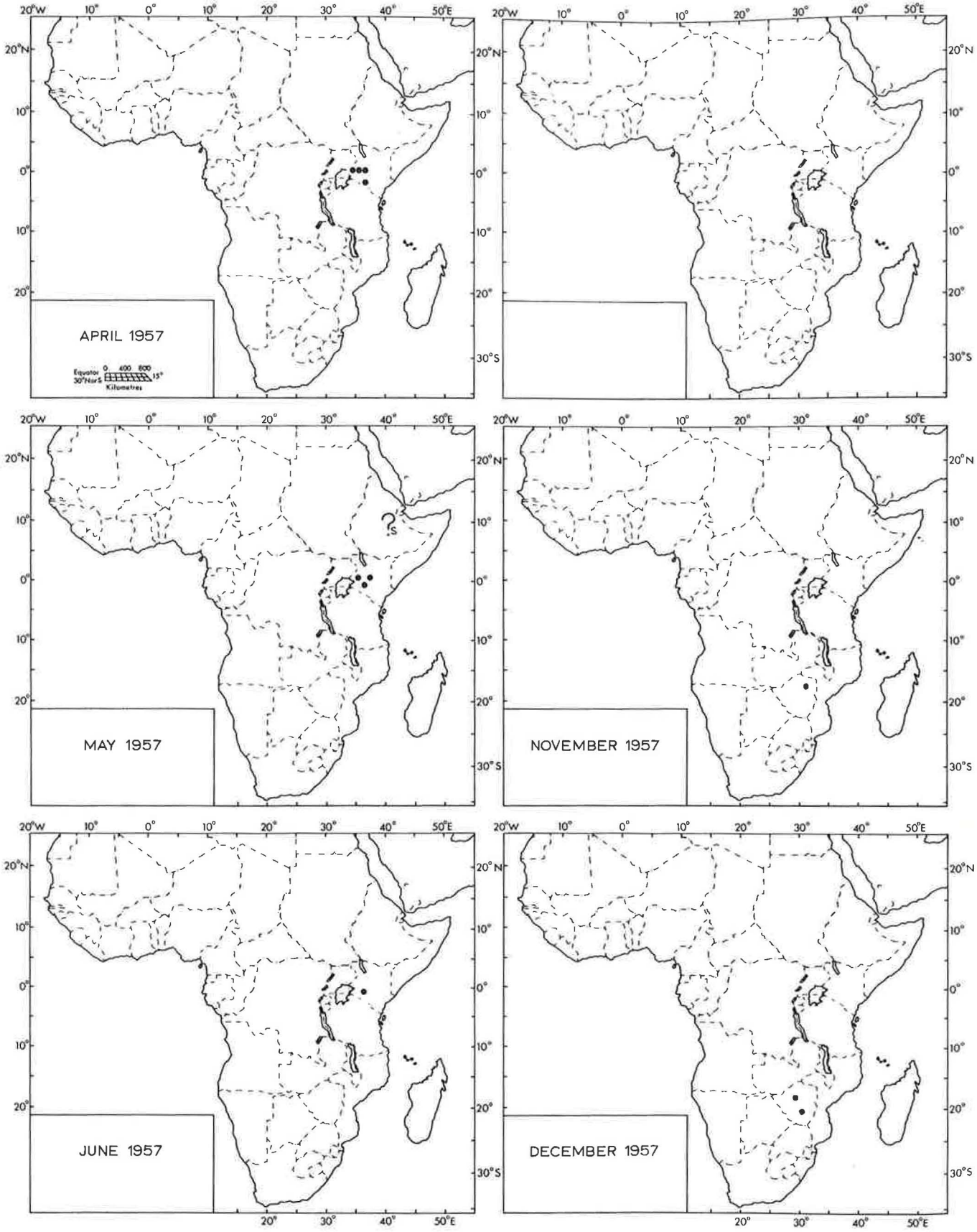

SEPTEMBER 1952
?s
Equator 0 400 800
30°N or S 15°
Kilometres
JANUARY 1953
m
OCTOBER 1952
MARCH 1953
m
DECEMBER 1953
yr?

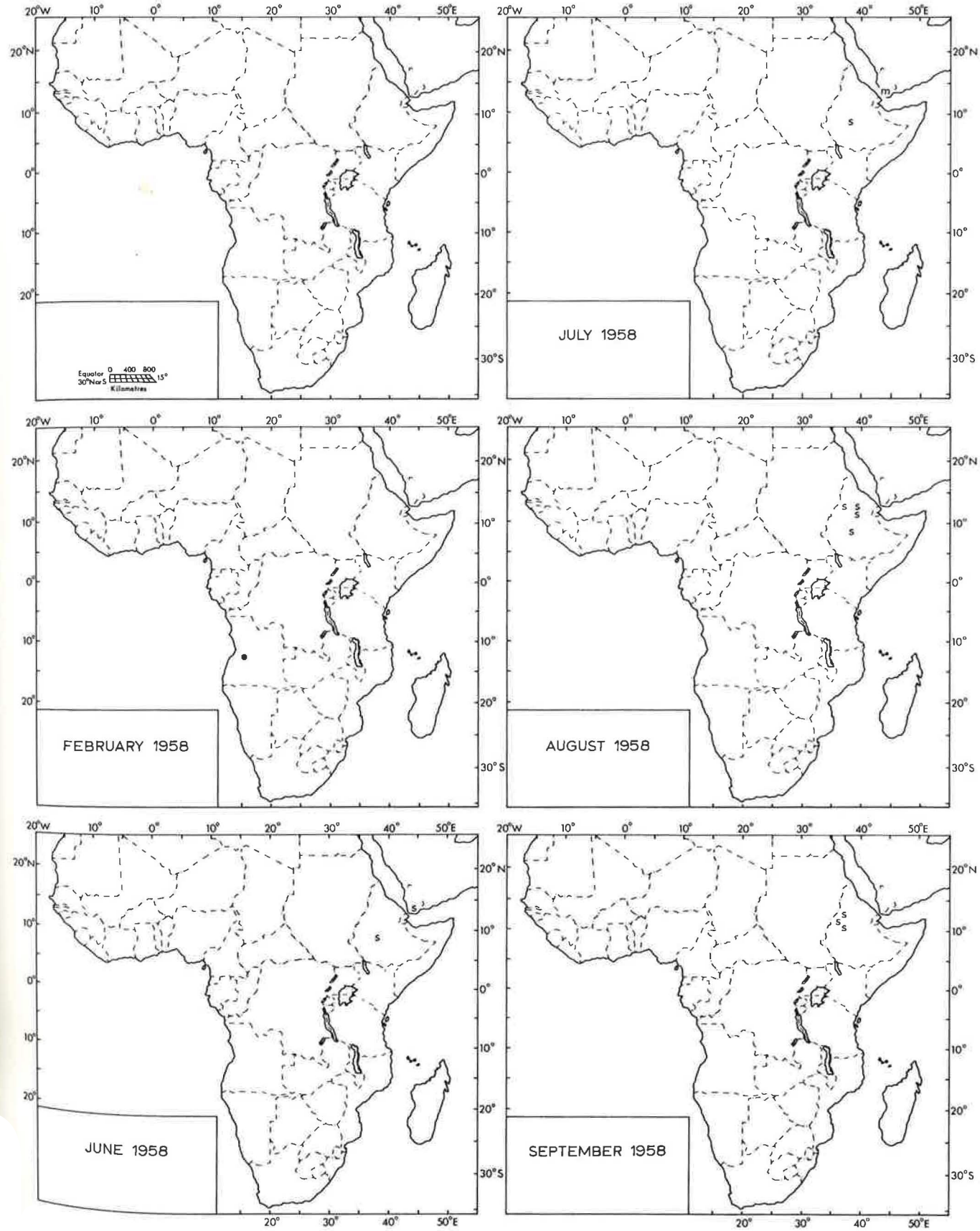

JANUARY 1954
mm
mm
APRIL 1954
FEBRUARY 1954
MAY 1954
?s
MARCH 1954
m
NOVEMBER 1954
Equator 0 400 800
30°N or S 15°
Kilometres

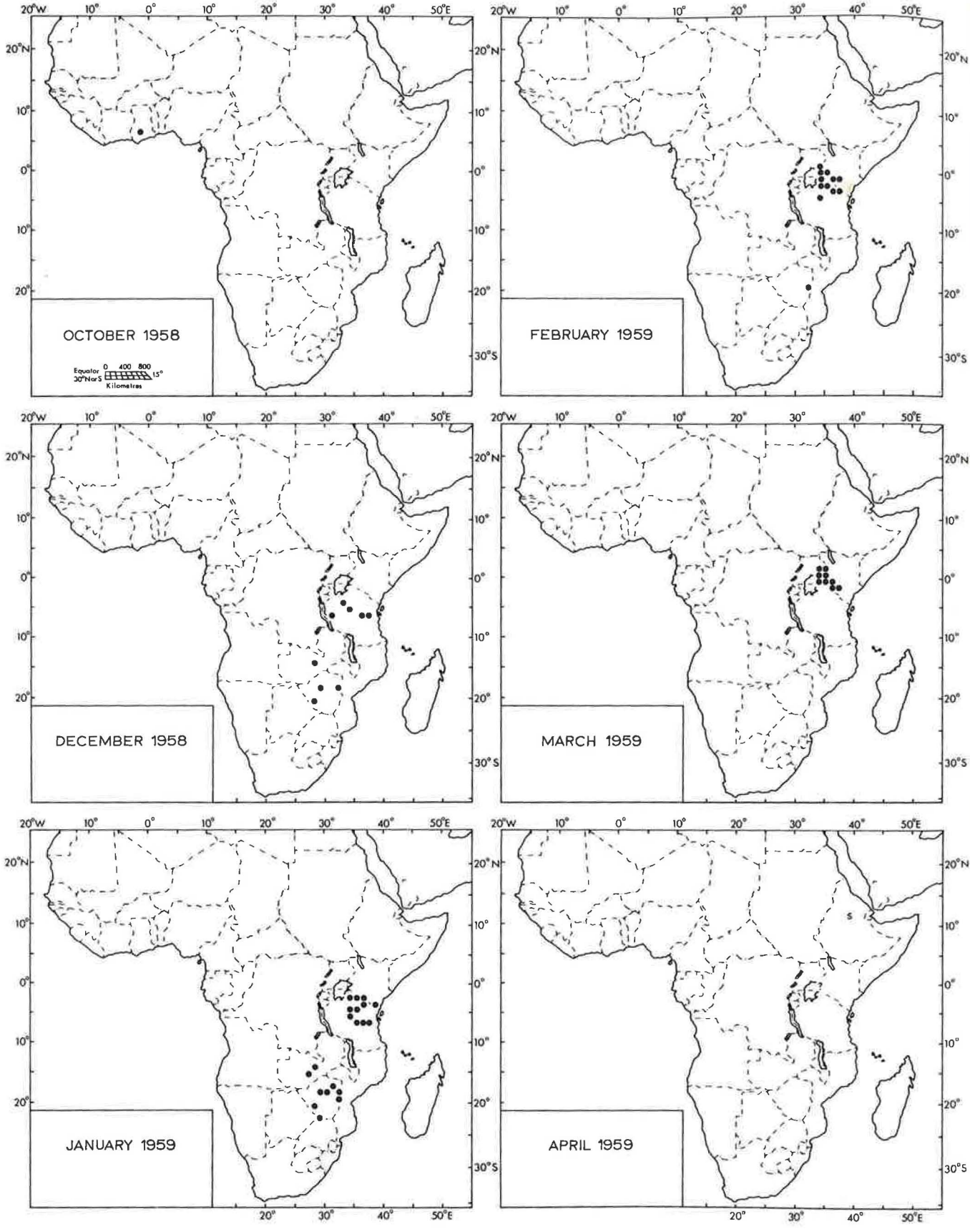

20°W 10° 0° 10° 20° 30° 40° 50°E
20°N
10°
0°
10°
20°
30°S
Equator 0 400 800
30°N or S 15°
Kilometres
FEBRUARY 1955
NOVEMBER 1955
DECEMBER 1955

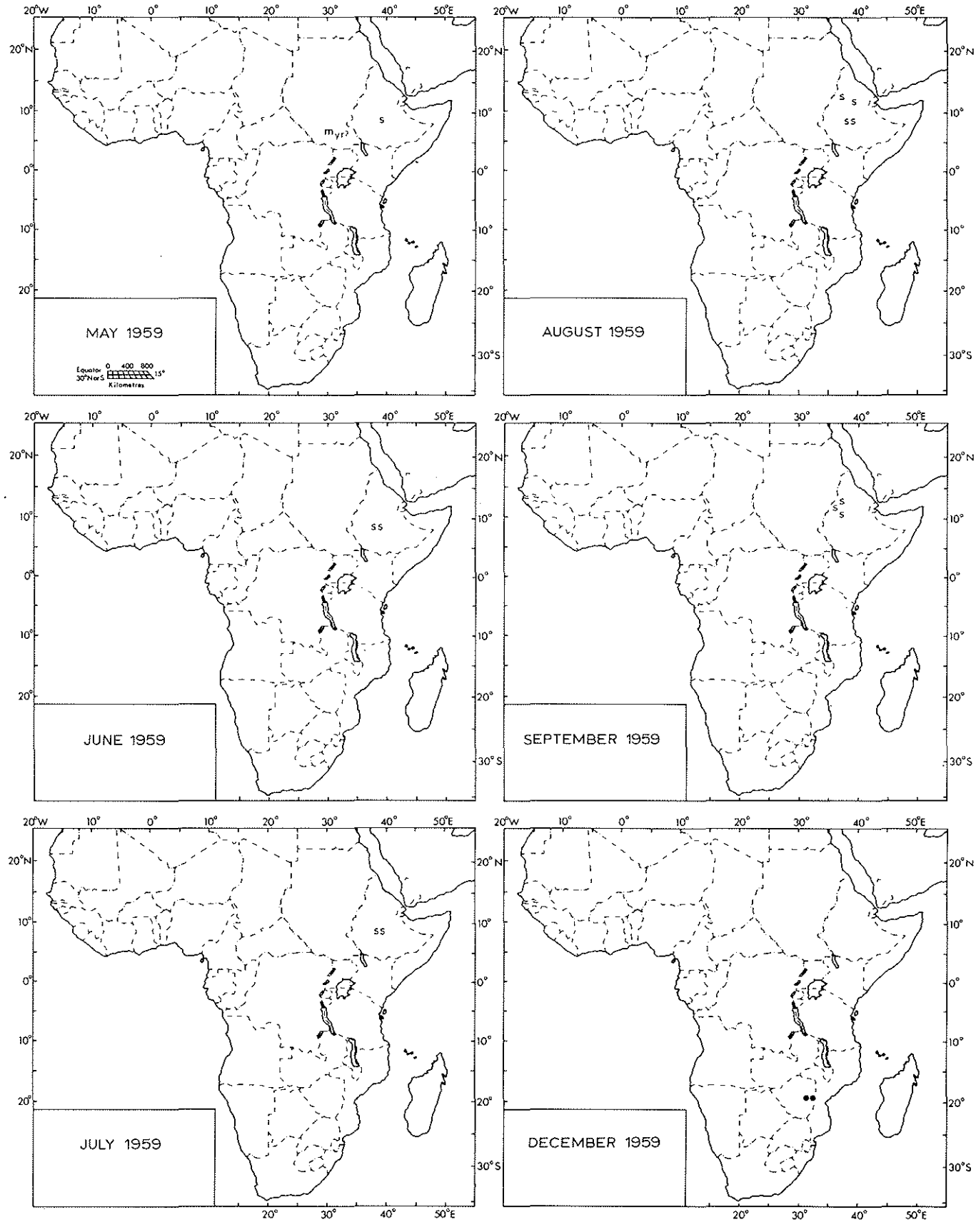

JANUARY 1956
Equator 0 400 800
30°N or S 15°
Kilometres
APRIL 1956
FEBRUARY 1956
MAY 1956
MARCH 1956
JUNE 1956

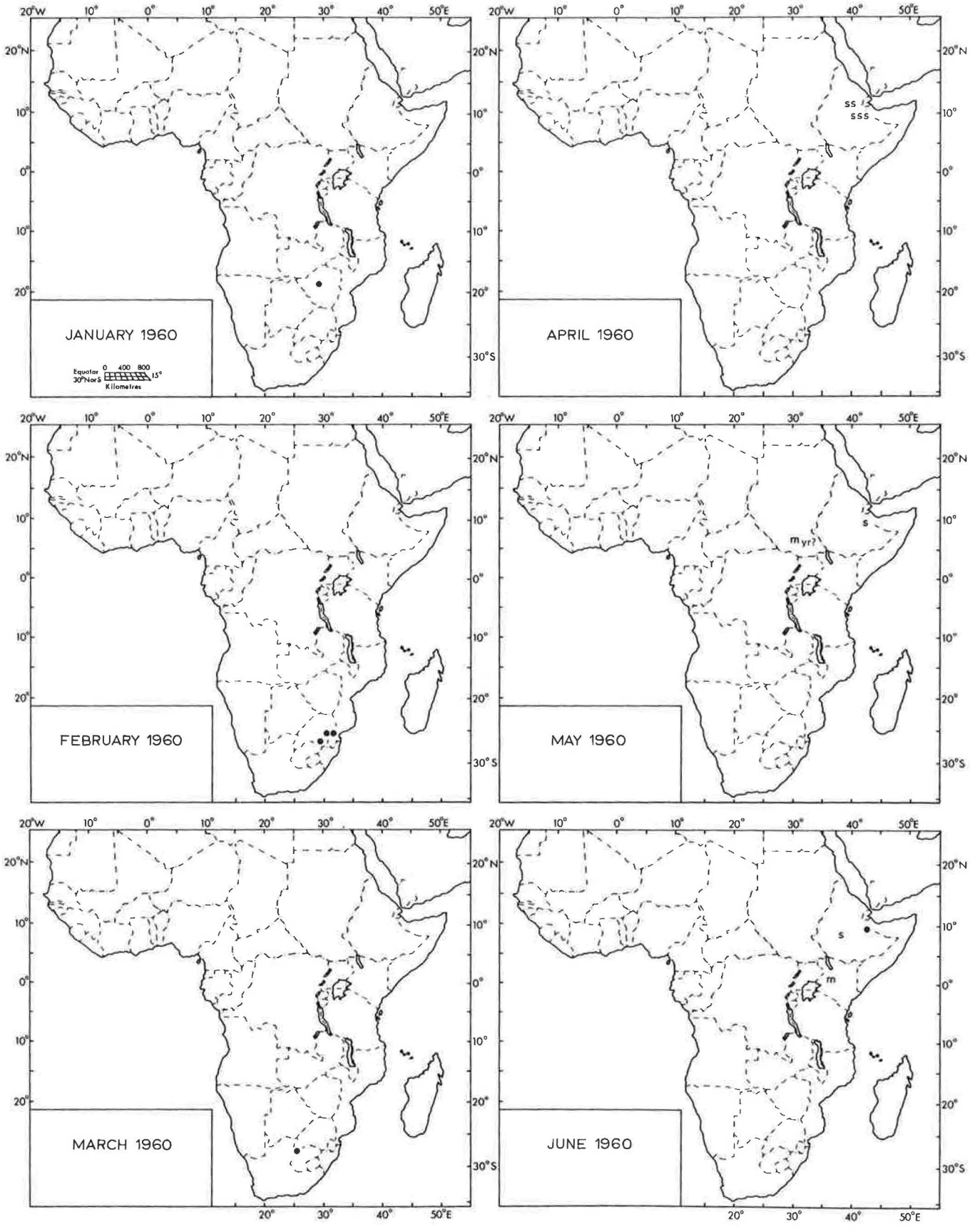

SEPTEMBER 1956
Equator 0 400 800 15°
30°N or S Kilometres
JANUARY 1957
OCTOBER 1956
FEBRUARY 1957
DECEMBER 1956
MARCH 1957

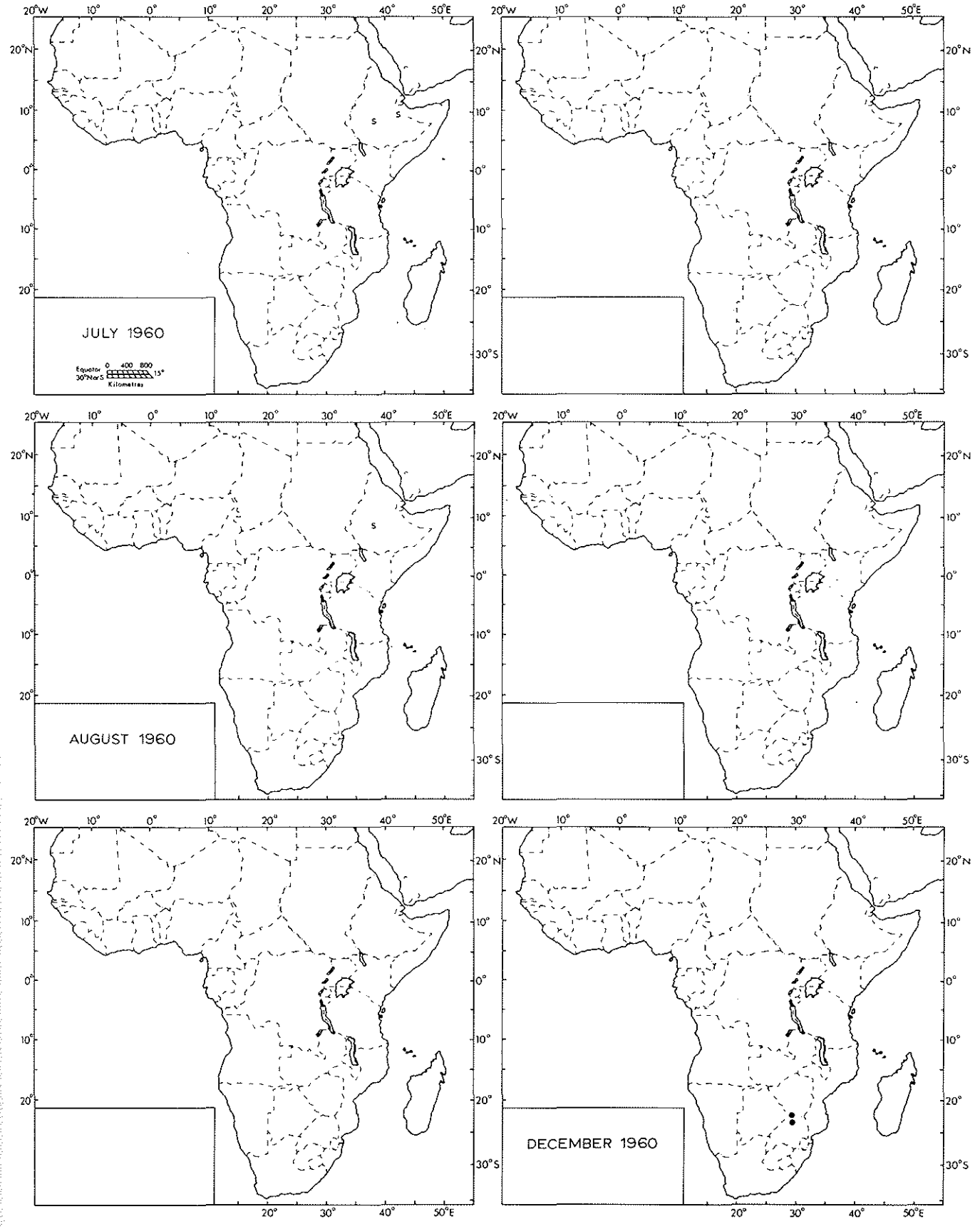

APRIL 1957
MAY 1957
NOVEMBER 1957
JUNE 1957
DECEMBER 1957
Equator 0 400 800
30°N or S 15°
Kilometres

