PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

General Discussion

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General discussion

K. A. Browning, F.R.S. (*Meteorological Office, Bracknell, U.K.*). I would like to recall Mr Boulahya's advocacy of an operational Locust Control Watch and suggest that in parallel we need a properly resourced research programme integrating the physical and biological aspects of the problem. Today we heard about the advances in our observational capability from satellite, radar and aircraft and about our understanding of aspects of the weather that affect insect migration. We seem to have a physically attractive hypothesis, that convergent wind patterns in the boundary layer play an important role in concentrating insects; but the hypothesis is still of unproven generality. There are a few case studies and a lot of circumstantial evidence, but to find out whether meteorological convergence events are abundant enough to be really important we need a research programme with much more comprehensive coverage in space and time of both meteorology and insects. Assuming we are able to prove that the convergence events are important, we would also need more research into the best methods to detect them and to control the insects, perhaps by using a combination of satellite, radar, aircraft and mesoscale numerical models as part of an integrated system. The question is who should run such an integrated research experiment bringing migrant pest, remote sensing and meteorological communities together. I would suggest that a joint FAO/WMO Programme is required.

D. Rijks (*World Meteorological Organization, Geneva, Switzerland*). Given the available knowledge about relationships between meteorology and the physiology and behaviour of at least some insects, and the possibilities to use this knowledge to monitor and combat outbreaks of migrant pests, am I right to think that there is, in this meeting, a consensus that this knowledge should be used now, to install a permanent preventive migrant pest watch, using among others the available meteorological infrastructure and reinforcing it, where necessary?

P. M. Symmons (*Food and Agriculture Organization of the United Nations, Rome, Italy*). My response concerns the relevance of what we have been talking about for the past couple of days. I suppose I stand as near to the customer as anyone can here. I've been involved with locust forecasting for twenty years. I ran the Desert Locust Information Service, at the Anti-Locust Research Centre and its successor, the Centre for Overseas Pest Research, in London for a half a dozen years and I am now responsible for Desert Locust forecasting with FAO.

On the subject of research there is a coordinating group for Desert Locust research, under UNDP auspices, consisting of a group of donors supported by a joint FAO/UNDP scientific advisory committee for which I am the secretary. This has the job of reviewing and attempting to coordinate research in general with a specific role of looking after, advising and managing any UNDP-financed projects or ones operated by FAO with funds entrusted to it. So this body could consider any initiative raised at this meeting which comes within the committee's general terms of reference, which are indeed very wide.

Some of the suggestions made here about general monitoring are unrealistic. A lot of what we have been discussing pre-supposes the existence of organizations in the field, but this is in doubt. It is depressing the way in which, within a few months of the disappearance of locust

swarms, reporting has gone down to a very low level and it appears that the will is not there, either in the donors or in the countries affected, to maintain organizations in the field on a long-term basis. I thing a pre-requisite for anything of this sort is a technical unit in FAO itself. In six months time, after my retirement, the current unit will cease to exist unless something is done in the interim. Without this unit, or something that can step in with advice and help on the appropriate scale if there is an emergency, I do not see locust organizations in the field having the central motivating core to keep them going. The only realistic hope is to try to create and maintain a relatively small unit (and I emphasise small) that can be properly and gainfully occupied during a recession. There are some schemes afoot involving very large scale, grandiose, preventative activities, but to my mind they are wholly unrealistic: they are talking in terms of tens of millions of dollars and I don't see this sort of thing being either sensible or continuously funded. We have got to look to donors to support operations on a small scale on a long-term basis. Donors don't like putting in money on a continuing basis, but that is the only way it can be done; vehicles have to be replaced and equipment has to be kept going, things that need hard currency to buy.

On the specific points of Desert Locust forecasting, I think we get a bit mixed up on the timescales, as I said earlier after Mr Boulahya's talk. What we try to do is forecast on three timescales. One of these scales is six months or more ahead, which can only be done in a very vague way, but if you are going to get extra money out of donors or even bring in pesticides on a large scale you have got to look that far ahead. The standard forecasting is done on a four to six weeks ahead basis, which is what has been done with the bulletin over many years, and is done now from FAO in Rome. Then there is the tactical forecasting on hours and days, but very little has been done at this scale. However I do feel, having operated at the sharp end in the field, that you can get away in a large measure without it. What is needed when operating in the field is a good information system; it is like war, as many people have said, and what is needed is intelligence. If you can get people out there looking and get the information back you can build on that very quickly. In other words you are forecasting only a very short time ahead and basically forecasting on the assumption that what has happened is going to continue to happen. That is a pretty good basis in meteorological forecasting as well as with locusts.

