Strategies to Control the Desert Locust *Schistocerca gregaria*

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ABSTRACT The desert locust *Schistocerca gregaria* (Forskål) can infest an area from Mauritania to India and roughly from the Mediterranean to the Equator. Plagues with many swarms of adults and very many bands of hoppers are separated in time by recessions, when most of the locusts are scattered and confined to the 16 million square kilometre arid central belt. Widespread and heavy rain in the recession belt may lead to outbreak breeding. This may be followed by an upsurge during which successful breeding occurs in areas to which the adults of successive generations migrate. Further population increases lead to a plague. In spite of recent studies, the cost of the damage caused by the desert locust is not known and it is not clear whether the costs of control balance the costs of the damage that is prevented. Nevertheless, the impact on individual farmers may be devastating. Local crop protection is not feasible and financial compensation is difficult. However, the main importance of the desert locust is "political" since swarms are both dramatic and migrate between countries. The current strategy is to prevent plagues by controlling the outbreak or the early upsurge, despite the lack of field evidence that this is effective, and theoretical studies that suggest it is not. Adherence to such a preventive strategy, the irregular occurrence of plagues, and the fact that even during a plague many countries will escape, has led to plague crisis management. Donors have supplied aid, usually in the form of insecticides and aircraft, during upsurges and plagues with no adequate assessment of the need or of the capacity of the recipient country to use what is supplied. Much insecticide has remained in stock after plagues, creating a difficult disposal problem. Recent research and development has concentrated on: (1) processing of survey data with geographical information systems (GIS), (2) survey and application techniques using global positioning systems (GPS) and precision spraying, (3) physiological and ecological studies focussing on phase change, (4) barrier applications with new persistent insecticides, (5) use of biopesticides, especially mycopesticides and insect growth regulators, and (6) environmental monitoring. Hope for the discovery of some novel solution to the desert locust problem should not detract attention from improving campaign organization, as this will be required with any feasible new research finding. However, priority needs are to gather more information about recession populations, evaluate control campaigns, elaborate a new strategy for outbreak prevention, develop contingency plans for a plague campaign, and provide training in the execution of such plans when the need arises.

KEY WORDS desert locust, *Schistocerca gregaria*, strategy, outbreak, upsurge, plague, prevention, insurance, contingency plan

1. Introduction

The desert locust *Schistocerca gregaria* (Forskål) can infest a huge area (29 million square kilometres) putting more than 65 countries intermittently at risk (Fig. 1). During recession periods when densities are low, the solitarious form of the desert locust generally are scattered over a broad, 16 million square kilometre, belt of arid and semi-arid land extending from the Atlantic Ocean to north-western India and covering more than 25 countries.

The desert locust lives in an arid environment and needs a certain amount of rainfall for the environment to become favourable for breeding. Since it has no resting stage to wait out prolonged periods of drought, it has to

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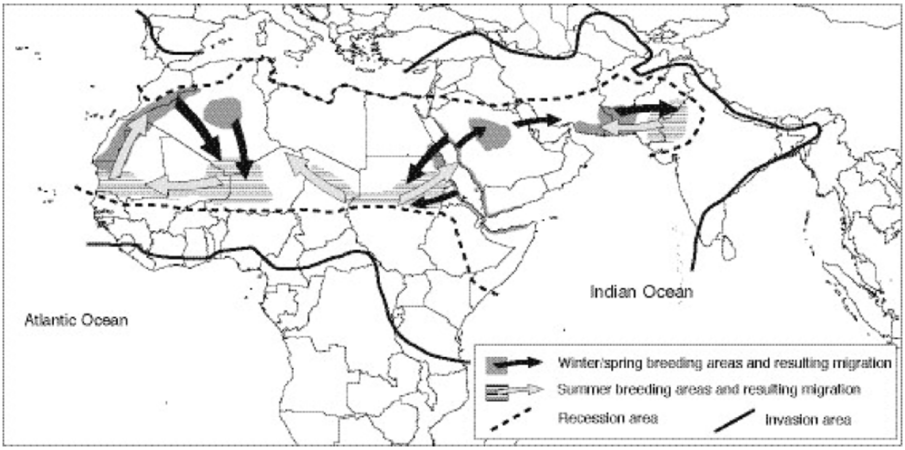

Figure 1. *Desert locust recession and invasion areas with recession migration circuits. Map modified after Symmons and Cressman (2001).*

migrate after one or sometimes two generations from areas that, were temporarily favourable for breeding but have dried out, to newly favourable areas where recent rains have fallen. During recession periods, in which overall populations are low and the locusts are in their solitarious stage, these migrations are inconspicuous.