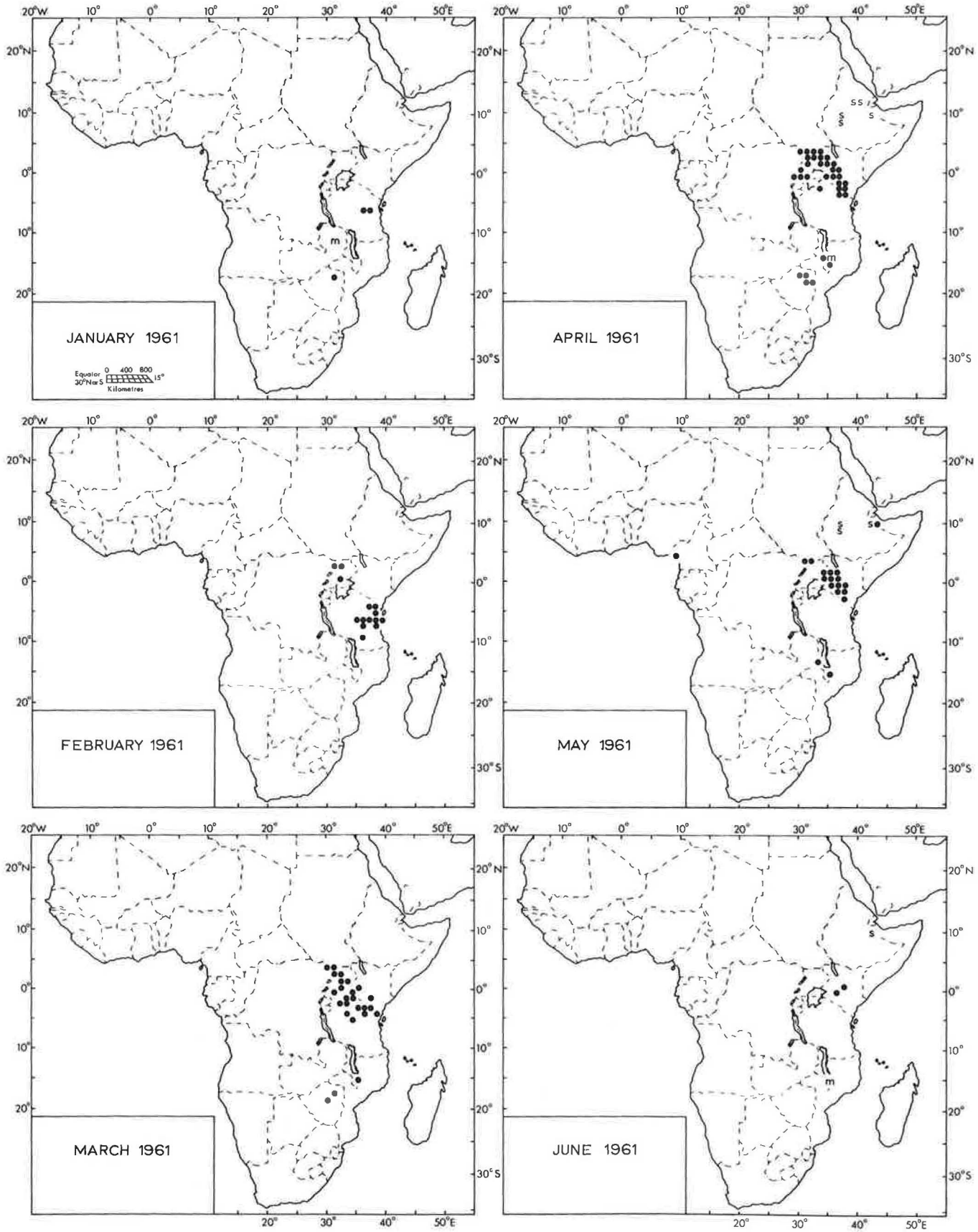

JULY 1958
FEBRUARY 1958
AUGUST 1958
JUNE 1958
SEPTEMBER 1958
Equator 0 400 800 15°
30°N or S
Kilometres

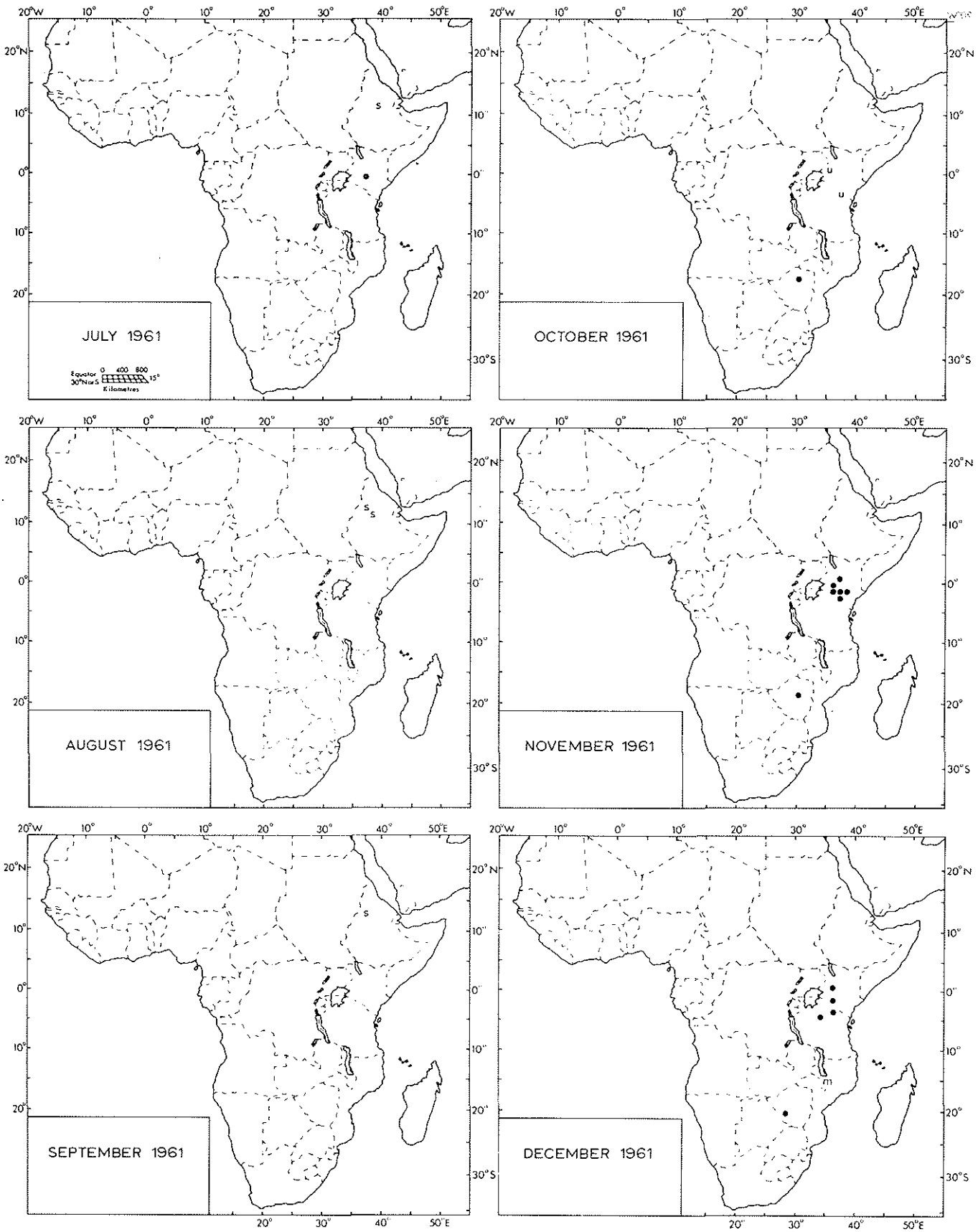

OCTOBER 1958
Equator 0 400 800
30°N or S 15°
Kilometres
FEBRUARY 1959
DECEMBER 1958
MARCH 1959
JANUARY 1959
APRIL 1959

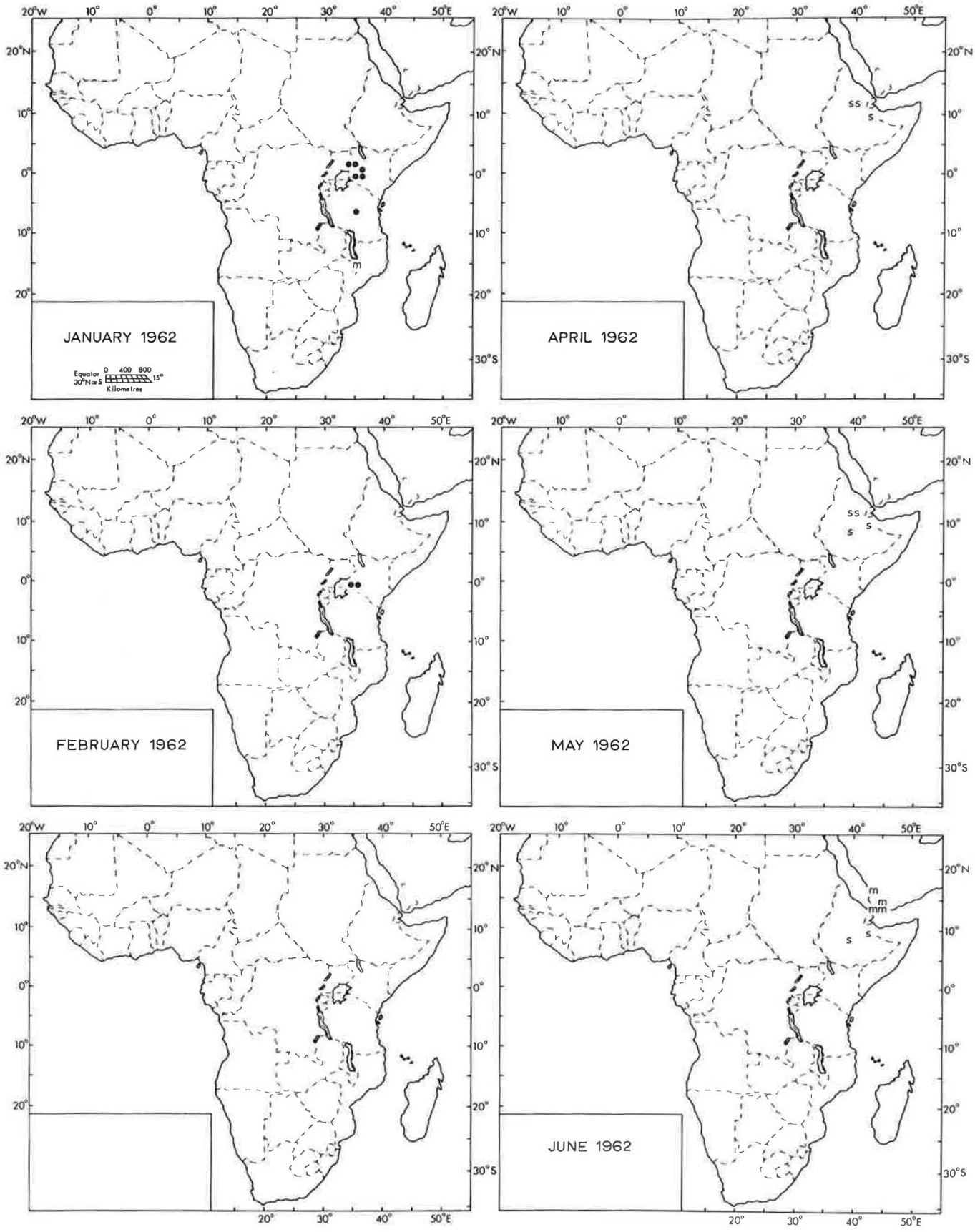

MAY 1959
AUGUST 1959
JUNE 1959
SEPTEMBER 1959
JULY 1959
DECEMBER 1959
Equator 30°N or S
0 400 800 1200
Kilometres

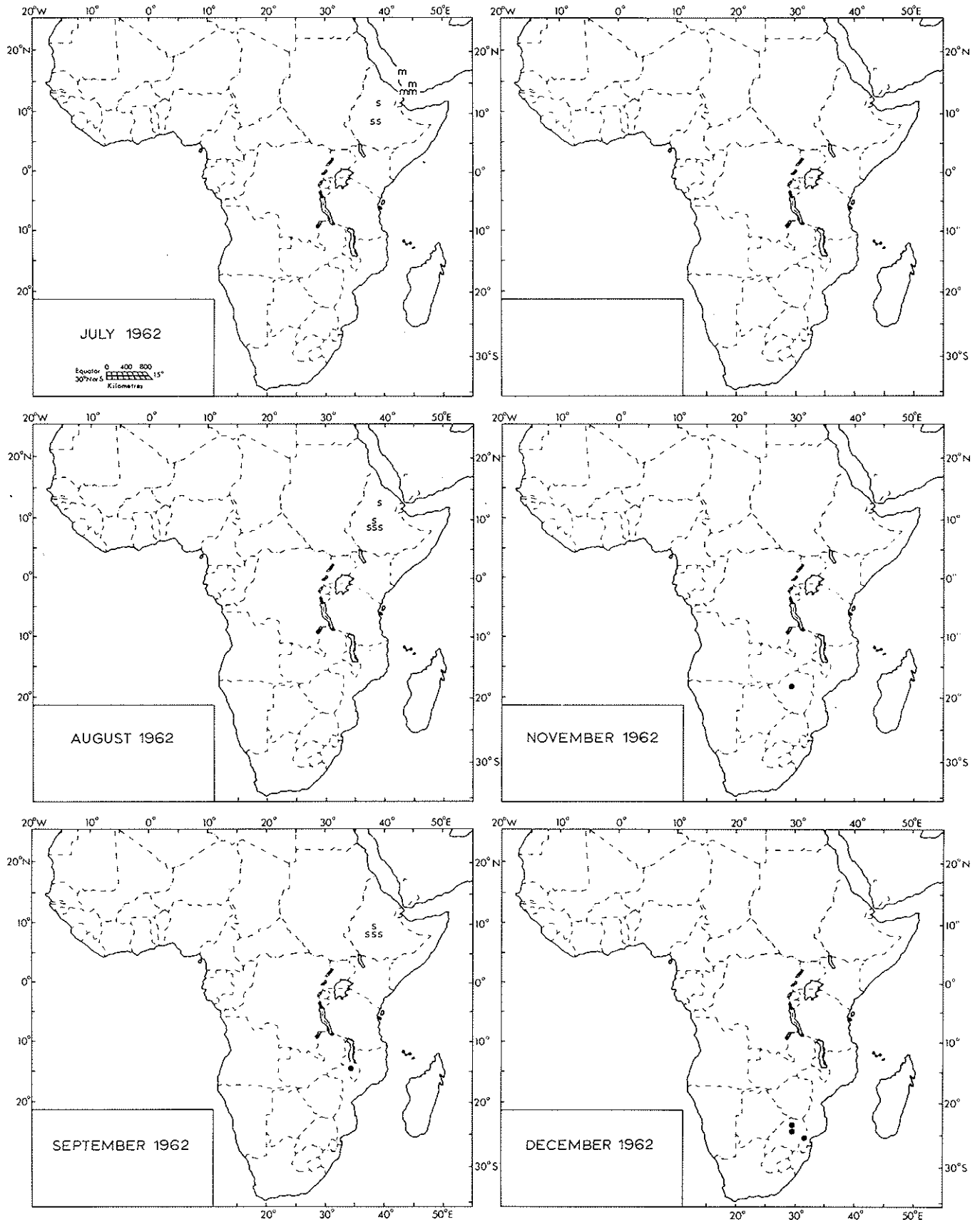

JANUARY 1960
Equator 0 400 800 15°
30°Nors Kilometres
APRIL 1960
ss
sss
FEBRUARY 1960
MAY 1960
m yr?
s
MARCH 1960
JUNE 1960
s
m

