Article

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Desert Locust Control in Ecologically Sensitive Areas: Need for Guidelines.

Chemical control of desert locust (DL) is carried out over large areas of land, covering a range of different landscapes and ecosystems. There are no real restrictions for spraying in or close to environmentally sensitive areas and awareness of sensitivity is not always obvious to the people involved in control. However, concern about environmental issues in connection with DL control is growing and clear guidelines are needed. The objectives were: to identify and delineate areas particularly sensitive to pesticide contamination in northeastern Africa, e.g. protected areas, wetlands, populated places, oases, and areas with concentrations of migratory birds. These areas were matched with actual DL control during 1986-1998. The conclusion is that chemical control occurred in environmentally sensitive areas especially wetlands, e.g. temporary waters and mangroves; close to human settlements; and, to some extent, in or near protected areas and areas with numerous migratory birds.

INTRODUCTION

Schistocerca gregaria, the desert locust (DL) is one of about 20 locust species present in tropical and subtropical areas. DL is probably the economically most important locust, mainly due to its vast area of distribution. During recessions, it is sparsely distributed in the Sahel in Africa, on the Arabian Peninsula, and in parts of Iran, Pakistan, and India. During plagues, the area of distribution increases to the Mediterranean area in the north to Tanzania in the south, and to large parts of oriental Asia to Bangladesh in the east (1).

DL (as well as other locusts) can occur in a solitarious and a gregarious (swarming) phase. Solitary locusts live separately, the hoppers (nymphs) do not move together and the adults usually fly individually at night. Gregarious hoppers move in marching bands and the adults move together in cohesive day-flying swarms. The direction of movement is mainly down wind both for hopper bands and swarms. This mode of direction will result in small hopper bands combining and forming larger hopper bands; the same is true for swarms. Large hopper bands can cover several ha and large swarms can cover hundreds of km^2; Gregarious phases develop in response to a combination of crowding, pheromones, and host-plant substances (1).

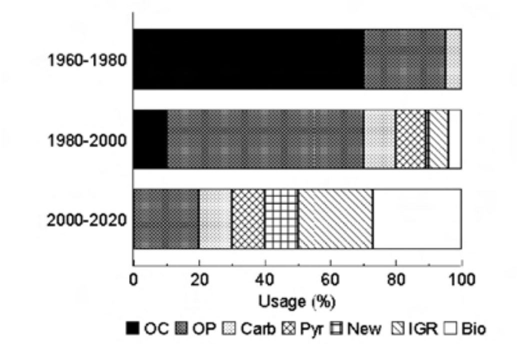


Figure 1. The usage of different pesticides for control of Desert Locust in the past and a prognosis for usage in the near future. OC = Organochlorines, OP = Organophosphates, Carb = Carbamates, Pyr = Synthetic pyretroids, IGR = Internal Growth Regulators, Bio = Bio-pesticides.

Plagues

DL is regarded as a serious threat to many crops, and plagues have occurred at irregular intervals for centuries. The most recent big plague occurred during 1986-1989 and smaller upsurges have occurred during 1992-1994 and 1996-1998. The cost of control can be enormous, e.g. during the 1986-1989 plague a total of about 15 million ha was treated at an approximate cost of 200 million USD (2).

Pesticides

There are 4 main classes of chemical pesticides that have been or still are used for DL control: organochlorines, organophosphates, carbamates and synthetic pyrethroids. A new class, phenyl pyrazoles, has recently been introduced. Other relatively new classes of pesticides are insect growth regulators (IGR) and biological pesticides, mainly fungus (1).

Organochlorines were widely used during the 1960s and 1970s. However, due to their persistence their use was stopped in the mid-1980s. The organochlorines were replaced mainly by organophosphates (Fig. 1.). The use of pyrethroids has increased during the last decade. The use of IGRs and biopesticides is expcted to increase. However, chemical pesticides will continue to be the main weapon against desert locust for the near future.

