WORKSHOP ON DESERT LOCUST FORECASTING

WORKSHOP TRAINING MANUAL

Cairo

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FAO REGIONAL COMMISSION FOR THE CONTROL OF DESERT LOCUST IN THE NEAR EAST

Overview of Workshop

Workshop Rationale

It is important to provide a rationale for the resources devoted to this workshop. As you are aware the workshop topic is Desert Locust forecasting.

It is presumed that everyone attending the workshop is aware of the general nature of the problem posed by Desert Locust not only to the Near East region but to the neighbouring regions of West and North Africa, East Africa and South West Asia.

To examine the rationale for the workshop it is necessary to touch, albeit briefly, on the overall nature of the problem posed by Desert Locust.

That Desert Locust pose a serious risk to agricultural production in regions which are already prone to food insecurity, where a significant proportion of the population derives their livelihood from subsistence agriculture. These facts are unlikely to be disputed. What may be argued is whether it is economically feasible to control Desert Locust populations with the technologies currently available.

The classical view of Desert Locust population dynamics holds that control of the early stages of a Desert Locust outbreak can result in plague prevention: the strategy of preventive control. This view probably held greater validity when control was able to be undertaken using persistent pesticides such as dieldrin. With the demise of dieldrin as an acceptable pesticide for Desert Locust control and the consequent reliance on other pesticides which are much less persistent the validity of the strategy of preventive control has come under increasing questioning.

Despite this questioning, the strategy of preventive control over the past 10 years no definitive evidence has been put forward that preventive control of the early stages of a locust outbreak can or cannot result in plague prevention. It should be said that trying to establish the answer to such a question is by no means easy as other factors, which are extremely difficult to quantify, may intervene to complicate a scientific analysis. For example, what may be claimed by proponents as successful early control may be interpreted by opponents as being primarily the impact of adverse climatic conditions with control only playing a minor role.

Whilst there is no definitive answer to the critical question as to the validity of the strategy of preventive control there is little disagreement on the need for early warning of the build up of Desert Locust populations. Early warning requires accurate and timely information, in particular field information collected by ground surveys, and correct interpretation of the data to produce an accurate forecast of likely events.

Workshop Objectives

- The overall objective of the workshop is to develop skills in Desert Locust Forecasting.
- This includes developing skills in the accessing, collecting and collating data;
- methods of analysing and interpreting such data;
- presenting this data for forecasting likely locust activity and to improve decision making for Desert Locust activities.

Workshop Activities

- The workshop is based on the delivery of a series of presentations which attempt to develop participant skills in Desert Locust forecasting.
- An important point which will be made consistently in the workshop is the need to access and interpret what is termed key data.
- A further point which will also be consistently made is that concerning the quality of data available.
- More often than not, the forecaster is faced with a lack of quality data. This effectively means that the forecaster often has to use inference as a analytical tool.
- The workshop will also reinforce the lecture material through the use of a series of practical exercises.
- Finally the workshop will look at the recent developments, mainly involving the use of computer software to access data, for improved Desert Locust survey and forecasting.

1. Introduction

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- **Audience**
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- **estimating the size of populations**

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- **Analysis of current situation**

- Elements of the forecast

- structure of the locust bulletin

1. Introduction to Forecasting

Rationale

- There is a need to clearly outline the rationale for Desert Locust forecasting**.**
- In other words, why do we forecast Desert Locust activity?
- At a very general level, one of the main reasons for forecasting is the highly variable nature of Desert Locust populations and the potential risk such populations pose to agriculture.
- At a more specific level we forecast Desert Locust to:

  - proritise surveys to those areas where populations are likely to be;
  - provide interested agencies and farmers with early warning of risk populations;
  - allow responsible authorities to mobilised control resources early; and
  - allow control at early stages of outbreaks thereby preventing plagues.

Audience

- It is important to consider what "audience" to which forecasting information is being directed.
- In most cases the primary audience to be informed is the national Ministry of Agriculture (or other Ministry with overall responsibility for locust control) and the locust control agency or plant protection agency responsible for Desert Locust control.
- The Ministry or national locust control agency should be using forecasts for a number of reasons including;

  - decisions on when and where to undertake ground or aerial surveys for locusts;
  - decisions regarding the possible advance mobilisation of control resources; and

- decisions on whether additional national funding may be required for such action.

- In addition, forecasts and locust information should be exchanged with regional and international organisations to allow a comprehensive view of the current Desert Locust situation to be obtained.
- Donors may also need to be informed on Desert Locust activities and the general situation especially if they are providing support or may be called upon to do so.

Essential Forecasting Questions

- Throughout the workshop you should keep at the forefront of your minds a number of essential forecasting questions.
- In any specific Desert Locust situation the critical questions which a forecaster needs to address are:
- ARE Desert Locust populations likely to be present?
- WHERE are Desert Locust populations likely to be present?
- WHEN or at what stage in the life cycle are populations likely to be present?
- At what LEVEL or SCALE are Desert Locust Populations likely to present?
- WHAT are such populations likely to do in the next 6 to 8 weeks?

In trying to answer these basic questions we also need to introduce the concept of probability: in other words the probability of the events occurring or not occurring.

2. Essential Forecasting Information

Locust Life Cycle

- The generalised life cycle of the Desert Locust is shown in Fig. 1
- The life cycle comprises three stages: adult, egg and nymph (hopper).
- An important point to realise is that the time spent in each stage can be highly variable depending primarily on when rainfall occurs and seasonal variations in temperature.