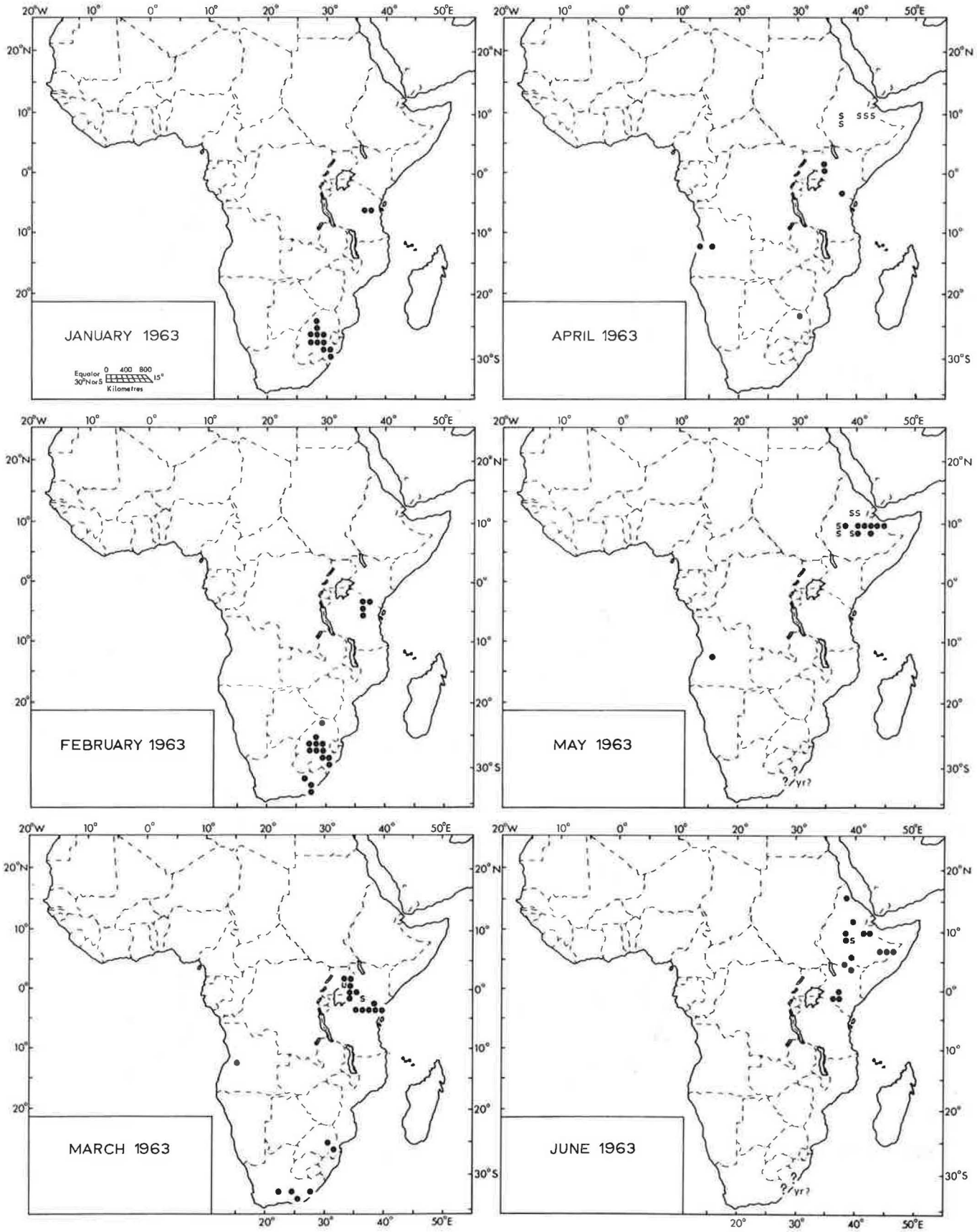

JULY 1960
AUGUST 1960
DECEMBER 1960
Equator 0 400 800
30°N or S 15°
Kilometres

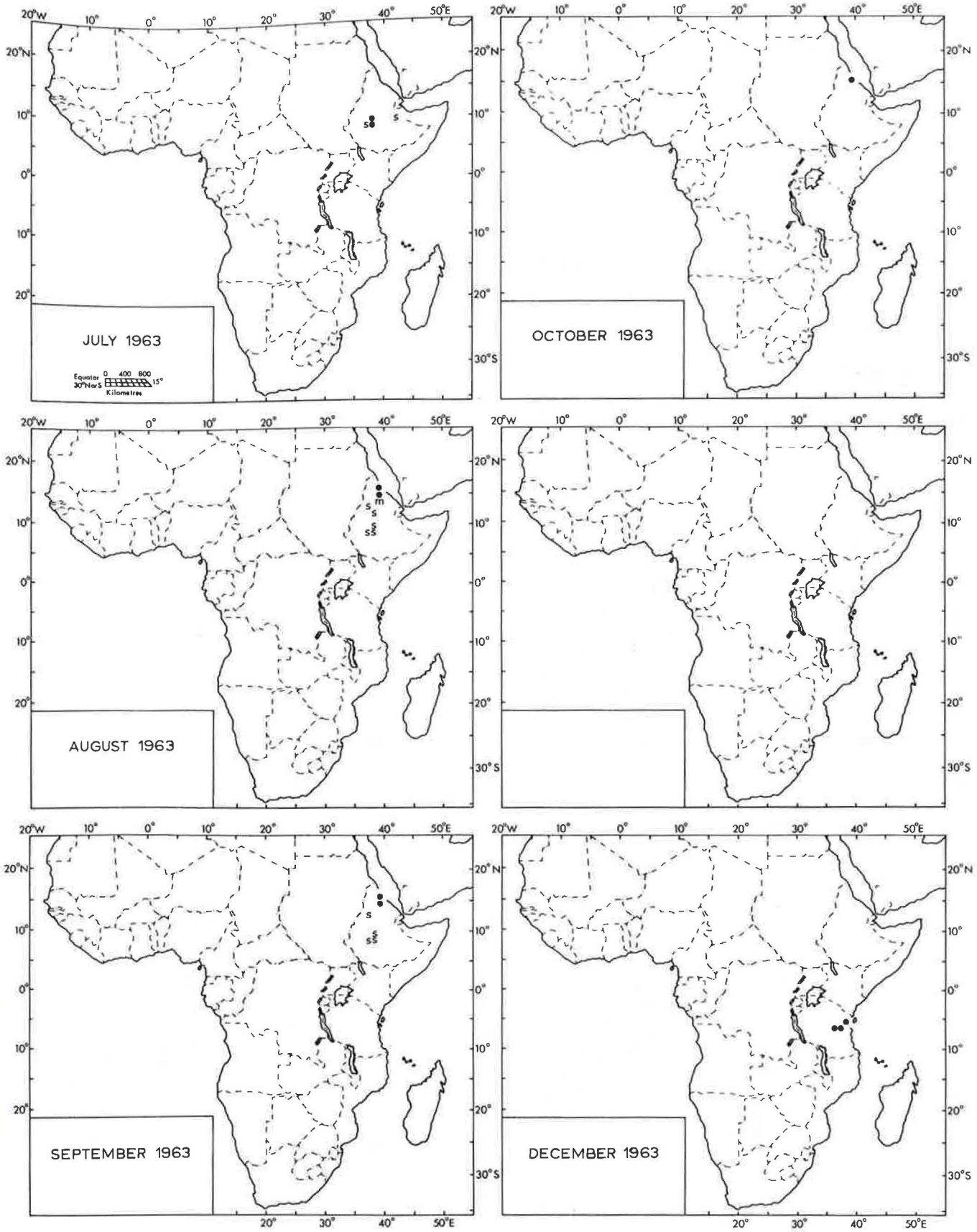

JANUARY 1961
Equator 0 400 800 15°
30°N or S Kilometres
APRIL 1961
FEBRUARY 1961
MAY 1961
MARCH 1961
JUNE 1961
20°W 10° 0° 10° 20° 30° 40° 50°E
20°N 10° 0° 10° 20° 30°S

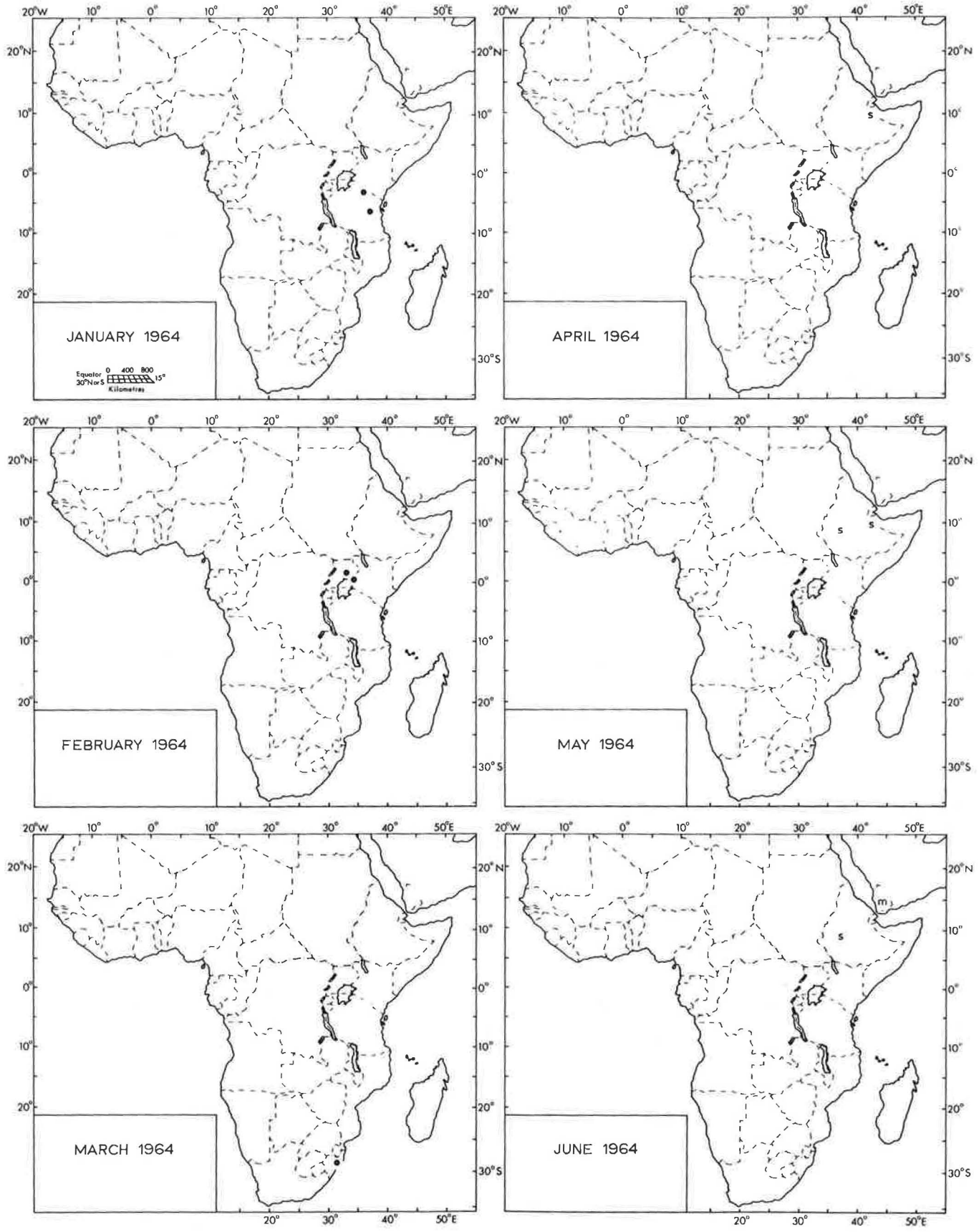

JULY 1961
OCTOBER 1961
AUGUST 1961
NOVEMBER 1961
SEPTEMBER 1961
DECEMBER 1961

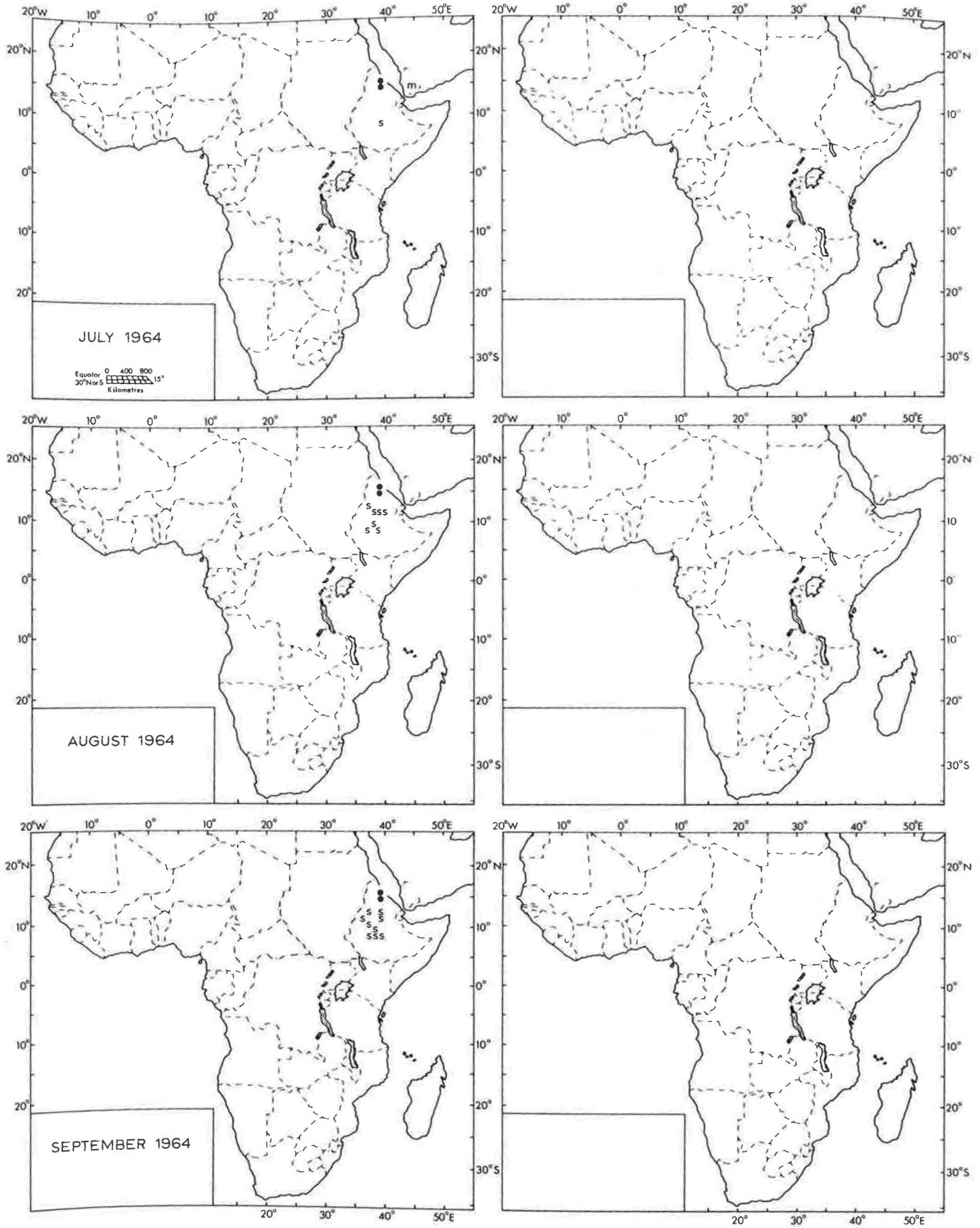

JANUARY 1962
APRIL 1962
FEBRUARY 1962
MAY 1962
JUNE 1962
Equator 0 400 800 15°
30°N or S
Kilometres

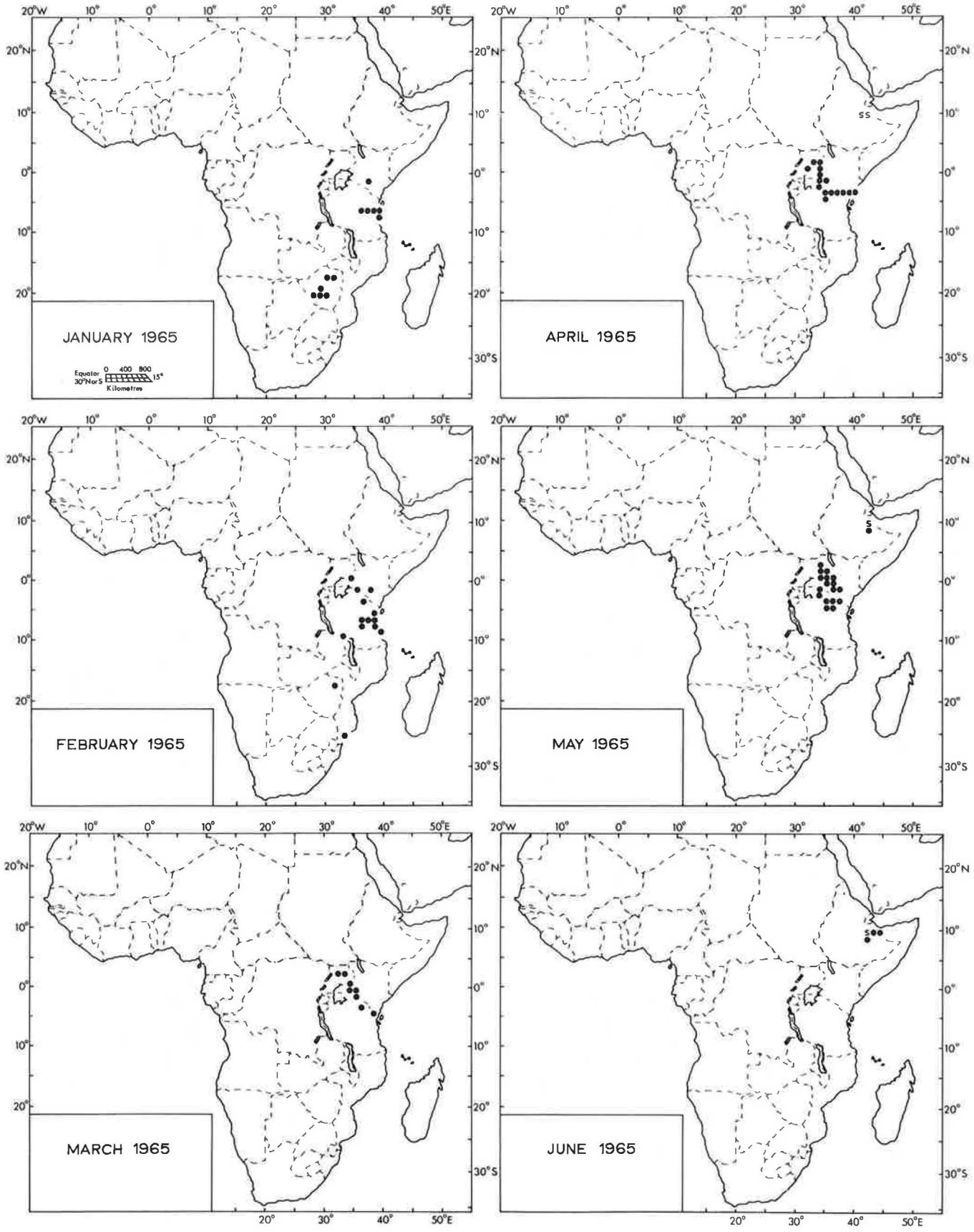

JULY 1962
m
m
mm
s
ss
AUGUST 1962
s
s
sss
NOVEMBER 1962
SEPTEMBER 1962
s
sss
DECEMBER 1962


JANUARY 1963
Equator 0 400 800
30°N or S 15°
Kilometres
APRIL 1963
FEBRUARY 1963
MAY 1963
?/yr?
MARCH 1963
JUNE 1963
?/yr?


JULY 1963
OCTOBER 1963
AUGUST 1963
SEPTEMBER 1963
DECEMBER 1963
Equator 0 400 800
30°N or S 15°
Kilometres


JANUARY 1964
APRIL 1964
FEBRUARY 1964
MAY 1964
MARCH 1964
JUNE 1964
Equator 0 400 800
30°N or S 15°
Kilometres