The properties of organophosphates, carbamates, and pyrethroids are essentially the same. They have a broad-spectrum activity and a rapid effect. They work mainly by

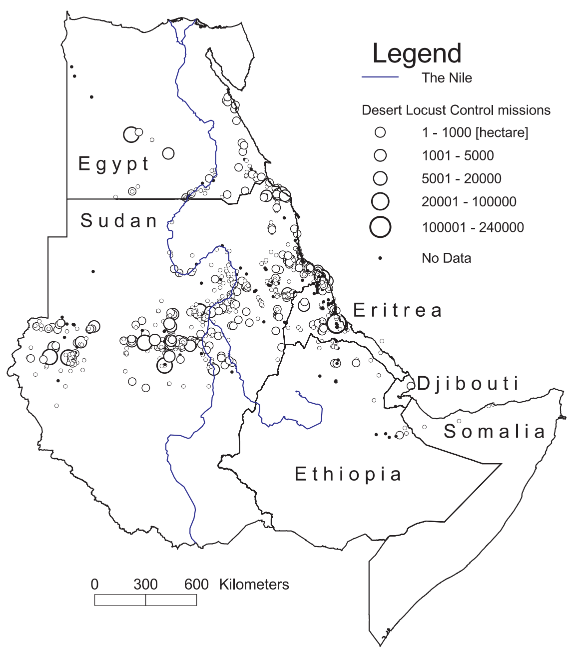


Figure 2. Control operations against desert locust 1986-1998. The size of the symbol indicates the area of control.

Table 1. The environmental risk of various groups of nontarget organisms, to pesticides used for Desert Locust control. The Table is an extract from a report from the FAO Pesticide Referee Group. (For the complete Table see ref. 11).

Insecticide[1]	Environmental risk[2]						WHO Toxicity Class[3]
	Aquatic organisms		Terrestrial vertebrates		Terrestrial invertebrates		
	Fish	Invertebrates	Mammals	Birds/reptiles	Bees	Other[4]	
Bendiocarb (CA)	M	L	M	L	H	M-H	II
Chlorpyrifos (OP)	M	H	L	M	H	H	II
Deltamethrin (PY)	L	H	L	L	M	M	U
Diflubenzuron (IGR)	L	H	L	L	L	L-M	U
Fenitrothion (OP)	L	M	L	M	H	L-M	II
Fipronil (PP)	L	L	L	L	H	M-H	U
Lambda-cyhalothrin (PY)	L	H	L	L	M	M	II
Malathion (OP)	L	M	L	L	H	M-H	III
Metarhizium (BI)	L	L	L	L	L	L	n.d.
Teflubezuron (IG)	L	H	L	L	L	L-M	U
Triflumoron (IG)	L	H	L	L	L	L-M	U

[1] Pesticide class: BI = biological agent, CA = carbamate, IGR = Insect growth regulator, OP = organophosphate, PP = phenyl pyrasol, PY = synthetic pyretroid. [2] L = low risk; M = moderate risk; H = high risk. [3] II = moderately hazardous; III = slightly hazardous; U = no acute hazard; n.d. = no data. [4] Natural enemies and/or soil insects

contact and are efficient for short periods only and, consequently, they need to be targeted directly on to the locusts. These pesticides can be used in plant protection as well as for strategic spraying against hopper bands and swarms.

The phenyl pyrasol (Fipronil) is a broad-spectrum pesticide with contact and stomach action. The active ingredient has recently been developed especially for locust control. It can be used in extremely low dosages (5 g a.i. ha^{-1}) and because of its persistence makes this pesticide potentially useful for barrier treatments. The IGRs are slow acting pesticides that can be used on hopper bands only. This makes them unsuitable for immediate plant protection. They are fairly persistent and can probably be used in barrier spraying.

Certain isolates of the fungus *Metarhizium* have been shown to be slow acting but efficient biological insecticides against DL. However, there are still some operational problems with these products, e.g. availability in sufficient quantities during locust emergencies.

Table 2. The number of control operations within 1 km, "hits" (see text for definition) of different sensitive areas between 1986 and 1998.

Sensitive area	No. of hits
Populated places	
Villages	65
Cities	45
Wetlands	
Permanent	73
Intermittent	657
Classified wetlands	
Freshwater marsh	2
Impoundment	14
Mangrove	54
Protected areas	88
Unprotected areas	33

Barrier Spraying

In barrier spraying, swathes of a persistent insecticide are applied at specific distances. The aim being that any hopper band will eventually march through one of the barriers and, thus, accumulate fatal doses of the pesticide. This was the main way in which organochlorines were used, especially dieldrin, until it was banned in 1985. Dieldrin was not only persistent it also accumulated in the locust body, and barriers up to 2 km apart could be applied allowing the rapid treatment of very large areas from the air. Thus, effective barrier treatments depend on reasonably persistent pesticides. IGRs and phenyl pyrazols are currently being tested in barrier treatments.