What one is trying to do during a plague is essentially to try to track the swarms. Your main interest here, as Mr Pedgley has pointed out, is to forecast for invasions, which means translation over very long distances and is certainly not related to convergence zones, though convergence on a large scale may be important in keeping swarms in a particular area where one can get at them. But on the whole, what people want to know is whether they are going to get some swarms from somewhere else and that means a large scale migration, often a thousand kilometres or more.

During a recession period, as Mr Boulahya implied, our main problem is where the locusts are breeding and for that we need to know where rain has fallen and where vegetation is likely to be growing: the rain providing both the necessary conditions for the eggs to mature and the green feed for the hoppers to come through. I am afraid that the products we have to do this, from the user end, are really not very satisfactory. One of the problems is that we are looking at a very narrow band in a critical area where it is not really very wet; the cold-cloud analysis does not work except in the west African Sahelian area and even then it has to be looked at it with very considerable care. I am very unhappy with the greenness index maps: the first product is the 1 km data and the big advance of that is that some sort of topographical

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structure underneath can be seen that can be related to it and wadis, for example, can be identified. But there are a lot of spurious responses: for instance, outcrops and suchlike which show up as things in the middle of the desert, which one knows very well as not real. The confidence from the users' end is simply not there at the moment and it will take quite a lot of use and testing to build it up.

S. G. Cornford (*Meteorological Office, Bracknell, U.K.*) The most notable progress in the field of migrant pests since the Society's 1977 meeting has been in operational meteorology. Data from meteorological satellites and analysed and predicted fields of wind and weather from mathematical models run on supercomputers can be available operationally.

Mr Hielkema has said ARTEMIS will process meteorological satellite data into a form useful to agriculturalists in Africa and DIANA will send the results to potential recipients there.

The size, lifetimes and speeds of movement of weather systems are such that the national meteorological services of the world must be interdependent. Those in Europe cannot be efficient unless those in Africa are, and vice versa. National meteorological services (NMSs) in Africa provide observations to Europe and those in Europe provide satellite data and the results from the numerical prediction models. It is therefore essential that any products coming from ARTEMIS and DIANA are complementary with those which will be distributed by the Meteorological Data Distribution (MDD) mission of the European meteorological satellite Meteosat. It is also essential that DIANA routes ARTEMIS products in ways that are agreed with the NMSs of Africa. If not, the NMSs will be undermined and that is against the interests of the national meteorological services of Europe, which control and fund Meteosat on which ARTEMIS depends.

At the intergovernmental level it is essential that cooperation between FAO and WMO be cordial and mutually understanding. In the context of this meeting, a possible framework for the cooperation is provided by the United Nations' International Decade for Natural Disaster Reduction.

A. G. Gatehouse (*University of Wales, Bangor, U.K.*). The papers and discussion at this meeting have, for the most part, emphasized the implications of advances in meteorological knowledge and remote sensing techniques for our understanding of the origin and development of outbreaks, upsurges and plagues of migratory insects. While these advances are undeniably important, there have also been significant advances in recent years in our knowledge and understanding of biological aspects of insect migration which have a direct bearing on the subject of this meeting.

Most important, perhaps, is the growing evidence from a wide range of species that the migratory potential of individuals and thus of populations is highly variable. While this variability is often modulated by environmental cues, particularly in temperate-zone species, there is now good evidence for primarily genetic determination of migratory potential in several subtropical/tropical insects. In these, which include some noctuid moths and one acridoid, *Melanoplus sanguinipes* (Fabricius), variations in the frequencies of persistent fliers within and between populations and/or seasons can be related to variations in the distribution of suitable habitats in time and space (Gatehouse 1989, and references therein). In the Desert Locust (and perhaps other gregarizing species), the distribution of low-density populations among the scattered and ephemeral habitats of the recession areas depends on nocturnal

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migration of individual solitary-phase locusts. Thus these movements must make a major contribution to the spatial and temporal dynamics leading to gregarization and the onset of upsurges. In spite of this, we know virtually nothing of the variation in migratory potential of solitary-phase locusts (although anecdotal accounts suggest it exists; G. Popov, personal communication). Neither do we know anything of the factors regulating their migratory behaviour. I suggest that these are questions of central importance in understanding the development of upsurges of the Desert Locust. What is more, I would argue strongly that the potential of the impressive meteorological and remote sensing techniques we have heard about to allow us to monitor and predict developments leading to upsurges will not be fully realised until these questions are answered.

