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Postscripts

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POSTSCRIPTS

Developments in the Desert Locust situation during 1976–9

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The period since the Discussion Meeting in June 1977 has witnessed the development of another major Desert Locust upsurge. What in retrospect may have been a key stage had occurred less than 3 weeks before the Meeting. The 1977–8 upsurge showed some striking similarities to earlier upsurges but also some individual characteristics.

In the latter part of 1976 the main Desert Locust populations were: in the western region, gregarious hoppers and young adults in northeast Mali, northwest Niger and southern Algeria and, arising from these, a few swarms in southwest Libya and adjacent Algeria; in the central region, groups of hoppers and adults on the Red Sea coast of Sudan; in the eastern region, gregarious populations in India and Pakistan had been reduced to low levels by insecticides. Details of the main populations (using the same criteria as Rainey & Betts in this symposium) and control measures are given in appendix 1 and their probable or possible interconnections are shown in figure 1.

In early 1977, Desert Locust numbers appeared to have declined to their lowest levels since early 1972. In northwest Africa, overwintered adults started to breed in northwest Libya and eastern Algeria as temperatures rose in the Spring and by early June young adults at swarm density were controlled in wadi Awal. Some survivors probably crossed the Sahara and augmented adults that had remained in Mali and Niger during the winter of 1976–7 while others may have reached the interior of the Sudan. Breeding began on summer rains and by late 1977 numbers had risen to warrant control in a few restricted localities of Niger and Mali. During early 1978, only small numbers of adults were reported from the spring breeding area of NW Africa but population levels again rose in Niger and Mali in late 1978 and control measures were applied at two localities in Niger in October.

In the central region the main populations in late 1976 were along the Red Sea coast of Sudan and northern Ethiopia. There were three successive generations in Sudan between September 1976 and May 1977 but no hopper bands or swarms were recorded, almost certainly because of the effectiveness of control measures. On the Arabian side of the Red Sea, only limited control measures were needed. In eastern Arabia, initially scattered adults, probably immigrants from the monsoon breeding area in India and Pakistan, were seen in Oman in November 1976. During Spring 1977, breeding occurred in several localities in the United Arab Emirates. Control measures were applied in April and May but fledglings were seen between early May and early June. In mid-June a cyclone gave rise to heavy widespread rain from Dhofar to the Batinah coast. Masirah recorded 430.9 mm in the 24 h period to 06h 00 on 13 June, which is believed to be the heaviest daily rainfall total ever recorded in eastern Arabia. It is probable that there was breeding at high density somewhere in the cyclone-affected area for on 7 October an adult which was pink (gregaricolor) though with extreme solitariform

