New Strategies in Locust Control
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Environmental effects of locust control: state of the art and perspectives*

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Summary. Chemical pesticides applied for locust control represent a risk for humans, terrestrial non-target fauna and aquatic ecosystems. This paper reviews the field experience on side-effects. Humans most at risk are field operators themselves. Of the insecticides recommended by the Food and Agriculture Organisation of the United Nations (FAO) specifically, organophosphates and carbamates should be handled with the most care. These compounds also pose a risk to birds, either by direct poisoning or by food depletion. Among the terrestrial non-target invertebrates, there are beneficial species. They appear to be generally affected by treatments, in some cases causing upsurges of secondary pests. Long-term disturbances (over one year) were observed in terrestrial invertebrate communities. The risk of environmental damage can be mitigated considerably by proper selection and use of pesticides. An improvement in the information given decision makers and in the training of operators are essential tools to achieve these goals.

Résumé. Les pesticides chimiques qui sont utilisés dans la lutte antiacridienne représentent un risque pour l'homme, la faune non-cible terrestre et pour les écosystème aquatiques. Cette revue est une synthèse des effets néfastes observés sur le terrain. Parmi les humains, ceux qui manipulent les produits sont le plus en danger. Ce sont spécifiquement les organophosphorés et les carbamates qui méritent une haute vigilance. Les mêmes molécules représentent des risques pour des oiseaux, soit par intoxication directe, soit par privation de nourriture (insectivores). Parmi les invertébrés terrestres non-cibles on trouve beaucoup d'espèces utiles. En général, ils sont toujours touchés par les traitements, parfois résultant des résurgence de déprédateurs secondaires. Ce n'est que dans ce groupe d'invertébrés qu'on a pu constater des effets à long terme, c'est-à-dire se prolongeant sur plus d'une année. Le risque de dégâts environnementaux peut être limité considérablement par une sélection propre et une utilisation judicieuse des produits. A cet effet, il est essentiel que les décideurs soient mieux informés sur les méthodes les moins néfastes et que le personnel opérationnel soit mieux formé.

Introduction

Synthetic pesticides are still an essential weapon in the war against locusts. The combination of large-scale treatment and the relatively high dosage required for effective control results in large amounts of pesticides being used. These are applied to a wide variety of ecosystems. In recession areas it concerns primarily "green islands" in an otherwise barren environment, such as in wadis and oases. Plagues, on the other hand, spread into cultivated and inhabited areas as well as pasture zones, forests and wetlands. Because of infrastructural limitations, the use of less discriminate methods of spraying, e.g. by fixed-wing aircraft, is often unavoidable.

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Furthermore, in the emergency of plagues poorly trained personnel are employed and the choice of pesticides is often limited. In arid zones, the areas most at risk are those with high biological productivity, i.e., where agriculture is concentrated and where crop protection is important. There are, however, factors that mitigate the risk of environmental damage.

Most communities of organisms in arid zones, for instance, are adapted to highly variable physical conditions and therefore exhibit remarkable resilience to disturbance. The fact that locust interventions are rarely repeated at the same place over consecutive seasons enhances the chances of recovery from damage, provided unaffected reservoirs for recolonisation (refugia or non-affected dormant stages) are available. High UV radiation and elevated temperatures in locust areas also accelerate degradation of pesticides.

Despite the limited training possibilities in emergency situations, the more regular control in recession areas is nevertheless carried out by professionals who are well aware of the risks involved.

Environmental risk

The potential risk from pesticides used in locust control can be derived through various models. We combined toxicity data available from the literature. These data from laboratory-based studies clearly indicate a general potential hazard for aquatic invertebrates. Fenitrothion is particularly toxic to bees and may also present a hazard to birds, as is the case with bendiocarb. Chlorpyrifos and lambdacyhalothrin exhibit the highest fish toxicity. On the other hand, the low vertebrate toxicity of diflubenzuron is striking. Toxic effects as observed under field conditions in these risk groups are discussed below.

