Chapter 1

The Basics

CONTENTS

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SETTING THE STAGE

In the late 1980s, several major species of locusts as well as significant populations of various grasshoppers simultaneously threatened Africa for the first time in 50 years (93). This infestation began in 1985 through 1986 after rains ended a severe, several-year drought and new, green vegetation allowed these pest species to proliferate.

Several grasshopper species in the West African Sahel reached levels high enough to result in large-scale control efforts from 1985 to 1989. Also, a major plague of Desert Locusts began in countries around the Red Sea, with swarms moving west across the Sahelian (see app. A) countries. By November 1988, swarms of the Desert Locust extended from Mauritania and Senegal in the west to Iraq, Iran, and Kuwait in the east, and some fragments of swarms even reached the Caribbean.

The last widespread Desert Locust plague extended from 1949 to 1%3. Following that plague, the infrastructure to fight locusts and grasshoppers deteriorated, and the recent plague caught Africa unprepared and highly vulnerable. For donors, including the U.S. Agency for International Development (USAID), the Desert Locust plague, along with other locust and grasshopper problems, caused shifts in funds, operations, and programs to cope with the apparent emergency.

Despite earlier forecasts that the Desert Locust plague might continue for several more years, in April 1989 the United Nations Food and Agriculture Organization (FAO) announced that the plague had dissipated (105). But longer-term issues remain. For example, experts differ widely in their assessment of the significance of locust and grasshopper outbreaks relative to other pest problems and in terms of the crop damage they cause on a national level; the information base on which major control decisions were based seems deficient; no sound technological alternatives exist for chemical pesticides; and education and training for the next generation of experts to deal with future plagues seems inadequate.

In this study (box l-A), OTA examines what happened during the 1986 to 1989 plague years and considers the implications of the longer-term issues. The major species of locusts and related aggregating grasshoppers in Africa and the Middle East (box 1-B) are the focus. From 1986 to 1989, most international control efforts in Africa were directed at the Desert Locust and the Senegalese Grasshopper, so most examples in this report deal with these two species.

LOCUSTS AND GRASSHOPPERS

Locusts and aggregating grasshoppers have fascinated biologists and caused farmers anxiety for centuries because of their unusual behavior. This section details the insects' biology and behavior. For readers with less need for detailed knowledge, the following information is critical to understanding later sections of this report and to making informed policy choices:

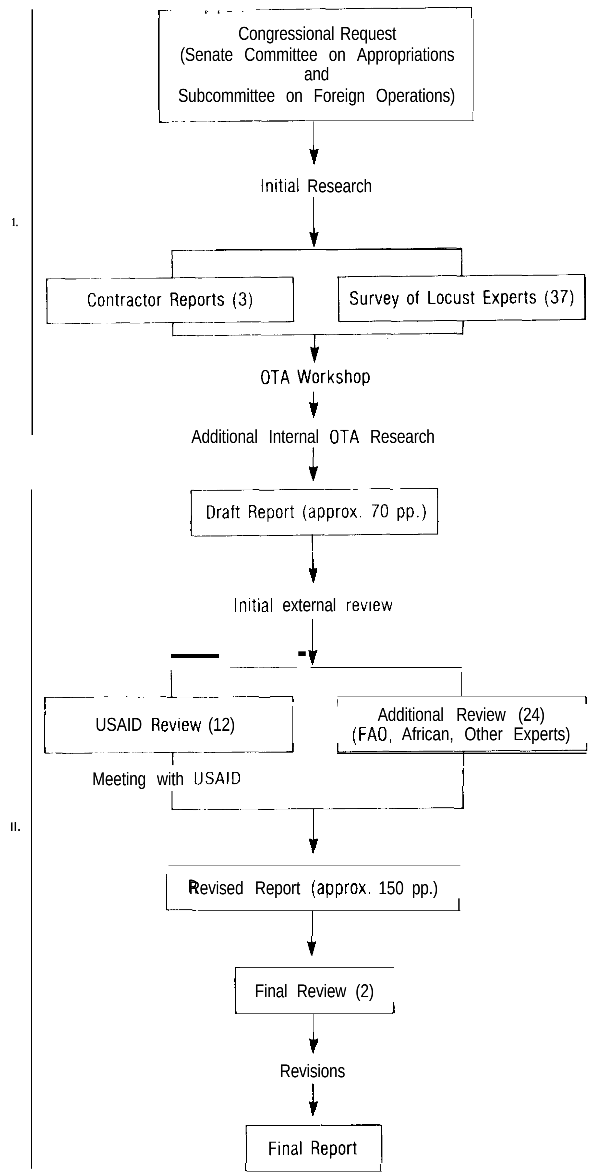
- Different locust and grasshopper species can be difficult to identify, yet they have distinct biologies that require different control strategies.
- Each insect can eat its own weight in vegetation each day. Damage mainly depends on the number of insects, how long they stay in a given area, which plants they eat (non-crop, commercial crop, subsistence crop) and the plants' stage of development
- When crowded (by breeding or congregating in moist places) these insects undergo a change–from living as scattered, sedentary individuals to becoming cohesive, gregarious bands of hoppers or highly mobile adult swarms. Swarms can migrate hundreds of miles in a few weeks.
- Locusts and grasshoppers' life cycles have three stages: eggs, hoppers, and adults. Gregarious insects are most concentrated and vulnerable to control during the second stage because hoppers cannot fly.

Box 1-A–Methods of This OTA Study

The process for this study falls into two broad phases: research and synthesis (I), then writing, review, and revision (II). In the first phase, three expert contractors examined: 1) the pest situation, control strategies, and institutional aspects in both the mid-1980s and in their historical context; 2) the role of climate in pest upsurges and declines; and 3) the ethical issues involved in control campaigns (app. B). In December 1988, OTA conducted a survey (app. C) of some 100 locust experts and officials representing the range of national, regional, and international organizations involved in locust and grasshopper control and research. The survey's objective was to assess current and past infestation trends, crop losses, control efforts, and needs for future control efforts. Twenty-six people responded in Africa, the Middle East, Europe, and Canada; 11 USAID staff completed the same form (app. D).

OTA began to synthesize the findings of the expert papers and the survey results at an OTA workshop. This meeting also identified major issues, additional data needed, and preliminary policy options. OTA prepared a draft report after conducting further interviews and reviewing more publications on these topics. This draft was reviewed by representatives of USAID, FAO, African national and regional organizations, and other experts from the United States, United Kingdom, and Africa (app. E). Also, USAID staff in Washington met with OTA in addition to providing extensive written materials. OTA's report was revised substantially following this review process. The revised draft was then reviewed a second time by one of the original three contractors and FAO. This final version includes revisions based on that review as well as additional information gathered by OTA independent of the review process.

Flowchart of Study Methods



Box 1-B–Major Species of Locusts and Related Aggregating Grasshoppers in Africa and the Middle East

Locusts

- Desert Locust, *Schistocerca gregaria:* This species is potentially the most dangerous of the locust pests because of its ability to swarm rapidly across great distances. The pest has two to five generations per year.

- African Migratory Locust, *Locusta migratoria migratorioides:* This species also may swarm over large areas. During plagues, the pest may invade nearly all of sub-Saharan Africa. The outbreak areas from which swarms arise are associated with extensive and seasonally flooded grass plains along the middle Niger River, the south-southeast Lake Chad Basin, and the Blue Nile Basin of Sudan. The pest has two to four generations per year.

- Red Locust, *Nomadacris septemfasciata:* This species, with only one generation per year, occurs in Eastern and Southern Africa. During outbreaks, it may invade nearly all of Africa south of the Equator.

- Brown Locust, *Locustana pardalina:* This species is primarily found in South Africa and southern Namibia. However, swarms may invade surrounding countries in southern Africa. The pest has two to four generations per year.

- Moroccan Locust, *Dociostaurus maroccanus*: This species, with only one generation per year, is found in arid areas of North Africa. During outbreaks, it may invade areas along a belt extending from Morocco in the west to the Near East and Soviet Central Asia.

- Tree Locust, *Anacridium melanorhodon:* During outbreaks, this species may infest an area south of the Sahara that extends from Senegal in the west to Somalia, Tanzania, and Saudi Arabia in the east. However, it is normally a problem only in Sudan where it defoliates the gum arabic tree *(Acacia senegal).* The species has one generation per year.

Aggregating Grasshoppers

- Senegalese Grasshopper, *Oedaleus senegalensis:* This species occurs in a band across Africa north of the Equator (but also reaching south in Tanzania), the Middle East, and southwest Asia. The pest has two to four generations per year.

- Sudan Plague Locust, *Aiolopus simulatrix:* This species extends from Sahel to Sudan and Egypt, southwest Asia to Bangladesh, and north to the Tadzhik Republic of the U.S.S.R. The populations are greatest in the Nile Valley, where this species is regarded as the most serious grasshopper pest. The pest can breed continuously.

- Variegated Grasshopper, *Zonocerus variegatus:* This species primarily affects forested areas of West Africa but may also extend into the Sudan and eastern Africa. It is primarily a problem in clearings of forested areas but also may be a problem in savanna areas. The pest has one generation per year.

SOURCES: Adapted by OTA from: Anti-Locust Research Centre, *Anti-Locust Handbook* (London, 1966); Dale G. Bottrell, "Locusts and Grasshoppers in Africa and the Middle East," contractor report prepared for the Office of Technology Assessment, Washington, DC, January 1989; TAMS Consultants and Consortium for International Crop Protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment,* Main Report, contractor report prepared for the U.S. Agency for International Development, March 1989; and B.P. Uvarov, *Grasshoppers and Locusts-A Handbook of General Acridology,* vol. 2 (London: Centre for Overseas Pest Research, 1977).

. Weather conditions affect insect behavior. Outbreaks occur after rainfall. Predominant reasons for declines also relate to weather–unfavorable breeding conditions (insufficient moisture, vegetation or low temperature) or wind patterns.

Definitions

Locusts belong to a large group of insects commonly called grasshoppers-insects recognized by powerful hind legs adapted for jumping–in the insect order Orthoptera. Technically, grasshoppers and locusts belong to the superfamily Acridoidea within that order. Therefore, they are close biological relatives.