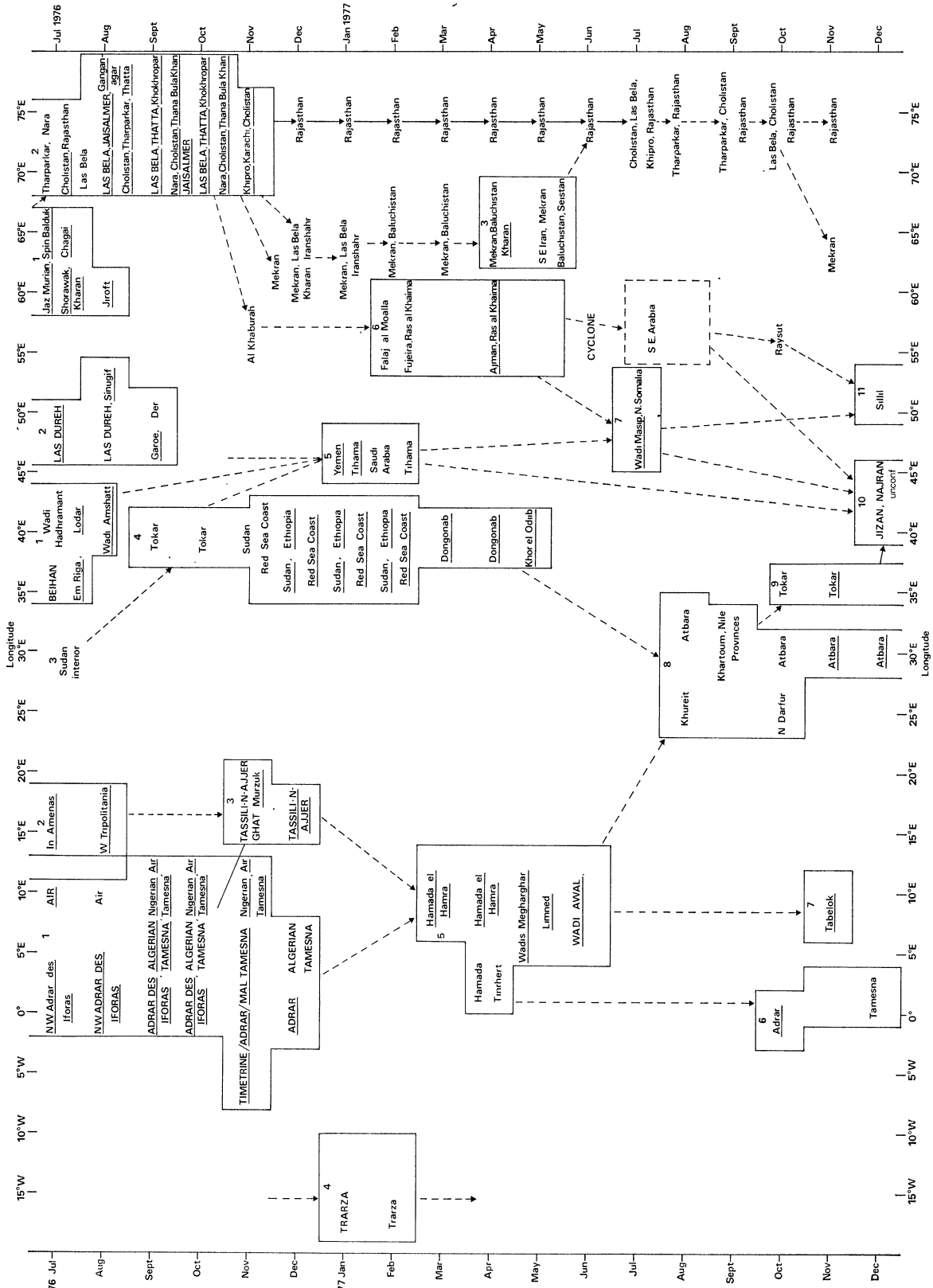

FIGURE 1. Desert Locust upsurge 1976–7. Key as figure 2 in Rainey & Betts (this symposium).

morphometrics (as might have resulted from gregarious breeding at high temperatures; Stower *et al.* 1960) was collected at Raysut near Salalah. The putative southwest movement from eastern Arabia apparently continued, for in late December 1977 mature swarms were seen on the Jizan Tihama of Saudi Arabia, and concentrations of late instar hoppers and fledglings were seen on the northwest coastal plains of Somalia, consistent with the arrival of adults in late October. The majority of the locusts that reached the Tihama, however, probably originated in Sudan, and possibly Eritrea, where summer breeding was almost certainly on a larger scale than was reported and where the first generation of adults produced along the Red Sea coast began to appear in mid-December.

In the Eastern Region, control operations in the summer breeding area were finally concluded in early November 1976. Some adults overwintered in Rajasthan but others, probably most, moved west into Mekran, southeast Iran and some reached Oman and United Arab Emirates (see above). Only limited control was undertaken against hoppers in Spring 1977 and no control was necessary in the summer breeding area in India and Pakistan in 1977 (for the first time since 1971).