JULY 1964
AUGUST 1964
SEPTEMBER 1964
Equator 0 400 800
30°N or S 15°
Kilometres


JANUARY 1965
Equator 0 400 800
30°N or S 15°
Kilometres
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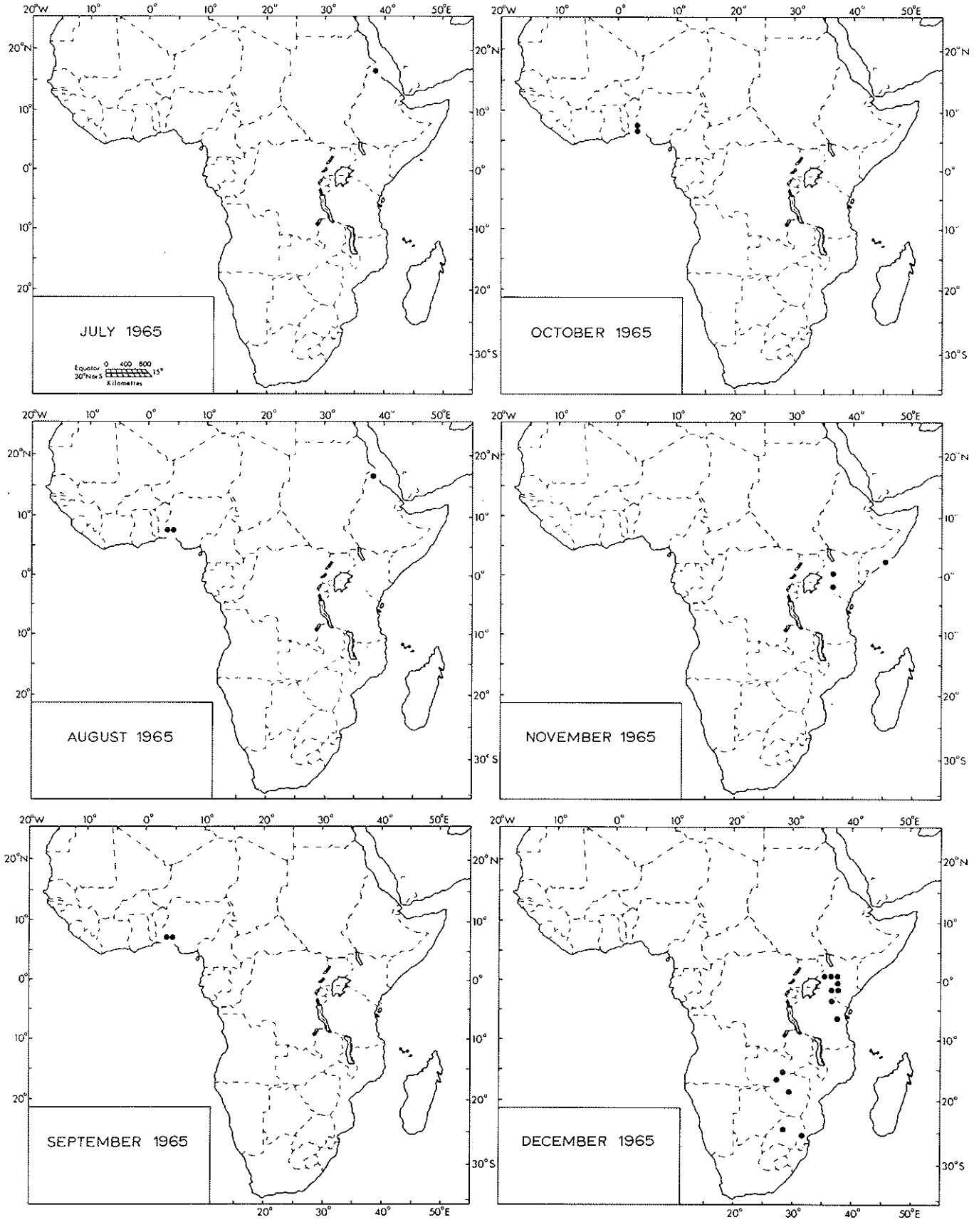
FEBRUARY 1965
MAY 1965
MARCH 1965
JUNE 1965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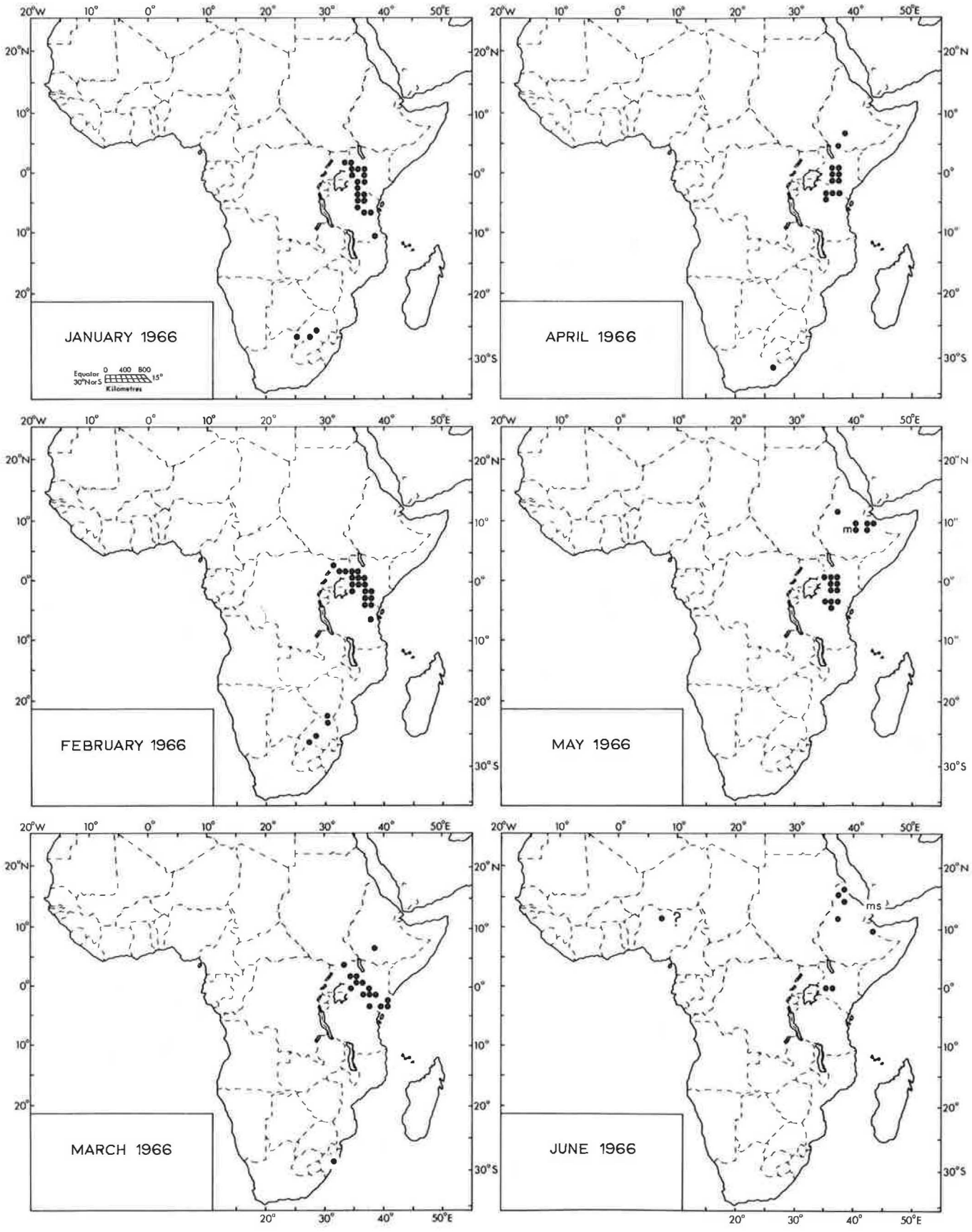
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Kilometres
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FEBRUARY 1966
MAY 1966
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MARCH 1966
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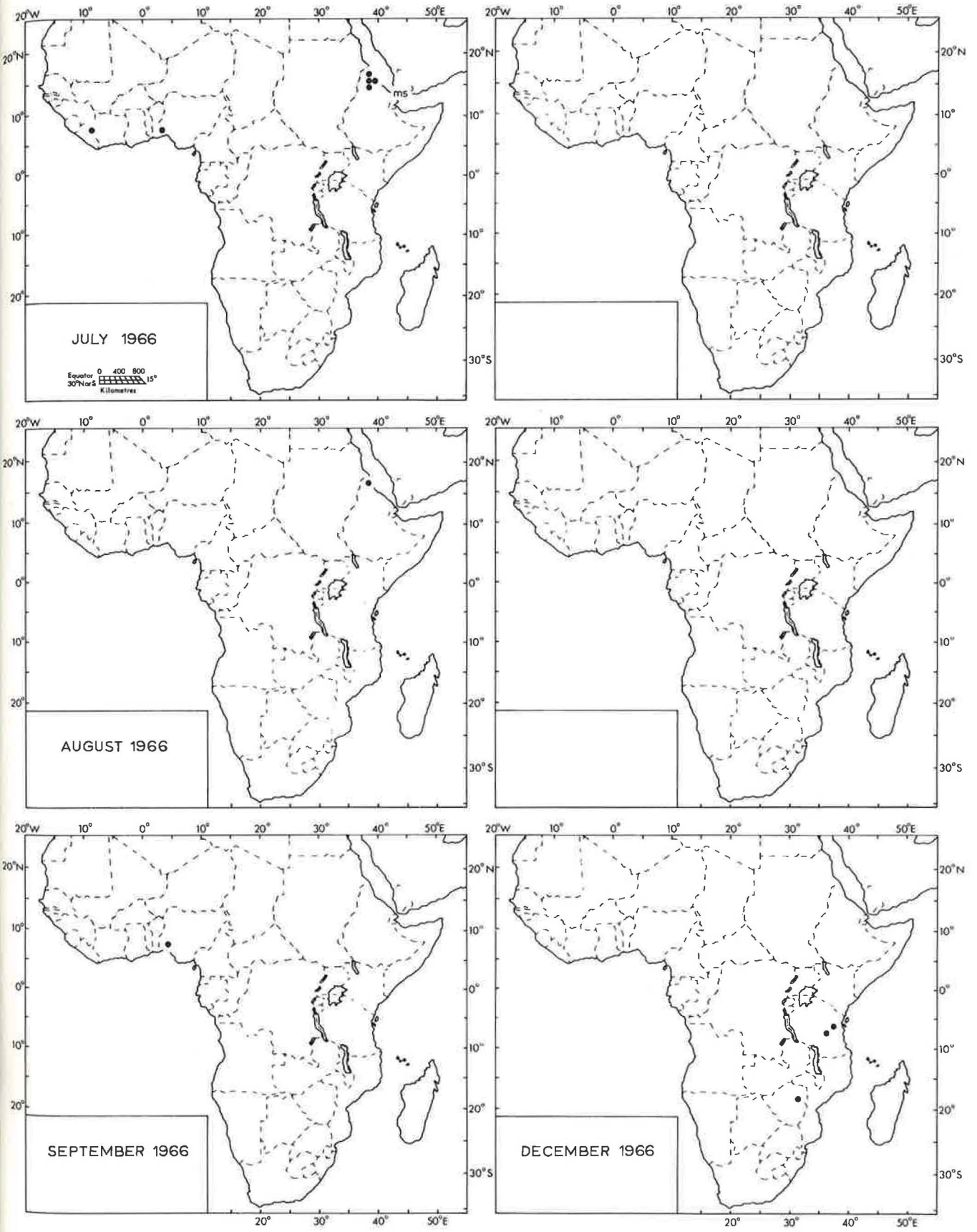
?
ms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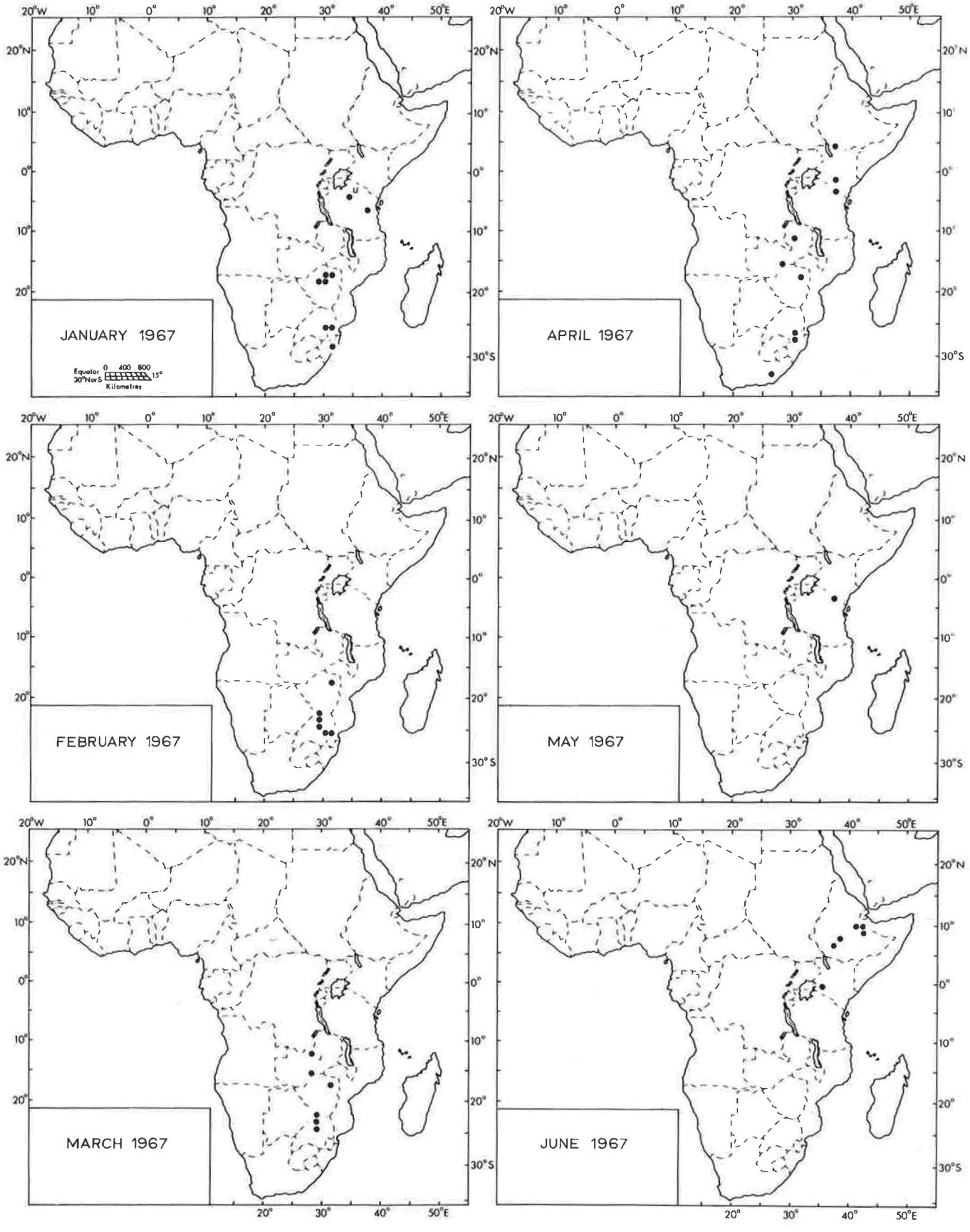
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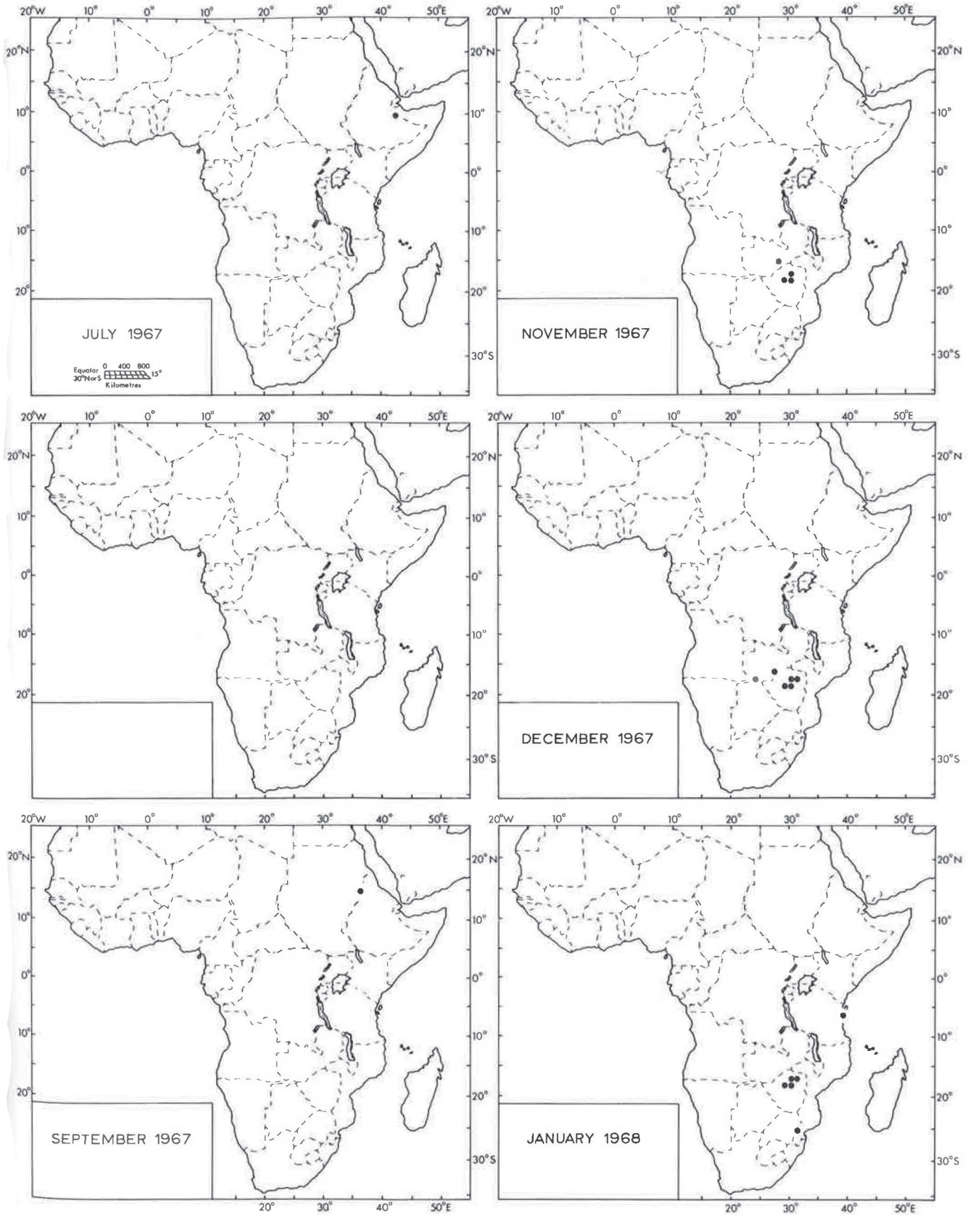