Many scientists distinguish locusts from grasshoppers based on locusts ability to form dense groups comprised of large numbers of insects. In some cases this distinction is not clear because “aggregating” grasshoppers can behave similarly. Thus, the terms “locust” and “grasshopper” are sometimes ambiguous.

Also, the term “locust” is used nontechnically. In the United States, for example, cicadas-a different type ofinsectintheorder Homoptera-are sometimes called “locusts.” Different kinds of cicadas occur in large numbers at regular 13- and 17-year intervals. Unlike locusts, periodical cicadas do little damage to vegetation. People who have experienced their dense hatching, however, know something of what locust outbreaks are like. “bust”, in French, is "criquet," but theinsectsAmericans call crickets also differ from locusts andgrsshoppers although the three insect types sharethe same scientific order.

At least 1,500 species of grasshopers and locusts exist in Africa, with a wide spectrum of characteristics. Some 200 species have been reported as pests. Accurate scientific identification, often essential to assessing the magnitude of a pest problem and selecting suitable control methods, can be difficult.

Life Cycles: Eggs, Hoppers, and Adults

The life cycle of all species of locusts and grasshoppers consists of three stages: eggs, hoppers, and adults. Usually eggs occur in frethy cylindrical pods deposited at shallow depths in moist ground. Eggs hatch into hoppers primarily during the rainy season after an incubation period affected by temperature. Hoppers periodically “molt,” or cast off their skins, as they grow. Usually the insects molt five times, with the growth stages between each known as "instars." After the last molt, the insects are considered “fledglings,” or immature adults, but have developed wings strong enough to fly (figure l-l). Desert Locusts live from 2.5 to 5 months (93) and, under optimal environmental renditions, populations probably can multiply 10 times in each generation (71).

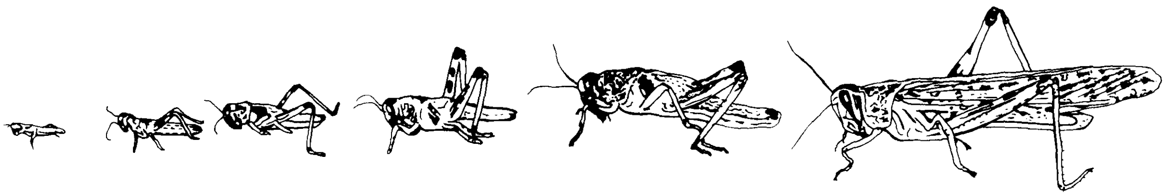
Various grasshopper and locust species differ in important ways, such as the length of time eggs can survive without rain and the insects’ vulnerability to natural enemies (predators, parasites, and pathogens). Desert Locust eggs are viable for up to 10 to 12 weeks in soil that remains sufficienty moist (118). On the other hand, Senegalese Grasshopper eggs can survive in dry soil for several years and hatch when rains come (55). Grasshopper often fall prey to natural enemies (99), but usually natural enemies only are significant sources of mortality for Desert Locusts when populations are in decline for other reasons (93). Weather, however, is the most important natural cause of Desert Locust mortality.

Behavior: Solitary and Gregarious Insects

Behavior patterns principally distinguish locusts from other grasshopers. Locusts behave as “typical” grasshoppers and live as solitary individuals when their populations are small. However, when locusts occur inlargenumbers andhighdensity theyundergo a transformation to a gregarious phase, and move together in dense groups. Gregarious locusts are called swarms when composed of adults, and bands when composed of young hoppers. A swarm of adult Desert Locusts may contain 20 million to 150 million individuals per square kilometer and spread over an area ranging from a few hectares to hundreds of square kilometers. Adult swarms of Desert Locusts can migrate several thousand kilometers while hopper bands move only a few kilometers. Fledgling swarms make the longest flights of all adults, traveling up to 1,000 km in a week (93).

Experts generally agree that rain and the availability of new vegetation create conditions conducive for the transformation of solitary insects into gregarious bands or swarms (93). **Outbreaks**–marked population increases leading to the appearance of gregarious groups-follow successful breeding. Three processes are involved: the concentration of solitary locusts in one area, their subsequent multiplication and, finally, the

Figure 1-1- Life Cycle of the Desert Locust



NOTE: The relative sizes of the five instar hoppers and adult Desert Locust, shown at approximately one-half actual size.

SOURCE: A. Steedman, cd., *Locust Handboo k* (United Kingdom: Overseas Development Natural Resources Institute, 1988), p. 20.

gregarization process (83). Sometimes solitary locusts breed successively in one location; other times they congregate in new breeding sites. The resultant crowding produces gregarious behavior (83).

Physiological changes in the insects' appearance also are associated with the gregarization process and maybe dramatic. Some species change so markedly that solitary and gregarious forms were originally described as different species. Often, solitary phase locusts resemble the color of their habitat, whereas gregarious phase locusts are brightly colored. In addition, color changes may occur with sexual maturity. For example, solitary Desert Locusts are pale gray or beige when sexually immature but males turn pale yellow when mature. Gregarious Desert Locusts are bright pink when sexually immature fledglings and bright yellow when mature.

Gregarious behavior is used often to distinguish locusts from grasshoppers. However, some species of grasshoppers behave periodically in a gregarious manner–multiplying rapidly and producing swarms like locusts Population increases maybe started by unusual weather or certain changes in land use (93).

Generally, gregarious behavior in locusts and aggregating grasshoppers proceeds by intermediate or transition stages and it is reversible if conditions change. Also some species are highly gregarious whereas others are less so. Still other species' behavior falls on the continuum in between. It is therefore not surprising that experts differ in drawing the line between locusts and grasshoppers. For example, one OTA reviewer wrote, "the Tree Locust is categorized by some acridologists among aggregating grasshoppers because of [its] poor swarming behavior" (64). Others call the Sudanese Grasshopper the Sudanese Locust (71) and the Senegalese Grasshopper the Senegalese Locust (69).

Locust and grasshopper species vary in their food preferences. Some species (e.g., the African Migratory Locust, Red Locust, Brown Locust, and the Senegalese Grasshopper) prefer grasses, including economically important food crops such as corn, millet, sorghum, and wheat (95). The Tree Locust prefers trees, shrubs, and bushes. The Desert Lore@ on the other hand, eats a wide range of food (93), although some believe it prefers grasses but eats other vegetation only when necessary (54, 95).

Locusts and aggregating grasshopper represent the greatest danger to agriculture during their gregarious phase. One analysis of records of Desert Locust damage showed that 8 percent of crop damage is done by hoppers, 69 percent by immature and maturing swarms, and 23 percent by sexually mature adult swarms (93). Crop damage by hoppers is low because the breeding areas where hoppers hatch are mostly outside crop areas. But once gregarious swarms begin to migrate, the potential for damage increases. Individual locusts and grasshoppers can eat their own weight (up to 2 grams) in food every day. Desert Locust swarms are particularly large so their potential for damage is especially great. One-half million Desert Locusts, a small part of an average swarm, weigh approximately 1 ton and eat as much "food" per day as about 2,500 people (93).

Geographic Distribution and Migration Patterns

The regional distribution of each locust and grasshopper species varies from year to year, but the species involved in large-scale outbreaks called upsurges–show general patterns (figure 1-2). For several species, outbreak areas, those permanent breeding and gregarization areas,

Figure 1-2–Distribution of Major Species of Locust and Aggregating Grasshoppers in Africa and the Middle East