Reference

Gatehouse, G. 1989 Genes, environment and insect flight. In *Insect flight* (ed. G. J. Goldsworthy & C. H. Wheeler), pp. 115–138. Florida: CRC Press.

R. J. V. Joyce (*Cranfield Institute of Technology, Bedfordshire, U.K.*). Dr Symmons fears that with the impending retirement from FAO of so many locust specialists, the ability of that organization to continue its work of coordination of locust control will be greatly impaired. Captain Kitenda has already drawn attention to the serious loss of operational capability for locust control in the Regions. Yet, it is near certain that, sometime, there will be a new upsurge of Desert Locusts. Moreover, as Dr Riley and others have pointed out, grasshoppers continue to be a serious annual threat to crops throughout the Sahel and no satisfactory, or cost effective methods are yet available to combat them.

In the absence of action now, the next upsurge of locusts will undoubtedly be accompanied by the need to provide emergency help, and this will inevitably be again of a kind which cannot fail to be less efficient than a well-planned operation. The supply of insecticides and formulations unsuitable for locust control, the employment of inappropriate and wasteful crop spraying techniques for controlling swarms and hopper bands, the execution of spraying by crop-spraying pilots inexperienced in locust control and without proper directions with regard to targets, or means of finding targets or of checking the results of control, the use of aircraft with navigation aids quite inadequate for work in featureless desert areas, these are among the factors which have resulted in an unacceptable waste of resources, especially insecticide, and grave environmental hazards. In my view, the banning of dieldrin and the absence of a substitute with adequate persistence, makes it impossible to expect any significant contribution to the regulation of Desert Locust numbers from the control of hoppers. The barrier spraying techniques which used dieldrin at a rate of 5–10 g active ingredient per hectare, permitted up to 500000 ha per day per aircraft to be treated for hopper infestations. The substitute (and more expensive) insecticides have to be directed at individual bands and applied at about 500 g ha^{-1} so that work rates are unlikely to reach 10000 ha per aircraft per day. This means that Desert Locust control must rely even more heavily on swarm control and this dictates the use of aircraft adequately instrumented to permit the crew to find their targets, spray them and return to them again to complete the job and assess results.

It is evident from the contributions to our discussions from Captains Kitenda and Kinvig, that skills and experience in locust control are not absent in the regions. What is lacking is a means of retaining and employing them, particularly during periods of recession and it is this to which I wish to address myself.

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Skaf *et al.* have emphasized the need for 'preventative control' to avoid the kind of emergency which otherwise results. Mr Popov has drawn attention to the type of habitat in the Sahel and elsewhere where gregarization and swarm formation occurs. Mr Hielkema and Mr Zick have graphically shown the irreplaceable role which satellite imagery can play in defining areas where recent rainfall makes such areas a current risk. These areas can be vast, many of them are difficult or impossible of access by ground-based teams, but they must be searched for infestations in about 4–6 weeks. Search in such areas can be economically achieved in the time available only by airborne crews, and systematic quantitative search only by aerial traverses by using aircraft fitted with suitable navigation and insect detecting equipment, namely of the type described in the paper by Dr Rainey and me. Such an aircraft, flown by pilots experienced in locust control, such as Captain Kitenda, could locate and search not only zones of wind discontinuities for flying swarms, but also areas where gregarization may have occurred, and so apply to infestations from either mechanism, control on the scale needed and, finally, assess the results quantitatively.

I would like to see funds made available to FAO for the provision of such an aircraft, and that organization, by using an experienced crew, undertake the responsibility for searching for swarm and hopper infestation in any areas which information from all sources indicate at possible risk. The same experienced aircrew would also have a training role to update the staff of Regional Control Organizations, and in an upsurge, any new emergency staff, on the best methods of survey and control. An annual expenditure of about $600 000 for operating such a '*search and strike*' procedure could well avoid emergency aid estimated, during the last upsurge, at $300 000 000.

L. G. Goodwin, F.R.S. (*Shepperlands Farm, Park Lane, Wokingham, U.K.*). In drawing this discussion meeting to a close I would stress that the key to its success has been the bringing together of physical and biological communities. This must be a feature of our future approach to the important problem of migrant pests. We have not made as much progress as we should over the past quarter century. Given better resources and the determination to go forward together, perhaps we can do better in the future. So, with thanks to our speakers, chairmen and organizers, and special thanks and best wishes to our absent friend and lead organizer, Reg Rainey, I close this meeting.

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