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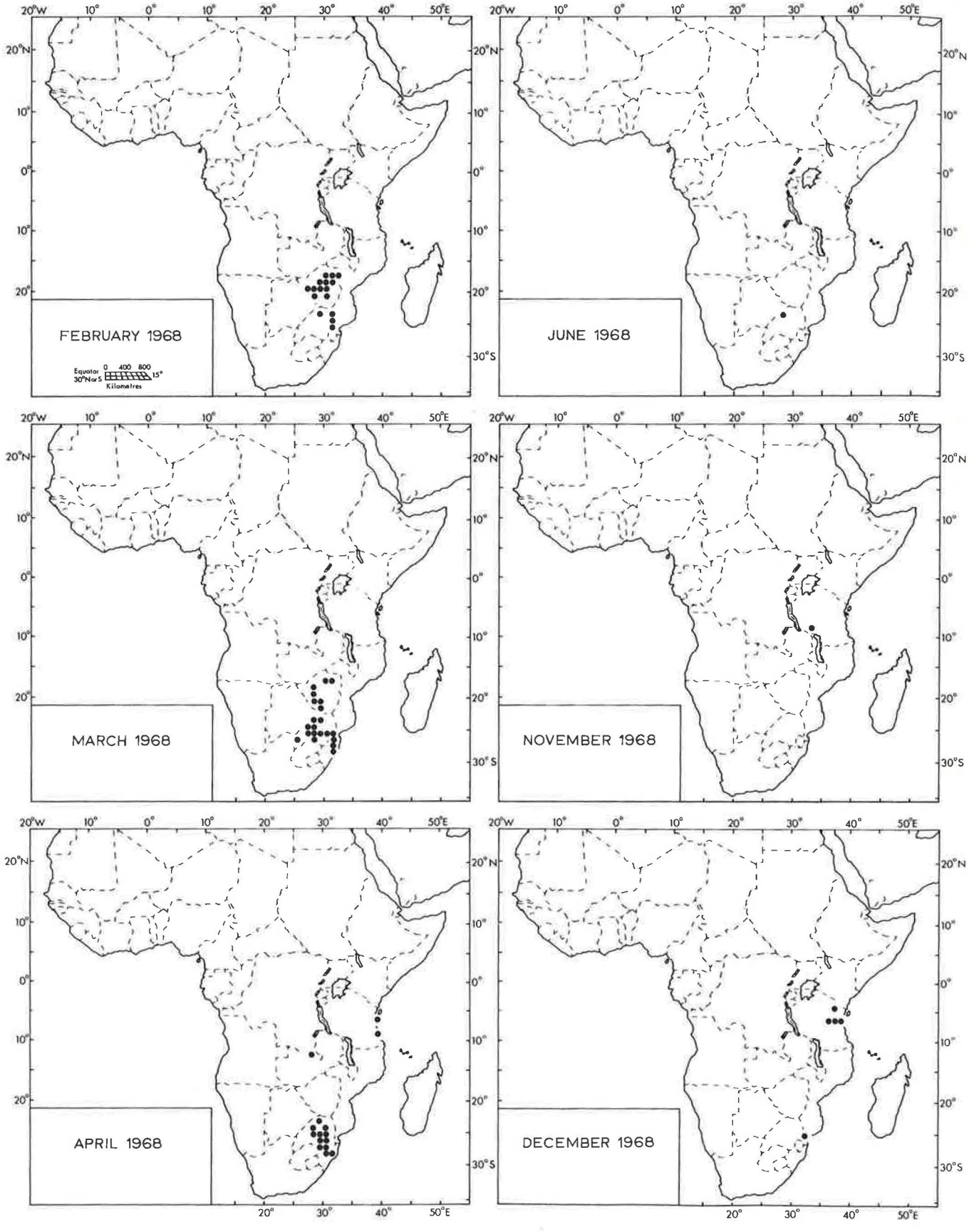
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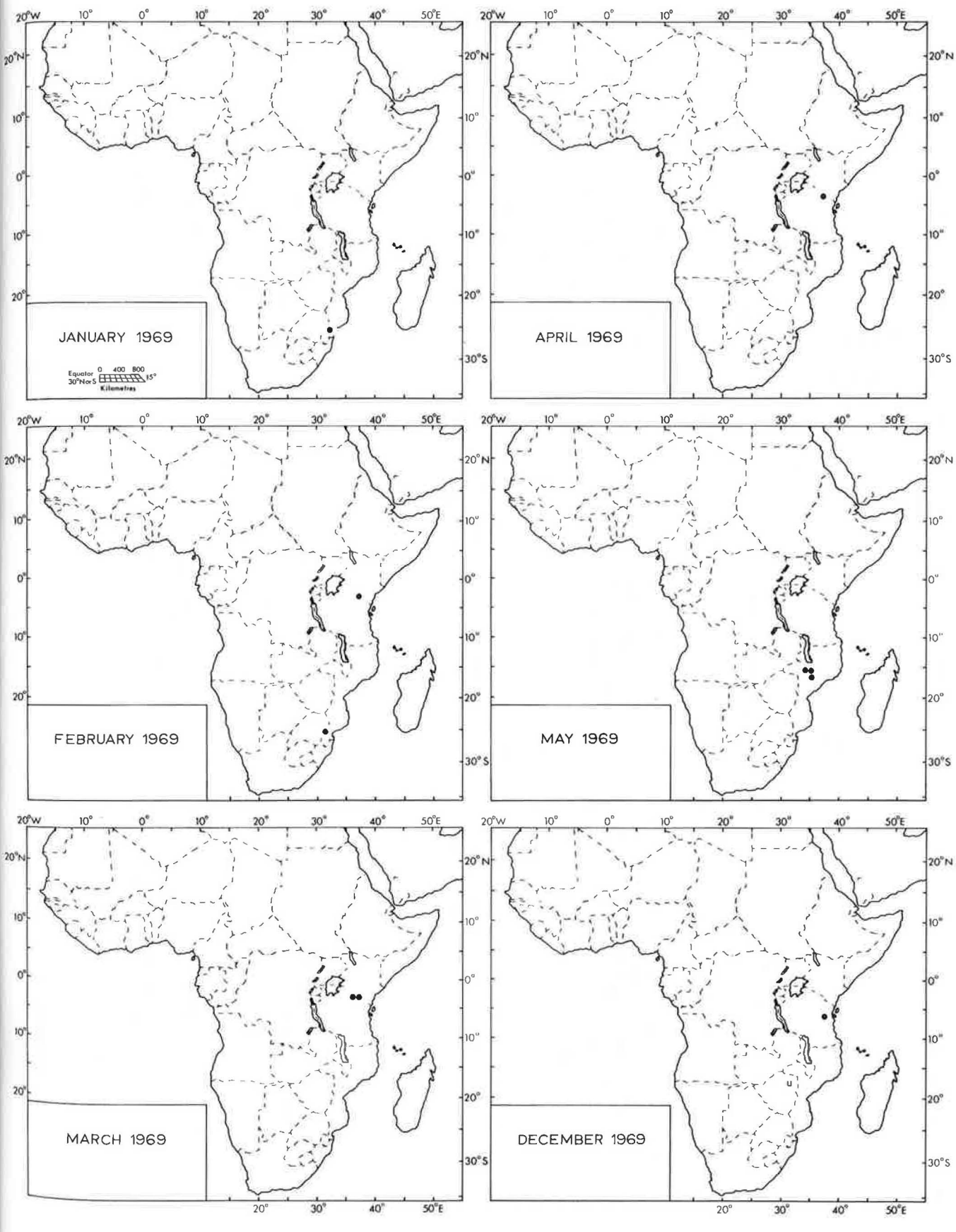
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30°N or S
Kilometres
APRIL 1969
FEBRUARY 1969
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MARCH 1969
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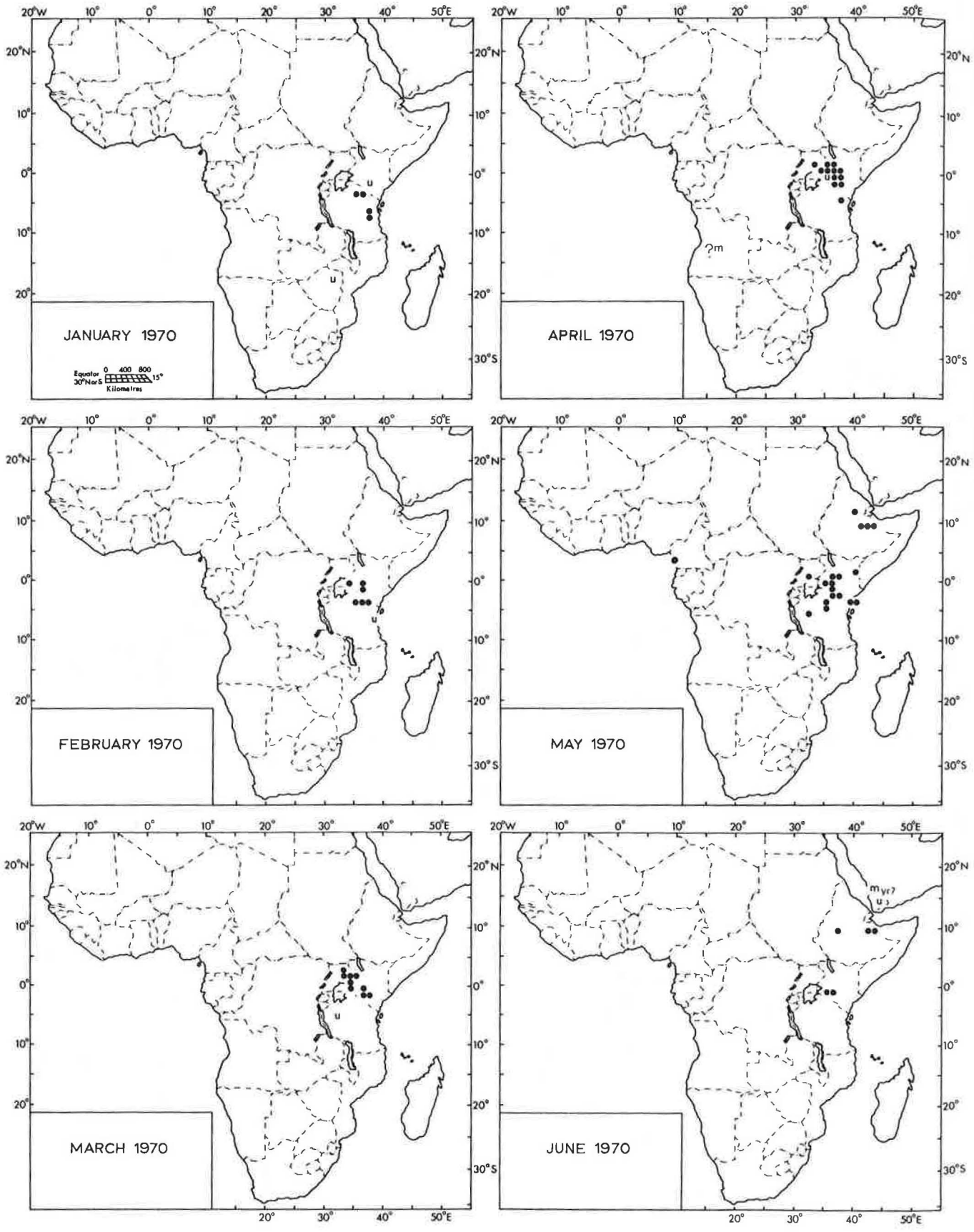
20°W 10° 0° 10° 20° 30° 40° 50°E
20°N 10° 0° 10° 20° 30°S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Kilometres
APRIL 1970
?m
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m yr?
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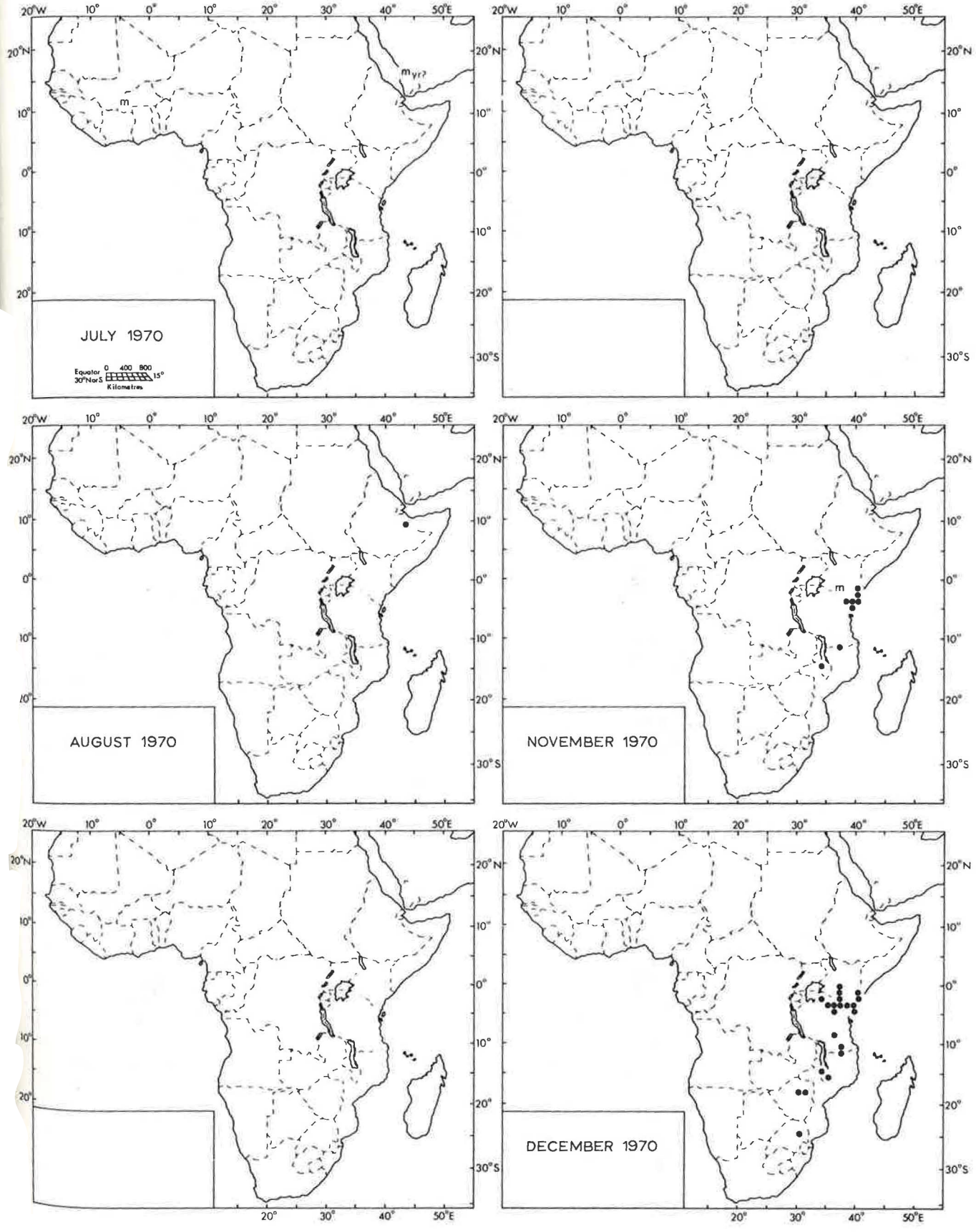
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m
m yr?