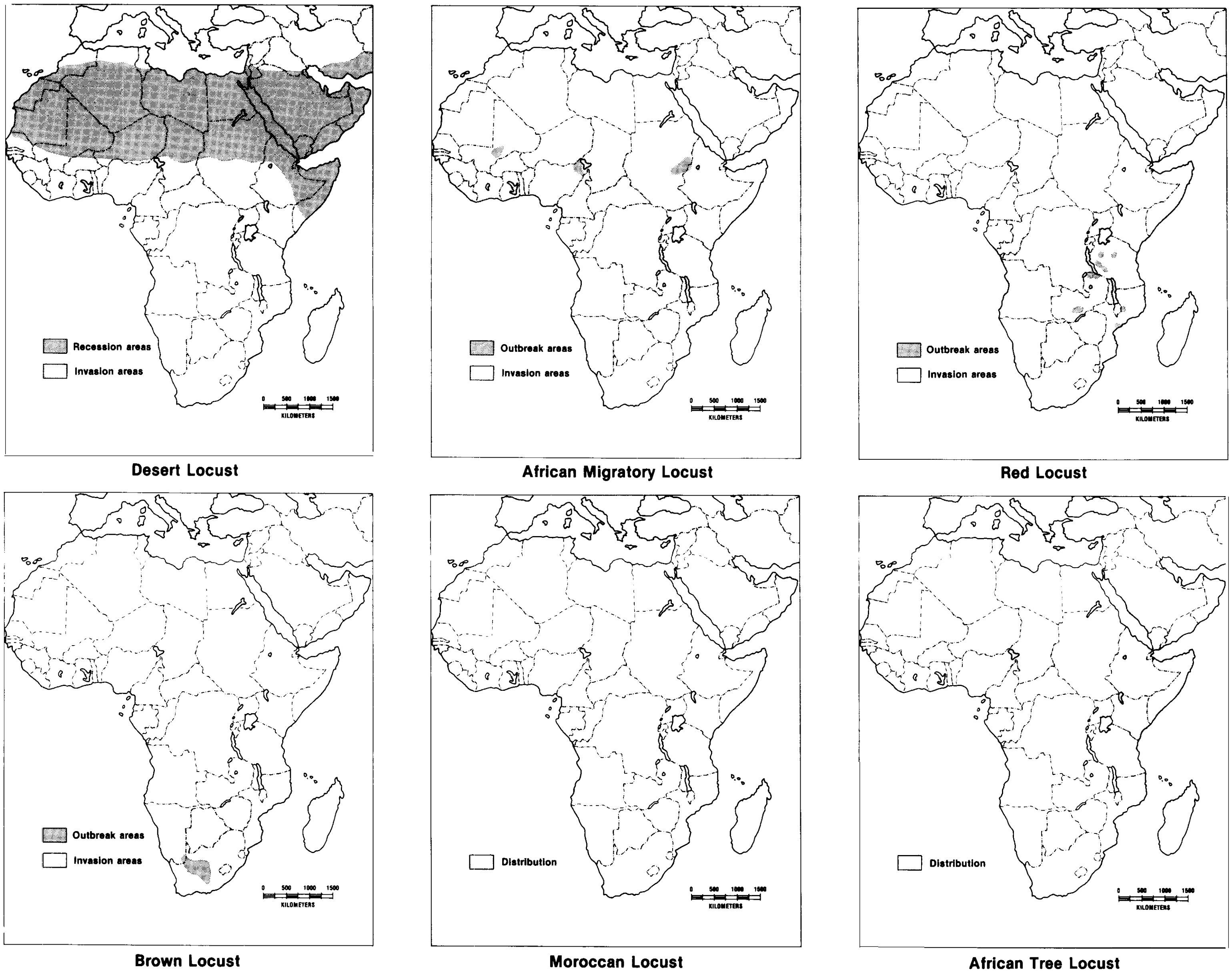
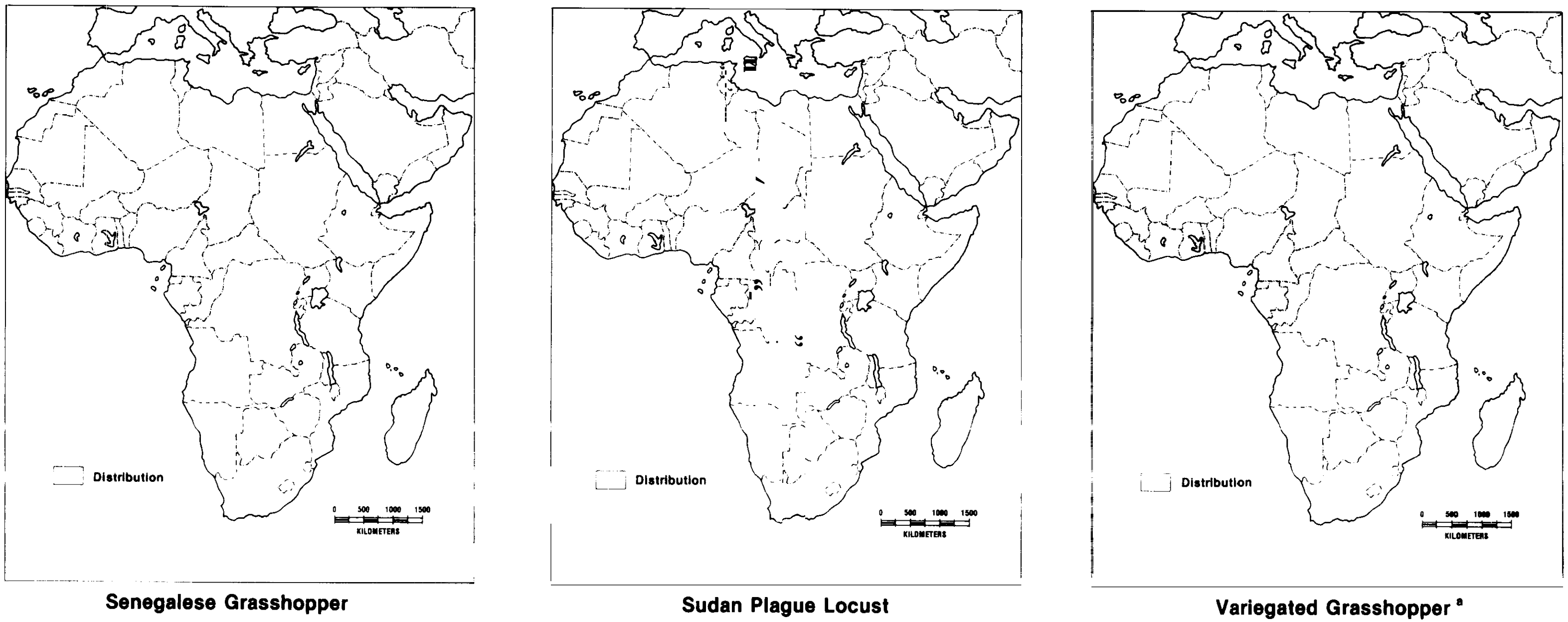


Figure -2–Distribution of Major Species of Locust and Aggregating Grasshoppers in Africa and the Middle East–Continued



NOTE:
[a]OTA reviewers from East Africa noted the presence of the Variegated grasshopper in Uganda, Kenya, Tanzania, Rwanda, and Burundi.

SOURCE: TAMS Consultants, Inc. and Consortium for International Crop Protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment,* Main Report, contractor report prepared for the U.S. Agency for International Development, March 1989, pp. C7-C23.

can be distinguished from larger invasion areas. For example, the Red Locust, the African Migratory Locust, and the Moroccan Locust all have defined outbreak areas. The larger, combined invasion areas of the major species cover virtually all of Africa

Desert Locusts have a particularly extensive distribution, with no localized or well-defined outbreak areas. Between outbreaks, bands and swarms are rare, and low-density solitary forms occupy the central, drier part of its distribution, known as the recession area. This vast desert and semi-desert north of the equator is about half the size of the invasion area. During plagues, migratory swarms of the Desert Locust may penetrate all of the invasion area–nearly 20 percent of the world's land area. Up to 57 nations in Africa, the Middle East, and Asia (and Spain and Portugal in Europe) may be affected (93).

Certain zones exist within the Desert Locust's recession area that are particularly suitable for breeding and formation of gregarious groups. These zones constitute a small part of the total recession area (12, 54). Locusts moving into such a seasonal breeding area may be further concentrated by wind convergence and moisture, laying their eggs in constricted sites. Major Desert Locust outbreaks occur when the amount and frequency of rainfall enables insect numbers to build from one generation to the next (71). Should the build-up continue long enough, a plague results. A Desert Locust plague occurs when many gregarious bands and swarms occur at the same time over a large area in different regions (12, 93). While Desert Locust outbreaks are frequent, upsurges large enough to start plagues are rare. More frequently, potentially dangerous, partially gregarious populations die down without producing bands or swarms, usually because of weather conditions but sometimes because parasites and predators kill hoppers (93).

Locusts and grasshoppers cause recurrent problems for Africa, the Near East, and Southwest Asia. Locust outbreaks are usually attributable to one species in a given area and they occur intermittently but irregularly. The Desert Locust in particular has widespread, sporadic, and unpredictable upsurges. Grasshopper outbreaks often involve a number of species with widely varied biological characteristics and cause chronic agricultural damage each year (93). The Sahelian region of Africa is particularly vulnerable.

Locusts' migratory patterns are affected by prevailing seasonal winds, topography, and temperature. Normally, insects drift downwind until they encounter conditions suitably moist for breeding and feeding. Nevertheless, broad seasonal patterns of movement are detectable. For example, in West Africa, summer Desert Locust breeding occurs in the Sahel and swarms produced there generally move from east-to-west north of a weather pattern known as the Inter-Tropical Convergence Zone and west-to-east to its south. Winter breeding areas are located in the Mahgreb countries and swarms move mostly north-to-south from there. Weather conditions also affect specific insect migration routes. For example, fragments of Desert Locust swarms reached the Caribbean with the aid of October 1988 storms. They crossed the Atlantic from West Africa-a distance of 5,000 kilometers–in a period estimated from several days (85) to a week (54). Mountains in Morocco, Algeria, Yemen, and Iran, highlands in Ethiopia, and the escarpment in Saudi Arabia affect wind patterns which, in turn, influence the direction and speed of locust movement. For example, the Anti-Atlas Mountains south of the Seuss Valley form a topographical barrier to northward-moving swarms. Low temperatures, commonly found at higher altitudes, stop flight activity and hatching and prolong insect development. Deserts, however, do not seem to impede movement.

Changing land-use patterns also influence the distribution of grasshoppers and locusts. Already a variety of environmental changes has led to certain changes as natural vegetation gives way to cultivated land, as irrigation brings moisture to areas, as cultivation disturbs eggpods, or as vegetation is reduced. For example, the Red Locust's importance declined in Mauritius as agricultural land expanded and locust populations became less dense (36). Likewise, the normally gregarious African Migratory Locust today is behaving more like a nongregarious grasshopper due to the break-up of its habitat in Mali (118). On the other hand, the Variegated Grasshopper, a minor nuisance in the 1930s, became a major problem in the 1970s following widespread forest clearing for coffee production in the Ivory Coast. The pest flourished in the environment created by certain weeds that invaded clearings (71). Similarly, Cavin (19) feels that desertification can be expected to increase the amount of habitat suitable for high intensity Desert Locust breeding.

LOCUST AND GRASSHOPPER UPSURGES, DECLINES, AND THE ROLE OF CLIMATE

Early civilizations knew that locust plagues occurred intermittently. Since then, people have tried without success to predict upsurges.

No evidence exists of regular intends between major or regional Desert Locust plagues of the last century (138) and no method is known to predict whether upsurges or declines will occur in a given year. Scientists can detect sequences of rainfall suitable for the types of outbreaks that lead to upsurges using modern surveillance and weather forecasting techniques, e.g., satellite remote sensing and computerized mathematical models. But they are unable to predict weather patterns sufficiently in advance to know whether an upsurge will actually materialize.

On the other hand, the mechanisms of Desert Locust upsurges have been described qualitatively and, in some cases, quantitatively. 'Upsurges," "outbreaks," and "plagues" are relative terms and no generally accepted, quantifiable standard exists for defining when a plague begins. Thus, experts differ in their analysis of the number and timing of the last century's plagues. The most thorough analysis of the upsurges and declines of the Desert Locust showed that seven major plagues, lasting from 7 to 22 years each, occurred in the 112-year period from 1860 to 1972 in Africa, the Middle East, and Southwest Asia (138, figure 1-3). Statistical analysis revealed two kinds of plagues in the individual regions: those lasting a year or so and those lasting 6 to 8 yearn.

Most agree that the last *major* plague subsided in 1962 to 1%3 (70, 93). Several major Desert Locust upsurges occurred since then: 1%7 to 1968, 1977 to 1978, and 1986 to 1989, but these were shorter and less extensive than earlier plagues (70, figure 1-3). Disagreement exists whether these upsurges in the 1970s (95) and 1980s reached plague status. FAO considers that the most recent upsurge, at least that portion which occurred in 1988, did qualify as a plague and was similar in scale to that in most years from 1950 to 1%2.