How do plagues develop? The change from the solitarious to the fully gregarious form takes a number of generations, and progresses from local outbreaks via upsurges to plagues. Outbreaks occur locally after unusually heavy rains, with the resulting vegetation allowing successful breeding and the development of gregarious behaviour in the form of very many small "patches" of nymphs (aggregations covering an area of about ten square metres). Upsurges occur when widespread and heavy rains fall in successive generations or adjacent breeding areas. This may finally result in a plague, characterized by many adult swarms and very many nymphal bands (also called hopper bands). A plague may last between three and 22 years. The last major plague occurred in large parts of Africa from 1986 to 1989. Insecticides sufficient to treat 260 000 square kilometres in the Sahel region and North Africa were supplied during this period, at a cost of about USD 315 million (Gruys 1991). The last upsurge developed following heavy rains in most of the Sahel region in 2003 and continued in 2004.

2. Economics of Locust Control

2.1. Costs and Benefits of Locust Control

A bioeconomic simulation model developed from historical data and an expert assessment commissioned by donors concluded that the costs and benefits of locust control were of the same order of magnitude (FAO 1998). Another study concluded that control investments exceeded potentially preventable losses (Herok and Krall 1995). However, both studies were not refereed and included a large number of uncertain assumptions. The desert locust is a "political pest" in the sense that its occurrence as a plague and its resulting damage are spectacular, creating popular demands for action. Furthermore, swarms can migrate great distances making the desert locust a transnational problem. Consequently, desert locust plagues receive much attention from the press, and therefore from politicians.

Issues that need to be taken into account when deciding to manage desert locust populations include: (1) interrelations, since failure to control in one area has negative effects on others. In fact, effective preventive control operations conducted simultaneously over the whole distribution area of the desert locust (i.e. area-wide) has never been implemented. This is because some infested areas are too remote, others are insecure and some are located in countries having desert locust control units that exist in name only. A more coordinated approach may change the above-described relationship between costs and benefits; (2) real costs, since it has been suggested that to detect and control early upsurges throughout the recession area may be too costly to be feasible (van Huis 1994); and (3) environmental and health issues arising from control campaigns, since the effect of spraying on the environment, the risk to operators and others, and the hazard associated with surplus insecticide storage, also have to be taken into account.

2.2. Insurance Schemes to Mitigate Risks?

Would the damage caused by desert locust qualify for insurance schemes in the context of disaster management? The inherently unpredictable nature of locust damage and the low overall probability of an individual farmer or village being affected, mean that crop insurance is an obvious means in principle to mitigate the risks (Hazell et al. 1986). In practice, high operating costs and premiums, especially when the infrastructure is weak (Hardeweg 2001), would render formal public or private insurance schemes impractical in the context of locusts threatening semi-arid farming systems (Anderson and Dillon 1992). Assistance towards community level informal risk mitigation (e.g. tenancy contracts or extended family networks) has better potential. The appropriateness of insurance schemes would probably also depend on the countries (Maghreb or Sahel) and the type of agriculture (cash or subsistence crops).

Hardeweg (2001) developed a conceptual framework for economic evaluation of desert locust interventions, suggesting that farmers would be willing to participate in insurance schemes. Another issue raised was whether the humanitarian aspect of people affected by locust invasions would be taken sufficiently into account (FAO 1998). Would the international donor community favour engagement in insurance schemes or food aid in preference to supporting control efforts? LeCoq (2001) and Krall (1995) found these options unrealistic and little adapted to the economic and social realities of the countries involved. Commercial insurance depends on statistical data on risk and cost; what is your house worth and how often does a house burn down? There is no basis for estimating the risk of a field being invaded by locusts, and even estimating the loss that might result would be difficult.