Aerial Spraying on Targets

Aerial spraying from fixed wing aircraft is widely used. Helicopters are more seldom used, mainly due to high costs and poor availability. The pesticide is normally applied as an Ultra Low Volume (ULV) formulation, i.e. using small drops in the range 40 μm – 120 μm. The spraying is wind assisted, which increases the chance of spray landing on the vegetation and insects and decreases the chance of spray simply dropping to the ground and being wasted. ULV spraying reduces the need for large amounts of water, which facilitates control operations in remote areas. In some cases, e.g. in crop protection, an emulsifiable concentrate (EC) formulation is used. This technique uses larger drops that result in uneven distribution and requires more water.

Ground Spraying

ULV (most common) or EC formulations can also be used with vehicle-mounted equipment for spraying of large areas of infestations. These products can also be applied with a knapsack sprayer for small infested areas.

Baiting and Dusting

Baiting and dusting can be very effective methods for controlling hoppers, but the logistical problem involved may be prohibitive. Both methods use large quantities of active ingredient and

Figure 3. The distribution of populated places.

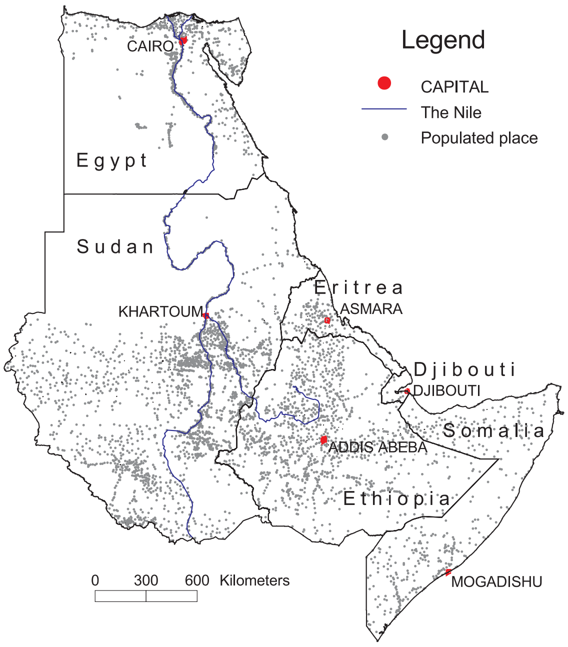
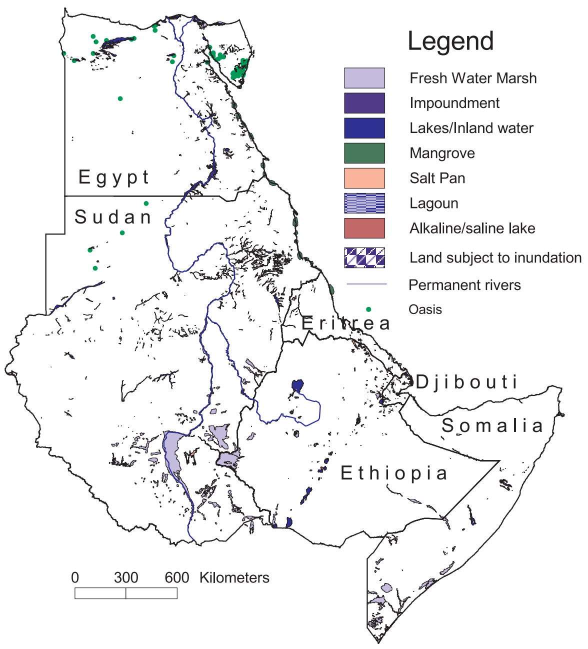


Figure 4. The distribution of different wetlands and oases.



carrier and large volumes are needed to treat even small or moderate infestations. These methods are no longer widely practiced.

Control Strategies

The Food and Agriculture Organization of the United Nations (FAO) has the mandate for monitoring desert locust activities, providing technical advice to affected countries and to coordinate the work of the various national and regional locust control organizations.