Ako, mo6t experts agree that locust and grasshopper upsurges are heavily influenced by meteorological factors. For example, the main factor (apart from locust invasions from the outside) associated with 1860 through 1972 Desert Locust plagues seemed to be above-average winter and s ring rains (138). Researchers have sought correlations of plagues with drought, wind circulation, even sun spots. The Inter-tropical Convergence Zone is of particular interest because areas of converging air masses are mo6t likely to receive rain and the swarm position can be related to this Zone (93).

Some contend that plague decline also is principally due to environmental causes, especially climatic factors (e.g., B.P. Uvarov, founder of the Anti-Locust Research Center in London). However, Waloff (138) concluded that". . . the causes for the [Desert Locust] plague declines remain obscure." Also, two researchers developed a mathematical model that could account for plagues and recessions of the Desert and Red Locusts over the past century without including environmental information (5). The main controversy regarding the decline of plagues is over the impact of control.

Most agree that widespread plague dynamics are influenced by successive conditions in seasonal breeding areas and areas where migrations occur, as illustrated here by the recent Desert Locust upsurge (figure 1-4). The first migrants probably entered the Sahel in late 1986 and swarmed into northwest Africa in late 1987, following favorable conditions that led to formation of gregarious swarms in the seasonal breeding areas around the Red Sea and in parts of the Sahel in 1985 and 1986. Following successful winter breeding in North Africa in early 1988, large numbers of swarms migrated south joining locusts breeding in the Sahel because of the abundant rainfall there (74). Lucas Brader (12) of FAO attributes the decline of the Desert Locust in late 1988 and early 1989 to three factors: efficient control campaigns in the affected countries, the loss of a large number of swarms from the Sahel in the Atlantic Ocean, and unfavorable breeding conditions (mainly low rainfall and low temperatures) during the winter and

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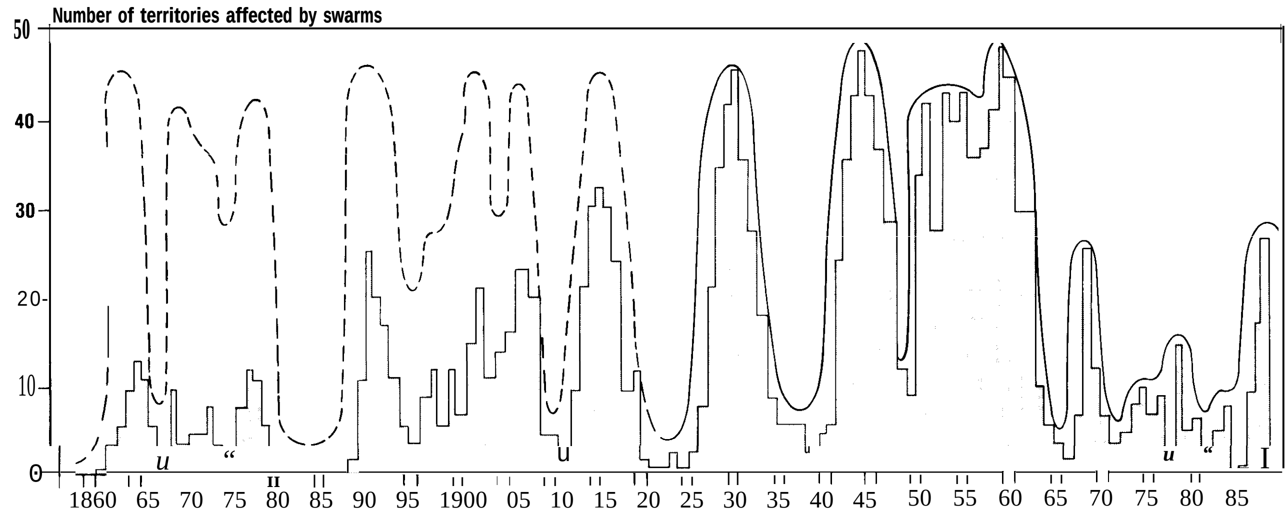
Figure 1-3-Major Plagues of the Desert Locust



NOTE: The undulating line above the graph outlines the plagues and recession periods, the broken portion suggesting the extent of infestation during the period 1860-1924 when records were incomplete.

SOURCE: Zena Waloff, "Some Temporal Characteristics of Desert Locust Plagues," *Anti-Locust Memoir 13* (London: Anti-Locust Research Center, 1976). Updated by Joyce Magor, "Joining Battle with the Desert Locust," *Shell Agriculture, No. 3,1989,* p. *13.*

spring breeding season in Northwest and East Africa. Throughout the period, USAID, FAO, and others were predicting that the plague would continue for times ranging from 1 to 10 years.

In summary, the reasons for the start of a locust or grasshopper upsurge are relatively well known, though inability to forecast weather precludes accurately predicting when upsurges will occur and their duration. Reasons for plagues' subsiding are less clear. Specifically, the importance of control in declines is debated (see ch. 2).

ORGANIZATIONS INVOLVED IN LOCUST AND GRASSHOPPER CONTROL

Many locust and grasshopper control responsibilities of the colonial period were shifted in the 1950s to FAO, along with the mandate to coordinate bilateral and multilateral activities. Newly formed national crop protection agencies and regional organizations supplanted colonial structures as African nations achieved independence in the 1960s.

Bilateral donors also play important roles. France and the United Kingdom continued to play important roles in locust and grasshopper control until 1985. USAID provided approximately 20 percent of all donor funding of the most recent campaign and assigned it some priority in its African programs (table l-l).

National Crop Protection Services and Other National and Local Groups

The national crop protection services, under the Ministry of Agriculture in most countries, have the mandate to protect crops. Therefore, they are the major national organizations responsible for grasshopper and locust control and take over when problems exceed the capacity of individual farmers. Generally, the crop protection services organized and carried out ground surveys and spraying in recent control campaigns, using four-wheel drive vehicles. Aerial spraying–often executed under regional and/or donor auspices in the Sahel–was used for more extensive or remote infestations or when the crop protection services could not meet needs.

Additional Ministry of Agriculture agencies also were involved in control efforts: agricultural extension agents assisted in monitoring, conducting control, and organizing local participation. National research and forestry services contributed knowledge, skills, and resources. Other government agencies, too, took part in the large control campaigns; these included public health departments, weather bureaus, customs services, and transportation ministries. In some countries, military pilots assisted with aerial spraying.

Local farmer brigades were a major component of the ground surveillance and control efforts in some countries. In Mali, 400,000 hectares were treated by ground spraying in 1988, and 45 farmer brigades received high praise for their effectiveness. Their expertise was developed in the previous 2 years' efforts: experienced farmers used hand or backpack sprayers and untrained ones used dusters. Niger reportedly had 10,000 five-person farmer brigades; Chad, 1,000 brigades with 10,000 farmers (99). Farmer committees were trained to recognize buildups of the Senegalese Grasshopper and initiate control in Burkina Faso, Gambia, Mali, Niger, and Sénégal (19, 71).

USAID estimates that the affected countries contributed $28.5 million in fiscal year 1988 and $124 million in fiscal year 1989 of their own funds to locust/grasshopper control (33). This was nearly as much as the donors provided in those years. For example, in fiscal year 1989, the governments of Morocco, Algeria, and Tunisia contributed $76 million, $58 million, and $10 million, respectively. Sudan, Somalia, Mali, and Sénégal contributed from $1 million to $4 million each. Many seriously affected countries, however, were Sahelian nations with little revenue to support the control effort.

Regional Organizations

Three semiautonomous regional organizations–the Desert Locust Control Organization for Eastern Africa (DLCO-EA), the Joint Locust and Bird Control Organization (OCLALAV), and the International Red Locust Control Organisation for Central and Southern Africa (IRLCO-CSA)–and three regional FAO commissions deal with migratory pests that transcend national boundaries in Africa, the Near East, and Southwest Asia (see table 1-2 and figure 1-5).

The organizational structure, mandate, membership, programs, and financial support of the African regional organizations continue to evolve. The most well-established of the regional organizations is DLCO-EA, founded in 1962 by Ethiopia, France (for Djibouti), Kenya, Somalia, Tanzania, and Uganda and joined by Sudan in 1968. Its main objective is control of the Desert Locust, but in 1976 its Council of Ministers decided to undertake control of grain-eating birds (e.g., the quelea), armyworms, and tsetse flies when locusts are in recession (63).

OCLALAV, created in 1965 to counter the Desert Locust and grain-eating birds, was restructured in March 1989 into a West African information and coordinating organization without an operational capacity. Its earlier operational role in survey and control was carried out by FAO during the recent upsurges and then was reassigned to the national crop protection services. In turn, the crop protection services' representatives began discussions with the Sahel Institute (INSA) of the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) regarding a regional approach (99). A previous regional crop protection project of CILSS was terminated in 1987, following withdrawal of USAID funding. The CILSS-associated meteorological organization AGRHYMET continues to provide valuable weather information to members.

Currently, IRLCO-CSA suffers from a lack of member states' payments, but its situation is improving, following locust and grasshopper upsurges in the region, and donor assistance is being sought (12). On the other hand, the International African Migratory Locust Organization was dissolved in 1986 (102).

The three regional FAO Commissions for Controlling the Desert Locust (for Northwest Africa, the Near East, and Southwest Asia) were begun in 1971, 1967, and 1964 respectively in areas where locust survey and control were already the responsibility of national structures. (In sub-Saharan Africa, survey and control were principally done by regional entities then (106)). These Commissions support survey, control, training, and research. Member nations set policy and determine control activities, whereas FAO coordinates the work and serves as secretariat.