3. Technical Strategy to Control Locusts

3.1. Outbreak Prevention

The current official strategy is to prevent plagues by control at the local outbreak or early upsurge stage. This is superficially attractive and it seems sensible to control when numbers are relatively low. However, control is not a matter of numbers but of the area needing treatment, of the difficulty of finding the targets, of the control methods that are appropriate, and of the time available to muster and deploy resources. For example, the swarms of a plague might number perhaps twenty with a total area of about 1000 square kilometres (with 5 x 10^9 locusts). The “patches” of an outbreak might be distributed over very many times that area although the total number of insects would be only a small fraction of the number in a plague population.

Symmons and van Huis (1997) calculated the efficiency of controlling an outbreak in an area of 20 000 square kilometres (of which 4000 square kilometres was green) treating either blocks using vehicle-mounted ultra-low volume sprayers or individual patches using hand-held ultra low volume sprayers. Spraying patches using a vehicle is not effective since they are too small; therefore blocks have to be identified that contain sufficient patches to make spraying efficient. Results indicated that one team with two vehicles could spray no more than 0.28 square kilometres during a day, and during a whole campaign not more than seven square kilometres. To effectively treat either all infested blocks or all patches would require more than 75 vehicles to control only 50% of the population.

During two contingency planning workshops in Egypt and Mauritania (FAO 2002a, 2004) when field monitoring was carried out with experienced survey operators, it was proven that the above-mentioned values were probably far too optimistic. It is very difficult to demarcate infested blocks and when deciding on treating each patch individually by hand-held sprayers, the problem is that these patches are very difficult to find. Magor (1999) also indicated the difficulty of finding locust infestations during early outbreaks. Besides, outbreaks in the immense recession area (Hemming et al. 1979), where the rain needed for breeding is often sporadic, appear suddenly (Roffey and Popov 1968), and are therefore often not detected. Therefore, outbreak prevention – namely the control of gregarizing locusts that might cause an outbreak – is almost certainly not possible.

3.2. Upsurge Prevention

So, what would be the appropriate control strategy when outbreak control to prevent upsurges or plagues is not possible? During outbreaks and the early stages of an upsurge only a certain proportion of the population behaves gregariously. During this stage numerous small gregarious hopper bands are scattered over a large area. During the development of an upsurge the bands and swarms become progressively larger and more cohesive, and the infested area diminishes. This can be illustrated using data from the development of the 1968 plague. Locust numbers during three generations increased from 2000 million to 30 000 million while the total area infested decreased from over 100 000 square kilometres to about 5000 square kilometres (Bennett 1976).

The crucial question is at which stage during the development of a plague a sufficient proportion of the population would be in the gregarious phase and become suitable targets for control. At which population densities and degrees of gregarization does upsurge prevention end and upsurge elimination begin? Upsurge prevention by outbreak elimination is almost certainly not feasible at reasonable costs. In practice, probably upsurge elimination is what is normally attempted, and if that fails, plague suppression. Upsurge elimination is difficult to define and probably difficult to carry out. The reason is that the populations are a mixture and the mix itself changes as the upsurge develops. At the hopper stage there may be medium-sized bands, small bands, groups, patches and scattered hoppers. Adults may be scattered, in groups, in "light flights", in low-density swarms that may well disperse and reform, as well as in small cohesive swarms. The definition of "prevention" is not clear and can be taken to mean different things (van Huis 1994, LeCoq 2001). It may include all control efforts up to upsurge elimination (Posamentier and Magor 1997).

3.3. Swarm or Hopper Control

During late upsurges and plagues, adult swarm spraying is much more efficient than hopper control and it has been claimed that it may be the only feasible method of achieving general population reduction (Courshee 1990, Symmons 1992). Symmons (1992) pointed out that ten square kilometres with a 5% band infestation would need to be treated to prevent one square kilometre of swarm on the probably generous assumption that one square kilometre of band would give rise to two square kilometre of swarm. Despite this, most campaigns concentrate on hopper control. This is unavoidable in the early stages of an upsurge when swarms are small and perhaps transitory. In late upsurges, swarm control is theoretically attractive. However, although swarm control is very effective, there is a risk that swarms will escape control because of their mobility and the limited time frame available for control actions. Control of swarms requires timely action and excellent organizational and logistic capabilities (van Huis 1997).