The preferred control strategy is prevention of upsurge or plague. This involves various techniques, e.g. aerial surveys, satellite imagery, weather reports, and information from scouts and nomads, in order to delimit potential locust breeding areas and to control any gregarizing populations found in this area (3). However, this strategy may fail due to, e.g. logistical or security difficulties and therefore, upsurge or plague elimination may have to be applied. The preventive strategy implies frequent control in a number of known breeding areas, e.g. the Red Sea coast whereas the upsurge or, to a greater extent, plague elimination may imply extensive but less frequent control over vast areas.

DESERT LOCUST CONTROL: ENVIRONMENTAL IMPACTS

Apart from the toxicity of the pesticides used, the potential hazard of locust control operations are closely related to certain properties that are unique to DL control. DL control often has the character of emergency operations that make it difficult to always enrol trained personnel and to choose pesticides with the least environmental impact for a particular situation. Treatments often cover large surfaces of otherwise unpolluted areas. Treatments are, on the other hand, not repeated over the same areas to the same extent as in conventional crop protection. Treatments often take place over a mosaic of different ecosystems and landscapes, e.g. green areas with a comparatively high biodiversity in an otherwise arid and barren environment. These green areas can be wadis or temporary ponds. The normal modes of spraying, i.e. wind assisted ULV spraying with vehicle or with fixed-wing aircraft, which are not particularly discriminate methods, reduce the possibility to choose pesticides that ensure minimal environmental damage in each situation. ULV spraying using aircraft also enhances the risk of spray-drift away from the target (4). The hot and high-radiation climate in DL areas reduces the half-life of most compounds, compared to temperate regions, but can also enhance the effect of the pesticide. Furthermore, DL control is carried out in a large number of ecosystems for which our knowledge is extremely limited. Although our knowledge is slowly growing, the data are highly skewed, both taxonomically and geographically.

Proper ecotoxicological studies have started during the last decade only. The most detailed study has been carried out in Senegal through a Dutch funded project, LOCUSTOX, run by FAO and the Senegalese Plant Protection Directorate (5, 6). The program includes studies on side-effects from pesticides on human health, domestic animals, higher fauna, and hydrobiology, as well as direct and indirect effects on beneficial and other nontarget arthropods. All pesticides as well as biological control agents that are used or that potentially can be used against locusts or grasshoppers are being tested in various ways both in laboratory trials as well as under field conditions. Results from the program have been published in 3 volumes (7-9). A review of earlier studies can be found in Ritchie and Dobson(10).

A report from the FAO Pesticide Referee Group presents information on the environmental risks to nontarget organisms (Table 1). The information is to a large extent based on work done at LOCUSTOX (11).

Several of the chemical pesticides (CA, OP and PY) used for desert locust control are highly or moderately toxic to other invertebrates, both terrestrial and aquatic. Chlorpyripos is toxic to fish as well as birds and bendiocarb is toxic to fish and mammals, whereas fenitrothion is moderately toxic to birds. Insect growth regulators (IGR) are highly toxic to aquatic invertebrates while the special strain of the fungus *Metarhizium* shows a low risk to most nontarget organisms. Potentially, this biopesticide could cause mortality in other Orthoptera, e.g. grasshoppers.

The term "risk" is defined as the actual probability of harming an organism or the proportion of the population that may be affected by a specific treatment (12). Thus, the risk is a function of susceptibility and exposure. Important factors when estimating real risk are, e.g. proportion of population in sprayed area, application volume, application frequency, persistence of active ingredient, intrinsic toxicity of active ingredient, mobility of nontarget organisms, degree of isolation, extent of depletion of food items, degree of polyphagy, etc. It is important to consider both temporal and spatial effects when estimating real risk. Pesticide treatment in an area in which large numbers of a particular species are aggregating (as can be the case of, e.g. migrating birds) can, potentially, have just as drastic an effect as spraying over a small pond with isolated and short-lived populations of some aquatic invertebrates.

DEFINITION OF SENSITIVE AREAS

The definition of sensitive areas has been done in cooperation with International Union for Conservation of Nature (IUCN) in Nairobi and LUCOSTOX. The following sensitive areas have been defined:

Human settlements. For obvious reasons pesticide treatment should always be avoided over or near human settlements.