U.N. Food and Agriculture Organization

The U.N. Food and Agriculture Organization (FAO) has been the principal coordinator of international locust and grasshopper control campaigns since the early 1950s, a role confirmed by the U.N. General Assembly in December 1988. Initially, FAO

Figure 1-4-Movement of Desert Locust Swarms, January 1985 -April 1989

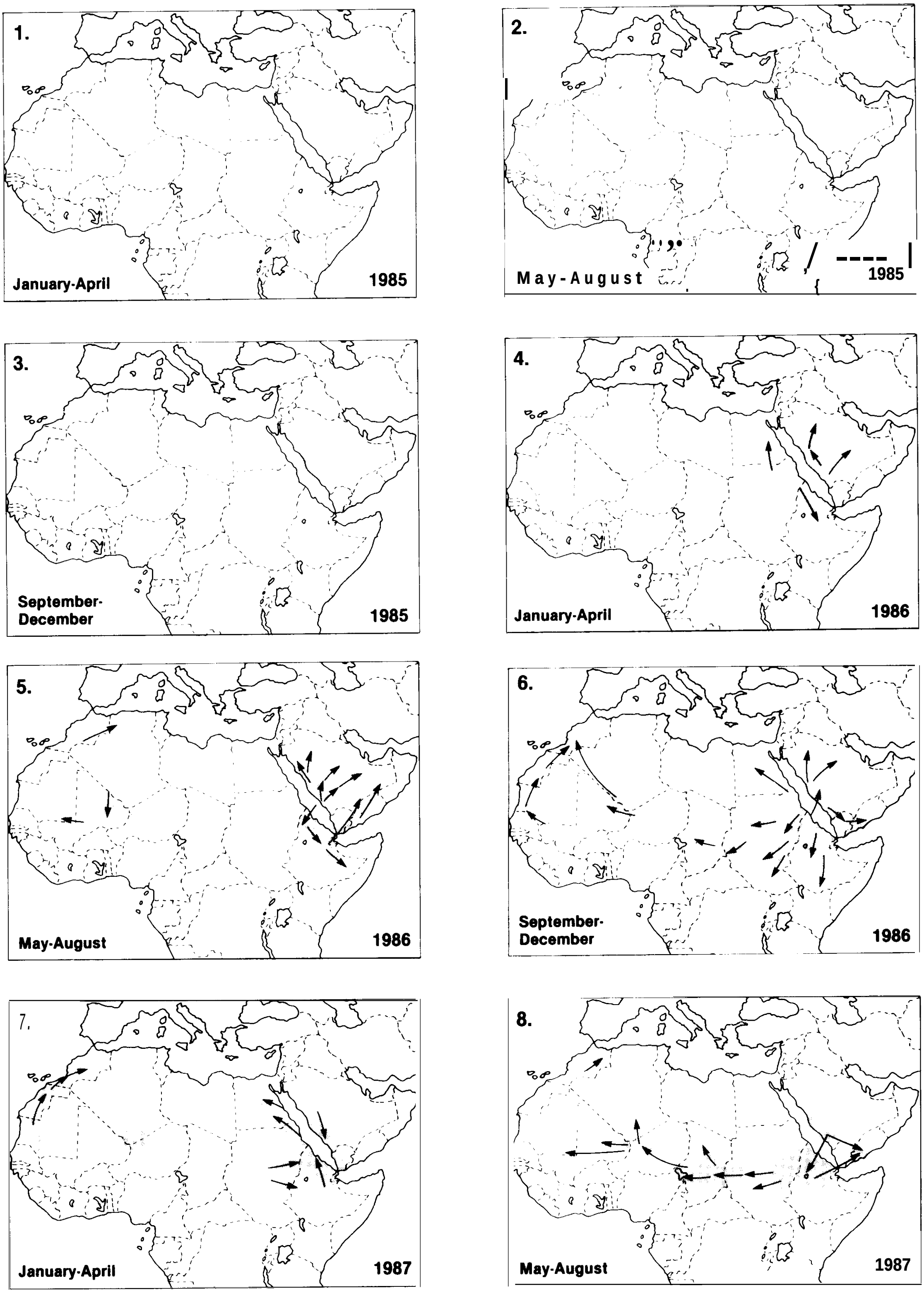
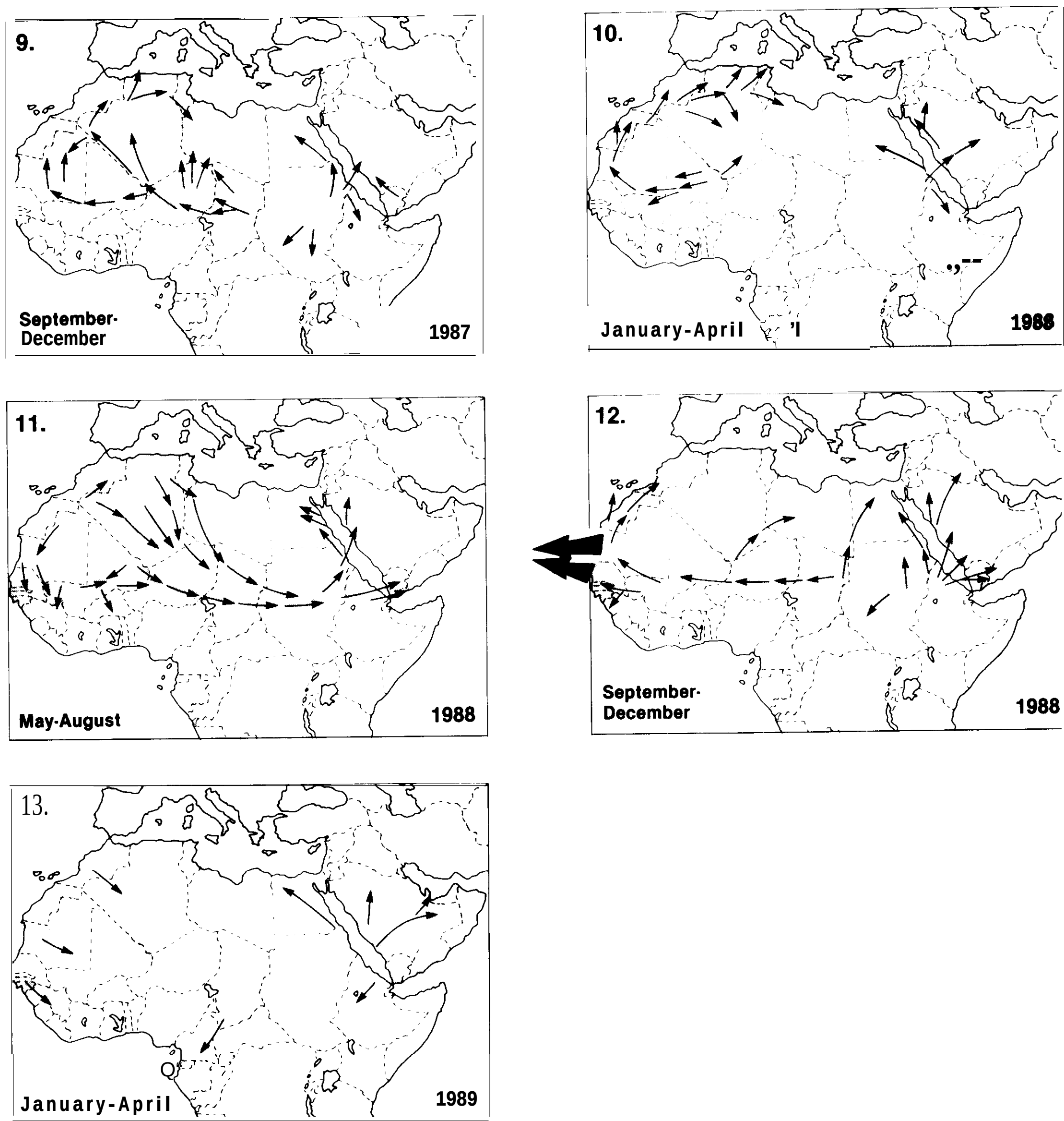


Figure 1-4—Movement of Desert Locust Swarms, January 1985-April 1989—Continued



SOURCE: PRIFAS "The SGR Saga in 13 Images," prepared by M. Launois and G. Blanca (Montpelier, France, 1989).

Table 1-1—Donor Assistance to Locust and Grasshopper Control Programs, 1986-89
(U.S. dollars/calendar year)

Donors	1986	1987[a]	1988	1989 (Jan.-May)	Total
Bilateral donors:					
Algeria	50,000	146,882	180,000	0	376,882
Australia	0	0	205,000	0	205,000
Austria	0	0	29,041	0	29,041
Belgium	130,000	266,714	500,000	1,300,000	2,1%,714
Canada	3,014,500	2,802,238	2,243,000	343,000	8,402,738
China	500,000	*	40,000	120,000	660,000
Denmark	692,500	635,369	2,813,068	2,400,000	6,540,937
Finland	400,000	0	208,455	75,000	683,455
France	1,792,537	3,491,738	6,030,127	3,150,000	14,464,402
Germany (FR)	3,025,887	6,209,031	11,992,000	14,250,000	35,476,918
Greece	50,000	0	160,000	0	210,000
Indonesia	0	10,000	25,000	0	35,000
Iran	0	0	7,500	0	7,500
Israel	0	*	0	0	*
Italy	2,659,000	2,471,386	2,994,675	1,000,000	9,125,061
Japan	1,288,000	*	4,100,368	13,620,000	19,008,368
Kuwait	0	0	1,000,000	0	1,000,000
Libya	0	0	1,212,000	0	1,212,000
Luxembourg	0	140,000	244,000	0	384,000
Morocco	20,000	0	320,000	0	340,000
Netherlands	2,350,000	1,850,000	6,592,347	0	10,792,347
Nigeria	0	0	400,000	0	400,000
Norway	3,127,000	1,500,000	1,615,000	2,000,000	8,242,000
Portugal	0	0	606,000	0	606,000
Qatar	0	0	12,000	0	12,000
Saudi Arabia	0	0	2,860,000	0	2,860,000
Spain	62,511	0	2,440,000	0	2,502,511
Sweden	1,185,929	0	2,599,386	0	3,785,315
Switzerland	403,000	92,790	944,268	338,000	1,778,058
Thailand	11,000	0	0	0	11,000
Tunisia	0	0	90,000	0	90,000
Turkey	0	0	500,000	0	500,000
United Kingdom	1,909,183	987,687	5,800,000	207,000	8,903,870
USAID	9,1%,245	6,983,332	21,599,859	12,000,000	49,779,436
U.S.S.R.	0	*	1,376,000	0	1,376,000
Yugoslavia	64,000	0	0	0	64,000
Subtotal bilateral donors	31,931,292	27,587,167	81,739,094	50,803,000	192,060,553