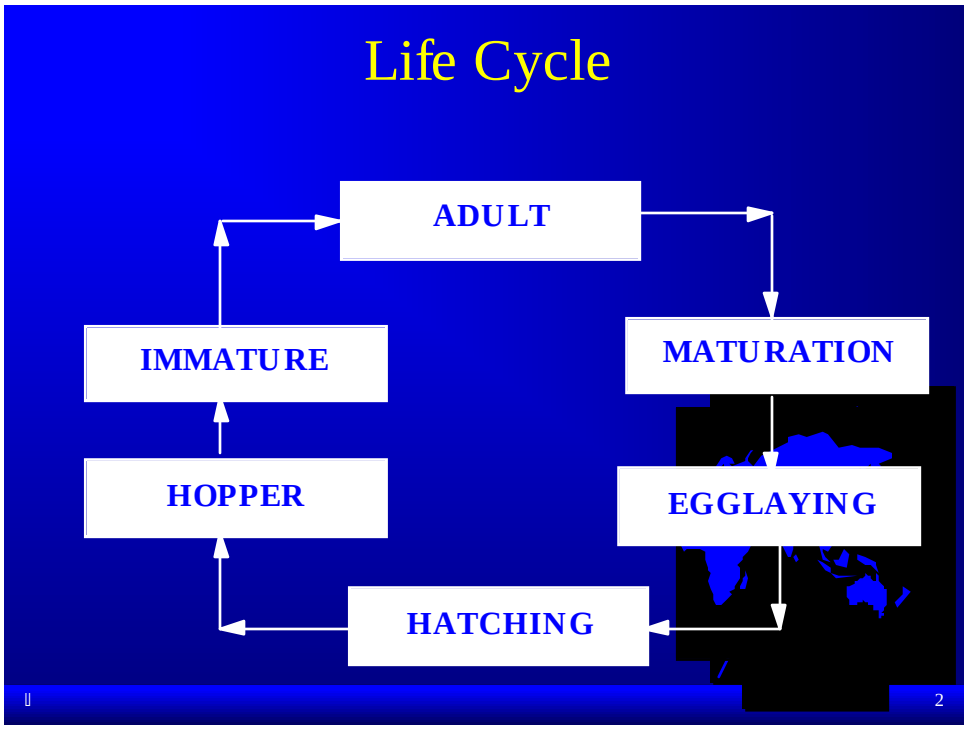


Figure 1: Locust life Cycle

Adult stage

- The duration of the Desert Locust immature adult period, that is when the adults will not breed and reproduce, can be highly variable and depends on environmental conditions.
- In unfavourable situations such as drought and/or low temperatures, the immature period may extend for several months.
- Under favourable conditions of high temperatures and adequate rainfall the period may be as short as two weeks.
- In the Central Region the main cause of an extended immature period is most likely drought since temperatures are generally moderate to high even in winter.
- Maturation is normally triggered by significant rainfall although the exact process is not well understood. There have been suggestions of Desert Locust adults becoming mature prior to rain falling but the evidence is weak.
- The change from immature to mature adult is normally associated with changes in Desert Locust colour and behaviour.

- Colour change in adult Desert Locust, in particular, is a key indicator for a forecaster to assess and predict likely developments in the population.
- Colour changes in adult Desert Locust associated with maturation depend also on the phase of the population.
- In the solitary phase immature adults are generally grey or peach in colour whereas in the gregarious phase they are normally red or pink.
- In the gregarious phase both males and females change from red to yellow whereas in the solitary phase this colour change may only occur in males.
- The occurrence of yellow adults of Desert Locust is a strong indication that breeding is in progress and if both yellow males and females are present the conclusion must be that the population is gregarious.
- Behavioural changes in adults associated with maturation include short daytime flight, as opposed to migratory movement, and copulation.
- Once maturation occurs the female starts to develop eggs.
- The period required for females to fully develop eggs will vary according to temperature. However, under good environmental conditions the period is probably in the vicinity of 7 to 10 days.
- Once the female has fully developed eggs she must lay within a very short period, probably 2-3 days.
- If mature adults are observed samples of females should be taken and egg development assessed.
- Following laying of eggs in an egg pod the female may survive to lay further batches of eggs at intervals of 8 to 12 days under optimal conditions.

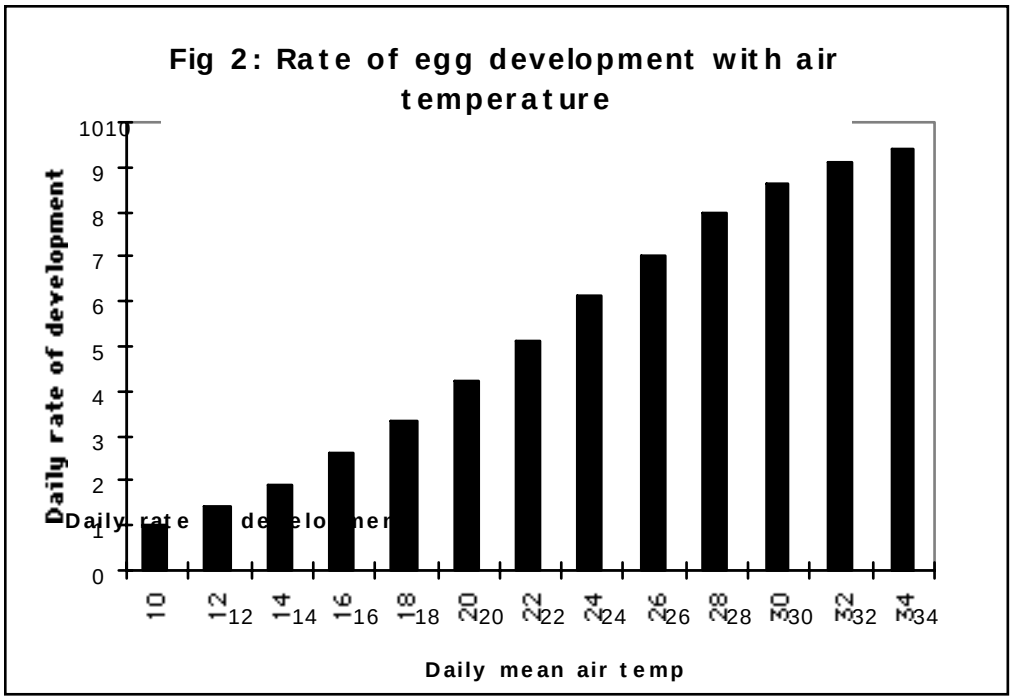
Egg stage

- In the field most female locusts will lay in the vicinity of 80 to 150 eggs per egg pod. There is a significant difference between the number of eggs per pod laid by solitarious (100 to 150) and gregarious females (around 80).
- Females may lay more than 1 egg pod during the life cycle but data on the frequency with which females may lay 2 or 3 or more egg pods is poor.