Human exposure

There are three principal human risk groups: persons handling pesticides, persons exposed to the treatments and consumers of contaminated food products. The first is the most important. In a recent study carried out in Senegal, toxic effects were monitored in operators of vehicle-mounted sprayers (ULVA mast and airblast canons). The latter was found the most hazardous device for operators, even those trained in the safe handling of pesticides. On the other hand, ground support teams for aerial operations appeared to work with utmost care whenever observed by us. For the second risk group, i.e., those directly exposed to the spray, the hazard is reduced. It concerns inhabitants or passers-by of areas that are treated by aircraft. In virtually all cases inhabitants are warned beforehand by radio by the local authorities. If they remain present in the spray zone, the pilots are often able to avoid direct overspray. Even when oversprayed by full dose, however, such exposure represents only a fraction of the highest, non-toxic dose. Contaminated crops are a risk to consumers. Although subject to rapid degradation, the residues may be unacceptably high shortly after spraying, with waiting periods of over two weeks after treatment.

Animal husbandry

There are two risk groups among domestic animals: those directly exposed to spray and those feeding on contaminated vegetation or fodder. Very often, herds are not removed from areas to be sprayed, even after extensive warning. However, dosages to which the animals may be exposed are too low to pose a serious problem (see: human exposure). Contamination of forage grass or fodder, on the other hand, may give rise to waiting periods of over two weeks. In the field, no proven cases of intoxication of grazing animals have been reported thus far.

Wildlife

Although most operators (both aerial sprayers and ground teams) avoid spraying of open water as much as possible, the risk of contamination is real, and is substantiated by reports of fish kills. These are likely to be observed. However, the aquatic invertebrate fauna (crustaceans and insects) is more sensitive. Experimental treatments have demonstrated devastating effects on these groups. The risk of unacceptable damage largely depends on the type of water involved. Three main types have to be considered: temporary pools, perennial standing water, streams and rivers. The fauna of temporary pools consists of organisms with a rapid life cycle in the active stage (mostly crustaceans), of immigrants (flying insects) and a few vertebrates which have a dormant stage in the dry season (toads, tortoises and (rarely) lungfish). Side-effects of locust treatments in these groups have been studied in experiments with fenitrothion, diflubenzuron, deltamethrin and bendiocarb. The primary concern for these waters is the risk of wiping out active stages of poorly migrating organisms, resulting in long-term perturbations. Despite some devastating acute effects, long-term effects (i.e., having consequences for the following season) have not been demonstrated thus far.

In perennial standing water the presence of fish often implicates an entirely different invertebrate community. Of the insecticides tested, i.e., fenitrothion, chlorpyrifos and diflubenzuron, only chlorpyrifos proved toxic to fish.

Running waters generally harbour large crustaceans, specifically shrimps, some of which may be of economic importance. Shrimps are known to be sensitive to insecticides, in particular to pyrethroids. FAO has demonstrated that two common Sahelian species (i.e., *Palaemonetes africanus* and *Caridina africana*) are at risk after treatments with fenitrothion and chlorpyrifos. Running water, however, is unlikely to become contaminated by locust treatments to such a degree that survival of populations is at risk. Locust treatments take place mostly in the wet season when water levels are high, thus avoiding the risk of wiping out relict communities in dry-season pools (an important reservoir for recolonisation of the lotic fauna).

The acute effects on birds are generally limited to individual cases of poisoning, and in many cases, no effects have been observed at all. The risk for birds includes both direct intoxication and deprivation of food supplies. Exposure to spray is supposed to be hazardous when toxic amounts of chemicals are ingested through preening. Uptake of contaminated food is another important risk factor: debilitated or dead insects provide easy prey. Although not quantitatively substantiated, this route of exposure is considered most important. Lasting effects on bird populations have yet to be proven. However, it has been suggested that the decline of stork populations in Western Europe since the 1950s is related to the success of locust control operations depriving migrant storks of an important source of food.

Although reptiles and amphibians play a key role in arid ecosystems, up to now the taxa have not been included in environmental impact surveys for locust control. Direct toxic effects are unlikely to occur. Occasionally, observed tadpoles exposed to experimental sprays did not appear to be sensitive. However, poisoning through uptake of contaminated food (the vast majority of species are either insectivorous and/or carrion eaters) is a risk which has yet to be studied. The lack of information on this group is a serious omission which will be addressed in the near future.