During the last decade of October 1977 a deep slow-moving trough in the mid-tropospheric westerlies and a persistent surface low pressure area which moved westwards from the Arabian Sea into the Gulf of Aden resulted in widespread heavy rain over eastern Africa and southern and western Arabia, and further heavy rain again fell in November and December 1977 and February 1978. As a result, the locusts that reached the coastal plains along the Red Sea and Gulf of Aden between October and December encountered exceptionally favourable breeding conditions and went through 2 or 3 generations in rapid succession, which resulted in the production of much more numerous swarms between March and May 1978.

The largest number of adults were probably produced on the coastal plains of Ethiopia, where the national and regional locust control organizations were unable to mount large-scale control operations. Some swarms moved into the Ethiopian highlands, others moved south to Haraghe Province and then rapidly eastwards across northern Somalia in late May, probably joined by swarms produced in Djibouti and northern Somalia. A number of swarms, apparently from Somalia, perhaps with others from southwest Arabia (see below), reached Gujarat in India in the second week of June, whence they moved north into Rajasthan, Punjab and Haryana, and subsequently invaded Pakistan. Such a movement has not been unequivocally recorded previously. On the Jizan Tihama and the Tihama of the Yemen Arab Republic, intensive control measures limited the scale of escapes but during March breeding extended north to Jeddah and, later, swarms reached central Arabia and bred. Breeding also occurred in interior Yemen P.D.R. and the eastern lowlands of Yemen A.R. and escapes may have contributed to the invasion of India.

The main breeding on the summer rains was in India and Pakistan where an intensive campaign against two successive generations, between June and October 1978, ultimately prevented large-scale escapers. Nevertheless there was evidence that some survivors moved west, into Oman, the United Arab Emirates, Yemen P.D.R. and Iran. There was widespread breeding in the highlands of Ethiopia where difficult terrain, bad weather and civil war hampered control operations, and in Sudan. Between October and December 1978 escaping swarms reached the Red Sea coast of Sudan and Saudia Arabia and, almost certainly, northern Ethiopia and started to breed. Extensive control in Sudan and Saudi Arabia prevented swarm formation. In the Horn of Africa, swarms held up along the escarpment in northern Somalia

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moved southwest with the onset of the northeast monsoon in late September and bred in the northern and eastern part of the Short Rains breeding area between October and December. A few swarms of the next generation moved southwest towards Kenya, but apparently did not reach there. Other swarms, probably escapes from uncontrolled breeding in the Ogaden, moved northwest and bred in the Railway Area and Dankalia in eastern Ethiopia. To date (June 1979), only scattered breeding has been reported from Pakistan in the eastern region but is almost certain to have occurred in southeastern Iran.

Summarizing, the key events in the upsurge appear to have been the widespread heavy rain in eastern Arabia in June 1977 followed by the sequence of heavy rain along the Red Sea and Gulf of Aden coastal plains between October 1977 and February 1978 and the lack of adequate preventative control measures along the Ethiopian coastal plain. The rapid decline in numbers in late 1978 and early 1979 could be attributed to chemical control, as was recognized by the Twenty-third Session of the FAO Desert Locust Control Committee held in Rome in May 1979. The main populations in the upsurge could be related to earlier populations against which control measures were conducted intermittently but which were not continuously gregarious.

Appendix 1. Main Desert Locust populations reported

(July 1976 – December 1977)

Western region (West and northwest Africa to eastern borders of Libya and Chad)

