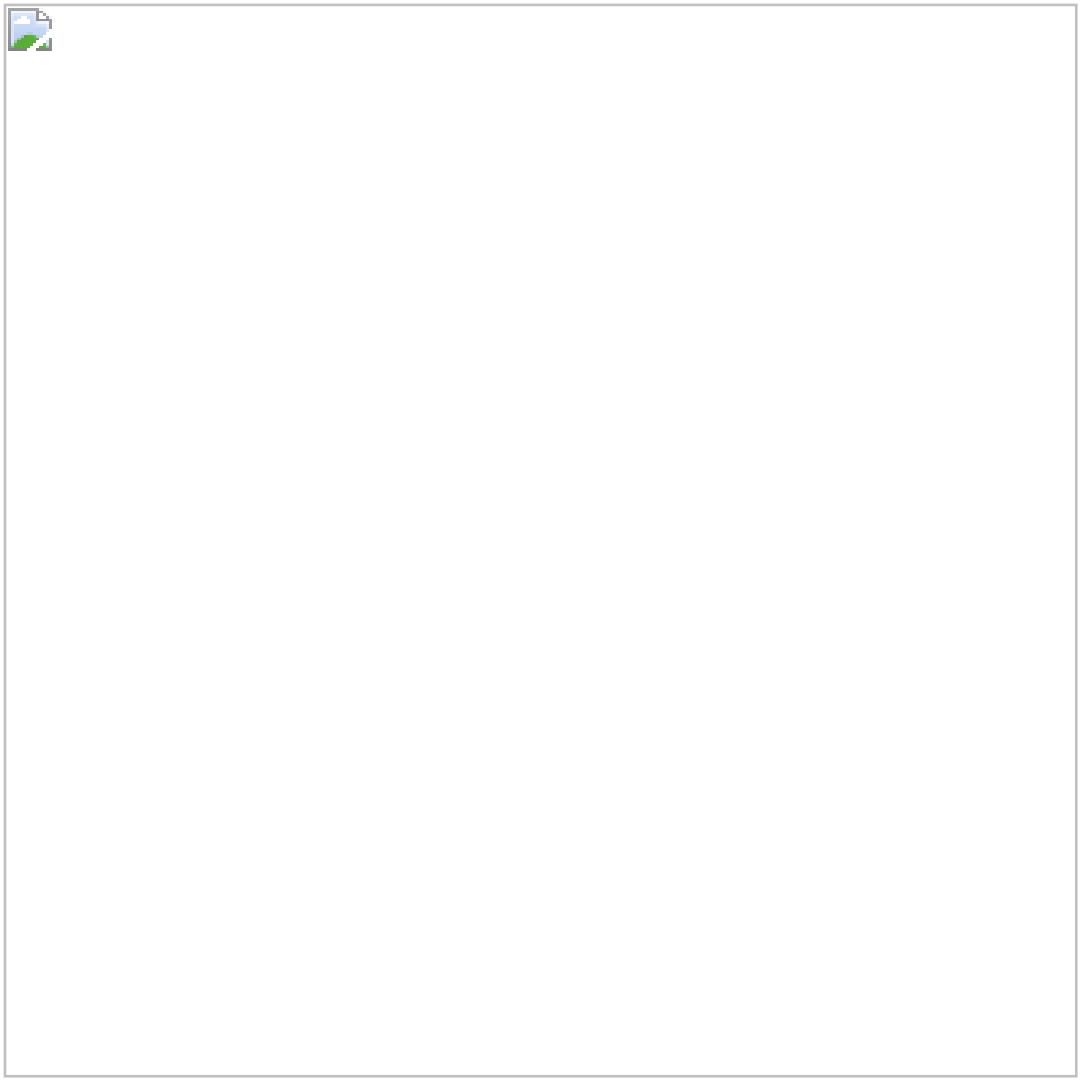

Desert locust management: from ecology to anthropology

Author: Lecoq, Michel

Source: Journal of Orthoptera Research, 14(2) : 179-186

Published By: Orthopterists' Society

URL: https://doi.org/10.1665/1082-6467(2005)14[179:DLMFET]2.0.CO;2

Journal of Orthoptera Research 2005,14(2): 179-186.

Desert locust management: from ecology to anthropology

MICHEL LECOQ

CIRAD, Center for International Co-operation in Agronomic research for Development, Locust Ecology and Control unit, TA40/D, Campus International de Baillarguet, 34398 Montpellier Cedex 5, France. E-mail: lecoq@cirad.fr

Abstract

Plague locusts are a major problem in many developing countries. For the desert locust, control by a preventive strategy proved effective, and led to a dramatic decrease in outbreak frequency and duration over the last 40 y. Principal problems are now of an organizational nature. Natural-risk management plans for locust outbreaks, associated with new financial mechanisms, must be implemented in order to ensure early reaction, efficiency of control and sustainability of the preventive approach. Studies of these outbreaks should be based on the ecological mechanisms considered to date, but also be broadened to include economic, social, organizational and cultural mechanisms that have been largely overlooked in the past. New concepts, such as risk-management systems, stakeholder strategies, and governance, should be given serious consideration. A new approach to locust issues is suggested, using techniques derived from sociological and anthropological sciences.