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AUGUST 1970
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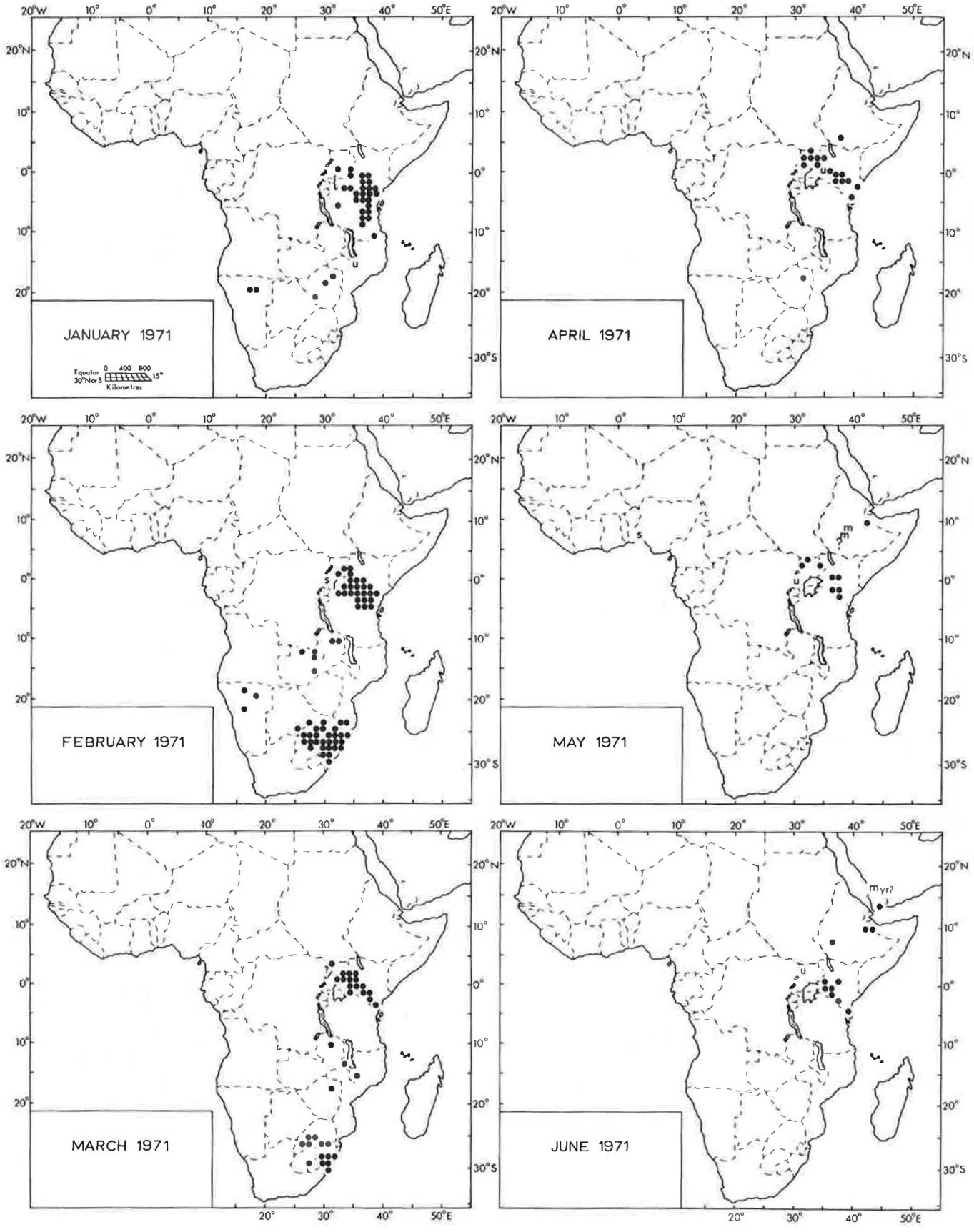
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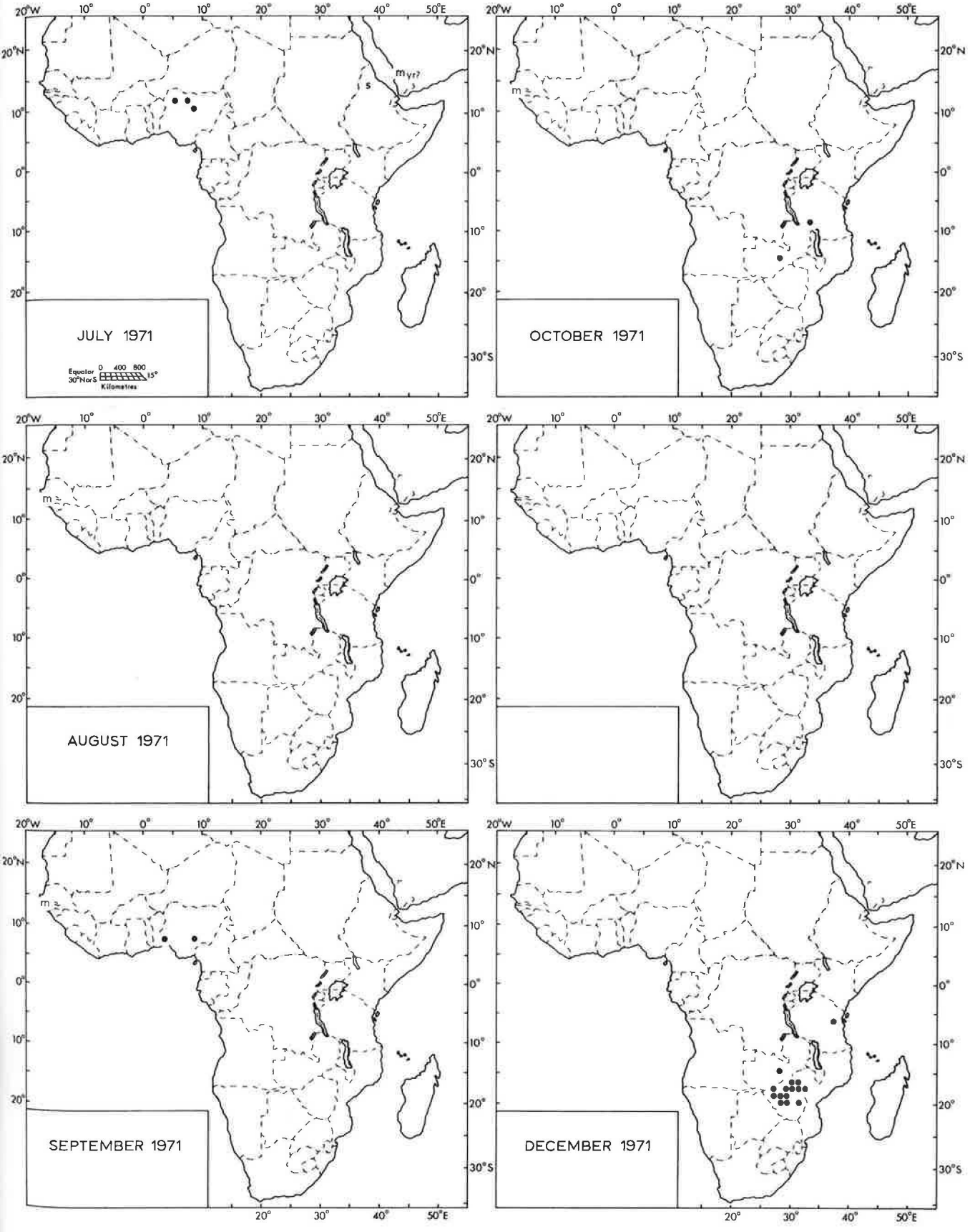
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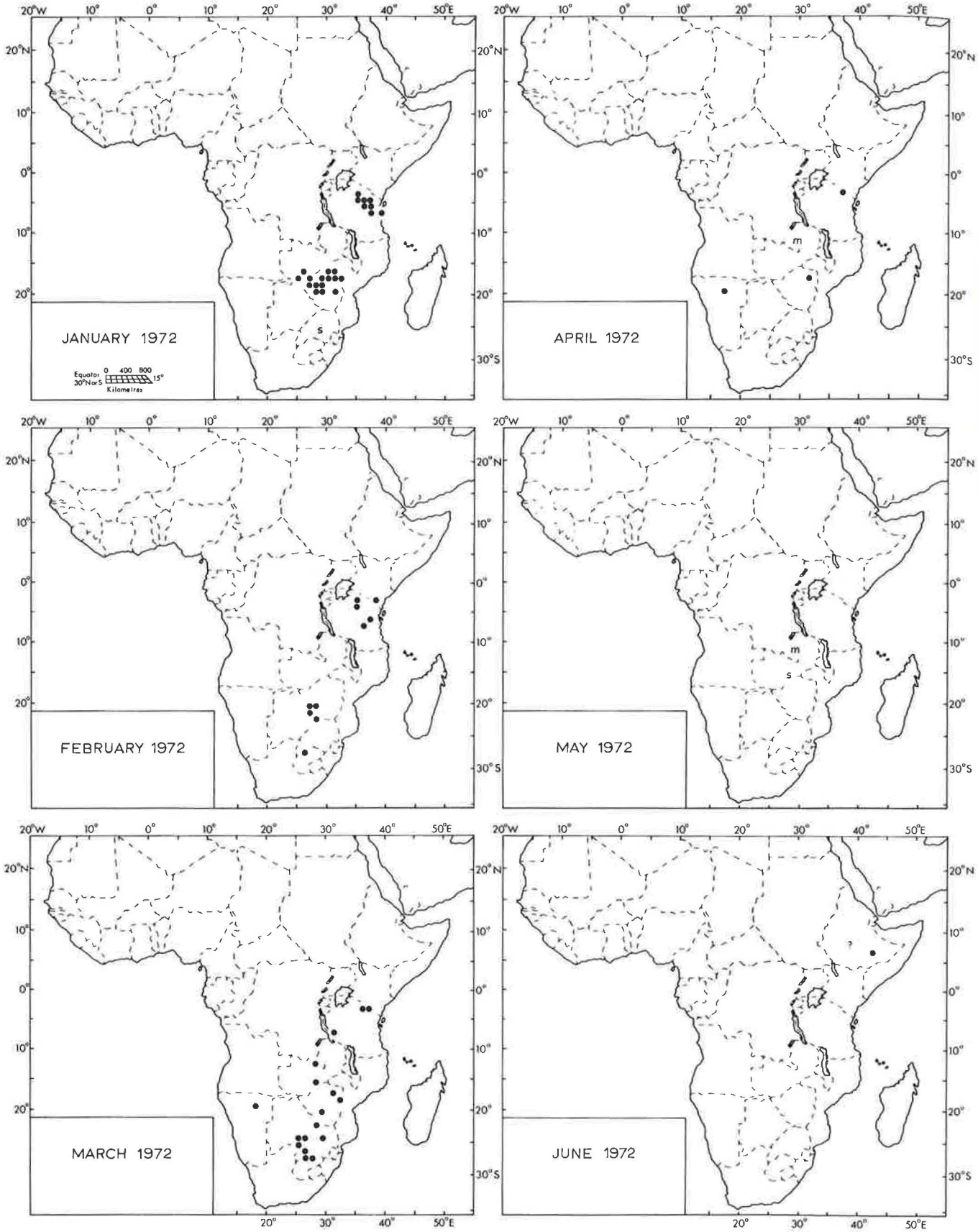
Kilometres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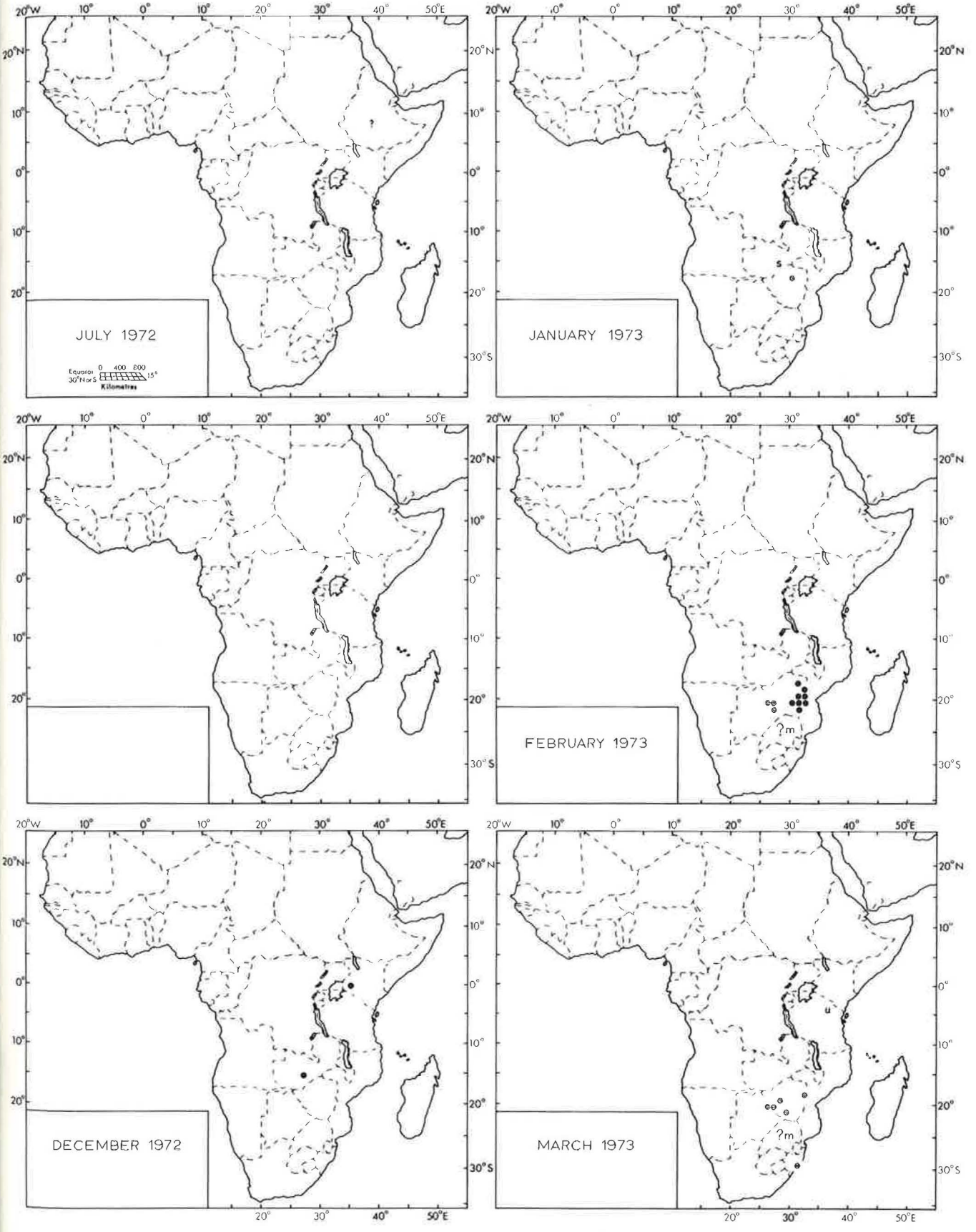
FEBRUARY 1972
MAY 1972
MARCH 1972
JUNE 1972
Equator 0 400 800
30°N or S 15°
Kilometres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JANUARY 1973
FEBRUARY 1973
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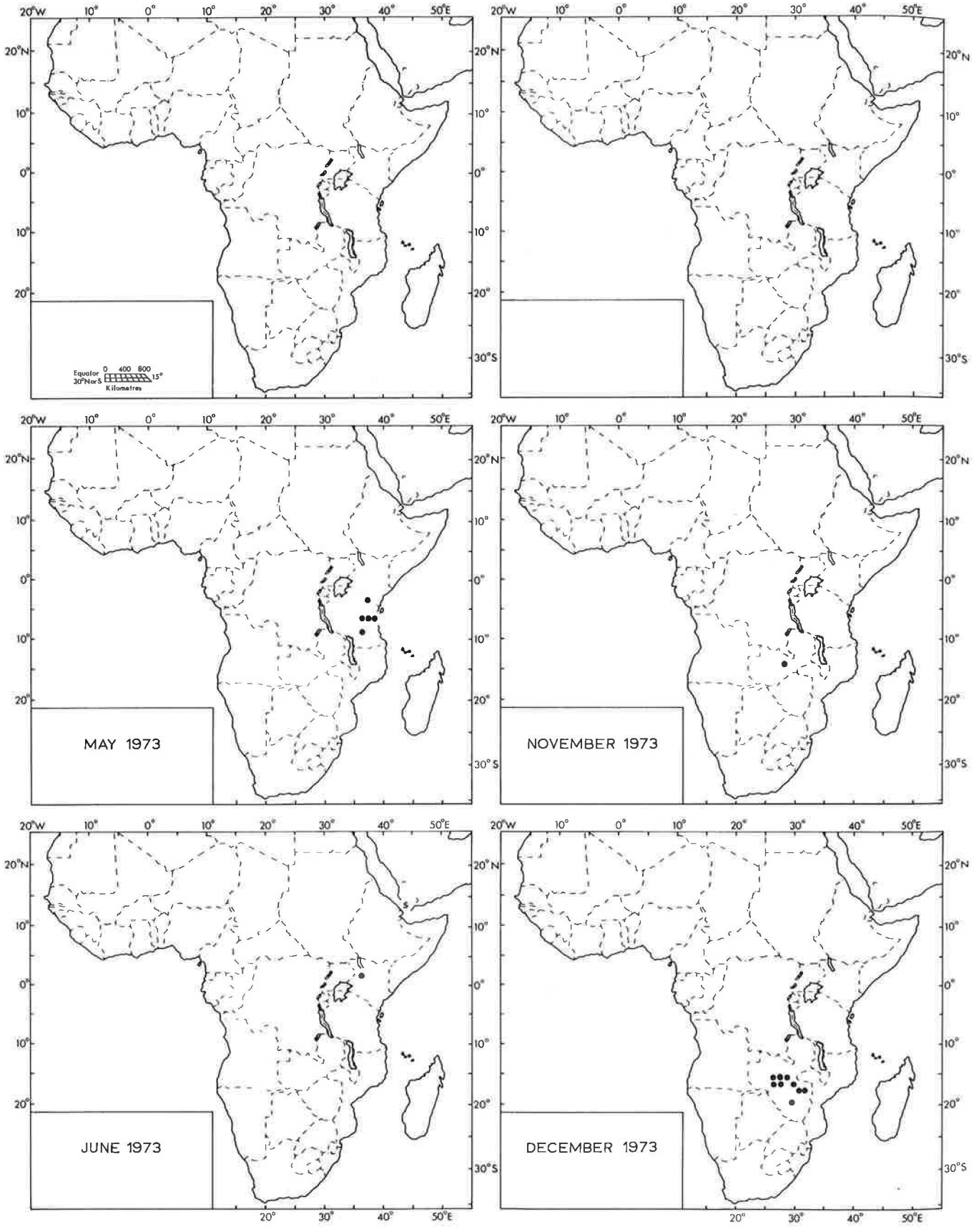
MARCH 1973
?m
?m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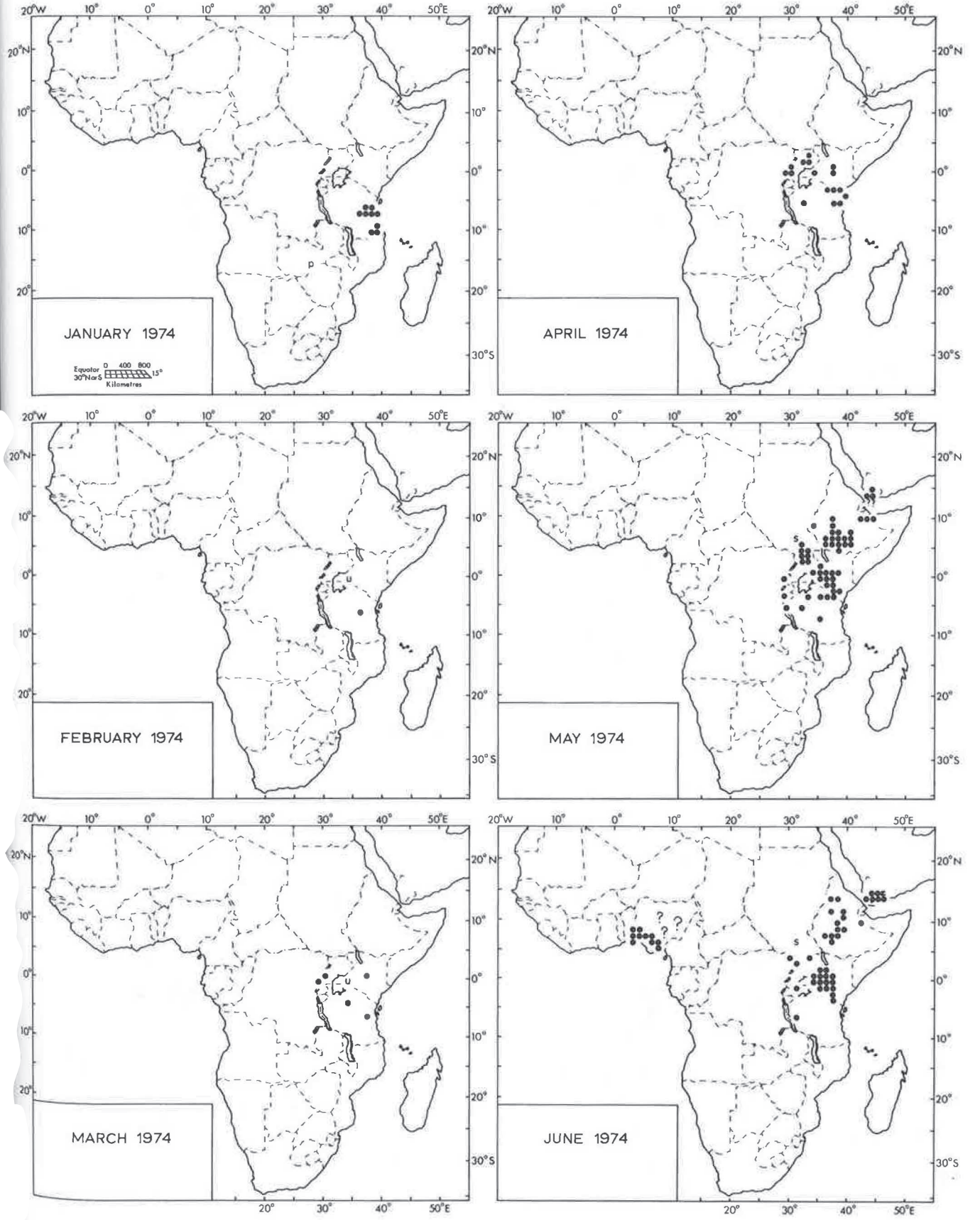
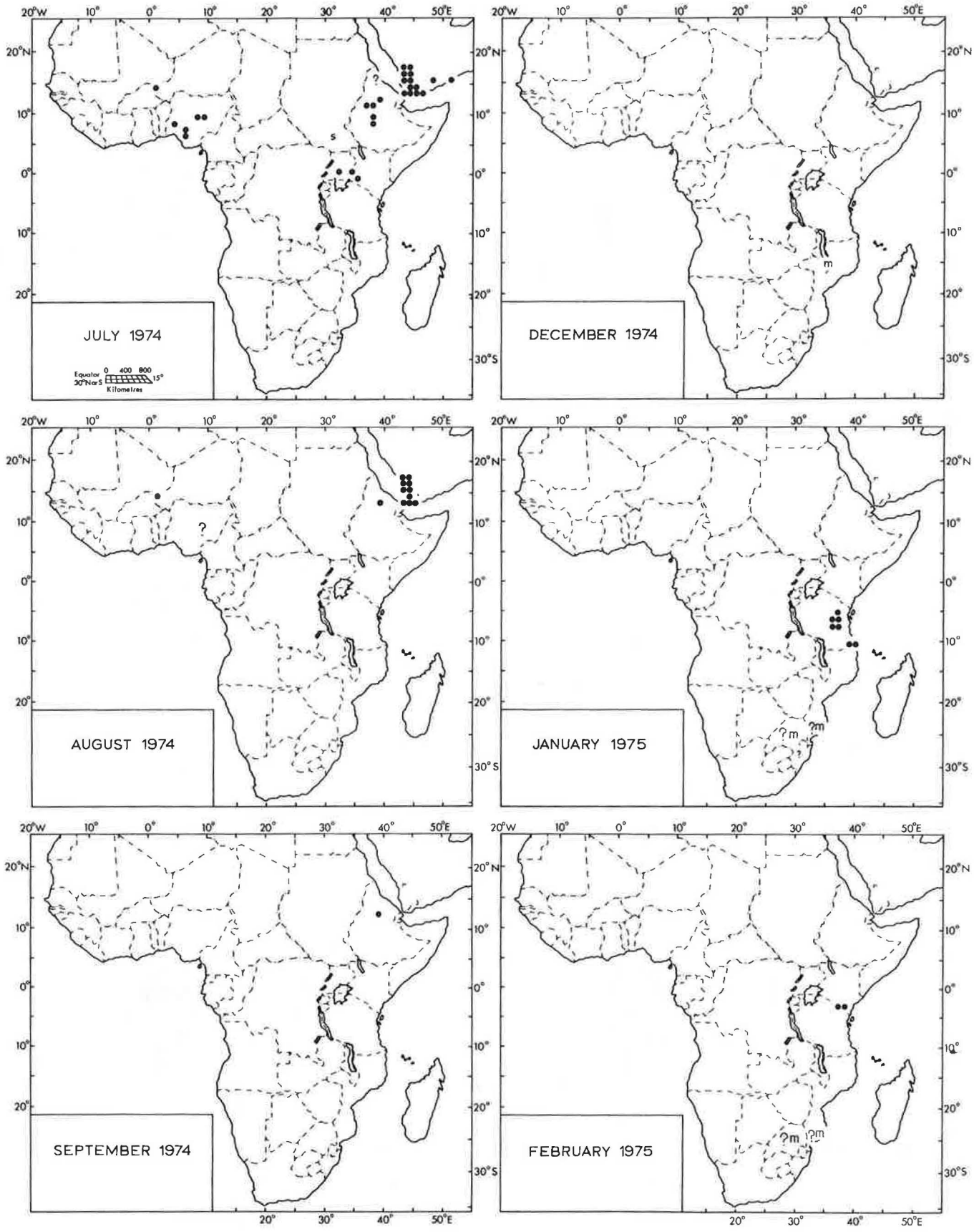