serial number	*month and year*	*country and locality*	*locust populations*
1	July–Dec. 1976	NW Mali (Adrar des Iforas, Tamesna, Timetrine), Niger (Aïr, Tamesna), S Algeria (Tamesna)	Breeding commenced May 1976; by July hoppers present at densities up to 50 m^{-2}, fledglings up to 40000 ha^{-1}. Aug., swarm of 140 ha and hopper bands reported. Sept. and Oct., swarms and bands reported in several localities. Nov. and Dec., bands present in several localities and fledglings at densities up to 30000 ha^{-1}. Over 44000 l 5% dieldrin and 6600 l 20% dieldrin applied over total area of 123000 ha.
2	July–Aug. 1976	Eastern Algeria (In Amenas), W Libya	Groups of hoppers controlled over 4000 ha around In Amenas in July; adults at densities up to 3000 ha^{-1} and hoppers controlled in Libya with 50% malathion in Aug.
3	Nov.–Dec. 1976	Eastern Algeria (Tassili-n-Ajjer), SW Libya (Ghat, Murzuk)	1 km^2 swarm reported in Tassili-n-Ajjer near the Libyan border; a few swarms were reported flying SW towards the Algerian border near Ghat, small groups of adults were reported in Murzuk. 6000 kg BHC applied in Murzuk.
4	Jan.–Feb. 1977	Mauritania (Trarza)	Nomads reported a 'vol' and bands in January. Scattered adults at densities of 30–40 ha^{-1} in areas of green vegetation in Feb.
5	Mar.–June 1977	Libya (Hamada el Hamra), Algeria (Hamada Tinrhert)	Groups of adults in Mar. and April; May, groups of I–IV instar hoppers at densities of 25–30 per clump over 75 km^2 in wadi Megharghar and at 15–20 per clump over 14 km^2. June, groups of immature adults at 25 m^{-2} over 19 km × 0.5 km in wadi Awal. 57625 kg poisoned bait applied.

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Western region (*West and northwest Africa to eastern borders of Libya and Chad*) (*cont.*)

serial number	*month and year*	*country and locality*	*locust population*
6	Oct.–Dec. 1977	NE Mali (Adrar des Iforas and Tamesna)	Oct., immature and mature adults and I–V instar hoppers found at densities of 5–2500 ha^{-1} over areas of 0.2–20 ha in 6 wadis between Bouressa and Tin Zaouaten; 20 ha controlled in wadi Tabelok. Dec., II–IV instar hoppers found at 1–2 m^{-2} over a total area of 50 ha at two localities in Tamesna.
7	Nov. 1977	Niger (E Tamesna)	Groups of hoppers at densities of 10–20 m^{-2} found over an area of 2800 ha at Tabelok; 1050 l of 5 % dieldrin applied over 1865 ha.
Central region (*Egypt, Sudan, Eastern Africa, Arabia*)			
1	July–Aug. 1976	People's Democratic Republic of Yemen	Swarm reported from Beihan on 2 July; groups of adults seen at three places by survey team on 6 July. Groups of adults seen in Wadi Hadhramaut on 12 July. Control operations begun in June against groups of hoppers in Em Riga and Lodar areas; 500 kg 10 % BHC dust and 200 l of 15 % BHC in oil applied. 30 kg 10 % BHC dust applied against V instar hoppers and fledglings in Aug.
2	July–Sept. 1976	Somalia (Northern)	In July 40 hopper bands of II–V instars, largest 40 ha, and fledglings, present in Las Dureh area; control measures applied. In early Aug. a further 7 bands reported near Las Dureh. V instar hoppers and fledglings reported near Sinugif in Aug.; control measures applied over 5 km^2. In Sept. adults in Garoe were sprayed with 10 % dieldrin and breeding was reported in Garoe and Der.
3	July–Aug. 1976	Sudan (Kassala, Gezira, White Nile Kordofan Provinces)	Scattered adults present at densities up to 120 ha^{-1} at five localities.
4	Sept. 1976–May 1977	Sudan (Red Sea Coast), N Ethiopia (Red Sea Coast)	Three generations of breeding; first must have started in late Sept. for in Sudan, fledglings at densities of up to 4380 ha^{-1} seen on 18 Nov. in the Tokar Delta over area of 280 ha. Groups of mature adults were present in the Tokar Delta from Nov. to Jan., south of Tokar in Jan., between Tokar and Port Sudan in Jan.–Feb., north of Port Sudan in Feb. Groups of hoppers present in Tokar in Dec.–Jan., south of Tokar in Dec.–Jan., between Tokar and Port Sudan in Dec.–Feb., and north of Port Sudan in Feb.–May. Over 250 000 kg BHC bait, 4000 kg BHC dust and 394 l 96 % malathion were applied. In N Ethiopia hoppers and adults reported in Dec.–Feb. but scale of infestations not known.
5	Jan.–Feb. 1977	Yemen Arab Republic (Tihama), Saudi Arabia (Tihama)	Green hoppers at 5–8 per plant at Al-Jarr and Wadi Hayran in Jan. 15 km^2 controlled with 2000 kg 10 % BHC dust. In Saudi Arabia mature adults at densities of 270–350 ha^{-1} over 200 km^2 on Qunfidah Tihama in Jan. In Feb., I instar hoppers at densities up to 7 per bush over area of 100 km^2 on Qunfidah Tihama.