Key words

desert locust, locust control, preventive control, risk management, stakeholder strategies

Introduction

Far into the distant past, for many of the poorest countries of Africa, the desert locust has been a most serious crop pest (Steedman 1990). People living in these countries have been terribly hampered by the damage caused by this insect. It is a very ancient and regularly occurring phenomenon. The research undertaken over many years has resulted in the conception and creation of a preventive control strategy (FAO 1968, 1972; Hafraoui & McCulloch 1993; Krall *et al.* 1997). Regularly applied and improved, this strategy made it possible from the nineteen sixties, to reduce the frequency and duration of the invasions (Lecoq 2001, 2003, 2004; Lecoq *et al.* 1997; Roy 2001; Showler 2001; Skaf *et al.* 1990). However, these invasions persist, the most recent date being 2003-2005. Once more, although forecast by the experts, it could not be stopped in time. This latest plague indicates it is now essential to radically change our way of thinking, perceiving and dealing with the problem, and to introduce new and innovative approaches to locust issues.

The recent Desert Locust plague

The recent desert locust plague that affected Africa from 2003 to 2005 is the worst that has occurred in the last 15 y (since 1987-88). Desert locust swarms spread throughout northern Africa and of course, this situation was extensively covered by the media. In many places there were spectacular scenes of locusts literally covering all vegetation over hundreds or thousands of hectares (Fig. 1). Such swarms, as usual, migrated extensively and over very long distances. Some even reached the Cape Verde Islands, the Canary Islands and southern Portugal. In the east, some swarms reached Egypt, Cyprus and Israel. But of course, the countries of West Africa were most often affected. Many control operations were required to stop this plague: ground control treatments as well as aerial treatments using light or large aircraft (Hercules C130). During the 2004-2005 winter, cold weather and snow probably also stalled the spread of locust populations. But the fact that a total of 13 M ha were treated, clearly had a decisive impact and was essential in stopping the plague. Furthermore, control operations were successful in preventing a longer duration invasion and the infestation of larger areas.

The chronology of the plague can be easily assembled from 'Situation Updates' published monthly by FAO's Desert Locust Information Service (Fig. 2) (FAO 2003-2005). In June 2003, the locust situation was extremely calm. However, the very exceptional rains that occurred throughout the Sahelian zone, from east to west, from Mauritania to Sudan, during the summer of 2003, had a major impact in this region. These rains were very favorable for desert locusts. As of August 2003, it became very clear something was going to happen. Unfortunately, survey and preventive control operations could not be carried out on a suitable scale, because of the lack of resources. The situation began worsening in October 2003 and the upsurge gradually developed into a plague. The experts issued the first warnings in late September. On 23 October FAO made its first call for international emergency assistance for the affected countries. The lack of advanced emergency planning and of readily available funding meant that operations to control the locusts at the beginning of the initial upsurge could not be effectively undertaken in late 2003.

Then the plague developed. Swarms slowly invaded North Africa, and from March to June extensive breeding occured in this region. Large-scale curative control measures were now required, and these operations were first undertaken in the spring in North Africa. These were insufficient and did not keep the swarms from invading the Sahel during the summer of 2004. In May, June and July swarms spread quickly throughout West Africa and all the Sahelian countries, from Mauritania to Chad. In the Sahel, control operations were conducted during the summer; they were unfortunately insufficient and North Africa was—again—invaded in the autumn of 2004. Meantime, locust control operation costs had skyrocketed, increasing from US$ 1million in 2003 to US$ 50 to 100 million a year later. This new invasion led to the infestation of areas that had remained relatively untouched over the previous 50 y. The plague finally regressed in

Fig. 1. Desert locust swarms during the recent invasion. A. Morocco. B. Senegal (photos. T. Ben Halima, FAO).

2005 after many control-treatment operations.

How did this situation arise when the desert locust is a well-known species and the focus of many scientific studies? The outbreak areas and ecological conditions that can trigger these outbreaks are known. An early warning system exists. What is the weak point of the preventive control system? The problem nowadays, has become primarily one of organization.

Basic scientific control principles and short history of preventive control

Basic scientific locust control principles were first outlined by Boris Uvarov as early as 1937, during an international conference on natural disasters (Uvarov 1938). The requirements are 2: a good understanding of the species' ecology—in order to be able to locate outbreak areas and carry out preventive control—and international cooperation, essential, due to the high migration potential of this locust. Where do we currently stand concerning these 2 requirements? We can look at the issue from a historical perspective, highlighting especially how knowledge grew with respect to plagues and how this knowledge was gradually applied in the organization of locust control operations.

During previous centuries, within nations, only people living in outbreak areas knew about the desert locust. On an international scale, only travellers, missionaries, naturalists, *etc.*, were aware of it. One of the first scientific reports on the topic was by Hippolyte Lucas in the mid-19th century (Buj Buj 1995). But it wasn't until the end of the 19th century that substantial information was published by Kunckel d'Herculais (1905), the locust control delegate in Algeria from 1888 to 1905. He described plagues and control operations in an enormous 3-volume document, 40 cm thick and weighing 10 kg. At that time, the phase polymorphism theory had not yet been developed and only the gregarious phase was known. Kunckel d'Herculais provided a first explanation of the evolution of colors in gregarious desert locusts: red for immature adults, yellow for mature adults. And even at this very early time, based on color indicating possible swarm origins, he attempted the first preventive-control applications.