Table I-1—Donor Assistance to Locust and Grasshopper Control Programs, 1986-89 (U. S. dollars/calendar year)—Continued

Donors	1986	1987[a]	1988	1989 (Jan.-May)	Total
Multilateral donors:					
African Development Bank	165,000	0	200,000	6,019,730	6,384,730
Banque Africaine de Developpement Africain (BADEA)	750,000	0	0	0	750,000
European Economic Community (EEC)	10,739,981	2,348,674	9,600,143	400,000	23,088,798
Islamic Development Bank	0	0	14,400,000	2,044,000	16,444,000
Organization of African Unity (OAU)	0	321,430	300,000	0	621,430
Organization of Petroleum Exporting Countries (OPEC)	300,000	0	39,000	0	339,000
UN Children's Fund (UNICEF)	86,000	*	10,000[c]	0	%,000
UN Development Program (UNDP)	1,839,000	54,000[b]	2,926,332	0	4,819,332
UN Environment Program (UNEP)	0	0	48,405	0	48,405
UN Food and Agriculture Organization (FAO)	2,601,000	20,000	4,700,000	610,000	7,931,000
UN World Food Program (WFP)	18,000	0	0	0	18,000
UN World Health Organization (WHO)	4,480	0	0	0	4,480
Subtotal multilateral donors	16,503,461	2,744,104	32,223,880	9,073,730	60,545,175
Non-Governmental Organizations	1,211,460	133,000[c]	1,111,000	0	2,455,460
Total	49,646,213	30,464,271a +20,000,000[d] 50,464,271	115,073,974	59,876,730	255,061,188 +20,000,000[b] 275,061,188
USAID as percent of total	18.5%	22.9%	18.7%	20.0%	19.5%

NOTES:

*Amount unknown (1987).

[a]Includes only assistance to Sahelian and West African countries.

[b]Includes only assistance to two of four recipient countries.

[c]Includes only assistance from section aid to Gambia.

[d]An additional $20 million was given by donors for programs in Northwest African countries, Sudan, Ethiopia, and Yemen (Jeremy Roffey, Emergency Center for Locust Operations, FAO, personal communication, June 26, 1989).

SOURCES:

Column 1: Jeremy Roffey, '1986 Funding Chart for Grasshopper and Locust campaigns in Africa" (Emergency Centre for Locust Operations, U.N. Food and Agriculture Organization, Rome, December 1986).

Column 2: U.N. Food and Agriculture Organization, "Report of the Meeting on the Evaluation of the 1987 Grasshopper Campaign in the Sahel, Annex V (Emergency Centre for Locust Operations, Rome, December 1987).

Columns 3 and 4: U.N. Food and Agriculture Organization, "Assistance Provided to Countries and Regional Organizations," Report of the Thirtieth Session of the FAO Desert Locust Control Committee, AGP:DLCC/89/4, Rome, Italy, June 12-16, 1989.

Table 1-2-Independent Regional Organizations and Their Member Nations

Organization	Member States	Headquarters
DLCO-EA: Desert Locust Control Organisation for Eastern Africa	Djibouti, Ethiopia, Sudan, Somalia, Kenya, Tanzania, Uganda	Addis Ababa, Ethiopia
OCLALAV: Organisation Commune de Lutte Antiacridienne et de Lutte Antiviare/Joint Locust and Bird Control Organization	Chad, Cameroon, Benin, Gambia, Ivory Coast, Niger, Mali, Mauritania, Senegal	Dakar, Senegal
IRLCO-CSA: International Red Locust Control Organisation for Central and Southern Africa	Kenya, Uganda, Tanzania, Zambia, Malawi, Zimbabwe, Botswana, Swaziland, Mozambique	Ndola, Zambia

SOURCE: Dale G. Bottrell, ''Locusts and Grasshoppers in Africa and the Middle East,'' contractor report prepared for the Office of Technology Assessment, January 1989.

focused only on Desert Locust problems, but its scope was broadened later to include other migratory pests.

The FAO Desert Locust Control Committee (DLCC) is the overall intergovernmental body that coordinates all Desert Locust-related control and research. In 1955, the United States was a founding member of the DLCC and remains one of some 50 member countries The Emergency Centre for Locust Operations (ECLO), created in 1986 and housed in FAO's headquarters in Rome, bears operational responsibility within FAO. It assumed responsibility for raising donor funds and coordinating control activities during the recent upsurge. ECLO has handled approximately $10 million in aid each year since 1986 in addition to coordinating some 150 projects funded by bilateral and multilateral donors, including FAO itself (109).

FAO's activities include:

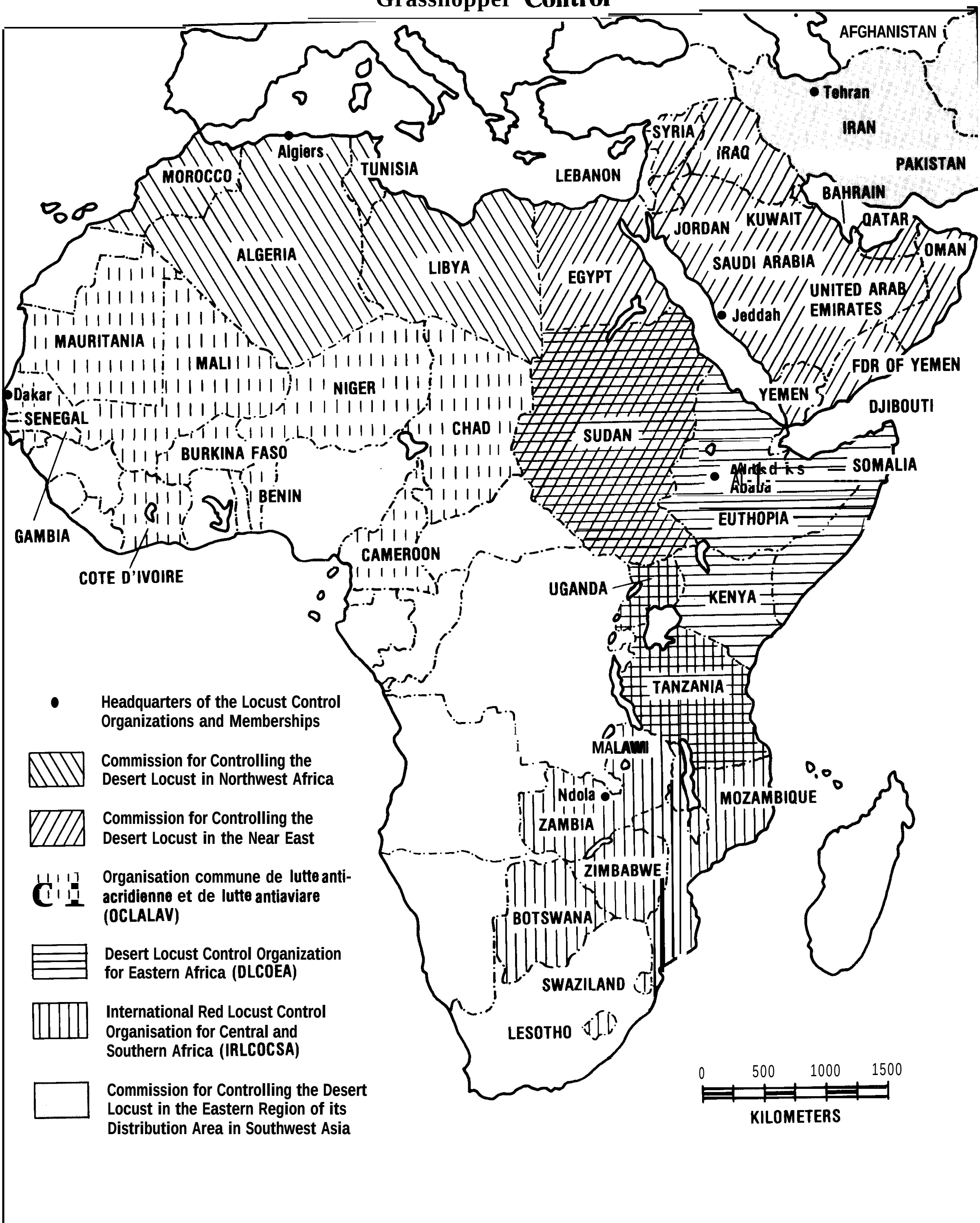
- supporting a centralized Desert Locust reporting and forecasting service in Rome;
- preparing and distributing the monthly FAO/ECLO Desert Locust Bulletin, special bulletins on other locusts and grasshoppers as need@ and a semiannual research registry beginning in 1989;
- organizing international meetings for representatives of donors and national governments;
- sponsoring research and training on locust surveillance and control; and
- implementing locust projects financed by FAO, the United Nations Development Programme, and the international community.

Also, FAOcoordinates activities of the African regional locust and grasshopper control organizations and sponsors the FAO regional Commissions in Africa and Donor Coordination Committees in each country receiving assistance.

USAID and Other Donors

Many donors contributed large amounts of money during the recent plague, principally for insecticides and spraying equipment, but also for training and technical assistance, vehicles, rotective clothing, radios, and spare parts. FAO's data indicate that total donor expenditures for programs

Figure l-5-Regional Organizations and FAO Commissions in Charge of Locust and Grasshopper Control



SOURCE: TAMS Consultants, Inc. and the Consortium for International Crop Protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment,* Executive Summary and Recommendations, contractor report prepared for the U.S. Agency for International Development, March 1989, p. Exsum-11.

in affected countries were at least $49.6 million in 1986, $50.5 million in 1987, $115.1 million in 1988, and $59.9 million through mid-1989, for a grand total of $275 million committed through mid-1989 (table l-l).

As a result of donor and African countries' efforts, approximately 14.6 million ha of land in 10 Sahelian and West Africa countries alone received aerial or ground insecticide treatments in 1986 and 1987, mostly against grasshoppers (table 1-3). In 1988, 10 million ha were sprayed in Northwest and West Africa, mostly against Desert Locusts (12).