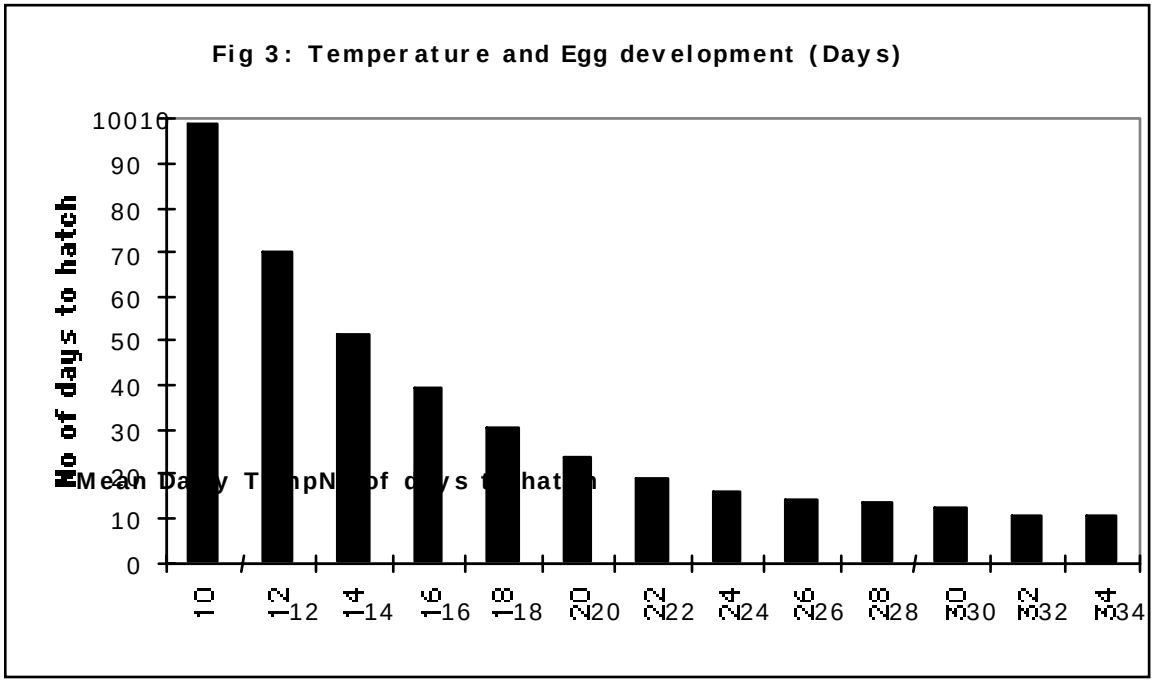
- However, there is circumstantial evidence to suggest that a significant proportion of females will survive to lay a second egg pod.
- However, data on egg survival is also very poor and eggs from a second laying may well have a higher risk of mortality especially if no follow up rains have occurred.
- There are a number of important consequences of multiple layings by females:
  - There will be an extended period in the timing of hatching of hoppers and fledging
  - The overall populations numbers are potentially substantially greater
- In addition, the forecaster needs to treat reports of laying with some caution and not necessarily assume that such reports are initial laying: they may be second or even third layings. If previous laying has occurred this will have implications for the timing of hatching and fledging and the overall population level.

Rate of Egg Development

- It can normally be assumed that if female locusts lay eggs then there will be sufficient soil moisture available for egg development.
- Assuming adequate soil moisture, the rate of egg development depends on temperature.
- There is a close relationship between the time taken for eggs to hatch and temperature.
- This relationship allows the forecaster to estimate fairly accurately when eggs will hatch if the date of laying is known or suspected: or conversely to estimate the date of laying if the date of hatching is known.
- FAO has a computer program which can be used to estimate hatching (or conversely laying dates).
- However, in most situations a simple arithmetic calculation will prove as accurate as the FAO computer program for most forecasting purposes.
- The relationship between daily percentage egg development and temperature is shown in Fig 2.



- An alternative way of expressing the relationship between egg development and temperature is to relate the number of days required for eggs to hatch at certain (constant) temperatures.
- A graphic representation of this relationship is shown in Fig 3.



- The methods outlined to estimate egg development periods are most reliable at higher temperatures certainly above 20°C. At temperatures below 20°C, or in other words in estimating egg development over winter periods, the errors involved increase significantly leading to less accurate results.

Hopper stage

- On emergence from the egg, hatchlings will make their way to the surface where they normally, at least in gregarious populations, turn a black colour.
- Desert Locust hoppers increase in size and weight throughout their life, necessitating a series of moults to accommodate the increase in volume.
- The period between successive moults is called an instar. Desert Locust hoppers have between 5 and 6 instars depending on the level of gregariousness.

- The rate of hopper development can be, as with egg development, closely related to temperature.
- However, hoppers have the ability to control their body temperature through activities such as basking.
- Field research data has indicated a fairly simple relationship between hopper development and mean daily air temperature.
- This relationship can be used to forecast the various hopper stages or instars and to predict when fledging is likely to occur.
- The equation Y=0.222T-3.16 can be used to calculate hopper development where:
  - Y is the daily percentage development; and
  - T is the mean daily air temperature which is not allowed to exceed 38^{o}C.
- In relating percentage hopper development to instar the following rule can be applied.