During the first half of the 20th century, there was a rapid increase in knowledge following Uvarov's discovery of the phase polymorphism phenomenon. During the 1930s, the main outbreak areas—still unknown—were sought. Through the late 1930s, the outbreak areas were generally outlined for the Desert Locust and the other main locust species. Uvarov then pointed out that it was essential to develop a new strategy for controlling populations in outbreak areas. This was actually a prevention strategy (Lecoq 2001). After World War II, new national and regional locust-control agencies were set up in or near the affected areas. Of these institutions for West Africa we should mention especially, OCLALAV, the Joint Anti-Locust and Anti-Aviarian Organization—since the current plague originated in this area. For a long time, until the mid 1980s, this organization was a mainstay for preventive Desert Locust control and a source of technical innovation. And there were many innovations in the 1950s. There was spectacular progress: control operations were more efficient after the development of barrier treatments, ULV applications and the use of new residual pesticides (Roy 2001).

Finally, as of the 1960s, a prevention strategy was developed. This strategy was recommended by FAO and applied by national and regional locust control units (FAO 1968, 1972). This strategy—simple, at least in principle—requires monitoring ecological conditions and locust populations in outbreak areas, and conducting preventive treatments against the first gregarious locusts.

Of course, since that time the outbreak areas, the focus of preventive control, are even better known. We now understand the spatio-temporal pattern of the functioning of the Desert Locust outbreak areas. Their limits have gradually been determined. They are scattered over a huge area covering 2 continents, and in most cases, located in remote and uninhabited regions. The time course is difficult to forecast. These outbreak areas are 'activated' by rainfall, which is extremely erratic and unpredictable across the main part of the desert locust distribution area. However, satellite images (from SPOT-VEGETATION or TERRA-MODIS) are used more and more to place the presence of suitable vegetation for the desert locust, in order to help the field survey teams plan survey routes (Ceccato 2005). Furthermore, recent results show it will be possible in the near future to improve the prediction of seasonal meteorological conditions (Barston *et al.* 2005). Obviously our knowledge of monitoring and surveying will continue to grow. But much of the essential scientific information establishing a preventive strategy has been known since the early 1960s.

To a similar extent, along with our scientific knowledge, international cooperation developed. It began in the 1920s with the first international conference on locust control, held in Rome under the aegis of the International Institute of Agriculture, and with the

signing of the International Convention for Locust Control. Uvarov, Zolotarevsky, and Vayssière played important roles (Buj Buj 1995) in this. Such cooperation became truly established in the 1950s, just after the founding of FAO—the Food and Agriculture Organization of the United Nations.

The main outlines the of current organization have been laid down since the 1960s: the National locust control units, the FAO Control Committee (the famous DLCC set up in 1954, which brings together all affected countries and coordinates international activities concerning desert locusts), the FAO Locust Group (including its survey and forecasting service), the Regional FAO commissions for Western, Central and Southeast Asian regions, responsible for ensuring essential regional coordination. And all of this works.

Thanks to both research efforts and the growth of international cooperation, the prevention strategy has been regularly applied and improved, resulting, from the 1960s to the present, in a remarkable reduction of plague frequency and duration. This reduction specifically coincided with the establishment of a new preventive control strategy and the introduction of more effective control resources and operations. This spectacular reduction of the problem, involved not just the desert locust but other locust species with completely different ecological requirements: for example, the migratory locust in Madagascar and the red locust in Central and Southern Africa (Fig. 3).

The use of simple population dynamics models shows that preventive control is efficient and can reduce plague frequency and duration, as observed in the field (Aouizerate *et al.* 2005). It's also possible to show that, after reaching a certain level of control, the locust population will by itself—and for noncontrol reasons—go back into the solitary phase. This is an important point as it shows that efforts to reduce or prevent invasions are really possible.

The year 1960 was a turning point in the situation. Plagues that had occurred since the 1940s and 50s had not been—temporally or spatially—as overwhelming as those of the past, because of the efficiency of control operations. The continuity of the research efforts and the continuous development of international cooperation had led to spectacular progress in controlling the locust problem. The main achievements were the discovery of the phase polymorphism phenomenon, the localization of outbreak areas, the determination of the ecological conditions that facilitate the transformation from solitary to gregarious phase, and finally, the creation of preventive control organizations. As a result, invasions became rare and brief.

But there remained a problem. Why were some plagues unavoidable? The problem, once manifest, could be overcome, but only after much expense, energy and the introduction of many liters of pesticides into the environment—all of which could have been avoided. Why, with all of this successful research, do locust plagues still occur? The answer is really quite simple: organization.

Lessons learned from the recent plagues

But first, is our knowledge base sufficient and what research should be undertaken? Researchers, of course, always have a broad range of research possibilities. In practical terms, I believe that research should be focused on the 3 key aspects of prevention. First, a better understanding of the functioning of outbreak areas (better determination of their boundaries and more thorough characterization; dynamics of the solitary phase and the first steps of the gregarisation process). Second, improved early detection of favorable ecological conditions in outbreak areas and, third , the development of alternative control methods (mycopesticides, pheromones), while taking into account that these methods should enable quick interventions, rapid action being critically necessary for efficient prevention.

But this research—which one would classify in general as ecological research—is no longer the key limiting factor with respect to plague control. For a long time it was thought that increasing ecological knowledge would enhance control efficiency. It was possible to read that "the rate of improvement will be determined by the rate at which relevant research findings are communicated". And this is what actually happened regularly throughout the 20th century. But this is no longer the case, or at least it is no longer sufficient.