The United States, through USAID, provided an average 20 percent of all donor contributions through mid-1989 to Northwest and sub-Saharan Africa. Data from USAID show U.S. expenditures, by fiscal year, totaling $58.8 million from 1986 to 1989: $7.4 million in fiscal year 1986, $7.5 million in fiscal year 1987, $20.4 million in fiscal year 1988, and $23.0 million in fiscal year 1989 (table 1-4). In 1988 and 1989, this amounted to approximately 4 percent of U.S. development assistance to sub-Saharan Africa (123).[1]

The United States has provided financial and technical assistance to locust and grasshopper control efforts in Africa since the 1950s. During the 1945 through 1963 upsurges, U.S. monetary contributions were less than the United Kingdom's and FAO's. However, in the 1950s and 1960s, the United States provided technical specialists and helped establish the DLCO-EA. Following a widespread grasshopper outbreak in the Sahel in 1974 and 1975, USAID set up a Regional Food Crop Protection Project to strengthen national services in West Africa and funded the CILSS Integrated Pest Management Project in the Sahel. In addition to supporting projects bilaterally in the various African nations, the United States helps Finance the work of FAO/ECLO.

USAID provides assistance through its Africa (AFR) and Asia and the Near East (ANE) regional bureaus, the Bureau for Science and Technology (S&T), the Office of Foreign Disaster Assistance (OFDA) and its missions (box l-C).

OFDA is responsible for short-term emergency assistance (3 to 6 months) and replaced AFR's temporary Office of Emergency Operations in taking the lead in USAID locust and grasshopper control efforts in 1987 (99). In July 1988, the AID Administrator created the Desert Locust Task Force, under the aegis of OFDA. The Task Force included staff from the various USAID bureaus (AFR and ANE), offices (contracts and legal sections, Public Affairs, Legislative Affairs, etc.) and missions; the State Department; the U.S. Department of Agriculture (USDA); the U.S. Environmental Protection Agency (EPA); the U.S. Geological Survey; and others. It met weekly before dissolving on June 1, 1989, following the decline of the locust swarms.

The regional bureaus' Offices of Technical Resources and S&T are responsible for longer-term development assistance but also managed the Africa Emergency Locust/Grasshopper Assistance project. Financial aspects of U.S. multilateral assistance (e.g., to the U.N. Development Programme and FAO) are handled by the Department of State's Bureau of International Organization Affairs.

USAID often hires outside technical expertise from U.S. consulting firms, universities, and USDA USDA's Office of International Cooperation and Development, for example, used $2.6 million "on of USAID from 1986 to 1989. Of this, $1.5 million supported technical experts from USDA agencies, such as the Animal and Plant Health Inspection Service and the Forest Service, and $1.1 million was spent on supplies for control campaigns (3).

Other U.S. agencies assist in control efforts, For example, the U.S. Geological Survey provided "greenness maps" showing where vegetation was abundant following rainfall; EPA staff, working with USAID, advised African governments-on safe disposal of surplus insecticides and empty containers; and U.S. Peace Corps volunteers participated in the Mauritania control campaign (119).

In addition to official government donors, a number of private, nongovernmental organizations (NGOs) provided assistance to African countries

[1]The Development Fund for Africa is the baseline against which these contributions were measured. This Fund does not include Food for Peace (Public Law 480), Economic Support Funds, or multilateral assistance.

Table I-kTotal Area Controlled in the Sahelian Countries in 1986 and 1987

	Ground (ha)		Aerial (ha)		Total (ha)	
	1986	987	1986	87	1986	1987
Mauritania	100,000	22,365	193,000	225,200	293,000	247,565
Senegal	300,000	36,556	1,159,800	134,872	1,458,800	171,428
Gambia	11,500	12,104	247,710	41,940	259,210	55,044
Mali	68,000	2,329	484,000	166,866	552,000	169,195
Burkina Faso	20,893	0	211,140		232,033	9,062
Chad	25,222	42,428	143,700	212,55!	186,922	254,983
Niger	151,414	75,420	270,505	230,834	421,919	3&,&4
Cameroon	0	54,000	0	0	0	
Guinea Bissau	0	9,000	0	0	0	9:000
Nigeria	0	0	0	0	60,000	60,000
Total	677,029	254,202	2,709,855	1,012,267	3,403,884	1,322,531

SOURCE: TAMS Consultants and Consortium for International Crop Protection, *Locust* and *Grasshopper Control in Africa/Asia: A Prograromatic Environmental Assessment*, Main Report, contractor report prepared for the U.S. Agency for International Development, March 1989, p. D-37.

affected by locusts an grasshoppers. Some of these organizations used U.S. foreign aid in addition to their own funds for these programs. Oxfam, Band Aid, CARE, Save the Children, Caritas, and World Vision were among the organizations that provided insecticides, vehicles, spraying equipment, and first aid kits. Band Aid made the largest single NGO contribution, donatingaplanetoMa "for aerial spraying (82).

Donor-Sponsored Research

Many organizations engaged in locust and grasshopper control also carry out related research. And some primarily research organizations are beginning to examine improved control methods. The International Center on Insect Physiology and Ecology in Nairobi, Kenya and the International Institute for Tropical Agriculture in West Africa are among the latter.

Some donors fund locust *and* grasshopper research projects by their own scientists, such as the United Win's Overseas Development Natural Resources Institute and the French grasshopper and locust research unit of the Center for International Cooperation in Agricultural Research for Development. On the other hand, USAID contracts out scientific research, usually to private consulting firms and universities. The Locust Research Task Force of the Special Program for African Agricultural Research of the World Bank maintains a computerized directory of donor-sponsored research. It listed 151 projects being planned or conducted in the Sahelian countries as of January 1989. Some of these projects involve collaboration with African research institutions and/or researchers, while others are solely donor efforts.

PAST AND CURRENT CONTROL METHODS FOR LOCUSTS AND GRASSHOPPERS

Often, individual farmers do nothing when faced with locusts or grasshoppers. But they also developed a variety of cultura and physical controls before the availability of chemical ones (table 1-5). Almost all these methods have been used in the' United States and Canada, too. Physical and cultural control methods continue to be practiced, alone or in combination with chemical control, especially against small infestations in crops or hopper bands near croplands. For example, some farmers combine the use of pesticides with fire, burning roosting locusts at night (32). Village brigades in Chad herded hopper bands into deep trenches and buried them in the recent campaign

Table 1-4—U.S. Assistance to Locust/Grasshopper Programs, Fiscal Years 1986-89

country	1986	1987	1988	1989	Dollars
Sahel and West Africa					
Burkina Faso	$268,800	$591,732	0	0	$860,532
Cameroon	200,000	200.000	0	0	400,000
Cape Verde	0	0	75,000	25,000	100,000
Chad	990,841	1,254,211	1,305,730	0	3550,782
Gambia	35,000	594,898	( )[a]	25,000	654,898
Guinea Bissau	29,000	290,320	0	0	319,320
Mali	1,287,080	1,012,433	1,775,110	200,000	4,274,623
Mauritania	154,000	227,500	1,446,964	866,256	2,694,720
Niger	61,000	337,386	1,199,647	317,000	1,915,033
Sénégal	1,657,349	1,923,752	245,892	3,362,320	7,189,313
Sahel Regional	244,000	0	0	0	244,000
East and Southern Africa					
Botswana	1,183,587	0	0	0	1,183,587
Ethiopia	75,000	380,516	407,820	13,800	877,136
Sudan	1,024,948	600,000	662,415	173,713	2,461,076
Tanzania	50,000	0	0	0	50,000
Zaire	10,860	0	0	0	10,860
Zambia	100,000	0	0	0	100,000
East Africa Regional	0	0	0	0	0
Northern Africa and S.W. Asia					
Algeria	0	0	1,070,032	18,866	1,088,898
Jordan	0	0	0	152,600	152,600
Morocco	0	0	5,295,713	10,308,974	15,985,203
Pakistan	0	0	0	2,000,000	2,000,000
Tunisia	0	0	1,361,447	1,410,535	2,771,982
Yemen	0	135,598	0	0	135,598
African Regional	75347	0	5.578.414	4.123.988	9.777.749
Total dollars	**$7,446,812**	**$7,548,346**	**$20,424,184**	**$22,998,052**	**$58,797,910**
Amount of total granted to FAO	**4,084,587**	**358,000**	**2,465,000**	**1,508,910**	**8,416,497**
Amount of total, OFDA funds[b,c]	**7,171,012**	**6,384,059**	**9,643,950**	**5,585,652**	**28,784,673**

NOTES:

[a] Assistance to Gambia in 1988 and some in 1989 included in amount for Senegal.

[b] U.S. assistance consists of OFDA funds, USAID mission funds, Africa or Asia/Near East Bureau regional funds, and some local currency. In fiscal year 1988, OFDA contributed $9,643,950, the missions $4,840,600? the re ional programs $6,689,656, and local currency $2,350,464, for a grand total of $23,524,670. In fiscal year 1989, OFDA contributed #,585,652, the missions $15,847,400, the regional programs $1,565,000 and local currency $1,850,343, for a grand total of $24,848,395. Thus, the percent of OFDA funding decreased significantly in 1988 and 1989.

conformation in this line from John Gelb, 1989, below.

SOURCES:

1986-John Gelb, Office of Foreign Disaster Assistance, AID, "USG Contributions to Locust/Grasshopper Threat in Africa–FY 1986 as of September 30, 1986," n.d.

1987–Office of Forei gn Disaster Assistance, "Insect Infestation," OFDA Annual Report Fiscal Year 1987 (Washington, DC: USAID, 1988). 1988-Office of Foreign Disaster Assistance, "Insect Infestation," OFDA Annual Report Fiscal Year 1988 (draft) (Washington, DC: USAID, 1989).

1989–John Gelb, Office of Forei gn Disaster Assistance, "U.S.A.I.D. Support, Desert Locust Task Force, FY 1987-89," dated July 22-23, 1989. Due to the decline of the locust problem in early 1989, some of the funds allocated have been reprogrammed for other crop protection activities.

Box 1-C–USAID's Operational Responsibility for Locust/Grasshopper Problems

Several groups within USAID have responsibility for various aspects of the United States' contributions to addressing locust and grasshopper problems in Africa. These include the Office of Foreign Disaster Assistance, the Bureaus for Africa and Asia and the Near East, and the Bureau for Science and Technology.