Percentage Hopper Development	**Instar**	**Indicative Period (Days)**
10	1	6
25	2	7
40	3	6
60	4	7
85	5	10

- At the end of the hopper development period the hopper will have full developed wings and will go through a final moult to become an adult locust capable of flight.
- This final moult is called fledging and is of crucial importance for forecasting purposes since within a short period of fledging adult locusts are capable of migration and thus invading adjacent countries or regions.

Practical: Estimating locust development from temperature (Data sheet 1)

Locust population data

Gregariousness of populations

- The gregariousness of locust populations, especially Desert Locust, is a function of density.
- As the density of the individuals within a population increases, individual behaviour is increasingly replaced by group behaviour.
- As the degree of gregariousness increases so also do the morphological characteristics, in particular colour. We can therefore use colour as a very accurate indicator of the level of gregariousness.
- In Desert Locust, the concentration of individuals appears to be a very important step leading to increasing gregariousness.
- Meteorological conditions play an important role in concentration of adult locusts. The density of adult Desert Locust can increase substantially as a result of wind convergence.
- In addition, as vegetation drys out locally, this may also result in increased density through adult locust preferring greener areas.
- The second factor leading to increased density is multiplication through breeding. Often the air mass systems which lead to convergence through wind also produce enough rainfall to enable breeding should locusts be present.
- Under favourable conditions the net reproduction rate (adult G1 to adult G2) may be in the order of X10 leading to significant density increases.
- Trying to attempt to forecast when and if a non gregarious population will change to a gregarious population is perhaps the most difficult prediction to make. There are a number of factors, such as weather, breeding success and the timing of such events which are extremely difficult to predict.
- There are few case studies on the factors which cause a population to change to the gregarious state and therefore attempting to quantify (and predict) such factors is virtually impossible.

Estimating the size of populations

- Estimating the size of Desert Locust populations, in particular, gregarious populations, is also a difficult task. This is an area which would benefit from further research.
- An approximate method for estimating the overall size of a population is to first estimate its geographic extent in kilometres. This can be done by delimiting the geographic extent of locust reports by various methods (approximate axis/ quarter degree square etc).
- Next we assume that, in most situations, the infestation level is likely to be of the order of 1 to 2 percent of the distribution area.
- The figure of 1-2 percent is based on research from the 1950's and, in general terms appears to have proven a reasonable rule of thumb in the plague of the late 1980's. In some situations it is possible that the infestation level could increase to 4 percent but it highly unlikely that it would exceed this level.
- Example: Reports of locust hoppers are plotted accurately on a 1:1 million map. From this map it is evident that the population occupies an area of approximately 100 km long and 40 km wide: a total area of 4,000 km2. Applying our percentage rule, we would expect that this means approximately 40 to 80km2 (4,000 to 8,000 ha) of bands or swarms will need to be controlled.
- Whilst this is a very crude method of estimation there is no more sophisticated method available at present and will probably suffice to give at least an indication of the level of magnitude of a population.

Meteorological data

Rainfall

- Rainfall Information is the most important environmental data due to its influence on Desert Locust breeding and population dynamics.
- However, rainfall is a highly variable meteorological event both in terms of geographic distribution and amount. This is particularly so in arid environments such as the recession area of the Desert Locust.

- This means that the forecaster cannot rely to any degree on the use of long term average rainfall data for forecasting Desert Locust.
- The Forecaster relies heavily on meteorological services to provide information on rainfall events.
- The most appropriate rainfall data from the meteorological service will be daily, weekly or decadal (10 day) data. However, it is important that such information is provided to the forecaster on a timely basis: meteo data provided late is usually signifcantly reduced in terms of its value.
- However, the rainfall reporting network in Desert Locust recession areas is very sparse and cannot be relied on solely to provide adequate and timely information.
- Due to this constraint, the forecaster must also seek to utilise other information which may be available on rainfall.
- Other information may include the development of networks such as the use of nomads or oil/gas companies which are located in remote parts of the Desert Locust recession area.
- In addition, the forecaster may also utilise remotely sensed data such as cold cloud cover images.
- The use of these other types of information is, however, not without problems, the most significant of which is reliability.
- In the case of informal networks, the main risk is that the information will not be provided in a timely manner due to problems with communications etc.
- In the case of remote sensed data, it is normally necessary to convert cold cloud cover frequency to an estimate of rainfall. However, studies to verify the relationship between cold cloud frequency and actual rainfall are relatively rare.
- The verification studies which have been undertaken do not suggest there is a very high correlation and most of these studies have been undertaken in the Sahelian zone where the relationship is likely to be more direct than in most of the central region.
- In addition, in the Central Region significant rainfall may result from low level cloud masses which often may not appear on cold cloud cover images.

- Access to timely cold cloud cover images may also be difficult. However, access to meteorological data, including cloud cover images and rainfall estimates, is improving through the use of the internet.
- It may be possible for forecasters to access internet sites which can provide information on actual and predicted weather, including rainfall, data.
- Some useful site addresses include www.wmo.ch and www.fao.org/giews
- The first site is that of the World Meteorological Organisation (WMO) where weather satellite images (METEOSAT) can be viewed on a routine basis.
- The FAO GIEWS (Global Early Warning) site provides very useful information on countries in the central region such as crop regions, weather patterns etc. In addition, you can also access rainfall estimates for the Central Region from this site, including variations from rainfall averages.
- The measurement of habitat or vegetation condition by remote sensing may also be used as an indirect method of monitoring where rainfall has occurred.
- However, as with the use of cold cloud cover estimates, the use of remote sensing to establish whether green vegetation (resulting from rain) is present presents some problems of reliability and access.
- The use of remotely sensed data will de discussed in some detail later in the workshop, in particular, the results of recent studies in the Central Region (Eritrea).
- In conclusion rainfall information, whilst the most important single meteorological parameter to predict WHERE Desert Locust breeding may occur, remains problematic in terms of the comprehensiveness and reliability of actual data.
- The forecaster must therefore use all possible information sources to determine where rainfall may have occurred to make informed decisions as to where surveys may be directed to detect locust breeding.