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Central region (*Egypt, Sudan, Eastern Africa, Arabia*) (*cont.*)

serial number	*month and year*	*country and locality*	*locust population*
6	Feb.–May 1977	United Arab Emirates	In early Feb. adults present at densities up to 500 ha^{-1} in Umm al Quwain, Sharjah and Ajman. In late Feb. mature adults were present at densities of 750–2850 km^{-2} in Fujeira and Ras al Khaima. In April and early May 350 hopper concentrations sprayed and hoppers in 5500 bushes dusted. Fledglings seen from early May to June.
7	July 1977	Yemen P.D.R., N Somalia	Groups of hoppers and fledglings formed in bushes in Wadi Masip in 6 ha; 500 kg BHC dust applied. Fledglings seen between Berbera and Las Dureh; immature adults seen at many places between Auguri and Gardo.
8	Aug. 1977–Jan. 1978	Sudan interior	Isolated green hoppers and immature adults seen at Khureir, NE of El Fasher in Aug. and adults at densities up to 60 ha^{-1} seen in Darfur in October. Isolated adults seen in Khartoum Province in Sept. In Nile Province isolated adults were seen in Aug., Sept. and Oct. In Nov., III–V instar hoppers and adults at densities up to 4200 ha^{-1} found at 4 sites along the Atbara river. 28 000 kg BHC bait and 360 l 57 % malathion were applied in Nov., and control continued until mid-Jan.
9	Oct.–Dec. 1977	Sudan and Ethiopia (Red Sea Coast)	In Oct. maturing adults seen in 4 blocks in Tokar Delta at densities ranging from 660 to 1680 ha^{-1} and hoppers at densities of 1000–6000 ha^{-1} seen in most wadis as far south as Emberemi and Wachiro. In Nov. maturing adults at densities of 180–1680 ha^{-1} and small groups of I–IV instars seen in 11 blocks; groups of adults also seen at Khor Arbaat. 32 600 kg BHC bait and 750 kg BHC dust applied. In Dec. most of delta infested with groups of adults and hoppers, and some fledglings. Adults at densities of 600–3600 ha^{-1} reported seen Tokar and Karora. 128 000 kg BHC bait, 3250 kg BHC dust and 3850 l of 96 % malathion applied.
10	Dec. 1977	Saudi Arabia	In mid-Dec. there was an unconfirmed report of a swarm in the Najran area. On 16 Dec. groups of laying adults reported near Jizan. On 26 Dec. first confirmed swarm reported since late Aug. seen laying near Jizan. Further eight reports of laying swarms in same area before end Dec.
11	Dec. 1977	Somalia (Sillil)	Patches of V instar hoppers, scattered fledglings and adults reported from Sillil in late Dec.
Eastern region (*Iran, Afghanistan, Pakistan and India*)			
1	July–Aug. 1976	Iran, Afghanistan, Pakistan (Baluchistan)	Concentrations of late instar hoppers and adults sprayed and dusted in three localities over an area of 5400 ha in Jaz Murian in July, and scattered adults were controlled over 200 ha in Aug. In Afghanistan II–V instar hoppers and adults dusted over 20 000 ha around Spin Buldak and 2000 ha around Shorawak in July. In Pakistan small groups of adults controlled in Chagai and Kharan in July.