1. Short-term–The Office of Foreign Disaster Assistance (OFDA) has the authority and responsibility to apply its resources to:
   - emergency pest situations in a host country when a disaster has been declared by the U.S. Ambassador to that country,
   - the mitigation of potential disaster situations, and
   - certain recovery and rehabilitation activities designed to prevent secondary disaster effects.
2. Medium-term–The Bureaus for Africa and Asia and the Near East have the authority and responsibility to:
   - implement nondisaster project activities required to put the pest emergency situation back under control; and
   - implement normal, longer-term development initiatives, vis-a-vis pest control programs.
3. Long term–The Bureau for Science and Technology, working with the Bureaus for Africa and Asia and the Near East, has the authority and responsibility to support development activities on a regional or bilateral basis, designed to improve the capabilities and capacities of national and regional institutions.

SOURCE: Adapted by OTA from TAMS Consultants and the Consortium for International Crop Protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment*, Main Report, contractor report prepared for the Agency for International Development, March 1989, pp. D1-D2.

(119), using what is probably the most effective traditional control.

Some traditional control methods are sometimes ineffective, e.g., plowing fields infested with pods (12). And some other means, e.g., planting resistant varieties of sorghum, cultivating grasslands, fallowing agricultural land, or rotating crops, are effective against some species but not others. For example, cassava, a root crop, is planted in some areas as a security against locusts but it is very vulnerable to attack by the Variegated Grasshopper (71). Planting rooted sorghum plants instead of seeds in flood-recession irrigated areas can protect crops from the Sudan Plague Locust but not other species (12).

Most traditional controls have been replaced by the use of chemical insecticides, at least in official control programs. Numerous synthetic organic insecticides are available now. The first chemical treatment, used from the 1880s through the 1940s, was an arsenic-poisoned bait. Baiting could be done by unskilled labor, but buying, storing, and transporting tons of wheat bran for bait made this costly, remote breeding sites were missed, and sometimes the pests did not eat the bait (79). In the 1940s and 1950s, first ground, and then aerial, spraying techniques were introduced and the persistent organochlorines BHC (benzene hexachloride) and dieldrin became the insecticides of choice (34, 79). In the 1960s, dieldrin was most often used against Desert Locust hopper bands and

Table l-5—Examples of Locust and Grasshopper Control Methods

Cultural methods	• Planting of security crops such as cassava • Crop rotation • Use of resistant or tolerant plants • Good land management (avoidance of deforestation, overgrazing, and heavy fallowing) • Planting short-season crop varieties or seeding or harvesting early or reseeding
Physical methods	• Beating or trampling on the hoppers • Digging up egg pods or plowing fields infested with egg pods • Scattering straw over roosting sites and then burning it • Lighting fires or making noise to prevent swarms from settling in crops • Driving hoppers into trenches and burning, drowning, or crushing them • Use of flame throwers • Use of horse-, tractor-, or truck-drawn collecting machines
Biological methods	• Running poultry in crops • Use of cattle to eat off and trample grass in locust breeding grounds • Introduction of pathogens
Chemical methods	• Use of conventional chemical insecticides • Use of botanical compounds, e.g., neem extracts

SOURCES: Compiled in Dale G. Bottrell, "Locusts and Grasshoppers in Africa and the Middle East," contractor report prepared for the Office of Technology Assessment, Washington, DC, January 1989, p. 24, from: D.L. Gunn, "Systems and Management–Strategies, Systems, Value Judgments and Dieldrin in control of Locust Hoppers," *Philosophical Transactions of the Royal Society of London, Series B, Vol. 287,1979,* pp. 429-445; C.F. Hemming *The Locust Menace,* Centre for Overseas Pest Research, London, 1974; J. Ledger, *African Wildlife,* vol. 41,1987, p . 197-210; J. Roffey, 'The Effects of Changing Land Use on Locusts and Grasshoppers, pp. 199-206, *Proceedings of the International Study Conference on Current and Future Problems of Acridology,* London, 1970; TAMS Consultants and Consortium for International Crop Protection, *Locust and Grasshopper Control in Africa/Asia: A Programmatic Environmental Assessment,* Main Report, contractor report prepared for the U.S. Agency for International Development, March 1989.

BHC against adult swarms (55). Also, BHC was used against Brown Locust upsurges in South Africa from the late 1940s through the 1980s (52). Dieldrin has been used against Red Locust outbreaks since the 1950s (79).

Initially, dieldrin and the other persistent pesticides seemed to be a major technological advance. Dieldrin, for example, remains toxic for 30 to 40 days on vegetation and longer in soil, despite rain or sun (34, 118). Hopper bands were controlled by spraying swathes of vegetation with dieldrin, forming "barriers" in front of marching bands. Since dieldrin acts as a stomach poison that accumulates over time, the insects eventually ingested a lethal dose by eating treated vegetation. Low doses were effective and respraying was unnecessary, even if a second hatching occurred (54, 104).

concern mounted in the 1970s regarding the heavy use of persistent pesticides. DDT, the prototype persistent organochlorine, was banned by the United States in 1972 and dieldrin came under increased scrutiny. Studies in developed countries in the 1960s showed substantial traces of dieldrin in human tissue. High levels of dieldrin are known to cause convulsions in humans and the chemical is responsible for 13 recorded deaths (104). The evidence of dieldrin's carcinogenicity is strong in mice, weaker in other experimental animals, and inconclusive or negative in humans (17, 104, 137). EPA canceled most dieldrin uses inthe United States in 1974 and European countries also banned its use. EPA cited dieldrin's carcinogenicity, bioaccumulation, hazards to wildlife, and other chronic effects (134).

USAID routinely sponsored overseas use of pesticides in the 1970s that EPA banned or restricted for use in the United States. In 1975, four environmental organizations sued USAID for failure to prepare an environmental impact statement (EIS) on these pesticide uses, as required by the 1969 National Environmental Policy Act. USAID, in response, prepared an EIS in 1977 and issued a pesticide policy the following year prescribing how pesticides should be treated in USAID activities (8). Since the 1978 publication of Regulation 16 (22 Federal Code of Regulations Part 216), the United States has required environmental assessments prior to approving purchase or use of pesticides overseas with U.S. funds. The chlorinated hydrocarbons dieldrin, lindane, and BHC could neither be purchased nor used in U. S.-supported efforts. USAID environmental offices in Washington approved individual USAID missions' requests for various insecticides depending on what was known at the time (43). Beginning in 1977, various amendments to the Foreign Assistance Act further required that USAID consider the environmental impacts of its overseas projects and specifically undertake activities to maintain and restore natural resources in developing countries (127).

The USAID policy on pesticides served as a model for other donors for developing regulations on their use of pesticides in Third World countries. The World Bank promulgated Guidelines *for the Selection and Use of Pesticides in Bank Financed Projects and Their Procurement When Financed by the Bank in 1985,* developed with the assistance of the United States. In the same year, FAO passed an *International Code of Conduct on the Distribution and Use of Pesticides.*

The type of insecticides used in African locust and grasshopper control programs has shifted markedly away from the persistent organochlorines (dieldrin, BHC, aldrin, and lindane) although some use continues (table 1-6). At least one-half of OTA survey respondents identified the use of BHC, dieldrin, and lindane in the past but only one or two respondents indicated their current use. Some European countries still allow the use of lindane, closely related to BHC chemically (12). The insecticides most commonly used for controlling grasshoppers and locusts in Africa are fenitrothion and malathion (10). These organophosphates are principally contact insecticides with short residual action (2 to 3 days) (118).

Most donors have requirements to purchase pesticides from domestic companies ("tied aid"), and USAID did so, by and large, even though purchases funded with OFDA money are exempt from these provisions due to their emergency nature. Fenitrothion, introduced by Sumitomo and independently by Bayer, is Japanese-owned and manufactured in the large quantities needed for locust control in Japan and Europe. Malathion is manufactured in the United States and elsewhere. Dieldrin is no longer produced in significant quantities in the United States, where it was developed, or in Europe. Thus, malathion was a major component of U.S. donations.

Table 1-6—Insecticides Used Presently and in the Past Against Locusts and Grasshoppers in Africa and the Near East

Name	Insecticide: Commercial name[a]	Insecticide: FAO[b]	OTA[c]	Present use: OTA[c]	Present use: LHB[d]
Aldrin				x	x
Alphacypermethrin	Fastac	x			
Alphamethrin		x		x	
Arsenic compounds			x		
Bendiocarb	Ficam	x	x		
BHC, Benzene Hexachloride			x	x	
Carbaryl	Sevin		x	x	
Chlorpyrifos	Dursban	x	x		
Darslean			x		
DDT				x	x
Dichlorvos	DDVP		x		
Deltamethrin	Decis	x	x		
Diazinon	Basudine	x	x	x	
Dieldrin	Ensodil		x	x	
DNOC				x	x
Esfenvalerate		x			
Fenitrothion	Sumithion Folithion	x	x	x	
Fenvalerate		x			
Heptachlor					x
Isobenzan					x
Lambdacyhalothrin	Karate	x	x		
Lindane			x		
Malathion		x	x		
Para-oxon					x
Parathion	PenCap				x
Propoxur/Phoxim	Undine	x	x		

NOTES:

[a]Illustrative examples, since many commercial brands exist.

[b]FAO's list of pesticides are those used on a substantial scale for Desert Locust control.

[c]Pesticides listed are those that OTA'S survey respondents indicated as currently used for locust/grasshopper control, regardless of the scale of that use.

[d]Insecticides no longer used for either locust or grasshopper control.

SOURCES:

FAO: U.N. Food and Agriculture Organization, Emergency Center for Locust Operations, "Pesticides for Desert Locust Control: June 1989 Update," *African Locust Bulletin,* No. 14/89, June 20, 1989, pp. 6-7.

OTA: Responses to OTA survey, 1988.

LHB: Steedman, A., *The Locust Handbook* (London: Overseas Development Natural Resources Institute), 1988, p. 119.

Name/commercial names: USAID, *Locust/Grasshopper Management: Operations Guidebook (Washington,* DC: January 1989), pp. VII-4-5, and PRIFAS, *SAS Newsletter,* No. 8, Aug. 7, 1989, p. 37.