Temperature

- The major importance of temperature from the forecaster's perspective is its influence on the speed (or rate) of locust development and also its influence on migration and adult maturation.

- The forecaster therefore uses temperature data mainly to predict the TIMING of important events, such as hatching or fledging, in the Desert Locust life cycle.
- In contrast to rainfall data, temperature data is relatively stable with very little variability at least on an annual basis.
- This is important since it allows the forecaster to use average temperature data. Daily or weekly or decadal data, whilst it can be useful, is not essential. Since temperature data, at least annually, varies little from long term averages, these long term averages can be used with a high degree of confidence to accurately predict the rate of egg and hopper development.
- In addition, the forecaster needs to be aware that low air temperatures (below 20oC) may also result in delayed maturation of Desert Locust adults. Whilst this is unlikely to impact in a major way in the Central Region, it can certainly impact in North Africa where Desert Locust adults may overwinter as immature adults in parts of Morocco and Algeria and only mature once temperatures rise in the spring.
- Similarly, low temperatures will inhibit Desert Locust migration. In general terms adult Desert Locust adults will not migrate where the temperature is below 20oC. Again this information is likely to be of only limited application in the Central Region.

Pressure and wind systems

- It is important that the forecaster have a basic understanding of pressure and wind systems since these can have a major influence on the life cycle of the Desert Locust.
- In simple terms winds results from differences in air pressure. Wind direction will be from high to low pressure with wind strength determined by the pressure difference or pressure gradient between air masses. Coriolis force also plays a role in determining wind direction but this is relatively minor and will not be discussed further.
- In addition, the forecaster needs to be aware of the concept of surface wind convergence and divergence.

- Wind convergence often plays an important and dual role in the locust life cycle and population dynamics.
- Zones of wind convergence have often been associated with an increased density of adult Desert Locusts. The fact that surface winds converge can often result in dramatic increases in locust density. Furthermore the air masses/pressure systems which are associated with surface convergence often produce rainfall which will allow Desert Locusts to breed.
- One of the most important wind convergence features in Africa is the Inter Tropical Convergence Zone (ITCZ). This feature is generally more prominent in West Africa and tends to be weaker over the Central Region and the Red Sea.
- However, the ITCZ can exert a major influence on Desert Locust migration. Case studies from West Africa are the best documented but the ITCZ and the "Red Sea Convergence Zone" can also exert significant influence.
- Apart from the major influence of the ITCZ, the Central Region is also influenced by low pressure systems (frontal and cyclonic systems). Again these low pressure systems frequently result in surface wind convergence over areas of several thousand kilometres and frequently are rain bearing.
- Upsurges of Desert Locust in the Central Region have been frequently associated with such low pressure systems traversing the region.
- Documented examples of the influence of wind and pressure systems, including examples from the Central Region, can be found in the Desert Locust Forecasting Manual.
- In general, the forecaster needs to be aware of wind and pressure systems particularly in situations where substantial rainfall occurs following the passage of a frontal or cyclonic system or during upsurges or outbreaks where the location of zones of wind convergence may need to be located to predict possible migration or even to make decisions regarding the deployment of control aircraft.
- Monitoring and interpreting wind and pressure systems will assist the forecaster in determining where Desert Locust populations may be present.

Remote sensing data

- The use of some types of remotely sensed data has been briefly covered under the rainfall section (see above) and detailed information on the use of remotely sensed data as a monitoring tool for the forecaster will be presented later in the workshop.
- There are various types of remotely sensed data which potentially could improve the monitoring and forecasting of Desert Locust.
- There are a number of satellites which can provide data on environmental conditions and changes in those conditions which may result in locust breeding in the recession area.
- However, there are various issues, relating to the reliability of data, its cost and availability, which impose constraints on the wide use of such data.
- The various products available and associated constraints will be presented later in the workshop.
- Some useful web sites, for those with internet access, for remotely sensed data include the following:

  http://www.fao.org/news/global/locusts/locuhome.htm

  http://metart.fao.org/default.htm

  http://geoweb.fao.org/

  http://www.cnn.com/weather/index.html

  http://www.meteo.fr/temps

  http://earthrise.sdsc.edu/

Practical: Accessing remotely sensed data : Data Sheet 2

Historical and Environmental data

- The forecaster should also be acquainted with the important historical data available on Desert Locust breeding.
- The historical monthly distribution of swarms and hopper band frequency in both the recession and invasion areas provide the forecaster with a very good overview of

expected timing and location of locust populations during upsurge and plague periods.

- This information provides a wealth of reference material on seasonal movements and breeding areas for the forecaster.
- In addition to the frequency maps, the more recent FAO Atlas of Desert Locust Breeding Habitats also provides valuable information for the forecaster. It is strongly recommended that individual forecasters devote some time to a detailed study, on their return home from this workshop, of the parts of the atlas relevant to their own country.
- Whilst the above publications provide a wealth of information on habitat types, Desert Locust frequency and seasonal movements, the forecaster should be aware that Desert Locust may not always behave or occur in accordance with historical precedent. The migration of Desert Locust across the Atlantic Ocean from West Africa in 1989 provides a useful illustration of the risks in using precedents rather than analysing curent data.
- The forecaster should primarily examine the available data, particularly meteorological data, to first determine likely locust developments. The conclusions drawn from such an examination should then be compared with historical precedents not vice versa.

3. Data organisation and storage

Accessing data

- One of the main sources of specific detailed locust information for the forecaster will be that collected by national survey teams.
- It is therefore important that the forecaster have some input to how survey teams report locust data and when the data is reported. The same will apply to control information during upsurges or plagues.
- The forecaster should liaise with survey teams and, as appropriate, conduct simple training courses for survey and control staff to ensure that information is being recorded properly and is available in a timely fashion.