March 1974 (month?): Infestations in southern Natal, 29°S 30°E and widespread (Information received since the maps were compiled).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AUGUST 1974
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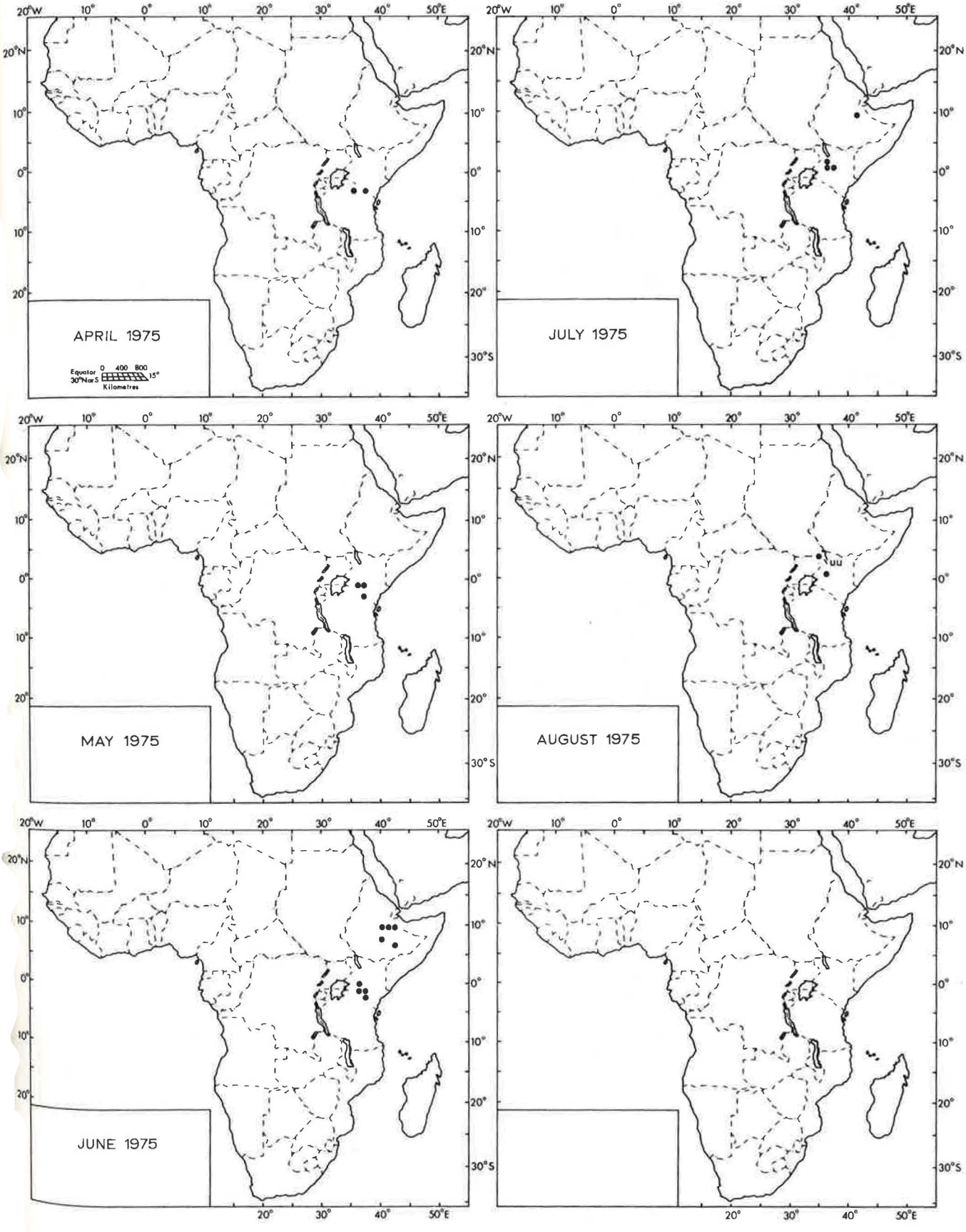
SEPTEMBER 1974
FEBRUARY 1975
Equator 0 400 800
30°N or S 15°
Kilometres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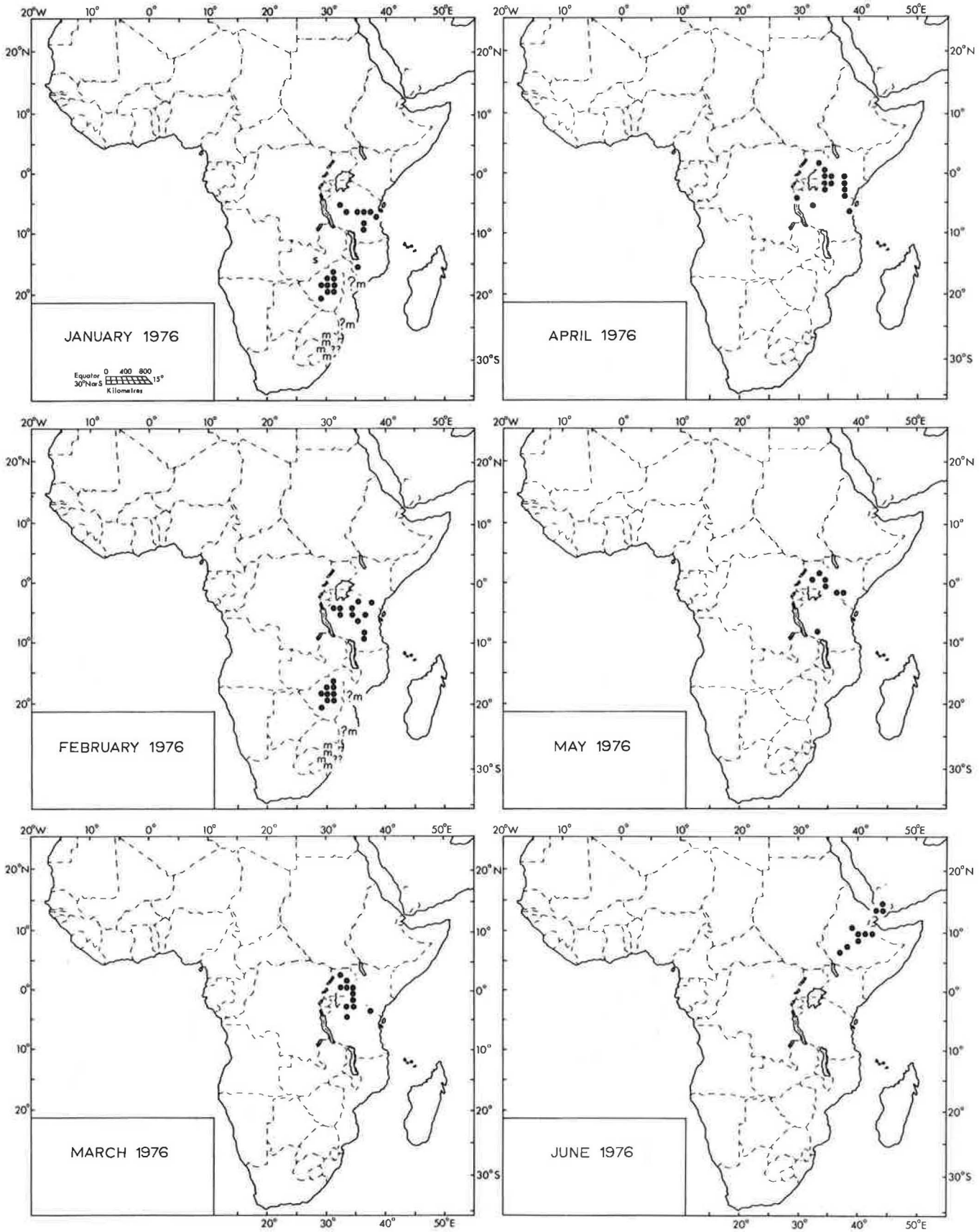
Kilometres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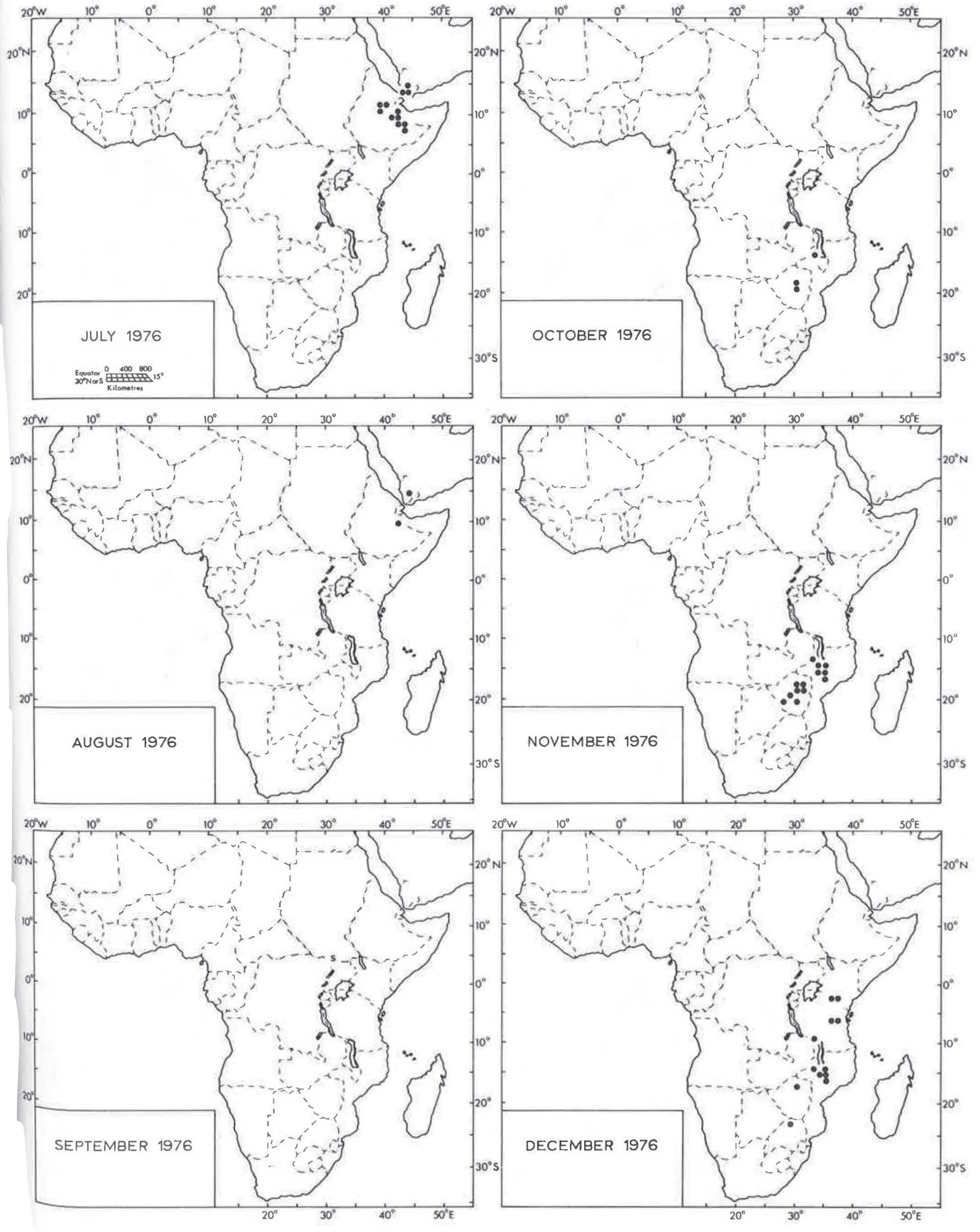
30°N or S 15°
Kilometres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Kilometres
OCTOBER 1976
AUGUST 1976
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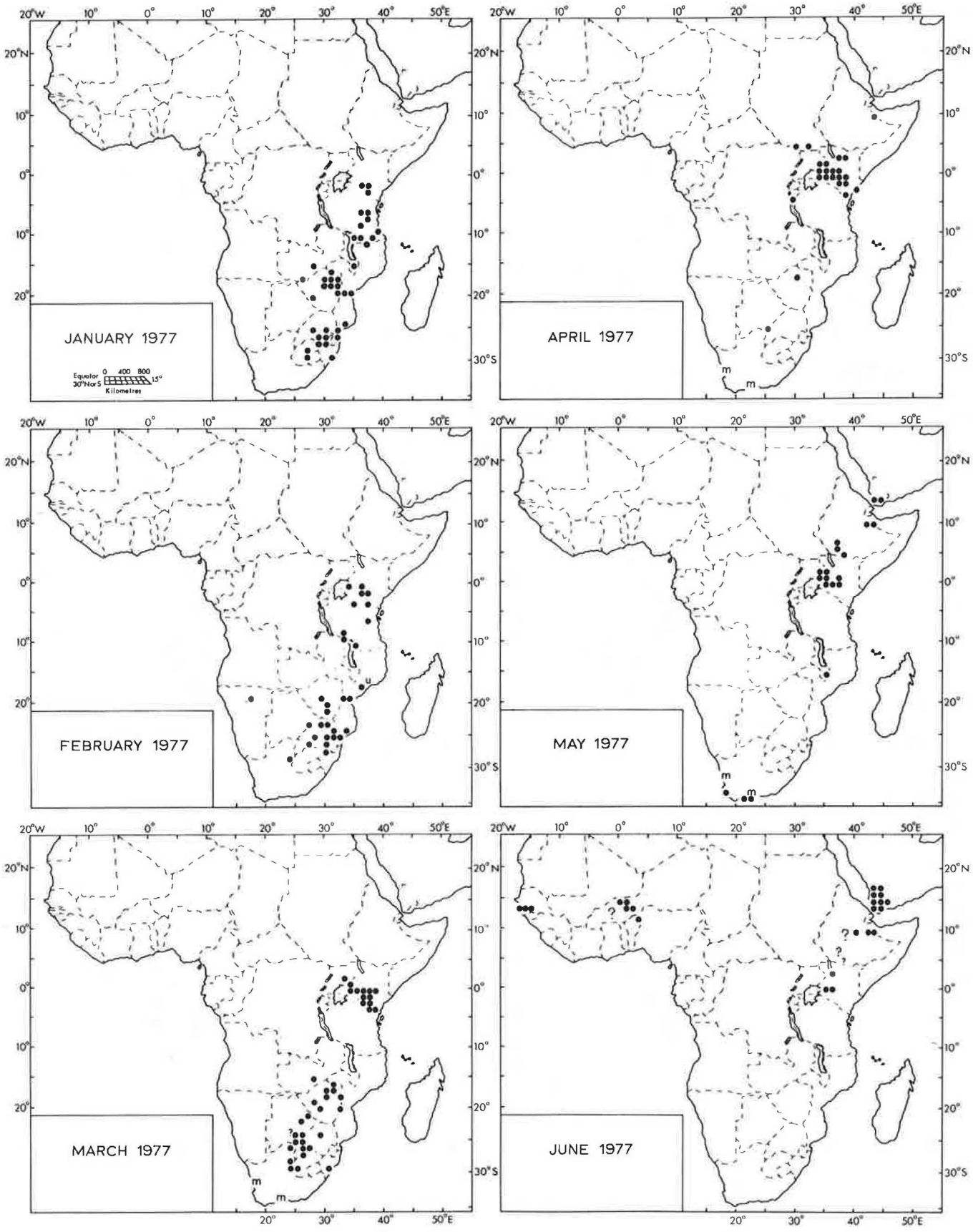
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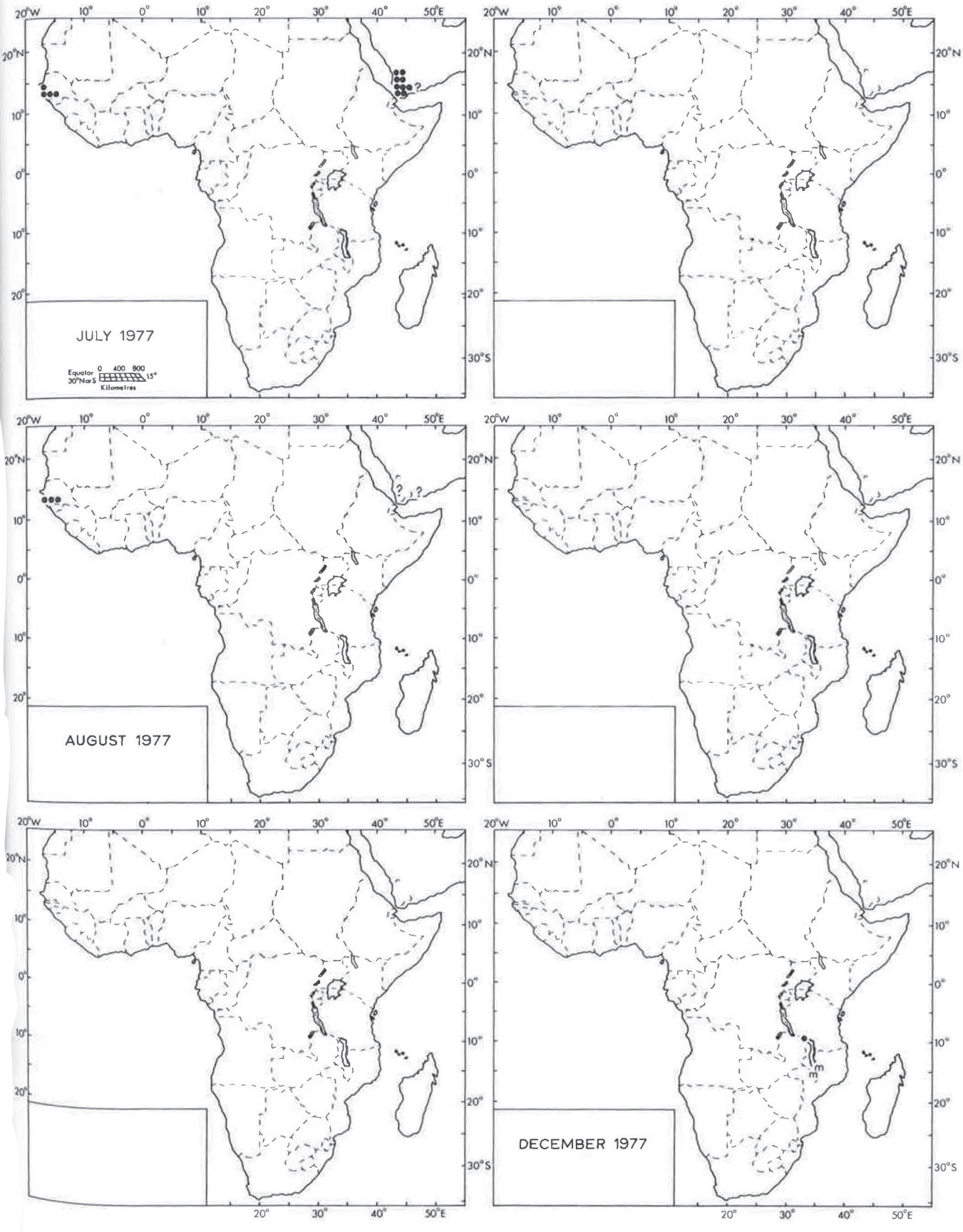
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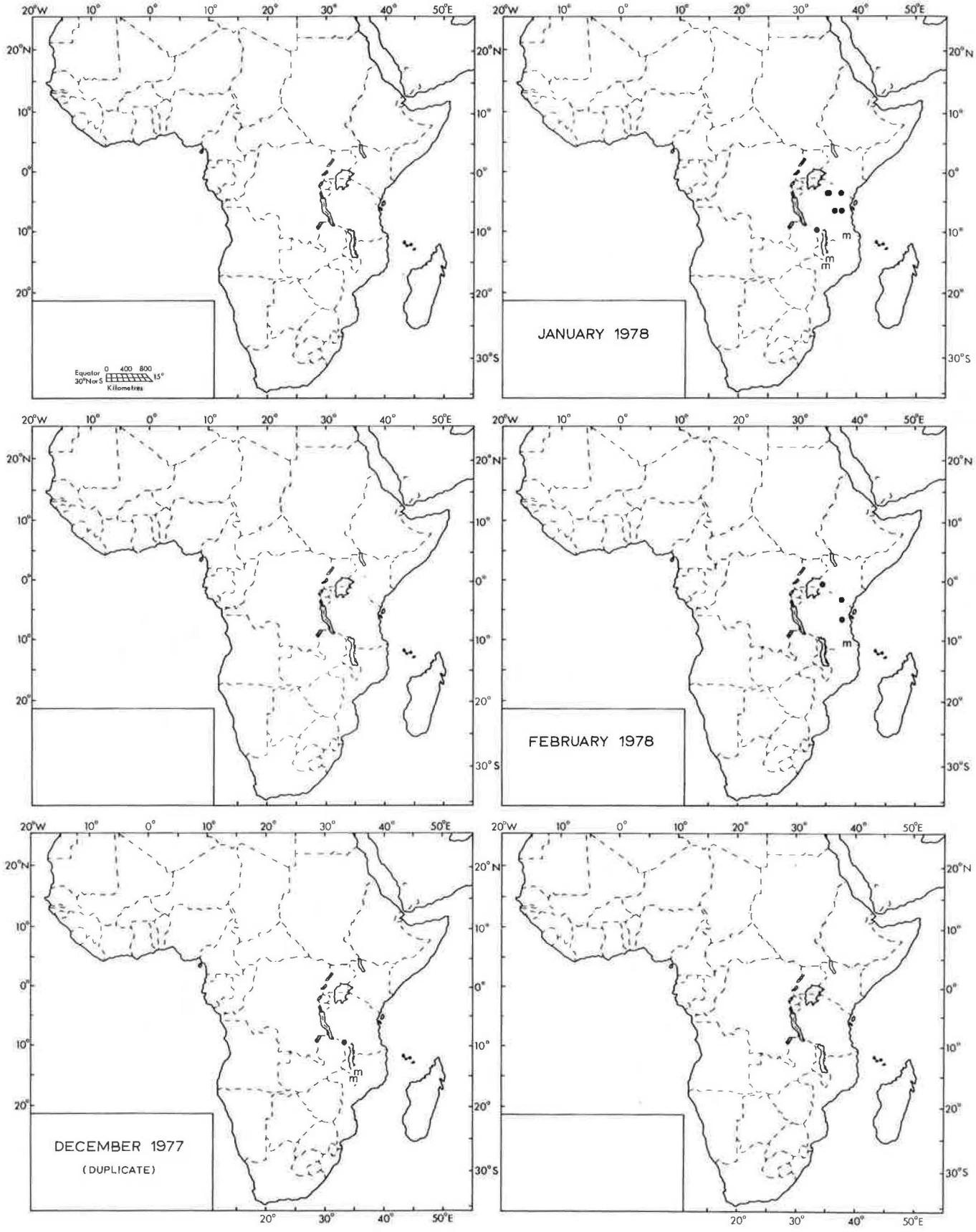
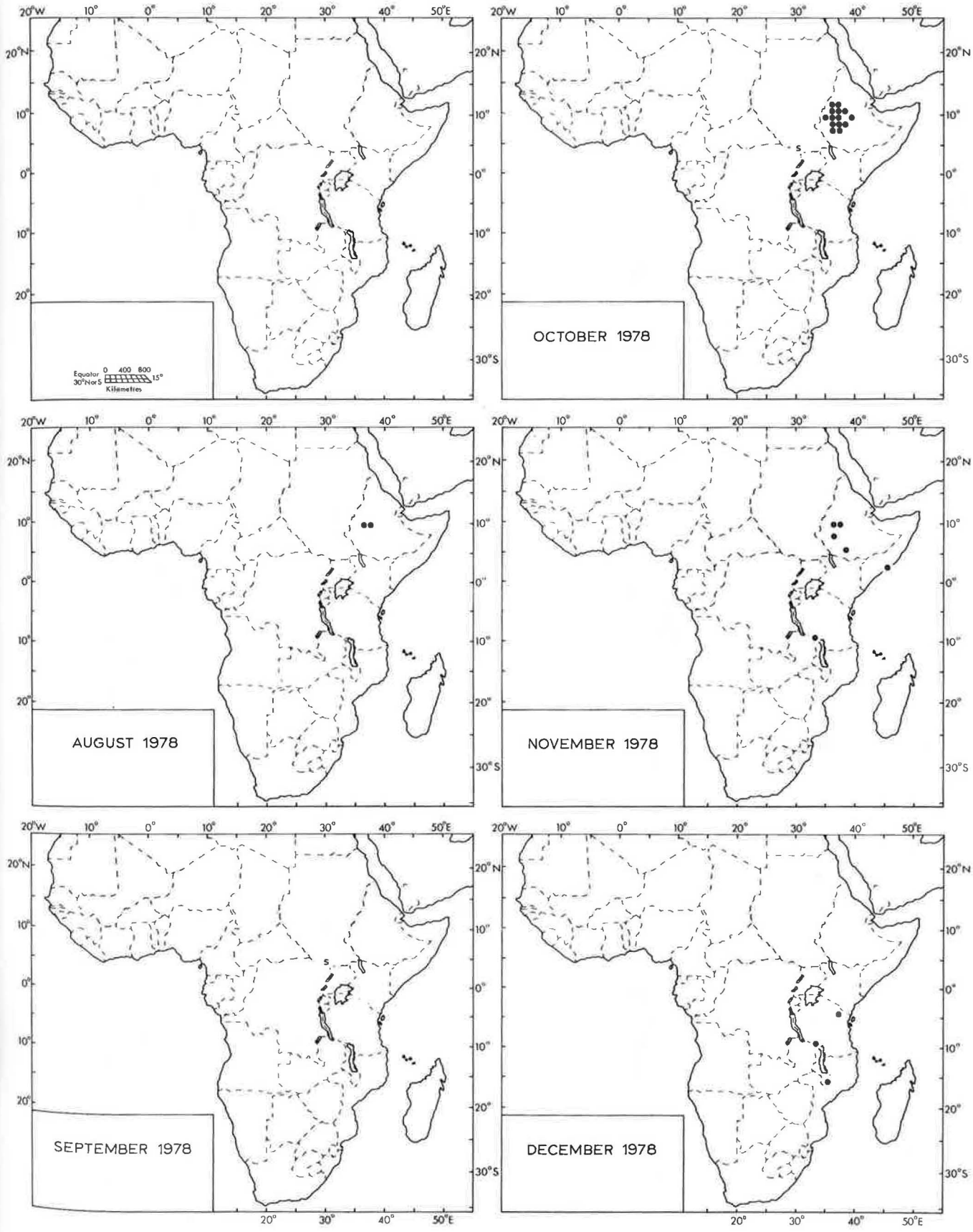
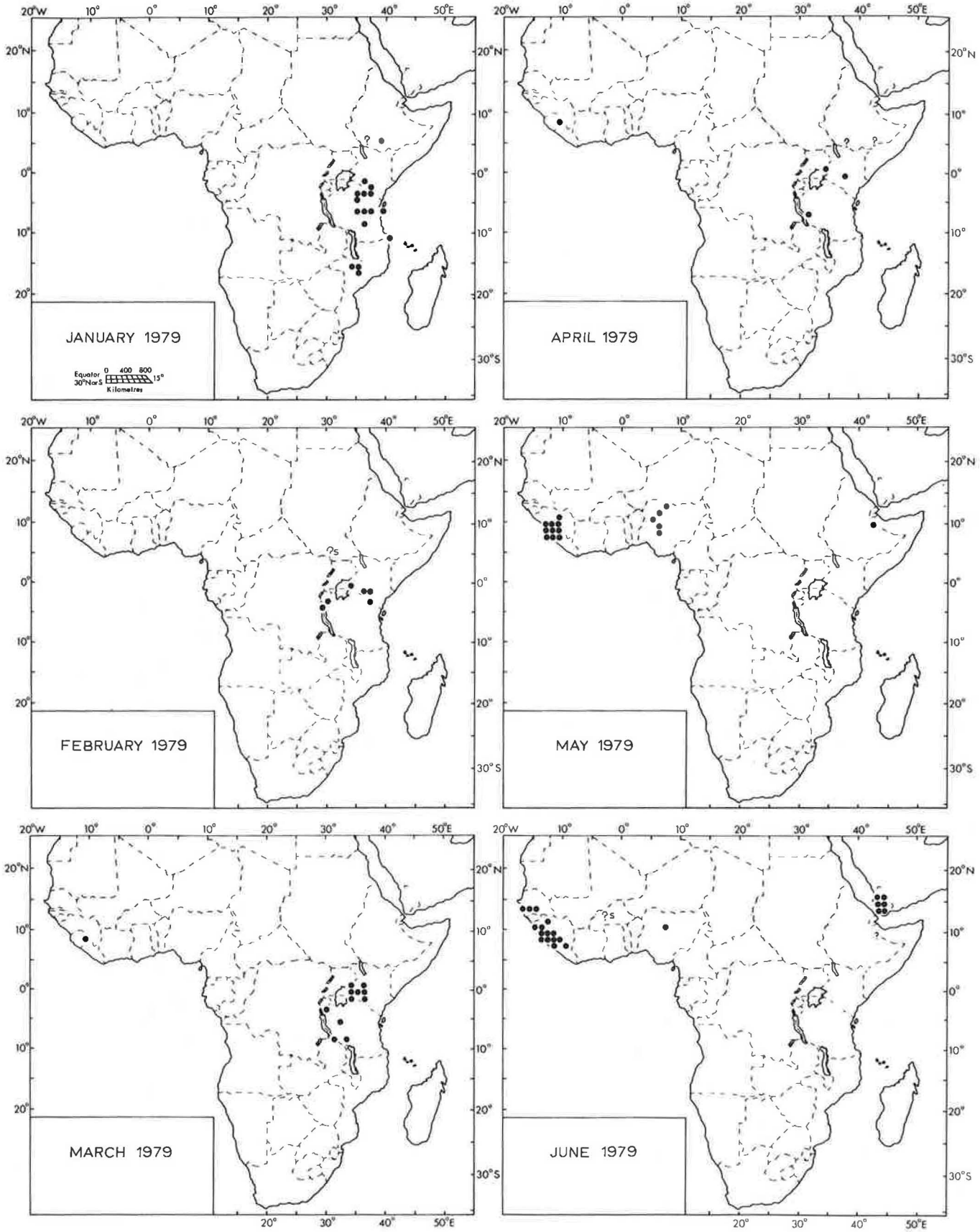
30°N or S
Kilometres
AUGUST 1977
DECEMBER 1977