Wetlands according to the Ramsar Convention on Wetlands. The Convention on Wetlands is an intergovernmental treaty adopted on 2 February 1971 in the Iranian city of Ramsar (13). The convention has been signed by 116 countries (only Egypt in the area of study). According to the convention “wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres”. Furthermore, under the convention there is a general obligation to include wetland conservation considerations in national land-use planning, i.e. “the wise use of wetlands in their territory” which includes pollution or other human interference.

Oases. Oases are normally both wetlands and human settlements. Furthermore, oases can be isolated habitats for highly specialized species.

Protected areas. Protected areas are, per definition, sensitive. They are protected because they contain species, ecosystems, landscapes or some recreational value that should remain undisturbed.

Areas with a concentration of migratory birds. These areas should normally be considered as temporary sensitive areas since migratory birds traversed certain areas during certain times of the year.

Areas with a high or unique biodiversity. The Convention on Biological Diversity that was adopted by the Intergovernmental Negotiating Committee in Nairobi in May 1992 and opened for signature during the United Nations Conference on Environment and Development in Rio de Janeiro later the same year, specifies a number of actions in terms of identifying and monitoring biological biodiversity (14). The convention also stresses the importance of identifying processes and activities that can have adverse effects on the conservation and sustainable use of biological diversity.

Table 3. The number of control operations within hotspots for migratory birds (Fig. 5) during spring (March – May) and autumn (August – October) migration.

Migration period	No. of operations
Spring	5
Autumn	20

DATABASES

We investigated the northeastern part of the African continent, i.e. Egypt, Sudan, Eritrea, Djibouti, Ethiopia and Somalia.

A desktop study was performed in order to determine ecologically sensitive areas in the study area, and to what extent these areas are close to or overlap previous records of chemical DL control. The aim of the project was mainly to compile available data from various sources into a useful framework. The data was either readily available in databases or had to be compiled from various sources.

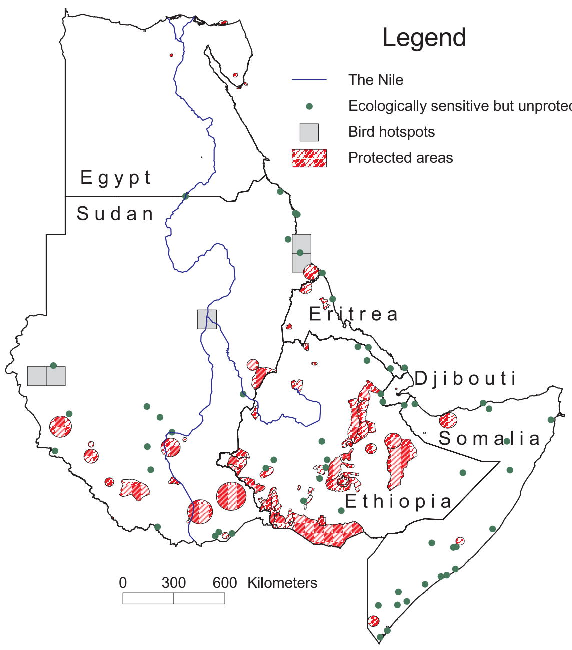
A spatially explicit database containing 1408 observations on chemical control of desert locust between 1986-1998 in the region has been created. The database contains the following information (if available): location (geographical coordinates), year and month, area, chemical compound and stage of the locust. Individual data that comprise the database were extracted from the files at Desert Locust Information Service at FAO, Rome. It contains telexes, faxes, or reports from plant protection authorities in the different countries or from organizations (e.g. DLCOEA) to FAO. The data were collected in a conservative way, i.e. only data that specifically state that control was carried out against desert locust was included and only data where geographical coordinates were given, or could be estimated with absolute certainty from the location given. As normally only one pair of coordinates were available per spray occasion, the area sprayed is assumed to be circular. All incoming telexes, faxes, or reports between 1986-1991 and 1993-1996 were screened. Information from messages for 1992-1994 and 1997-1998 was already available from a database at Department of Geography, University of Edinburgh, UK.