The insecticides used in locust control have been selected for low mammalian toxicity. Side-effects, if any, are to be expected among the insectivores. However, only in rodents have indications of toxicity been demonstrated thus far.

Terrestrial invertebrates

Insecticides are meant to kill insects. The dosage rates required for locust control, represent a high potential risk for non-target insects. This has been confirmed in all field studies carried out thus far. Nevertheless, there is a sharp differentiation between the various pesticides with respect to the taxa and, more important, the functional groups that are affected.

The functional groups we are primarily interested in are pollinators, natural enemies of locusts and other pests, and insects essential for maintaining soil functions. It has been demonstrated that bees can be seriously affected by malathion. Of the other recommended pesticides, fenitrothion is classified as "highly toxic" to bees, while bendiocarb and chlorpyrifos are classified as "dangerous". Of all side-effects, those on parasitoids and predators of crop pests have been most extensively studied. Serious effects have been observed in species which correlated with pest upsurges.

Ants and termites are essential for the productivity of tropical and semi-arid soils. In many places tree growth is directly related to termite activity, aiding root penetration and transport of organic material into the subsoil. Side-effects on ants have been observed by various authors, malathion and fenitrothion being especially harmful. The few observations made on termites indicate that the latter insecticide was toxic to this group as well.

Key soil processes

Studies on key soil processes such as respiration, nitrification and chlorophyll production showed only marginal disturbances, even at high dosages. The insecticides tested (i.e., fenitrothion, chlorpyrifos, diflubenzuron and deltamethrin) may be considered not harmful for key soil processes, under the given circumstances.

Evaluation

A number of conclusions can be drawn from the recorded side-effects of chemical control:

- All the current insecticides present a risk to non-target organisms.
- The groups of organisms at risk differ for each insecticide.
- Long-term effects are rare and, as far as known, limited to secondary disturbances within insect communities.
- Terrestrial vertebrates are primarily at risk at the individual level.
- Fish are at risk where chlorpyrifos is used near open water.
- Aquatic invertebrates are sensitive to all recommended locust pesticides.
- Terrestrial invertebrates are at risk in all cases, sometimes leading to undesirable effects (i.e., upsurges of secondary pests).

In order to appraise the risk posed by chemical locust control to the ecosystems in the invasion area, we should compare the scale and intensity of treatments to the surface area covered by the ecosystems or communities concerned. It is clear that the treatments may have a deleterious effect, specifically on invertebrates, sometimes resulting in long-lasting disturbances in numerical relationships. However serious these effects may be, they are always characterised by their limited scale when compared to the size of the ecosystem concerned. In some cases the majority of wadis within a certain area may be treated and, thus, damaged. However, not all wadis in the invasion area are likely to be sprayed. In an extremely serious upsurge probably not more than 10% of the (potentially) productive (green) area is infested. Recovery will always occur, albeit in some cases slowly. This holds for the terrestrial communities and for temporary aquatic communities. Perennial aquatic communities found in arid areas, on the other hand, may harbour entirely isolated relict populations (e.g. aquatic tortoises in oases). Local extinction in such cases could affect biodiversity in the desert locust area. Fortunately, this risk is limited. Locally appointed operators are generally very aware of the risk of contaminating open waters (= drinking water) in arid zones.

Although recent research has revealed some of the hazards related to chemical locust control, for the most part the potential risk is still largely unknown. We know, for instance, virtually nothing about the risk to reptiles and insectivorous mammals. The mechanisms of observed disturbed interspecies relationships in invertebrate communities are unknown, which hinders extrapolation to other situations. We know that ants are at risk. However, which species are affected and the ecological consequences of their temporary disappearance is not known. Furthermore, in describing the resilience of some of this fauna, we still refer to qualitative or phenomenological observations. Until the underlying processes have been studied, recovery rates cannot be predicted and the factor "recovery" cannot be used for risk assessments.

Wherever insecticides are used, humans are at risk. The most important risk group, the personnel handling the chemicals, can be easily trained and provided with protective material at low cost. Negligence, however, is a global problem and accidents will consequently occur.

The final solution to all ecotoxicological problems is to reduce the use of toxic chemicals for locust control. This can be achieved primarily by improving the selectivity and efficacy of the available chemical methods and also by further development of non-chemical methods of control.

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