3.4. Strategy Question Unresolved

The Food and Agriculture Organization of the United Nations (FAO) established in 1994 an Emergency Prevention System (EMPRES) for Transboundary Animal and Plant Pests and Diseases in order to minimize the risk of such emergencies developing. During a meeting of EMPRES aimed at desert locust plague prevention in the central region (those countries bordering the Red Sea), it was concluded that an optimal control strategy could not be identified, due to insufficient data, and called for the collection and analysis of data during future outbreaks and upsurges (FAO 1997). However, during the past seven years only recession populations could be studied.

An outbreak occurred in 2003 in West Africa, an upsurge was underway in 2004 and ended due to adverse climatic conditions during the spring of 2005 in the Maghreb countries. However, the impact of the upsurge control actions in 2004 has not been quantified. At times when control is needed there is an understandable demand to devote all available resources to control. Therefore, the question when to intervene remains unresolved.

4. Contribution of Research to Improve Control

In 2000 a group of desert locust experts identified the following research areas (FAO 2000): (1) population dynamics (migration monitoring, intervention threshold parameters, genetic studies to characterize populations and to understand migration), (2) mapping of gregarization biotopes, (3) changes of ecological factors in recession areas, (4) mortality factors, (5) alternatives to synthetic insecticides (mycopesticides, semiochemicals and botanicals), (6) application techniques in particular barrier treatments, (7) environmental impact assessment, and (8) economic impact assessment.

The main constraints in conducting desert locust research are the lack of a coordination body, lack of partnership between southern and northern institutes, operational locust data not being utilized, the difficulty and costs of conducting field research, and the lack of continuity of research not only in terms of the unpredictable occurrence of locust infestations but also of funds. The longer the recession period, the less local authorities and international donors are willing to support research.

4.1. Forecasting, Monitoring and Early Warning

Ground and aerial survey teams transmit their data to the national plant protection organizations (NPPOs) for collation and analysis as well as to FAO headquarters, where analysis and forecasting is carried out at the international level. In 1996, FAO introduced the Schistocerca Warning Management System (SWARMS), a geographic information system (GIS) for desert locusts. This allows storage of data in several databases, display of current data on maps consisting of various thematic overlays (e.g. rainfall, habitat conditions, locust incidence), and comparison to historical data (Cressman 1997).

In terms of monitoring and early warning, progress has been made with the development of a GIS called Reconnaissance and Management Systems for the Environment of Schistocerca (RAMSES) (Rosenberg 2000). The system is a computerized application that allows the nationally designated locust information officer to store, view and retrieve locust-related data for his/her country. The use of eLocust (a handheld computer that the locust officer uses in the field to enter data and transmit it to RAMSES) has further improved data management capability within the country. RAMSES can also display and analyse remote sensing imagery. The combination of satellite images, complementary geographical information such as soil maps, and locust data gives information about the regions at risk and assists in planning field surveys and may facilitate an area-wide approach that eventually may reduce or prevent plague development.

4.2. Physiological and Ecological Studies

A number of physiological and ecological studies have been carried out during the last ten years to gain a better understanding of the behaviour of desert locust populations. Of particular importance were studies conducted on the causes of shifts from solitarious to gregarious behaviour. It appears that patchiness of vegetation and insufficient nutrition increases activity and crowding of locusts (Despland and Simpson 2000), and the resulting mechanical stimulation of the hind femur seems to play an important role in the phase transition (Simpson et al. 2001).

Woldewahid et al. (2004, 2006) found a strong association between the occurrence of solitary locusts and a certain plant community that covered only 5% of the area. Application of these findings to surveys will considerably improve their efficiency. Various authorities have suggested that the apparent association of outbreaks and "drought-breaking rains" may be caused by an unusually high quality of food plants at such times.

4.3. New Insecticides

New products have been investigated such as semiochemicals, botanicals, and mycopesticides. Mycopesticides are currently operationally used in Australia against the Australian plague locust *Chortoicetes terminifera* (Walker). Against the desert locust, a consortium of donors supported for 13 years a programme called Lutte Biologie Contre les Locustes et les Sautériaux (LUBILOSA) to develop a mycopesticide based on an African strain of the fungus *Metarhizium anisopliae* var. *acridum* (Gams and Rozyspal). It is applied as an oil suspension and can be sprayed using standard ultra low volume spinning disk spray equipment. It has a shelf-life of more than five years under refrigeration and approximately one year at 30°C. The biopesticide kills 70-90% of treated locusts within 14 to 20 days with no measurable impact on non-target organisms (Lomer et al. 2001).