Spatial explicit data regarding environmentally sensitive areas were integrated with the desert locust control data in a geographic information system (GIS), permitting spatial analysis. National and administrative borders, human settlements and general wetland data were taken from the Vector Smart Map Level 0 (VMAP0) (15). Additional wetland data were derived from WCMC (16), which is based on Hughes and Hughes (17). Protected areas including national parks, game reserves, wildlife reserves, controlled hunting areas, etc. were extracted from Iremonger et al. (18). Additional information was adapted by Environmental Research Group, Oxford Limited from data supplied by FAO, Rome and ILRI, Nairobi. Ecologically sensitive (but unprotected) sites were digitized from the World Bank (19). Areas overlapping with protected sites were removed. Oases were extracted from VMAP0 (15) and from Sandford (20).

Recoveries from about 1500 ringed birds of more than 100 species in Northeast Africa, held by the European Union for Bird Ringing (EURING) databank, were used to elucidate important areas for migrating birds.

The potential risk for a sensitive area to be contaminated with pesticides was estimated by the number of “hits”. Around each of the sensitive areas, a 1-km wide buffer zone was created. All DL control operations located within the sensitive area or within the 1-km buffer zone were counted as “hits”. The reason for choosing this buffer zone instead of a direct “hit” is mainly because of the inaccuracy in the positions and shapes of areas. The positions for control operations against DL are reported with only 1 decimal (units = decimal degrees) and are, in the present study, assumed to have circular shapes. For some of the control operations area is not indicated at all. In the present study, these are regarded as single points without area. Some of the sensitive areas for which data on the actual shape were missing are also assumed to have a circular shape. These assumptions are necessary simplifications of the true situation and may slightly influence the result of the analysis. However, they will not distort the overall pattern or influence the possible conclusions to be drawn.

Figure 5. The distribution of protected areas and sensitive but unprotected areas (according to IUCN). The map also includes areas with a high concentration of migratory birds during migration periods in spring and autumn (hotspots).



DESERT LOCUST CONTROL

Sudan and Eritrea had the largest number of spray operations with 1054 and 219 operations, respectively (Fig. 2). The largest area sprayed was 240 000 ha (1986, near Massawa in Eritrea), roughly 20% of the areas were greater than 1000 ha and the median size was 400 ha. No size was indicated in about 20% of all operations. The Red Sea coast was sprayed mainly during December to February and the interior of Sudan was sprayed during July to November. This follows the extent of the breeding areas in different seasons (1).

The highest frequency of spraying was in areas on the Red Sea coast, e.g. in the Tokar Delta (478 operations within a 50 x 50 km area with the town approximately in the middle) and near Suakin (56 operations) in Sudan and the area around Massawa (32 operations) in Eritrea.

The frequency of spraying operations was different for different years. Many spraying operations were carried out in 1987 and 1988 as well as in 1993 and 1995, whereas no operations at all took place in 1990 and 1991. This is, of course a consequence of the irregular incidence of desert locust outbreaks.

SENSITIVE AREAS IN RELATION TO SPRAY OPERATIONS.

Human Settlements

There are a number of hits with populated places (Fig. 3) (Table 2). The highest incidence (about 80% of all hits) is in Sudan, which is partly due to a comparatively large number of spray operations near the densely populated Nile both north and south of Khartoum.

Wetlands

The area contains large mangroves along the Red Sea coast and several temporary rivers as well as marshes and other wetlands (Fig. 4). A total of 70 hits were in IUCN classified wetlands, of which 54 were in mangroves (Table 2). A more detailed risk assessment for mangroves is at present being carried out at the Red Sea area of Sudan. Preliminary results indicate that wind drift of pesticides into mangrove can occur occasionally (Eriksson, pers. comm.).

Oases

The oases are located mainly in the Sinai Desert and northern Sahara in Egypt, and a few small oases are located in northern Sudan (Fig. 4). There is no incidence of spray operations in or in the vicinity of oases.