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Eastern region (*Iran, Afghanistan, Pakistan and India*) (*cont.*)

serial number	*month and year*	*country and locality*	*locust population*
2	July–Nov. 1976	Pakistan, India	Maturing adults reported from many localities in summer breeding area in July; 15 km² sprayed in Cholistan. In Aug., 9 mature swarms and hopper bands present in Las Bela and one mature swarm reached Jaisalmer district. Early instar bands controlled in Las Bela, Thatta and Jaisalmer. Lower density hoppers controlled in Cholistan, Tharparkar and Ganganagar. In India 7500 kg 10 % BHC dust and 110 l 18 % dieldrin applied. In Sept. further control in above areas and Khokhropar, Nara and Thana Bula Khan areas. In India 2000 ha of hoppers controlled by 8180 kg 10 % BHC dust and 850 l of 18 % dieldrin. In Oct. and early Nov. late instar hoppers sprayed in Cholistan, Khipro and Karachi. In India maximum density of adults fell from 9750 km^{-2} in Oct. to 1275 km^{-2} in Nov. to 450 km^{-2} in Dec.
3	April–May 1977	Pakistan (Baluchistan, Mekram), S.E. Iran, Afghanistan (Seistan)	In April I–II instar hoppers at densities of 1–3 per bush sprayed in Kharan district, two late instar hoppers found in Jaz Murian, and adults at densities up to 1250 km^{-2} recorded in Chagai (Baluchistan). In May, 1 hopper found in Seistan basin near Shorawak.

Postscript on global climatic régime

By H. H. Lamb

Since the meeting, later observations and analyses seem generally to confirm that the global climatic régime that became apparent in the 1960s has continued and developed somewhat further. Its most dramatic feature is the persistence of the colder régime in the Arctic, particularly clearly indicated by the temperature of the lower half of the atmosphere (1000–500 mbar thickness), on which I am indebted to Professor H. Flohn, Meteorologisches Institut der Universität Bonn, for his unpublished compilation of the 1949–78 data for 50–90° N. This has been coupled with the decline in the frequency of westerly weather situations over the British Isles (average 97 days per year from 1868 to 1967, average 71 days per year from 1968 to 1978, no less than 5 of these last 11 years producing totals lower than any year in the previous 107 years). Further details are given in Lamb (1977). A study published by Lamb & Mörth (1978) gives a reasonable statistical foundation for regarding the 10 year means of the frequency of westerly winds in England, and of the incidence of the Arctic sea ice at the coast of Iceland, as useful indicators of the state of World climate, of global temperature level and (*inter alia*) of the rainfall in the Sahel zone of Africa. A paper published jointly by a group of European, American and Japanese meteorologists (Kukla *et al.* 1977) confirms that, despite rather localized warming in New Zealand and two extensive sectors of Antarctica, the cooling established in

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the Arctic is paralleled by a (lesser) cooling that affects most latitude zones on the Earth. Indeed, temperature averages for most zones show some continued cooling trend up to the latest observations available, the only obvious exception being the zone 60–90° S. Similarly, Lake Victoria in equatorial Africa so far shows no sign of reverting to the lower level that it maintained from the 1890s to 1960 while in latitudes 15–20° N in Africa (the Sahel) the rainfall continues generally deficient by the standards of 1930–60. Another severe drought year affected the Sahel in 1977, and again in 1978 the rains were much below normal in the western part and food shortages were reported.

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Comments on Desert Locust developments of 1976–9

By R. C. Rainey, F.R.S.

The latest Desert Locust upsurge provides new evidence on a number of the points discussed at the meeting. On the view that locusts are no longer a problem, it is perhaps only necessary to say that effects of this view have added to the difficulties faced by those responsible for combating the upsurge.