Enhancing ecological knowledge is no longer the only factor to consider for plague control. Now we have knowledge and good international organization. And despite this, we saw the recent plague developing but were unable to stop it at an early stage. Why? Because, for Desert Locust, the key problems are elsewhere. The current limiting factors are mainly organizational in nature. To clarify our understanding, let's look at the lessons learned from the last 2 plagues: 1987-1988 and 2003-2005.

1987-1989 plague.—The main lesson to be derived from the 1987- 89 plague is that after 25 y of recession, it was revitalized due to a weakening of preventive control, especially in Sahelian countries—Mauritania, Mali, Niger, Chad—key countries that host many outbreak areas (Gruys 1994, Joffe 1995, US Congress 1990). Following this plague, and based on this lesson, measures were taken to strengthen the early warning and reaction capacities of concerned countries. FAO's EMPRES programme was thus launched in 1994 (FA0 1994). It was applied in the central region, in countries on the edge of the Red Sea, in 1997. Then the EMPRES Programme was extended to the western region, Sahelian Africa and North Africa in 2001 (Martini *et al.* 1998). But adequate funding was not obtained. At that time, only US$8 million was collected for a 4-y preventive-control programme. During a meeting of donors in Paris (Ministry of Foreign Affairs) in the summer of 2003, it was noted that most countries of the western region did not utilize an efficient monitoring and prevention system, despite the fact that such a system was available. It was also noted that most Sahelian countries were generally unable to deal with any desert locust upsurge. And consequently, that in the instance of an upsurge, substantial funding would be required from the international community. So, inevitably, 2 mo later, the first signs of a worsening of the situation appeared, and steadily degenerated into a plague.

2003-2005 plague.—The lessons learned from the 2003-2005 plague are very similar. The main reason for control failure remained the weakness of the preventive control system in the western region (due to a lack of funding for EMPRES). Considering that the central region was the main source area for desert locust plagues in the past, this invasion, starting from the western region, was unusual enough,but not unique, to take many specialists by surprise. Their surprise is an excellent indication that we need more information on the biology, ecology and population dynamics of the desert locust. And, almost as significantly, control failure arose from the absence of emergency planning, which hampered rapid control organization at the onset of the locust upsurge, together with the very slow mobilization of the international community of donors.

Regarding mobilization we have to remember that the experts first issued warnings in September 2003; the first appeal for emergency assistance was in October 2003; most assistance was only promised