- It is recommended that standardised systems (forms) of recording locust information be used. The current FAO locust recording proforma should be used.
- Even where information is recorded from radio or telephone conversations with field staff it is important that the actual locust forms are eventually sent to the forecaster so there is a detailed physical record which can be used for review and/or research purposes.
- Other locust information such as that provided by FAO, regional organisations, national networks or other national reports should also be recorded and treated, as far as possible, in a manner similar to survey information.
- However, the forecaster often has little control of the quality of these types of other information and often needs to treat information from local sources with some caution.

Mapping data

- With Desert Locust the forecaster is dealing with information which is primarily geographic in nature: the location of Desert Locust populations.
- In order to properly analyse the information it is critical that the data is presented in a geographic context: that is the data should be mapped.
- The Desert Locust Guidelines (III: Information and Forecasting) provides detailed information to the forecaster on presenting and recording locust and other environmental data. These guidelines should be followed, with adaptations as necessary, to the extent possible by forecasting officers.
- Current locust information should be plotted on a suitable scale wall map (1:1 million or 1:500,00) immediately it is received and subject to quality control checks.
- In terms of determining location geographically for plotting, each locust record should be identified by a system of coordinates: latitude and longitude from a GPS if available.
- The forecaster will need to devise a symbol system to represent various locust stages, density and behaviour. eg a system for representing various categories of adults : mature: immature, isolated/scattered/group/swarm etc

- Each locust report should be plotted on the map with the actual date of the observation and the relevant symbol. The map then gives an accurate picture of the current locust situation.
- It is also useful to have a transparent overlay of the map to show additional information such as the routes taken by survey teams and habitat condition.
- It is recommended that the locust data be plotted on the wall map, and forecasts made. on a monthly basis.
- The forecaster should also consider having a larger scale map (1:5 million) of the region which would show Desert Locust developments in other parts of the region derived from the FAO monthly Locust Bulletin. This would serve as an early warning system for the possible impact of developments in the region.

Data Storage

- All physical records of locust and environmental information, including meteorological information, should be stored in chronological order on a monthly basis. The forecaster should also consider whether to use a registration system to assign locust reports an individual identifier to allow easy retrieval of specific records.
- Participants should refer to the FAO Desert Locust Guidelines (III: Information and Forecasting) for further information/details.
- The Desert Locust Guidelines are currently being revised by FAO. Participants should ensure that they obtain a copy of the new guidelines from FAO once they are finalised.

New Developments in Locust Information Management

- There have been some recent developments in the use of computer technology for the management of Desert Locust information.
- A sophisticated computerised Geographical Information System has been developed for FAO by the Natural Resources Institute (NRI).

- This system provides a very powerful tool to integrate various types of locust information, including historical and habitat information, and the facility to display such data in a geographic manner.
- It is understood that a version of this GIS may be made available to national plant protection services to assist in the management of locust data and forecasting.
- Whether a manual system or a sophisticated computerised system is used the basic principles remain the same. The forecaster needs to exert some quality control over the data, to map and then to interpret the data.

4. Forecasting

General

- It is strongly recommended that forecasters undertake a formal forecast of Desert Locust on a monthly basis.
- This will ensure that skills in forecasting are maintained and develop a discipline. In addition, it will also assist in developing skills further.
- The formal forecast should also be written and, as appropriate, distributed to interested parties. The forecaster should also, particularly in recession periods where Desert Locust activity is low, undertake an retrospective evaluation of the forecast made to verify conclusions and assumptions which were made.

Analysis of current situation

- The forecast relies heavily on the interpretation of current locust and environmental information. The required information is likely to be derived from three main sources: national surveys, FAO and meteorological sources.
- The forecaster needs to ensure that the risk posed by Desert Locust populations both in the region and in adjacent regions are taken into account in framing the forecast.
- In addition, the forecaster will inevitably need to make some assumptions/inferences to predict what locust populations are likely to do in the next 6 to 8 weeks.
- The forecaster needs to focus on key data in making the forecast. Key data would include locust colour and behaviour.
- The forecaster should also consider at the outset as to whether it may be useful to provide forecasts by region(s) as a way of providing some detail but not overwhelming the eventual reader.
- Finally, the forecaster must be focused on what a forecast is trying to achieve.
- The forecast should be aimed at informing the reader as to the probability of the following:
    - where Desert Locust populations are likely to occur;
    - when they are likely to occur

- the scale or level of such populations
- whether surveys are planned (where and when)
- whether control measures may be required

Elements of the forecast

Locust data: in country

- The first step in preparing a forecast is to closely examine the existing in-country locust data which should have been plotted on the current situation map.
- If eggs are known or suspected to have been laid in an area then the forecaster needs to calculate hatching and fledging dates based on temperature data. (WHERE and WHEN).
- The forecaster also needs to consider whether there is likely to be a spread in the timing of hatching and fledging. In doing this the forecaster needs to consider the timing of reported laying and may also need to consider whether there is evidence of second laying.
- The forecaster also needs to attempt to give an indication of the scale of hatching (large scale/moderate scale/small scale) and whether band formation is likely to occur and , once again, the level of band formation.
- Determining the likely scale of laying and hatching and, by implication, the resultant population is often very difficult especially as the Desert Locust tends to disperse into smaller groups to lay.
- Similarly, the possible timing and scale of adult populations which are likely to develop need to be estimated.
- It is important to be consistent in estimating the scale of hopper and later adult infestations. For example, it would not be consistent to predict small scale band formation and then forecast large scale swarm formation.
- The next step is to try to predict the behaviour of resultant adult populations. Are such populations likely to migrate, and if so when and in what direction, or are such populations likely to remain in situ and breed again.