Protected Areas

Most of the protected areas are located in the southern part of the region, e.g. in Ethiopia and southern Sudan where locust spray operations do not occur (Fig. 5). The total number of hits between protected areas and spray operations are 88 (Table 2). However, 80 of these are from Tokar Game Reserve in Sudan, which is probably protected on paper only. In addition, there were 4 hits in Nakfa Wildlife reserve and 1 hit in Gash-Setit in Eritrea, as well as 1 hit in Babile Elephant Sanctuary, and 1 hit in Erer Ghota in Ethiopia. There are 33 hits in unprotected but sensitive areas (according to IUCN). Of those hits 27 are in Jebel Elba in northeastern Sudan and 5 are near Suakin on the Red Sea coast of Sudan, and 1 hit in Lake Nubia in Sudan, near the border with Egypt.

Migratory Birds

During spring and autumn, a large number of birds migrate between breeding sites in western Palaearctic and wintering sites south of Sahara in Africa (Fig. 5). Recoveries of ringed birds show that the passage of northeast Africa regularly involves birds from a breeding area extending from Britain in the west to the river Yenisei, in Russia, in the east. This area covers about 90° longitude. Even though most of the bird migration across the Saharan Desert is known to take place on a broad front, the distribution of recoveries in Sudan shows concentrations (hotspots) along the Nile and at some other sites south of the desert. This is further supported from observations of distinct migration in Sudan, where many species have been observed migrating at the Red Sea Coast, along the Nile in the Khartoum area, and in the Darfur area in the west (data compiled from Nikolaus (21)). The temporal pattern of migration in the area shows a strong seasonal pattern with most autumn migration occurring during the period 20 August to 20 October and most spring migration during the period 10 March to 20 May (compiled from Hogg et al. (22)) (Fig. 6). There have been only a few control operations in the hotspots during migration periods (Table 3). Most hits occurred during autumn migration in the vicinity of Khartoum

Areas of High or Unique Biodiversity

This kind of area is partially covered by the IUCN database on unprotected but sensitive areas, and probably also by including oases. Further information was requested from the appropriate authorities in each country without success.

CONCLUSIONS

This paper does not aim to show the exact frequency of incidences where there has been a spatial overlap of chemical control of DL, and what we have defined as ecologically sensitive areas. The aim is rather to indicate the potential risk that this can occur. Even if the number of actual overlaps is low, it is evident that chemical control of DL has been conducted in or close to ecologically sensitive areas. This will probably continue in the near future. However, the concern about environmental issues is growing both among the affected countries and donors and it is our strong belief that a more prudent strategy could be applied.

The present paper contains part of the data for total distribution of DL. Spraying operations against DL occur in other parts of Africa (e.g. Niger, Mauritania, Morocco, and Algiers), in the Middle East (e.g. Saudi Arabia, Yemen, and Oman), and in other parts of Asia (e.g. Iran, Pakistan, and India). The situation is most likely the same in these areas, i.e. chemical control does occur in or near ecologically sensitive areas. FAO is at present developing guidelines for "Safety and Environmental Precautions" in their series on Desert Locust Guidelines. These guidelines will include general recommendations, i.e. to notify people before spraying operations, to choose pesticides less toxic to fish, mammals, and birds if spraying occurs in their respective habitats, etc.

These guidelines are applicable for the campaign coordinator and/or the operation team leader. We believe that there is also a need for guidelines or a change in policy at the country level. This means that certain areas, e.g. national parks and other protected areas of high priority, should not be sprayed at all or that certain areas should be sprayed with extreme caution in terms of choice of pesticide and prevailing weather conditions, e.g. risk for spray drift into mangrove and other wetlands or that temporal inhibitions in areas with a high concentration of migratory birds should be adopted. We believe that a discussion on these issues should be started as soon as possible and that FAO should play a leading role in initiating these discussions.

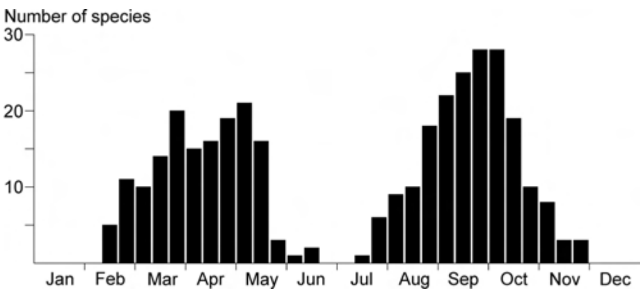


Figure 6. Temporal distribution of bird species observed on migration in Central Sudan, divided on thirds of months (data extracted from (22)).

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