February 1978: Outbreaks in southern Malawi (Information received since the maps were compiled).



October 1978 (year?) Outbreak in northern Malawi, 9°S 33°E (Information received since the maps were compiled).


JANUARY 1979
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Kilometres
APRIL 1979
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MAY 1979
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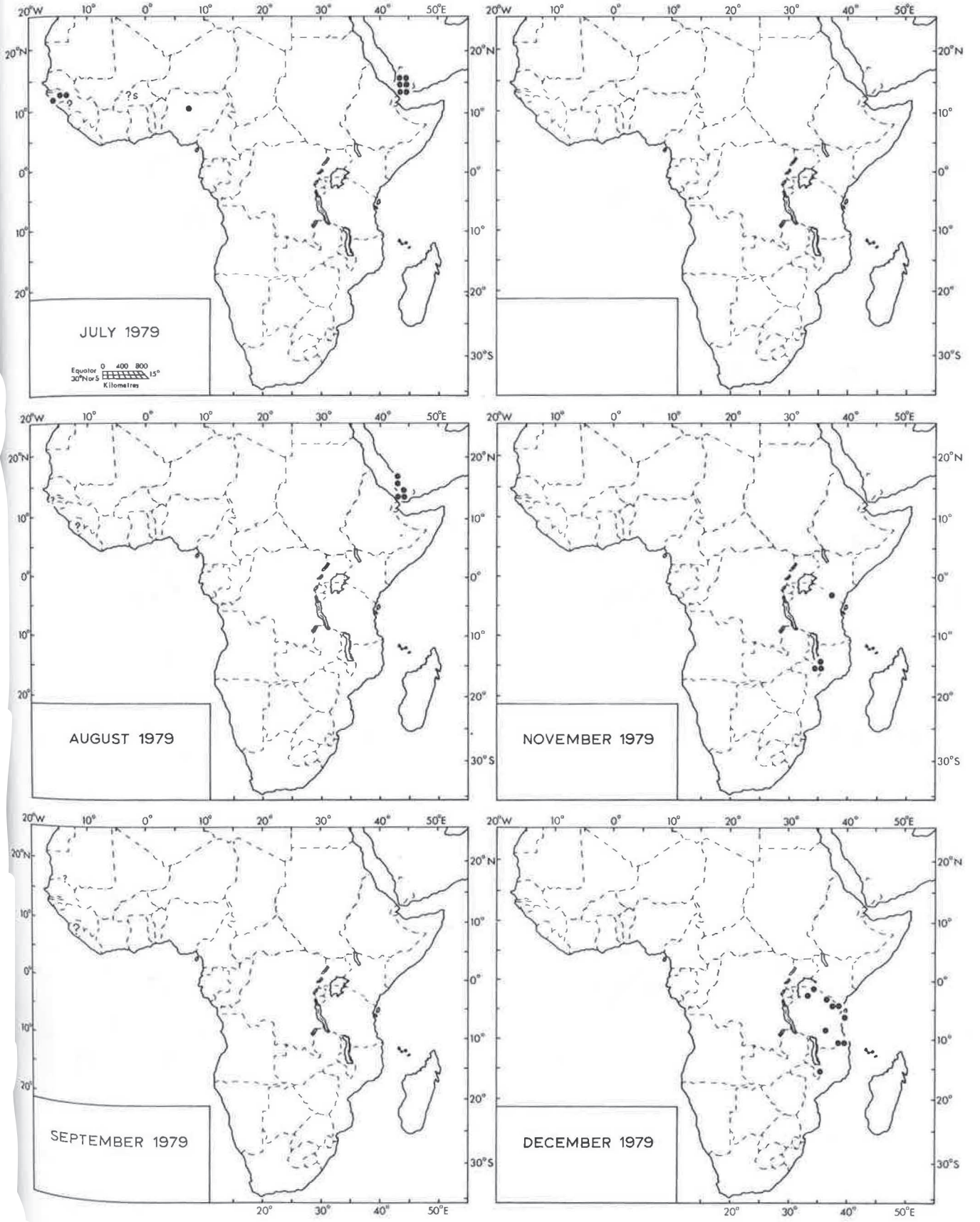
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Kilometres
AUGUST 1979
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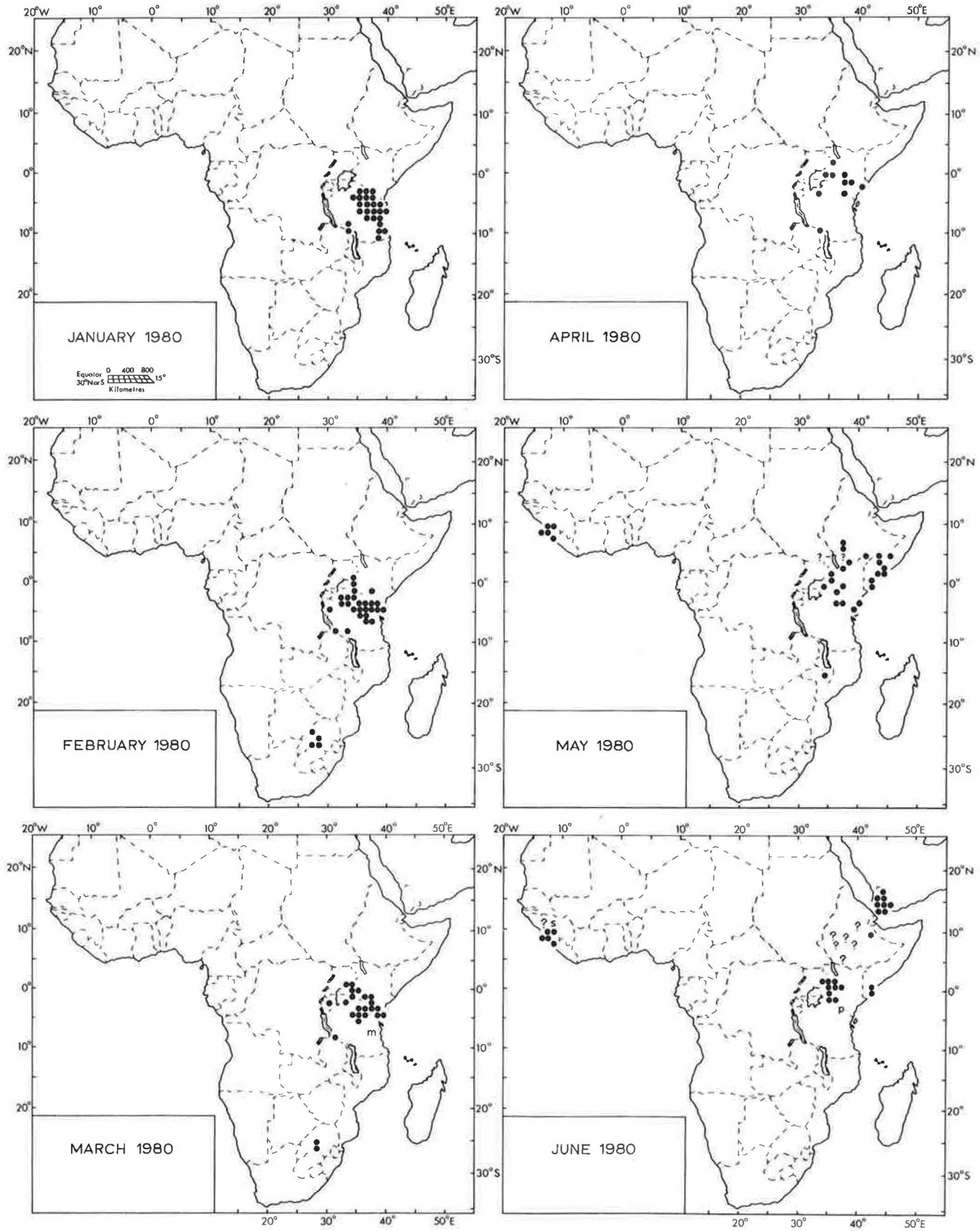
JANUARY 1980
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30°N or S Kilometres
APRIL 1980
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MAY 1980
MARCH 1980
m
JUNE 1980
20°W 10° 0° 10° 20° 30° 40° 50°E
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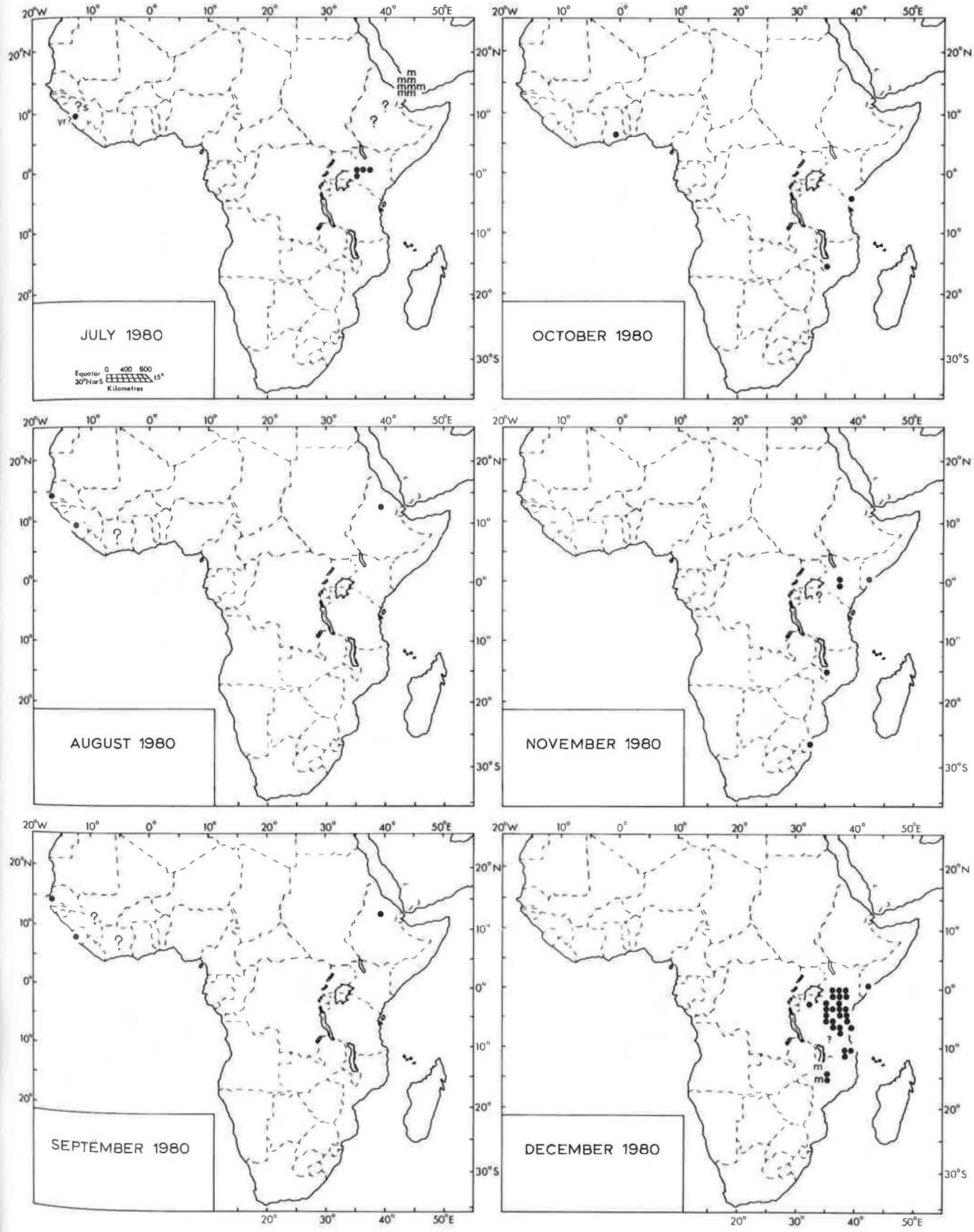
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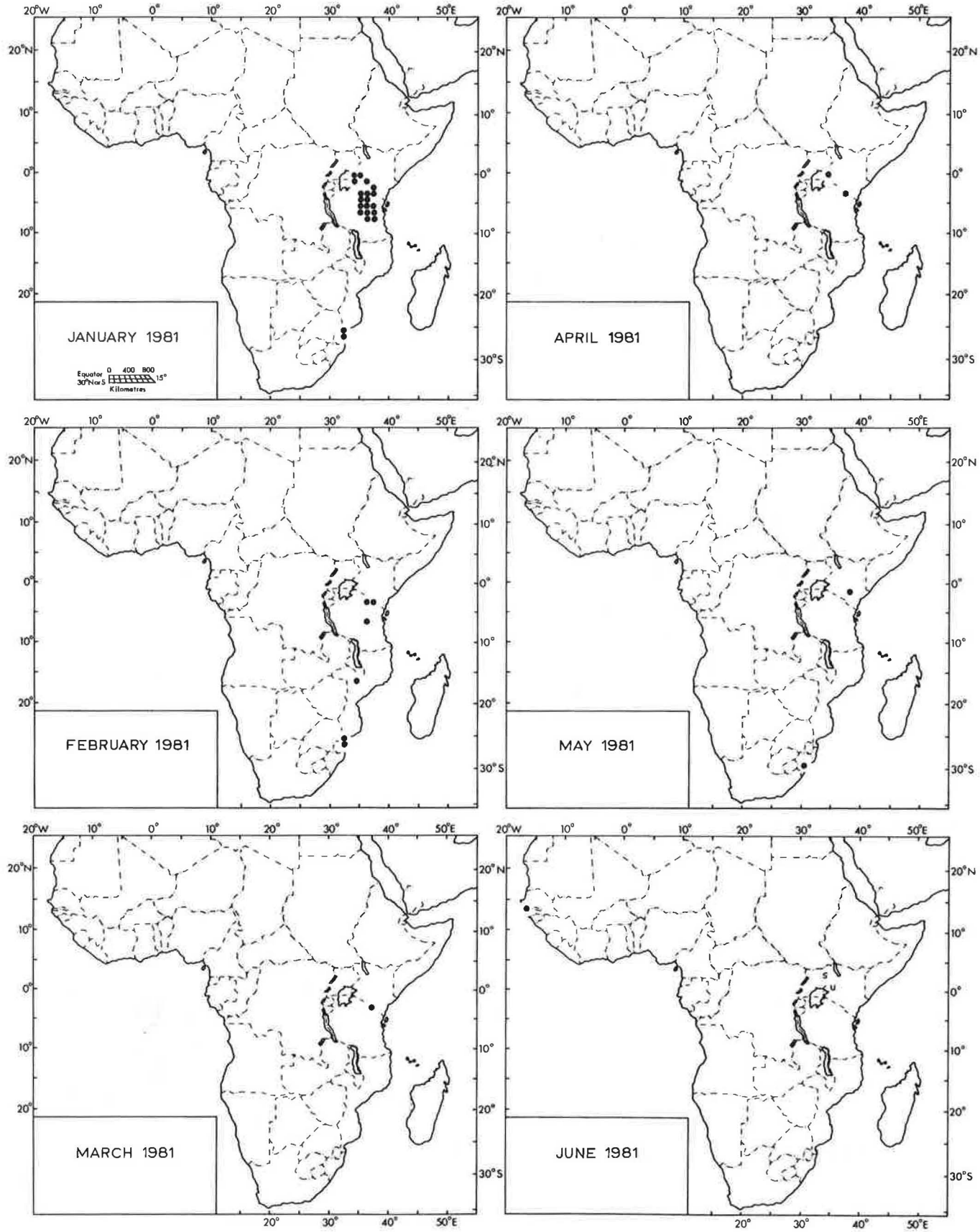
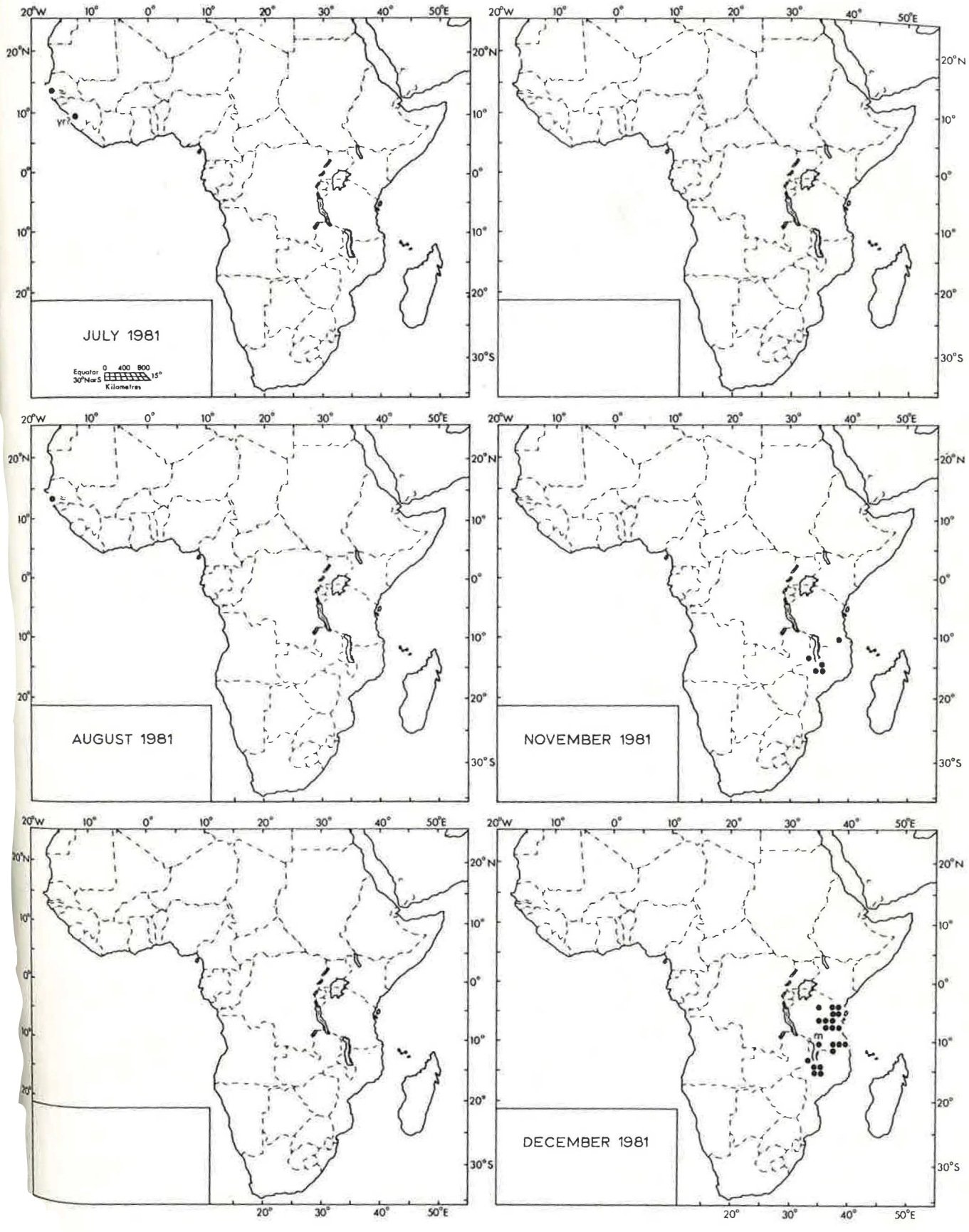


March 1981: Infestations in southern Natal, 29°S 30°E and widespread (Information received since the maps were compiled).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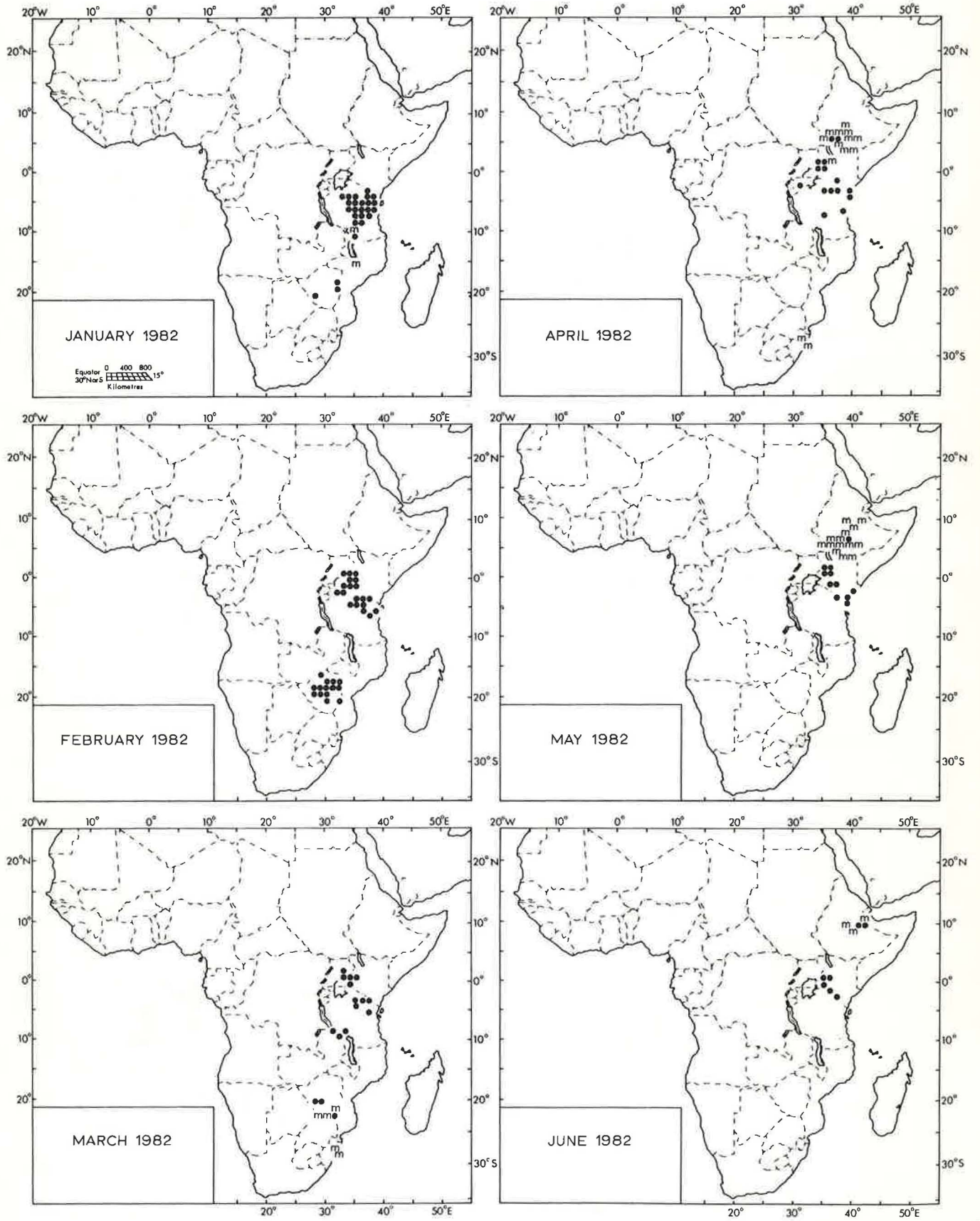

February and (?) **March 1982** (not in April 1982): Infestations in northern Natal, 27°S 32°E (Information received since the maps were compiled).

(656) Hobbs the Printers Ltd, Southampton