Phenylacetonitrile inhibits pheromonal communication of gregarious nymphs resulting in loss of their gregarious behaviour (Hassanali et al. 2005). Phenylacetonitrile also seems to increase the vulnerability of locusts to conventional insecticides. Combining phenylacetonitrile with the biopesticide would enable the concentration of the biopesticide to be reduced by a factor of four (Pettit and Jenkins 2005). However, it is unlikely that the biopesticide can be effectively used in large-scale desert locust plague situations due to the time necessary to produce the product and its delayed control action. Its use will probably be restricted to environmental sensitive areas (Lomer et al. 2001).

Skaf et al. (1990) reasoned that since barrier spraying with the very effective dieldrin, which is both extremely persistent and biocumulative, was no longer possible there would be major technical, logistic and financial problems in containing plagues. Fipronil and insect growth regulators (IGRs) have been proposed as replacements to dieldrin (which is not being produced and used anymore). However, there are concerns that these products have negative environmental impacts. For example, the environmental impact of fipronil was tested in large-scale, long-term field trials mimicking locust control operations and found to have devastating effects on termite and ant populations (Tingle et al. 2000, Peveling et al. 2003).

It is often tacitly assumed that barrier treatment solves the block demarcation problem. In fact, it makes that task more difficult. Blocks must be larger and percentage infestation less, and the lower the percentage infestation, the more difficult demarcation becomes. The alternative is to define the area for treatment on the basis of reports of mature swarms. However, that might lead to treating hundreds of thousands of square kilometres to control the resulting hoppers from those swarms. Barrier treatment will not work during an outbreak and would probably not be successful during an upsurge, since it relies on hopper mobility and at those stages hoppers move little.

4.4. Contribution of New Techniques and Products to Control

Control application techniques have been improved by the use of global positioning systems (GPS) and differential GPS. Details of these and other new techniques are given in the Desert Locust Control Committee (DLCC) reports and by LeCoq (2001). Whatever control method is going to be used, most of the above-mentioned products are contact insecticides meaning that targets have to be sprayed very likely in blocks. However, finding the targets and demarcating them in blocks is a prerequisite to being able to use them. Therefore, LeCoq (2001) stated that locust control depends more on political and institutional choices than on scientific and technological innovations. It is probably better to say that control depends more on organization and technical choice than on innovation, but the organization and technical choices are influenced by politics.

5. Sustaining Locust Capacity During Recession Years

When there are no upsurges or plagues it may be difficult to convince national governments of the necessity to maintain a locust unit, in particular when other crop protection problems arise. However, due to the transboundary character of the plague, a minimum capacity is required to ensure that locusts are monitored to find outbreaks and upsurges and that the country is prepared when populations are building up (continuous actualization of emergency action plans). This minimum level of activity should be determined by each country (in terms of number and capacity of human resources, and of survey, control and communication equipment). National governments should commit themselves to sustain such small flexible locust units. This has the attention of EMPRES. Separate anti-locust units in countries within the invasion area but outside the recession area are not considered necessary.

6. Upsurge and Plague Control

During plagues and upsurges the main actors are: national governments, FAO, regional locust organizations, and donors. What are the roles and responsibilities of each of these organizations?

6.1. National Governments

Many locust-affected countries are among the poorest in the world. In several of these countries locust control has no priority. In any given country a plague will be a rare event. Few countries in the recession area have organizations, in a permanent state of readiness, capable of combating such locust plagues. It follows that when a plague does threaten there is a need to either expand or create a powerful anti-locust capability quickly. The issues to be dealt with at the national level are: (1) justification, (2) scale of operations, (3) definitions of threats, (4) selection of survey and control methods, (5) resources needed and available during recessions (within locust unit and elsewhere), upsurges and plagues, (6) sources of funds, (7) time to acquire resources, (8) organizational arrangements, (9) responsibilities at different levels of threat, and (10) timetables (Annex 3 in Symmons and van Huis 1997).