- Th second step, having examined and prepared the draft forecast for the in-country locust population is to consider whether there are locust populations in adjacent countries or regions which could impact on the situation in-country.
- The forecaster must therefore look at the locust information in the FAO bulletins and in the bulletins from regional organisations to try to assess external populations.
- If such populations are present, the forecaster will need to consider the risk they pose in terms of whether an invasion can be expected, the probability of such an invasion, its timing and scale.
- The FAO locust bulletin is likely to provide some guidance on these questions but the forecaster should not rely solely on FAO forecasts. The forecaster should attempt to make an independent assessment and utilise historical information.

External Populations

- If external populations are present the forecaster will need to make an assessment of the risk these pose, in particular the threat of invasion. If it is assessed that such populations do pose a reasonable risk then the forecaster should also monitor the meteorological situation closely (daily) and keep an especial look out for unusual weather features which could be conducive to invasion.
- The forecaster will need to determine the possible timing, scale and location of any potential invasion by such external populations.
- Finally, the forecaster should, based on the forecast, make recommendations, on what actions should be taken.
- Such recommendations may involve areas which need to be surveyed by ground teams or the need for aerial survey or whether to consider initial deployment of control resources.
- The nature of the recommendations will obviously depend on the locust situation and the forecast made.
- The forecaster should ensure that colleagues involved in survey and control are consulted and made aware of the forecast. The recommendations made by the forecaster need also to be realistic.

Structure of the Locust Bulletin

General situation and Outlook

- The first section of a Locust Bulletin, or even in a less formal analysis, would be to describe the overall situation and outlook. It is this section that the forecaster try to provide a general overview of the current locust situation and likely significant developments.
- This section is a summary section and should not, except perhaps in plague periods, exceed 1 page maximum.
- Perhaps the most important objective of this section is to attempt to predict the risk to the region in terms of when, where and level.
- This section should have the broadest view possible of Desert Locust. The current international Desert Locust situation should be briefly described, particularly the situation in the Central Region, and the predicted development of such populations.
- Even if no significant populations were present in the situation period (month) this should be clearly indicated.
- The emphasis should be accorded to those populations which pose the greatest immediate threat to the country or region.
- If significant control measures are being implemented internationally or regionally this should also be mentioned.
- Significant weather events such as very heavy widespread rainfall in the country or neighbouring countries in which, historically, Desert Locust Breeding could be expected also be briefly described.
- Finally, any national plans for survey or control measures or plans should also be provided.

Meteorological Data and habitat conditions

- The second section of the bulletin should describe the general weather situation in the region/country over the past month.
- The main focus of this section would be on the distribution, both location and amount, of known or suspected rainfall.

- The movement of wind convergence zones , if known, should also be described.
- The suitability, both known and suspected or estimated, of habitat conditions should be described and linked to weather. For example, if significant rain has fallen in an area it is reasonable to assume that potential breeding conditions are suitable or improving.

Current National Locust Situation and Forecast

- The third section of the bulletin should comprise a detailed description of the locust situation and forecast in the country by province or other suitable administrative unit.
- This can be done relatively simply if the situation data has been mapped beforehand.
- The situation section (by province) should provide details of locusts reported and should also provide clear indications of the source of such reports. For example, it is often important to know if locusts were reported as a result of surveys or not in order to make an assessment of the quality of the information.
- In addition, the description should also indicate the suitability of the vegetation (habitat) conditions for locust breeding.
- If control measures are being undertaken then details should be given, The details should include, where possible, the area treated (ha), whether ground or aerial control was undertaken and the number of ground and/or aircraft used.
- The control information should be given by province(s).
- It is extremely important that if surveys were undertaken but no locusts found that this be clearly indicated.
- Finally, the forecast for the provinces for the next six weeks should be given.
- The focus should be on whether the situation is likely to change and if so why and the level of changes expected.
- For example, if significant populations are present are these likely to persist or migrate or be controlled. Is the province likely to be invaded ? etc
- Details of planned surveys or possible control should also be mentioned in this section.

Control Information

- If control measures have been undertaken it is useful to include these in the bulletin.
- It is recommended that such details be given by province. Details would include the area treated, pesticide used (type and formulation) by ground and air.
- The period of control should also be given and if considered necessary details of control in the previous month may also be included to indicate whether the situation is improving or otherwise.
- Consideration should also be given to providing information on the level of remaining pesticide stocks in-country.
- Detailed analysis of current control information and control statistics can also prove a valuable for the forecaster to identify general trends in the overall population.

LOCUST BULLETIN STRUCTURE: Check List

1. General situation and outlook

- Brief overview of international Desert Locust situation and outlook
- Priority should be given to populations which pose most immediate risk
- Mention significant meteorological events in the region
- Try to specify risk (when, where, scale) to the region
- Mention if significant control measures are being undertaken internationally or regionally.

2. Meteorological and Habitat conditions

- Include significant meteorological events in the region especially widespread/heavy rain
- Describe seasonal movements in wind convergence zones if known and possible implications of these on locust migration.
- Describe whether habitat conditions are suitable or unsuitable for breeding. Link habitat condition to weather (rainfall information) whether this be actual data or estimated data.

3. Detailed Situations and forecast by province

Province 1 situation

- Details of locust activity (when, where, Lat/Long)
- Details of source of reports (survey/nomads/travellers/etc)
- Describe whether breeding conditions are (or may have been) suitable
- Details of control (amount/ground/air/number of ground units/aircraft)

Province 1: Forecast

- Forecast locust developments over next six weeks
- Focus on whether any changes likely. Is so specify these and likely level of changes and factors causing the changes (control/emigration/invasion).
- Describe any plans for survey or control measures.