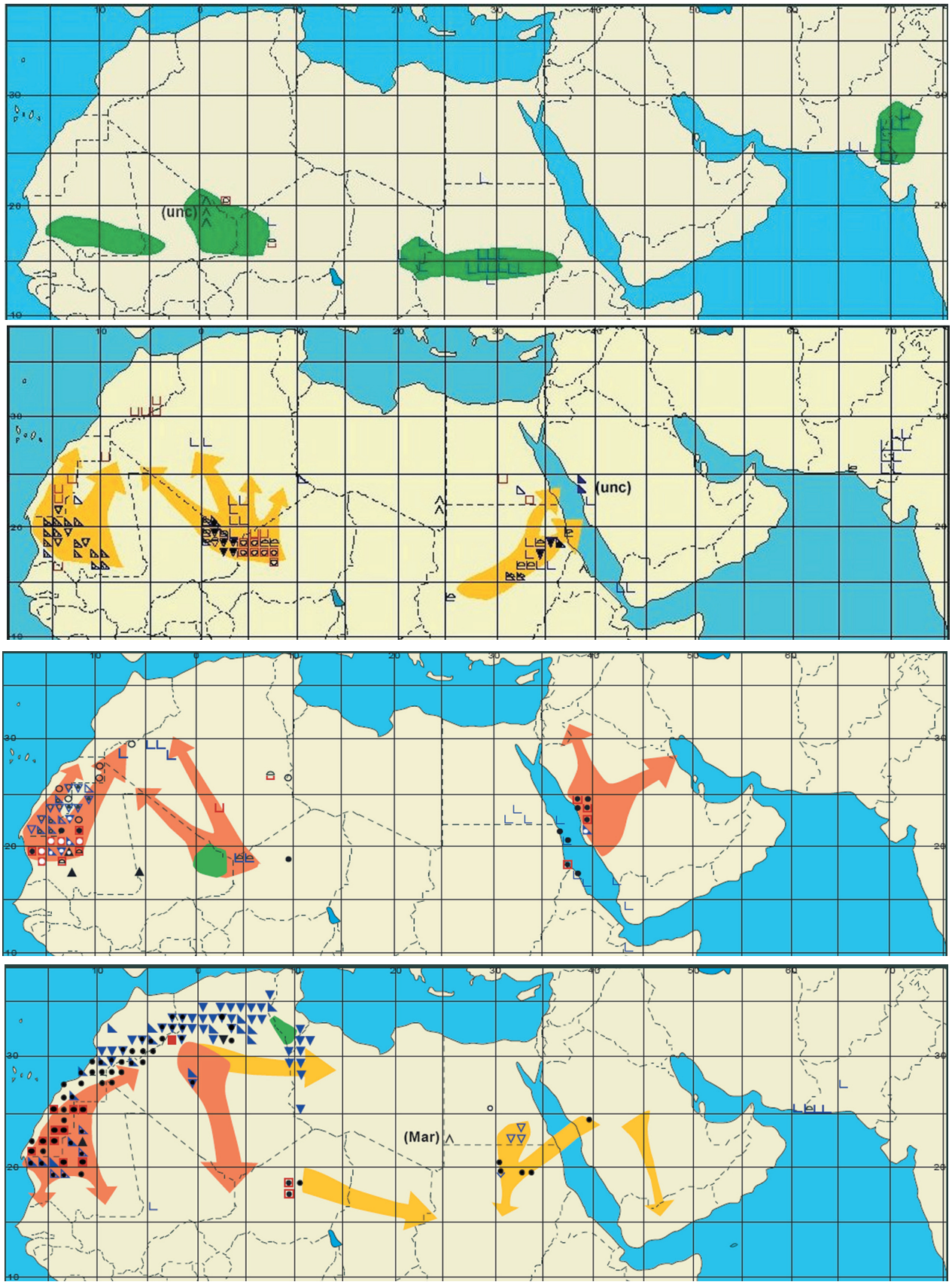

Fig. 2. Development of the 2003-2005 Desert Locust invasion (source: FAO, Desert Locust Information Service).
Red square: immature swarms. Blue triangle (up): mature swarms. Blue triangle (down): laying swarms. Black spot: hopper bands. Arrows: probable direction of swarms (for more detailed legends, see FAO Desert Locust Bulletins).

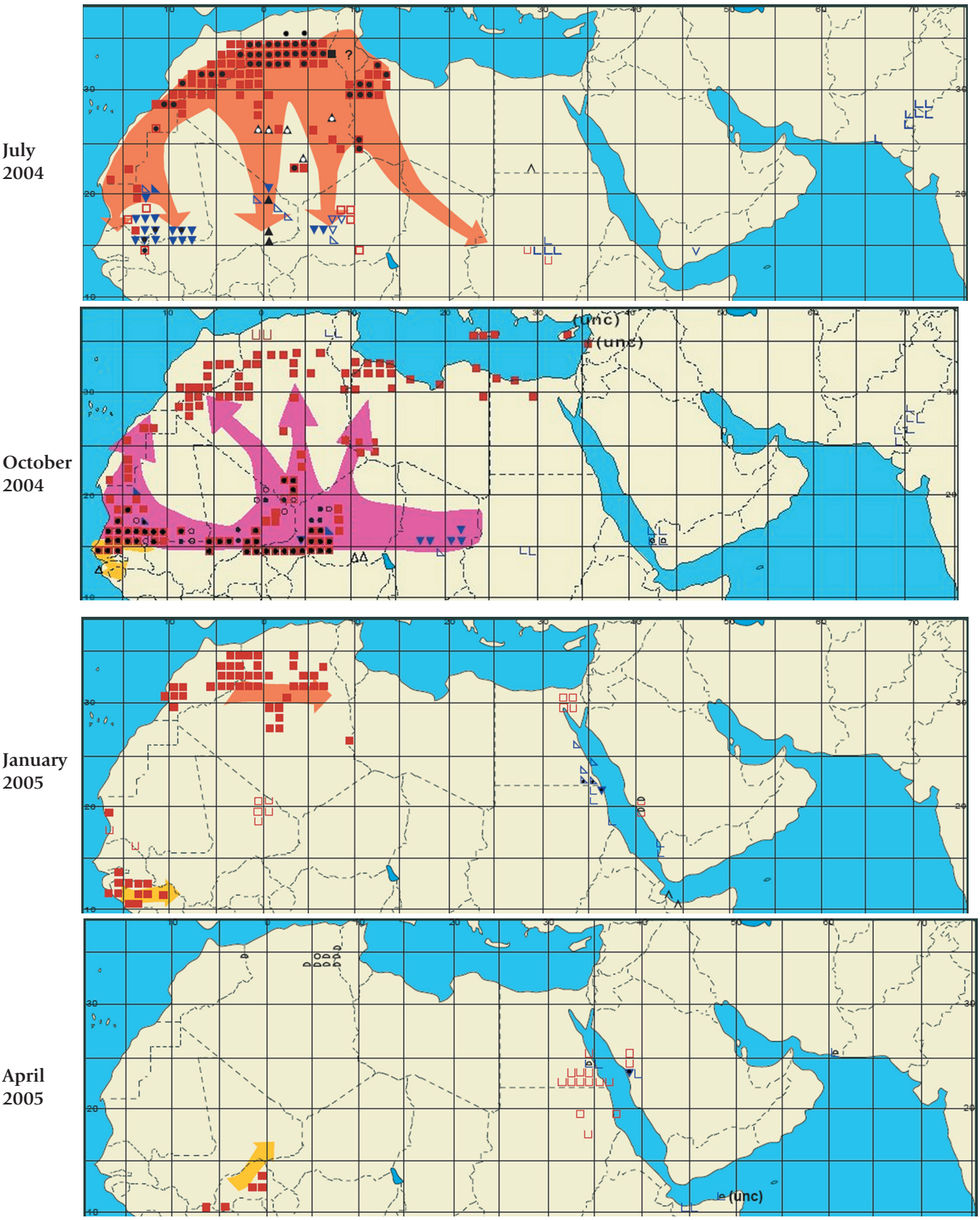

Fig. 2. continued.