Previous plagues have been a matter of crisis management with the approach being reactive instead of proactive. During the 1986-89 plague, mismanagement resulted in a waste of resources and non-judicious use of insecticides (OTA 1990, Joffe 1995). Was there any improvement 15 years after the 1986-1989 plague events?

6.2. FAO

The desert locust was considered the first priority problem to be addressed by EMPRES (see section 3.4) and activities were initiated in the central region of the desert locust distribution area since this was where most desert locust plagues had originated in the past. The nine frontline countries along both sides of the Red Sea and in the Arabian Peninsula are included in the programme. In 2006 its activities were handed over to the FAO Commission for Controlling the Desert Locust in the Central Region (CRC). There are 16 member countries in the CRC with a secretariat based in Cairo, Egypt. The desert locust component of EMPRES in the western region commenced in 2005 and involved nine frontline countries in the Maghreb and the Sahel. Activities and management are closely linked to the FAO Commission for Controlling the Desert Locust in the Western Region (CLCPRO). There is an EMPRES office in Dakar, Senegal while the commission's secretariat is located in Algiers, Algeria.

The main objectives of the desert locust component of EMPRES are to harmonize regional cooperation, to enhance national and regional communication, to improve early warning and information systems, to improve survey systems, to set-up and implement contingency plans, to introduce efficient and environmentally safer control methods, and to develop systematic methods of campaign evaluation. Strengthening national locust units in training, survey and research is the main objective. The overall programme goal was redefined in February 2000 (FAO 2002b) as:

> *To strengthen the capabilities and capacities of the national, regional, and international components of the desert locust management system to implement effective and efficient preventive control strategies based on early warning and timely, environmentally sound, early control interventions.*

Although the term "preventive" is subject to many interpretations, there is no doubt that this statement refers to outbreak and early upsurge control, tacitly assuming that this is feasible. In practice, those now running the programme have come to realize that prevention can fail and therefore plague campaign contingency plans are needed. Therefore regional contingency workshops were conducted in Egypt and Mauritania and guidelines provided to countries.

A contingency plan or an emergency action plan is the crux of any locust plague campaign. Without such a plan, the establishment of locust units would be a waste of time. Often locust campaigns against major upsurges and plagues have been compared to a war. What is needed during a war are: (1) weapons (insecticides), (2) people who know how to use them (trained people), (3) means of finding the enemy (monitoring capacity), (4) intelligence in the information sense and analysis (information service), (5) a command structure to allow deployment and redeployment (an efficient and effective control organization), and (6) adequate resources in personnel, equipment and materials (resources to survey and control).

Having a clear understanding of these issues is most important for containing locust plagues. It means that for different levels of threat it should be clear what is available and what should be done. For example: (1) existence, procurement and distribution of insecticides, control equipment, vehicles, planes, camping equipment etc. (from national plant protection organizations, other ministries, and donors), (2) the kind of actions needed in terms of information, training, monitoring and control, and (3) who is responsible for what (FAO headquarters, national plant protection organizations, ministries of agriculture, finance and defence, donors), etc.

Another complicating issue is that when bands and swarms exist, all efforts are concentrated in eliminating them. Estimates of the total number of locusts present or the total area infested are only rarely made (Bennett and Symmons 1972). Such estimates are not easy, but without them, assessments of the impact of campaigns are not possible. The effectiveness of individual treatments has not been monitored, and moreover there is often inadequate knowledge of the technique of "incremental" spraying of concentrated insecticides (ultra low volume spraying) against locusts. This means there is not yet a clear strategy for locust control.

Locust plagues are an international event. Uvarov (1953) stated

> *Locusts recognize no frontiers...*

and

> *...in many cases, the ability of locust swarms to cross frontiers is more readily admitted when they are entering a country than when they are leaving it for the neighbouring one.*

The organization responsible for, and the only organization capable of international coordination is FAO. Currently, apart from its EMPRES-related desert locust and other long-term coordination activities such as those embodied in the Desert Locust Control Committee, FAO's main involvement is forecasting. This is done by the Desert Locust Information Service (DLIS) at FAO headquarters based on rainfall and habitat information provided by satellite images and locust data provided by countries. However, the difficulties for the countries to provide adequate information should not be underestimated because of the logistical problems involved in surveying immense areas.