J. Roffey's demonstration that the main locust populations in this upsurge could be related to known earlier populations perhaps reinforces the evidence of continuity similarly provided by the 1963–8 recession; and, while the behaviour of his earlier populations was not continuously gregarious, neither was that of many (and perhaps all) of the populations of plague periods. Fledglings commonly move out from breeding areas in open formation (as Dr Gunn has described); the largest populations of scattered locusts appear indeed to be those seen in transit from one area of heavy gregarious breeding to another during plague periods. Incidentally, the assessment of fledglings flying out of breeding areas may now be suggested as a second major strategic role for airborne radar, which alone offers possibilities not only of providing representative quantitative data but also of doing so with appropriate speed. One was recently and very forcibly reminded of the importance of this problem, so far quite unresolved, in the course of a brief return to Desert Locust forecasting. Roffeys' graphical presentation of the events of 1976–9, together with ours for 1963–8 (and a similar treatment for 1969–77), provide a framework for series of detailed case-studies in dynamic biogeography, to test and amend the various links suggested and to assess their relative importance, and so to contribute to further improvements in control strategy by directing attention to particular areas and seasons in which by analogy improved reconnaissance and control in the future would be likely to contribute most to prolonging the recession.

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This upsurge, apparently short-lived like that of 1967–9, similarly suggests further circumstantial evidence of effects of control measures, particularly in Pakistan, India and Arabia, using as in the early 1960s the then new methods and materials on a large and perhaps locally unprecedented scale. However, Professor Lamb's note on the persistence of the global climatic régime which became established in the 1960s adds further weight to the warning, sounded at the meeting, that the general climatic régime may at any time become abruptly more favourable to the locusts than it has been since the 1950s.

The African Armyworm Research Project, 1977–9

By D. J. W. Rose and P. O. Odiyo

During the last 2 years, 207 pheromone traps have been installed in eight countries in eastern and central Africa to supplement the light trap network and to extend its range beyond the areas of mains electricity supply. Although there is a positive correlation between numbers of male moths captured in pheromone and nearby light traps, numbers in pheromone traps are usually much lower except when moths have settled in the area; then catches in pheromone raps may be higher than those in light traps. This has enabled the accuracy of forecasting to be improved. For example, the pheromone traps have given better warning of major outbreaks at Kisumu, Kenya (19 February – 4 March 1979, light trap 605 moths: pheromone trap 4151 moths), at Kibaha, Tanzania (1–3 December 1978, light trap 0 moths: pheromone trap 269 moths), and at Bako, Ethiopia (22 September 1978, light trap 0 moths: pheromone trap 324 moths). Although light trap catches may be greatly reduced during periods of full moon, this did not account for the predominance of pheromone trap catches persisting for several weeks at Kisumu.

Light and pheromone traps seem to vary in their ability to attract males of different ages and physiological condition, and both traps are necessary at each locality for best interpretation of catch data. Pheromone traps are being used alone experimentally to identify areas in which low density populations may persist.

In the current season (1978–9), extensive field observations have been made in Kenya on the flight activity of moths at emergence sites. The peak periods of activity at dusk and before dawn closely correspond to those of earlier, indoor experiments (Rose, unpublished) and to those currently being measured in the laboratory (Gatehouse, unpublished). The hitherto least reported moth activity, and the most unexpected, was mass settling in nearby trees on the night of emergence. Mating by older moths in trees after midnight was also observed (Rose & Dewhurst, unpublished) in the locality of a wind-shift (Pedgley & Tucker, unpublished) where moths flying from an emergence site may have settled. The various observations will be reported elsewhere by the different scientists involved, on radar studies (J. Riley and D. R. Reynolds), sophisticated optical studies (M. Farmery), visual observations (D. J. W. Rose and C. F. Dewhurst) and laboratory techniques (A. G. Gatehouse).

Since the date of the meeting the papers listed in the bibliography have been produced by members of the African Armyworm Project.

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