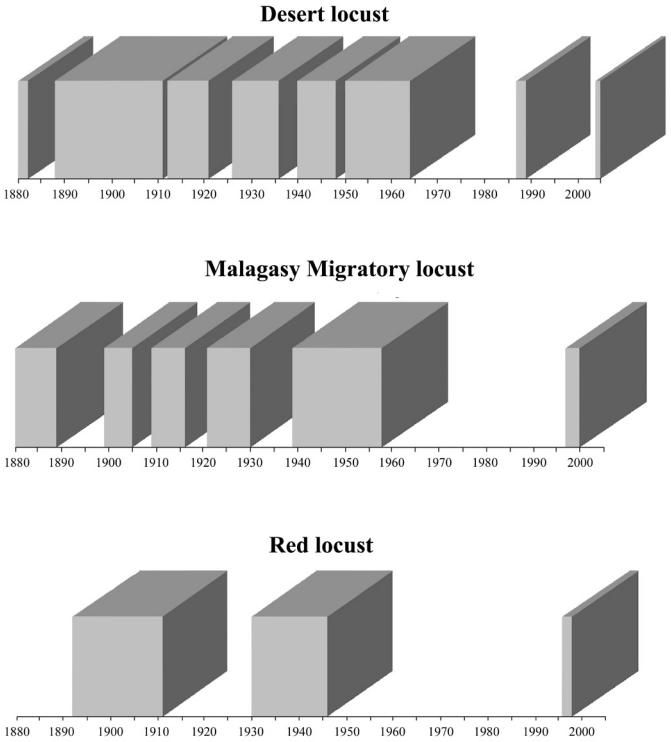

Fig. 3. Plague frequency and duration for the 3 main African locust species: desert locust, Malagasy migratory locust and red locust (modified from Waloff, 1976).

The year 1960 was a turning point. During recent years, better efficacy in locust control operations reduced sharply the frequency and duration of plagues. This phenomenon is evident in 3 different species with disparate biological composition, that live in different environments and geographical areas. Before 1960, the differences between species in relation to the frequency and duration of invasions, was the result of their more or less pronounced tendency to gregarize. The gregarization threshold is estimated to be 500 adults/hectare for the desert locust, 2000 adults/hectare for the migratory locust and 5000 adults/hectare for the red locust (Franc *et al.*, 2005). Therefore, the desert locust gregarizes more frequently and its invasions, in the absence of control, are also more frequent. On the other hand, the red locust gregarizes, but not so easily, and its invasions are not so frequent. The situation is intermediary for the migratory locust. Some other phenomena may play a role: e.g., changes in land use may affect outbreaks, which explains the absence of invasions from the African migratory locust since the last large plague of 1928-1934 which affected much of Africa South of the Sahara.

for the beginning of the summer of 2004, or even late 2004, and only part of the funds could be used in 2005, 1½ years after the first warning. Clearly, the problem of controlling this pest is no longer just a matter of science and technique—as was the case for decades.

The recent plague—like the previous one—was the result of major malfunctioning of the desert locust preventive control strategy, and it is clear that current problems in the management of this natural risk are mainly organizational. These organizational issues must be given priority, otherwise the research findings will be wasted. Succinctly: *the locust is no longer the real problem, humans are the real problem*. Every time there has been an outbreak over the last 50 y, the main problem has been human organization: funds not available in time, control units too weak, emergency planning lacking, disorganized donors addressing the problem ineffectively, insufficient communication/information at various levels, political considerations supplanting technical aspects, divergences of opinion on the control strategy or on the pesticides to be used, *etc*. Only rarely has lack of knowledge been a cause. This doesn't mean that ecological research is now useless. But, it does mean that such scientific research must be supplemented with research in alternative and less traditional fields.

Key long-term measures to be taken?

Toward a risk management system.—What key long-term measures should be taken? First, a standard measure: **strengthen national locust-control units.** These national units are the basis of the early warning system. They are responsible for constantly monitoring outbreak areas and conducting preventive control treatments. Strengthening has not been possible previously because of a lack of support funds. The situation is now better—thanks to recent increases in donor funds. It's easy to strengthen these units: it's just a question of money. But increased money in itself will not be sufficient and is not the critical solution to the problem.

In most cases, we are dealing with very poor developing countries. Experience has shown that efficient structures are too heavy and costly to be sustainable over the long term. Such structures do not survive through long recession periods and end up deteriorating and becoming inefficient (Lockwood *et al.* 2001). In fact, flexibility is a key to the sustainability of any effective international control organization. But it's very hard to meet this organizational flexibility challenge. For this it is essential to consider the locust problem not solely in terms of crop protection. It is a much more far-reaching issue. The desert locust, like other locusts, is a natural hazard with many effects: agricultural, economic, social, environmental and political. It should be considered broadly as a risk threatening not only farmers, but many others, one able to generate crisis situations.

An effective **locust risk-management plan** must be developed to deal with this problem. This risk management plan should be developed at different levels—international, regional and national—and include several warning levels, with a specific arrangement for each warning level in order to forestall crises before they worsen. This type of instrument could provide a suitable degree of flexibility and reaction potential. But it will only work if funding is readily available to deal with locust situations and if the needs are clearly known in advance. It would require the creation of an **international contingency fund** (Lecoq 2004).