Province 2 etc

4. Control Information

November 1999 2982 ha treated (2200 hoppers: 782 adults)
December 1999

Province	Period	Type	Total(ha)	Ground(ha)	Air(ha)
Province 1	1-21/12	Adult	3780	2420	1360
Province 2	1-3/12	Hopper	420	420	------
	1-14/12	Adult	2900	1200	1700
Total	1-21/12		7100	4040	3060

REFERENCES AND FURTHER READING

FAO (1992) The Desert Locust Guidelines.

Pedgley, D.E. (1981) Desert Locust Forcasting Manual, Centre for Overseas Pest Research.

Popov, G. B. (1996) The Desert Locust Atlas.

Steedman, A (Ed.) (1990). Locust handbook. (3rd edn) Chatham: Natural Resources Institute.

DATA SHEET 1

Exercise 1: Data

- Gregarious mature Desert Locust groups are reported as laying in Sudan on 10 August
- The average daily temperature for August from the nearest meteorological station is 27^{o}C

Exercise 1: Questions

1.1 Estimate the date when these eggs will hatch using the data provided in Fig 1

Answer: Estimated hatching date is.....

1.2 Estimate the date when these eggs will hatch using the data provided for El Obeid in Table 1a of the Guidelines.

Answer: Estimated hatching date is.....

Exercise 2: Data

- In the Sudan example given above, there are a number of reports of hatching in the general area on 16 August

Exercise 2: Question

2.1 How do you explain any differences between your estimated hatching date for the eggs as calculated in response to Q1.1 and 1.2 with the reports of hatching on 16 August ?

Answer:.....
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DATA SHEET 2 (Continued)

Exercise 3: Question

Predominantly fourth instar, with some fifth instars, Desert Locust bands are observed in northern Eritrea on 15 July. When would you have expected the significant rainfall, which would have allowed such successful breeding, to have occurred ? **Write your answer below and** explain how you arrived at your answer

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DATA SHEET 2

In this practical the task is simply to access remotely sensed and other relevant locust forecasting data through the internet. Suggested sites include :

http://www.fao.org/news/global/locusts/locuhome.htm
http://metart.fao.org/default.htm
http://geoweb.fao.org/
http://www.cnn.com/weather/index.html
http://www.meteo.fr/temps
http://earthrise.sdsc.edu/

In your groups you should access various sites to find out the types of information available.

There will be a short discussion at the end of the practical.

DATA SHEET 3

Data: Map 1 provides various surface pressure readings over part of the central region.

Task 1:What is the dominant meteorological feature of the map ?

Answer.....
.....
.....

Task 2: What direction and strength of winds would you expect over the region ? Draw these on your pressure map.

Task 4: Gregarious immature Desert Locust swarms are present in Saudi Arabia and Yemen as indicated on the map. In which direction do you predict these Desert Locust may have migrated ?

Answer.....
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.....

Task 5: The maps below shows the location of the ITCZ over West Africa over a period of 3 days together with the distribution of Desert Locust on day 1. What would you expect to happen over days 2 and 3 ?

Answer.....
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.....
.....

Day 2

Day 3

DATA SHEET 4

Data:. Below are data from a survey in Eritrea. The area received widespread heavy rain on 15 December. The rainfall was heavy along most of the western Red Sea coast extending as far north as Port Sudan. Vegetation conditions in the area are good (green). From discussions with local villagers they report red locusts were first noticed in the area around 18 December. The average mean daily temperature for December is 24oC and January is 25oC.

You will need to devise a system of symbols to denote the populations and density.

Date	Lat N	Long E	Population Type	Area Infest	Density	Stage	Colour	Comments	
8/1	1720	3845	Adult	20ha	8/100m			Yellow	Laying
8/1	1719	3835	Adult	40ha	10/100m		Yellow		
9/1	1723	3830	Adult	10ha	5/100m			Yellow	
9/1	1704	3855	Adult	200ha	12/100m		Yellow		
10/1	1705	3856	Adult	500m	15/500m		Yellow		
10/1	1705	3852	Adult	500m	42/500m		Yellow		
10/1	1715	3845	Adult	2ha	1-2m2			Yellow	Gravid
11/1	1712	3845	Hopper	1ha	200m2		I	Black	Hatching
11/1	1635	3854	Adult	200ha	25/100m2			Yellow	Laying
11/1	1635	3854	Hopper	20ha	200/m2		I	Black	Small bands
11/1	1633	3856	Adult	120ha	1/m2			Yellow	Mature swarm
12/1	1750	3833	Adult	35ha	12/100m2			Yellow	
12/1	1737	3831	Adult	100ha	25/m2			Yellow	
12/1	1756	3837	Adult	120ha	8/m2			Yellow	
12/1	1730	3845	Adult	55ha	32/100m2			Yellow	

Task 1 Plot the following survey data on the map provided

Task 2 Using the method described on page 13 estimate the approximate size of the population likely to be produced in terms of ha or Km2

Task 3: Note relevant points (scale? timing? behaviour? recommendations?) emerging from an analysis of the data provided and mapped

1.....

2.....

3.....

4.....

5.....

6.....

Task 4: Analyse the data and write up a Locust Bulletin General Situation and Forecast and a specific situation and forecast.

Task 5: Plot the additional data below

Date	**Lat N**	**Long E**	**Population Type**	**Area Infest**	**Density**	**Stage**	**Colour**	**Comments**	
8/1	1800	3830	Adult	45ha	12/100m		Yellow	Laying	
8/1	1805	3827	Adult	56ha	19/100m		Yellow		
9/1	1802	3830	Adult	10ha	18/100m		Yellow		
9/1	1804	3825	Adult	200ha	21/100m		Yellow	Eggs	
10/1	1815	3735	Adult	22ha	25/500m		Yellow		
10/1	1900	3720	Adult	6ha	42/500m		Yellow		
10/1	1830	3730	Adult	78ha	1-2m2			Yellow	Gravid
11/1	1832	3738	Hopper	40ha	200m2		I	Black	Hatching

Task 6: Will this additional data change your forecast. If so explain how your forecast would change.

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