In emergencies, the Locust and Other Migratory Pests Group of FAO becomes the Emergency Centre for Locust Operations (ECLO) with additional competencies to manage the locust situation. The most important issues to be dealt with by FAO during an emergency are: (1) the collection, analysis and dissemination of information, (2) the assessment of the situation through provision of consultant services, (3) the assessment of survey and control efficiency, (4) the procurement and management of contingency funds from donors, (5) donor coordination, (6) the arrangement of international meetings for all stakeholders, (7) insecticide management (procurement, contingency stocks, distribution, and avoiding the problem of obsolete products), and (8) contact with commercial organizations (provision of aircraft, equipment and insecticides). The donors could collaborate by making available a permanent "desert locust emergency fund", large enough to start emergency operations.

6.3. Regional Locust Organizations

There is only one operational regional locust organization: the Desert Locust Control Organization for East Africa (DLCO-EA). It specializes in aerial surveillance and control of the desert locust, grain-eating birds and the tsetse fly. Member countries can apply for assistance in control activities. Another regional organization Organisation Commune de Lutte Antiacridienne et de Lutte Antiaviare (OCLALAV) in West Africa is not operational.

6.4. Donors

Donors are particularly interested in evaluating the effectiveness and efficiency of desert locust campaign operations. The following aspects are considered important: (1) organizational issues – role of local, regional, international and donor organizations, cooperation, coordination, communication, logistics, training, contingency planning, (2) technical issues – collection, analysis and dissemination of information, improved forecasting, integrated pest management approaches, efficacy of insecticide applications, locust population dynamics, crop damage, and sustainability, (3) financial issues – national and emergency funds, management of funds, and contingency planning, and (4) health and environmental issues – insecticide banks, obsolete insecticides, biodiversity (pollinators and biodiversity), alternatives to synthetic insecticides, safety procedures (food residues, water contamination, toxicological monitoring of staff, existence of protocols), procurement of insecticides, insecticide stocks, disposal of insecticides, and quality of insecticides.

To record what has been done and to evaluate the impact of any action undertaken is the crux of locust control. Independence of surveys and control, the extent of the area infested and the populations of locusts therein should be determined. This is the only way to determine which part of the population was destroyed during an outbreak or upsurge, and whether control is making any sense. Probably the best criterion is the extent (area) of the infestation, more than the density of the population.

Campaign evaluation during outbreaks/ upsurges, and outbreak prevention during recessions are other crucial issues that need to be addressed (effectiveness of control operations). The way in which this can be done most effectively has to be considered. Probably the best approach for regional coordination would be to establish an independent group responsible for these activities, but hosted at FAO.

7. Conclusions

Popov (1972) stated that the objectives of locust surveys are simple:

> *To find economically important locust populations and destroy them as efficiently as possible.*

It often seems that miracles are expected from technical innovations. Large funds have been spent on satellite imagery, remote sensing, new control agents and application techniques, etc. to improve future prevention capacities that avoid plague development. However, the core business of locust control still depends on the organization, logistics, finances, and politics of controlling upsurges/swarms. Locust affected countries, FAO, and donors need to be organized for locust prevention and control (contingency plans).

During upsurges and plagues it is very common for national governments and FAO to request funds for buying insecticides, and survey and application equipment. However, almost never is it indicated how these will be used. Donors should only provide funds to governments of locust-affected countries when there is a plan showing how these resources will be used to find and efficiently destroy economically important locust populations. Equally important, they should follow up to see that some attempt has been made to execute the plan. Such plans of course concern the items already listed. The execution of a campaign requires flexibility. No battle ever goes according to plan. During recession periods there is enough time to develop contingency plans to execute an effective campaign in time of need.

Another issue of crucial importance is the strategy of locust control. Campaigns need to be evaluated independently during outbreaks/ upsurges to determine the extent of infestations and the effect of control efforts. The other issue is how to prevent outbreaks during recessions. Can surveys be better targeted? When done effectively on an area-wide basis could this lead to a new strategy of outbreak prevention?

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