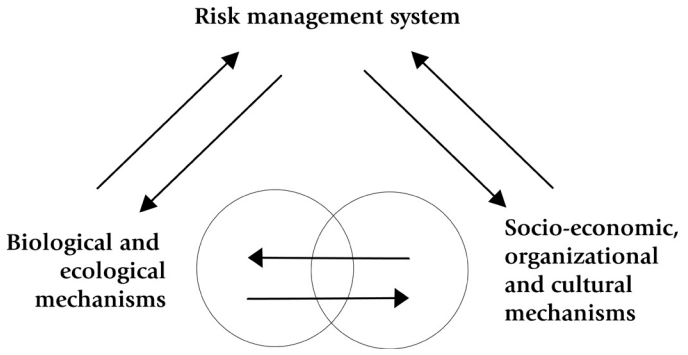

Fig. 4. Mechanisms to be taken into account in setting up a risk-management system to control desert locust in the long term.

Finally, a **new governance strategy**, involving all stakeholders, countries and donors, would be required to ensure that this system will function properly in the long term. A traditional development aid system, whereby countries are left to manage their problems after they have received aid, just would not work in dealing with the desert locust problem. The donors are also stakeholders, whether they want to be or not. They are involved when a crisis arises. They should be involved as co-managers so as to be able to act more efficiently and cost-effectively when there is a threat.

Understanding better the role of locust-control stakeholders

More generally, focus should be placed on another key point recently noted: the many stakeholders involved in desert locust control. They include local citizens, locust control units, governments and local administrations, international organizations, donors, scientists, NGOs, private companies and the media. And there are many stakeholders identifiable within each of these categories, each playing an important role. Local people, herders, farmers, scientists, representatives of international institutions, and even local witch doctors, trying to fight locusts using magic powers: all of these stakeholders play important roles. It is clear that the rationales and strategies of these diverse stakeholders can differ markedly, converge or diverge, and thus enhance or hamper efficient locust control.

A few examples: what is the interest of affected countries? Is it to conduct early operations to benefit inhabitants, or to start working later when 100-fold more funds can be obtained from donors to deal with a major outbreak? What are the donors' intervention criteria at the beginning of an upsurge? Are they rational and technical, or just political, as when the leaders of affected countries start shouting and when donors can get a better media impact? Why is international funding so slow in coming? Is it just a question of ill-adapted funding mechanisms, or are there other underlying reasons? Many things are said better left unsaid; some things that should be said are not.

It would improve things to be aware of the many different operators involved in locust control, and to understand their expectations, rationales and operational strategies. The lack of recognition and understanding concerning the many different stakeholders involved in desert locust management, and their operational rationales, is a critical shortcoming. It can also be considered a major cause of the malfunctioning of locust management and is detrimental to control efficacy. This stakeholder strategy concept is the focus of research for optimizing processes in different fields (Crozier & Friedberg 1977). It could be profitably applied to locust control, as well as strategic environmental management analysis (Mermet *et al.* 2005), whose framework could be instrumental in overcoming widespread contradictions, confusions or misconceptions in fields that are crucial for the sustainable development of desert locust management.

Conclusion

Old and new locust control concepts: a new paradigm

Finally, desert locust problems should clearly be approached in the future by thinking in terms of 1) a risk-management system for a natural disaster, 2) still considering standard biological and ecological mechanisms as in the past, while 3) integrating studies on socioeconomic, organizational and cultural mechanisms that were generally overlooked in the past (Doré, 2005; Fig. 4). I believe that such an approach will be one of the keys to ensuring the sustainability of the locust management system.

Even during the last few months this point of view has evolved. We now observe new concepts gradually being introduced in locust control. The old locust control concepts are based on "phases", "outbreak areas", "ecological conditions", "crop protection", "preventive control", "emergency planning", *etc*. New concepts are being introduced, involving "natural risk management systems", "stakeholder strategies", "governance", "regional public assets", "strategic analysis", *etc*. We consider that these new concepts highlight the recent development of what could be called a truly new locust-control paradigm. The old paradigm was focused on the locust and its ecology, studied with the aim of gaining insight. The new paradigm is more focused on humans and the interactions between them and locusts. The focus of locust control studies, if a sustainable solution is to be found, should not simply be the locust, but also humanity, its real motives, competing interests and organization strategies. This is surely a new avenue of research, at the interface of ecology and human science, that must be integrated with more traditional ecological research. We have to turn to an anthropological approach to locust issues.

References

Aouizerate G., Ben Slimane B., Jeangros G., Krivine N., Lissot P., Laborde D.-L., Semaan A., 2005. Les invasions acridiennes en Afrique. Projet scientifique collectif. Ecole Polytechnique. Département de Biologie, Paris. 81 pp.

Barston A.G., Kumar A., Goddard L., Hoerling M.P. 2005. Improving seasonal prediction practices through attribution of climate variability. Bulletin of the American Meteorological Society 86: 59-72.

Buj Buj A. 1995. International experimentation and control of the locust plague. Africa in the first half of the 20th century, pp. 93-105. In: Chatelin Y., Bonneuil C. (Eds). Nature et Environnement. Vol. 3, Les sciences hors d'Occident au XXe siècle, ORSTOM, Paris.

Ceccato P. 2005. Operational early warning system using SPOT-VGT and TERRA-MODIS to predict Desert Locust outbreaks. In: Antwerpen. Veroustraete F., Bartholomé E., Verstraeten W.W. (Eds) Proceedings of the 2nd VEGETATION International Users Conference, 24-26 March 2004. Office for Official Publication of the European Communities, Luxembourg. ISBN 92-894-9004-7.

Crozier M., Friedberg E. 1977. L'Acteur et le Système. Seuil, Paris.

Doré A. 2005. Gouvernance autour d'un bio-agresseur : peut-on "s'arranger" avec les soldats de Dieu? Masters dissertation, Institut National d'Agronomie de Paris-Grignon, Paris.

FAO 1968. Desert Locust Project. Final report. Report no FAO/SF :34/DLC. Food and Agriculture Organization of the United Nations, Rome.

FAO 1972. Projet relatif au Criquet pèlerin. Rapport complémentaire (juillet 1966-décembre 1970). Report no FAO/SF:34/DLC. Food and Agriculture Organization of the United Nations, Rome.

FAO 1994. FAO Emergency Prevention System (EMPRES) for Transboundary Animal and Plant Pests and Diseases. Desert Locust - A Concept Paper. Food and Agriculture Organization of the United Nations, Rome.

FAO 2003-2005. Desert Locust Bulletin no 295 to 319. Locusts and Other Migratory Pest Group, AGP Division, FAO, Rome, Italy. Web site: http://www.fao.org/ag/locusts.

Franc A., Rabesisoa F.L., Luong-Skovmand M.H., Lecoq M. 2005. Red locust phases in Madagascar (*Nomadacris septemfasciata* Serville, Orthoptera, Cyrtacanthacridinae). International Journal of Tropical Insect Science 25: 182-189.

Gruys P. 1994. Leçons à tirer du dernier fléau du Criquet pèlerin de 1986-1989, pp. 19-30. In: Van Huis A. Lutte contre le Criquet pèlerin par les techniques existantes: évaluation des stratégies. Compte-rendu du Séminaire de Wageningen, 6-11 décembre 1993. Université Agronomique, Wageningen, Pays-Bas.

Hafraoui A., McCulloch L. 1993. Present Practices of Controlling Desert Locust Outbreaks. In: Atelier international de la FAO sur la recherche et la planification en matière de lutte contre le Criquet pèlerin tenu à Marrakech (Maroc) du 24 au 28 mai 1993. Food and Agriculture Organization of the United Nations, Rome.

Joffe S. 1995. Desert locust management: a time for change. World Bank discussion paper 284. The World Bank, Washington.

Krall S., Peveling R., Ba Daoule Diallo (Eds) 1997. New Strategies in Locust Control. Birkhäuser Verlag, Basel, Switzerland.

Künckel d'Herculais J. 1905. Invasion des acridiens, vulgo sauterelles, en Algérie (1893-1905). Imprimerie administrative et commerciale Giralt, Alger. 3 Vols.

Lecoq M. 2001. Recent progress in Desert and Migratory Locust management in Africa. Are preventative actions possible? Journal of Orthoptera Research 10: 277-291.

Lecoq M. 2003. Desert locust threat to agricultural development and food security and FAO/ International role in its control. Arab Journal of Plant Protection 21: 188-193.

Lecoq M. 2004. Vers une solution durable au problème au problème du criquet pèlerin? Science et changements planétaires/Sécheresse 15: 217-224.

Lecoq M., Duranton J.F., Rachadi T. 1997. Towards an integrated strategy for the control of the Desert Locust, pp. 467-474. In: Krall S., Peveling R., Ba Daoule Diallo (Eds) New strategies in locust control. Birkhäuser Verlag, Basel, Switzerland.

Lockwood J.A., Showler A.T., Latchininsky A.V. 2001. Can we make locust and grasshopper management sustainable? Journal of Orthoptera Research 10: 315-329.

Martini P., Lecoq M, Soumaré L., Chara B. 1998. Proposition de Programme de lutte contre le Criquet pèlerin dans la partie occidentale de son aire d'habitat. EMPRES, Composante acridienne (Criquet pèlerin) en Région occidentale. Rapport W9963/F. FAO/AGP-P. Organisation des Nations Unies pour l'alimentation et l'agriculture, Rome.

Mermet L., Billé R., Leroy M., Narcy J.-B., Poux X. 2005. L'analyse stratégique de la gestion environnementale : un cadre théorique pour penser l'efficacité en matière d'environnement. Natures Sciences Sociétés 13: 127-137.

Roy J. 2001. Histoire d'un siècle de lutte anti-acridienne en Afrique. Contributions de la France. L'Harmatan, Paris.

Skaf R., Popov G.B., Roffey J. 1990. The Desert Locust: an international challenge. Philosophical Transactions of the Royal Society of London series B 328: 525-538.

Showler A. 2001. Synopsis of the 1997-1998 Desert locust campaign in the Red Sea region. In: Advances in Applied Acridology 2001. The Association for Applied Acridology International, Laramie, WY, U.S.A, 22-24.

Steedman A. (Ed) 1990. Locust Handbook. Natural Resources Institute, Chatham, United Kingdom.

U.S. Congress, Office of Technology Assessment 1990. A plague of locusts. Special Report, OTA-F-450. Government Printing Office, Washington, DC, U.S.A.

Uvarov B.P. 1938. Locust as a world problem, pp. 376-382 In: Première Conférence internationale pour la protection contre les Calamités naturelles, Paris, 13-17 septembre 1937. Published by « Commission française d'études des calamités » with the support of « Union Internationale de Secours », 1938.

Waloff Z. 1976. Some temporal characteristics of Desert Locust plagues. Anti-Locust Memoir 13. Anti-Locust research Centre, London.